Solar-Terrestrial Centre of Excellence

Activity Report 2007-2008

1 Introduction

On 22nd March 2006 the Belgian government approved the creation of a *Solar-Terrestrial Centre of Excellence (STCE)* in which the activities of 3 Belgian federal institutes in the field of solar-terrestrial physics are joined and expanded. Combining the existing expertise concerning physics all the way from the sun to the earth and the valuable collaboration and strengthening of the scientific research of the three institutes makes the difference on international level.

The Solar-Terrestrial Center of Excellence is a scientific project that aims at the creation of an international expert center and the valorization of Solar and Solar-Terrestrial research and services. The STCE clusters the know-how of 3 Belgian Federal institutes:

- Royal Observatory of Belgium ROB
- Royal Meteorological Institute RMI
- Belgian Institute for Space Aeronomy BISA

The STCE is built upon existing experience present in the 3 institutes related to Solar-Terrestrial physics, which includes

- SPENVIS, the Space Environment Information System (BISA),
- The World Data Center for the Sunspot Index (ROB/SIDC),
- Principal Investigator of the telescope VIRGO-DIARAD onboard of the ESA/NASA mission SOHO (RMI),
- Lead of PICARD, i.e. French microsatellite, mission center (BISA/BUSOC),
- SOVAP instrument for solar constant measurements onboard of PICARD (RMI),
- SOVIM-DIARAD instrument for solar constant measurements for the International Space Station (RMI),
- Dourbes geomagnetic station (RMI),
- Regional Warning Center for ISES concerning space weather services (ROB/SIDC),
- Co-Investigator of SWENET (BISA),
- Investigation of the ionosphere by the Ionosonde (RMI),
- Principal Investigator of the innovating telescopes SWAP & LYRA onboard of the European micro-satellite PROBA2 (ROB/SIDC),
- Lead of SOLAR, i.e.Solar Monitoring Observatory onboard the International Space Station (BISA/BUSOC),
- SOLSPEC instrument for solar spectrum measurements onboard the International Space Station (BISA),
- UV observations network (BISA).
- European Network EUREF of continuous observing GPS stations (ROB).

The STCE operates in a strong collaborative spirit within the international environment: we expect strong benefits from joint work within the networks created by ESA (SWWT, SWENET), EU (COST, FP7) and others (ISSI, ...).

Another goal of the STCE was to achieve a higher degree of integration between the existing Belgian research groups in the field of solar-terrestrial physics, especially those at the KMI-IRM, KSB-ORB, and BIRA-IASB. Of course, while several groups in these institutes are working on related topics in adjacent fields, a closer inspection showed that there is not much overlap in the actual science subjects that are being studied. There are, however, more opportunities for collaboration concerning generic supporting activities:

- Collective use of facilities and infrastructure,
- Sharing of engineering know-how,
- Operational support,
- Numerical techniques,
- High performance computing support,
- Public outreach, …

The first funding for the STCE arrived in November 2007, signaling the effective start of the center's activities in collaboration with existing projects at the 3 institutes, but likewise making new initiatives possible. Although some activities had already started before the arrival of the first slice of funding, the budgetary constraints of the three institutes only permitted full startup of the STCE after November 2007.

A formal kick-off meeting of the STCE, in presence of all staff concerned and the Directors of the three institutes was held on March 21, 2008. This year's annual meeting is planned for June 08, 2009.

2 Common Budget Activities

2.1 STCE internal coordination and external representation

2.1.1 Personnel

A project that has the size and breadth of the STCE needs a dedicated senior scientist for day-to-day management, using the allocated resources in an optimal way compliant to the consortium agreement, to coordinate and integrate the various activities related to the Center in the three institutes. At the same time, the STCE coordinator needs to be an interface for the external representation of the project as a whole, in particular in the international context. Since a lot of administrative work will be involved, especially towards the future, an administrative assistant is likewise required.

The function of STCE coordinator is provisionally filled by R. Van der Linden, ROB Director General, until a suitable dedicated coordinator is found. The administrative support position was left unoccupied in 2007-2008 as it was less relevant for the start-up phase. Also the two collaborators for Education and Public Outreach (see below) have an important role to play in this activity.

2.1.2 Long Term Goal

We are dedicated to establish the STCE as an international center of excellence for scientific research and scientific services in the different domains that it addresses, providing a stable framework for these activities. A specific role of the STCE coordinator is to foster cross-institute collaborations and make sure that the STCE activities are overall coherent.

One of these domains, and when taken in its broad sense by far the largest segment of the STCE, concerns space weather. In this domain, the STCE should lay the foundation to build a European Space Weather forecast, monitoring and research centre that could constitute the European equivalent of NOAA's Space Weather Prediction Centre in the US.

2.1.3 Activities

2.1.3.1 Recruitments

At the end of 2007, a procedure was launched for the recruitment of the STCE coordinator and the 2 responsible for Education and Public Outreach. All three positions were advertised at the international level. For the latter two, Petra Vanlommel and Sophie Raynal were selected for the Dutch-speaking and French-speaking positions respectively.

For the STCE coordinator post, seven applications were received, but one candidate withdrew just before the interviews were held. Three shortlisted candidates were interviewed by teleconference in December 2007. One candidate was found to be suitable for the position, but declined the job offer based mostly on financial considerations. In subsequent months, several potentially suitable persons were approached personally, but none were found willing to consider applying in the conditions that we can offer. It was therefore finally decided to hold the vacancy until the approval of the new salary scales for the contractual members of staff would render it possible to offer more attractive conditions to the candidates.

2.1.3.2 Internal coordination

Coordination of proposal writing

Besides the initial proposal (in the form of a note to the Council of Ministers), a number of subsequent documents were required before the STCE could finally kick off. These include:

- A detailed description of the background, research themes, work packages and budgets
- A document detailing the destination of the budgets
- A cost-benefit analysis
- A convention between the parties involved

Acceptance of these documents and signature of the convention led to a final approval and the allocation of the first budget at the end of 2007.

Internal Meeting organization

The general coordinator of the STCE initiates and organizes meetings of the 'general assembly', Steering Board, Executive Committee and Evaluation Committee.

The first annual meeting of the whole STCE community was the kick-off meeting, which was held on March 21st, 2008. It was the first occasion to meet the other participants of the action, discover the diversity of activities that form part of the STCE and exchange ideas about the future orientations and strategies.

The executive committee consists of 2 group leaders from each of the participating institutes and the general coordinator. This committee assembled for the first time on 9 June 2008 and discussed among other things the practical implementation of the visiting scientist grants and the international contexts and representations of the STCE. Although the intention is to meet at least 4 times a year, time constraints from the general coordinator prevented a second meeting in 2008. It is the intention to meet once every 3 months in future years.

Reporting

The STCE general coordinator is also responsible for initiating and coordinating the reporting obligations. In first instance, the 'kick-off report' was produced in the summer of 2008. In view of the startup of activities, this report consisted mainly of an actualization of the work packages and a clarification of the state of affairs.

The current report is the sequel and is the first full annual report of the STCE.

2.1.3.3 The fifth European Space Weather Week, esww5

The international significance of the STCE is translated in the confidence that the international community places in us for the organization of the European Space Weather Week, in 2008 of its 5th edition. The 5th European Space Weather Week took place in Brussels on Nov 17-21, 2008. The Space Weather week brings together the different space weather actors in Europe: scientists, commercial entities and end-users. The keywords of this year: the ESA Space Situational Awareness action, GNSS, offshore drilling, magnetic surveying and geomagnetism, space weather models, data-tools-services, solar weather. The logo is presented in Figure 1.

Figure 1: The logo of the European Space Weather Week, designed by W. Vander Putte@planetarium, Heizel. It shows the Earth in the grip of the Sun. The logo is easy to interpret and the trading brand of the ESWW.

Besides the large number of participants (222), the success of the conference was reflected by the numerous splinters (10) and side meetings (8). The European Space Weather Week offered a convenient platform to discuss past and future collaborations. Also some special events were organized. The Space Weather Tutorial '*Space Weather: ingredients, effects*' together with the review in the form of a quiz, focused on students and people new to the space weather community. More than 60 people welcomed the new concept. The Space Weather Fair turned into a vivid workshop showing hands-on tools and concrete user-friendly space weather products.

This year's keynote lecture was 'A European Weathering Space in a Week in Dec 2006', given by the ESA astronaut Dr Christer Fuglesang who held the interest of 150 people for his talk about his close encounter with the SPEs of Dec 2006: a space weather expert at first hand. The contest 'the best of' was won by H. Bochnicek in the category posters and by A. Veronig in the category oral presentations. Both are young female scientists who presented their work in a clear, understandable way attracting people's attention. The press release attracted the attention of the press and resulted in several written publications in newspapers and a live radio interview.
Special effort was done for the organisation of social events: welcome reception, beer tasting and conference dinner. Availability of meeting places like the cozy corners, a permanent coffee stand, an information desk, the numerous wired internet points, wireless internet, ... were strongly appreciated by the participants.

Scientific outreach: STCE@esww5fair

During the fifth European Space Weather, a fair was organized. The fair was intended as a hands-on workshop to show products, services to the space weather community. The RWC-WDC WP was present with a lively and, if we may say so, a nice stand. On a daily basis, the space weather was broadcast. Visitors could browse through solar data with the Solar Weather Browser while explanation was given by one of the forecasters. We displayed the maquettes of PROBA2 and HI onboard of STEREO, see Figure 2. A radio antenna was installed measuring real-time the radio waves in the local environment. This was a reference to the ROB radio station in Humain, Belgium.

Figure 2. A scientist browsing through solar data with the Solar Weather Browser at the space weather fair. In the right picture we see technicians mounting the PROBA2 mock-up, which was also displayed at the fair.

A 'taste' of the esww5 was presented afterwards: http://www.sidc.be/news/108/welcome.html. We can certainly conclude that through the scientific and local organisation of the esww5, the STCE manifests itself as a strong Belgian player in the international space weather community.

New scientific side events

- Space Weather Tutorial and quiz
- Space Weather Fair
- First Attendees Meeting
- Contest: "The Best of …"

Field missions:

- Visit to the Belgian Institute of Natural Sciences, November 4, Brussels, Belgium
- Visit to The Royal Library of Belgium, November 6, Brussels, Belgium
- Preparing the venue for the start of the conference, November 14, Royal Library, Brussels, Belgium

Wikis and Websites

- A wiki: http://pb2sc.oma.be:8000/ESWW/
- http://www.sidc.be/esww5

Actions towards the Press

- Press release (Nl, Fr, Eng), published on the website and distributed to the list of journalists: http://www.sidc.be/news/107/persberichtesww5_eng_web.pdf
- Interview of R. Van der Linden with journalist from 'De Zondag'
- Live radio interview of R. Van der Linden on RTBF radio.

Lectures

- P. Vanlommel, *Space Weather Quiz,* ESWW5, November 16-20, Brussels, Belgium.

2.1.3.4 External representations & participation to programmes related to Space Weather

Although we should not lose sight of the importance of non-space-weather-related issues that are being studied within the STCE, it cannot be ignored that this field is one of the focus areas, and this will be even more so in the future, in view of the recent evolution in the international context and opportunities that are thereby offered. Therefore, the role of the general coordinator and all other project participants to advocate the STCE's activities is also highly important in this domain. This blends in well with the interests of the 3 institutes in Space Weather issues.

Thus, it is necessary that the STCE assumes a responsibility for the international representation in a number of programmes and bodies. Frequently, the general coordinator can be expected to assume this role, but this is not necessarily the case. The programmes that spring to mind are:

- *International Heliospheric Year (IHY)*: several STCE participants were member of the Belgian IHY Committee.
- *International Space Environment Service (ISES)*: role assumed by R. Van der Linden but shared by others. The ISES is the main international body overlooking Space Weather Services worldwide. Although this participation follows on also from the specific activity of RWC Belgium (see below), is is quite relevant for the STCE as a whole.
- *International Living With a Star (ILWS)*: role assumed by D. Berghmans.
- *Space Environments and Effects Network of Technical Competences (SEENOTC)*: role assumed by N. Crosby.
- *United Nations Committee on Peaceful Uses of Outer Space (UNCOPUOS)*: an informal working group of this Committee is currently drafting a resolution on the long term sustainability of space activities. Through our involvement in ISES, R. Van der Linden is member of this committee to ensure that space weather finds its right place in this work.
- *Space Situational Awareness (SSA)*: a future programme of ESA that has a large Space Weather component and substantial Belgian contribution specifically to this component. R. Van der Linden is the Belgian representative in the User Representatives Group.
- *Space Weather Working Team (SWWT)*: this is an advisory board set by ESA. Many STCE participants are member of the SWWT. N. Crosby chairs one of its Topical Subgroups.
- *COST-ES0803*: as a continuation of the very successful COST-724 action, a new proposal was introduced by a core team and accepted in 2008. Both the old COST-724 and the new COST-ES0803 are fully dedicated to Space Weather. R. Van der Linden was member of the proposing team. As general coordinator of the STCE, he currently assumes the role of Grantholder of the action and at the same time is the chairperson of one of the three working groups.

2.1.3.5 Visiting Scientist Programme

The visiting scientist program allows inviting external experts for short or long stays at one of the three institutes. Thus, we may benefit from the expertise they inject into the programs, while at the same time

the foreign experts get to know the STCE and its partners, which should lead to increased international collaborations and contribute to the visibility and recognition of the STCE.
This program was extensively discussed in the Executive Committee, and it was decided to extend the scope of the scheme to encompass three types:

- Long duration visits (up to several months), typical for joint work or lecture series.
- ISSI-type workshops: invite a group of experts for 3-5 days to brainstorm on some subject(s). This could include publications as result, for which STCE will also cover costs.
- Short visits for seminars. The seminar should be clearly labeled 'STCE' and widely advertised (can be done by the EPO people). Copies of the presentation should be made available and will be put on the STCE website.

Most of the visitors so far fell in the third category, but also the highly appreciated lecture series by P. Stammes was supported by the scheme. The organization of joint seminars offers a very practical road to increased collaboration, and also creates a place where the people involved can meet and discuss.
A list of the seminars organized in the STCE context is given in Table 1 .

Table 1: ***Main seminars organized in the STCE context (those funded by STCE are highlighted in blue)***

Date	Speaker	Subject	Host
2007-02-03	Koen Stegen BIRA-IASB	Version control with Subversion	BISA
2007-03-01	Russell Howard Naval Research Laboratory (USA)	The First Stereoscopic Solar TErrestrial RElations Observatory	ROB
2007-04-27	David Bolsée BIRA-IASB	Optical characterisation of space and ground-based instruments at IASB: potentiality of optics laboratory	BISA
2008-05-10	Jim Ray NOAA - Washington, USA	Anomalous Harmonics in the Spectra of GPS Position Estimates	ROB
2008-05-31	Juliette Legrand KSB-ORB	From GPS satellite signals to a European velocity field	ROB
2007-06-05	Milan Maksimovic LESIA & CNRS - Observatoire de Paris, France	The PHOIBOS mission: Probing Heliospheric Origins with an Inner Boundary Observing Spacecraft	ROB
2007-06-08	Sean Bruinsma CNES, Toulouse, France	Atmospheric Neutral Density Observed With Accelerometers	ROB
2007-06-25	Romain Maggiolo CNRS/CESR, Toulouse, France	Ionospheric ion outflows above the polar caps: CLUSTER results	BISA
2007-09-27	Dieter Nickeler Ondrejov Observatory, Czech Republic	Finite Time Singularities in MHD - a Possible Mechanism for Eruptive Flares or Excitation Mechanism for Coronal Waves?	ROB
2007-10-05	Dr. Isabel Braun Max-Planck-Institut für Kernphysik, Heidelberg, Germany	Probing the first and the last steps of a Cosmic Ray's journey	BISA
2007-11-29	Natasha Romanova Institute of the Physics of the Earth, Moscow, Russia	Partial Least Squares Model for the Prediction of Magnetospheric Relativistic Electron Dynamics	BISA

2008-01-22	David Berghmans KSB-ORB	SWAP Towards Improved Space Weather Monitoring	ROB
2008-02-29	Johan De Keyser BIRA-IASB	Experiences with MATLAB tools for spacecraft data analysis and modelling	BISA
2008-03-20	Boris Filippov Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation, RAS, Russia	Sources and Coronal Responses to Eruptive Phenomena	ROB
2008-05-22	Joseph Lemaire BIRA-IASB	Kinetic and Fluid Models in Space Plasmas	ROB
2008-05-28	Christian Monstein ETH Zurich, Switzerland	Radio Astronomical Instrumentation at ETH Zurich	ROB
2008-05-29	Bidzina Shergelashvili KULeuven	MHD Waves in the Nonequilibrium Media	ROB
2008-06-23	S. Fred Singer University of Virginia, US	Mercury, Venus, Earth, Mars: Different yet similar	ROB
2008-07-09	Bernd Inhester Max-Planck-Institut fuer Sonnensystemforschung, Germany	Coronal Magnetic Field Extrapolation - Presence, Problems, Prospects	IRM
2008-07-15	Shanggen Jin Korean Astronomy and Space Science Institute, South Korea	GNSS Observations from Space to Earth's interior: recent results, new capability and challenges	ROB
2008-08-12	H. De Bruin Univ. Wageningen, The Netherlands	Scintillometry: a brief review	IRM
2008-09-11	Cyril Simon ESA/ESTEC, The Netherlands	Modelling planetary ionospheres and their airglow. Application to the Earth, Mars and Venus	BISA
2008-09-25	Piet Stammes KNMI, The Netherlands	Lecture 1 : Radiative transfer in the atmosphere	BISA
2008-09-26	Piet Stammes KNMI, The Netherlands	Workshop 1 : Radiative transfer in the atmosphere	BISA
2008-10-03	Svetlana Kotchenova BIRA-IASB	Radiative Transfer Modelling for Atmospheric Correction of MODIS Data	BISA
2008-10-09	Piet Stammes KNMI, The Netherlands	Lecture 2 : Radiative transfer in the atmosphere	BISA
2008-10-10	Piet Stammes KNMI, The Netherlands	Workshop 2 : Radiative transfer in the atmosphere	BISA
2008-10-16	Mirela Voiculescu University of Galati, Romania	Ionospheric signature of particular magnetospheric configurations - ASAIDs	BISA
2008-10-17	Oleg Postylyakov Institute of Atmospheric Physics, Moscow, Russia	Radiative transfer model MCC++ and some its applications	BISA
2008-10-20	Bjorn Gustavsson Swedish Institute of Space Physics, Kiruna, Sweden	Optical and Incoherent Scatter radar observations of flickering aurora and their theoretical interpretations.	BISA
2008-10-30	Sergey Kuzin Lebedev Physical Institute, Russian	The EUV Imaging Spectroscopic Experiment TESIS onboard the CORONAS-Photon Satellite	ROB

	Academy of Sciences, Russia		
2008-11-06	Nandita Srivastava Udaipur Solar Observatory, India	Use of Statistical Models for Predicting Geo-effective Events	ROB
2008-11-24	Bojan Vršnak Hvar Observatory, Faculty of Geodesy, University of Zagreb, Croatia	Large-Scale MHD Shocks in the Solar Corona and Interplanetary Space	RMI
2008-11-13	Piet Stammes KNMI, The Netherlands	Lecture 3 : Radiative transfer in the atmosphere	BISA
2008-11-14	Piet Stammes KNMI, The Netherlands	Workshop 3 : Radiative transfer in the atmosphere	BISA
2008-12-04	Sabri Mekaoui KMI-IRM	Preliminary Measurements of the Total Solar Irradiance Using DIARAD:SOVIM onboard the International Space Station	ROB
2008-12-11	Piet Stammes KNMI, The Netherlands	Lecture 4 : Radiative transfer in the atmosphere	BISA
2008-12-12	Piet Stammes KNMI, The Netherlands	Workshop 4 : Radiative transfer in the atmosphere	BISA

2.1.4 Perspective for next years

2.1.4.1 The sixth European Space Weather Week

As a consequence of the virtually flawless organization of the previous 3 editions of the European Space Weather Weeks, the next edition of this frontispiece event in the agenda of all Space Weather scientists in Europe has again been confided to the STCE-SIDC. ESWW6 will be held on Nov 16-22, 2009 in Brugge and again be organized by the STCE with substantial support from the Royal Observatory of Belgium. R.A.M. Van der Linden and P. Vanlommel are members of the program committee.

A first part of the website is online: http://www.sidc.be/esww6.

2.1.4.2 Continuation of internal coordination and external representations

- After the finalisation of this report, and in agreement with the Steering Board, an Evaluation Committee will be formed that will be asked to assess the STCE activities.
- Regular meetings will be held: annual meeting of the 'general assembly' meetings of the Executive Committee and the Steering Board and ad hoc meetings of working groups addressing particular issues.
- The participation in the international organisations and programmes will be continued.
- Special attention will be devoted to the SSA programme, with the intention to take the lead in the Space Weather component of this programme.

2.1.4.3 Recruitments

The search for a good candidate to become a fully dedicated STCE general coordinator will continue.

By the time of writing of this report, an administrative support was selected and hired.

2.2 Public outreach and science communication

2.2.1 Personnel

Outreach and science communication is part of the mission of federal scientific institutes like BISA, RMI and ROB. It is logic that this tradition is integrated in the STCE-project. Two collaborators in the field of communication, Dutch and French were recruited to make this task more concrete: Sophie Raynal and Petra Vanlommel. Their job content centres on education and public outreach: EPO officers.

2.2.2 Long Term Goal

The STCE encompasses sciences from Sun to Earth. Those sciences and the resulting applications converge to Space Weather. Modern life has become dependent on space weather.

The STCE has also the task to communicate this knowledge and related services to other parties: companies, scientists, amateur astronomers, and the general public.

The goal of the WP is to highlight the justification and relevance of a project like the STCE. Through the activities and expertise of the STCE, we have to *raise the awareness* of the existence and consequences of space weather effects to third parties. From this point of view, companies with space related activities, companies with interest in navigation and radio-communication, energy plants, aviation… are important targets.

Further objectives are to increase the *visibility* of the STCE as the Belgian expertise in the solar-terrestrial domain and as an important international partner in scientific research and space weather services.

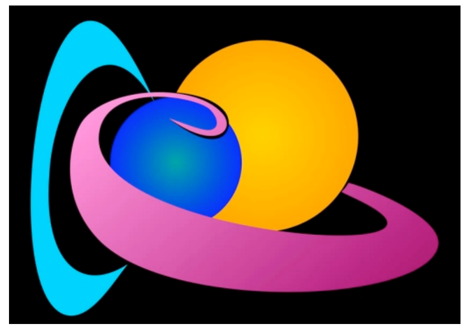


Figure 3: The STCE logo shows the blue Earth and the orange Sun. The Sun influences the Earth in different ways: instantaneous e.m. output, solar wind, particle events. The Sun embraces Earth with the 'e' shaped arm. The magnetic field of the Earth is shown as a light blue 'C'.

We distinguish between the professional and the non-professional community. The EPO-officer have to play an important role to set up a regular communication channel with the non-professional community, e.g. in the form of educative presentations.

2.2.3 Activities

Internal communication is one of the priorities of a new entity and a necessity to perform well. A website, regular meetings, email contact, (in)formal live contacts, ... can contribute to a good internal communication

'External' means outside the STCE itself. The communication is directed towards the scientists of the world wide space weather community, towards providers of space weather services, the space weather user-community, science students, the professional and non-professional community and the general public. The STCE acts as an institute or commerce that provides a product: knowledge and services.

A formal kick-off meeting of the STCE, in presence of all staff concerned and the Directors of the three institutes was held on March 21, 2008. An overview, status and goals of the STCE were presented, as well as all WP's. The meeting offered the chance to meet the general manager, the other STCE scientists and the EPO-officers and learn about the concrete science involved. The kick-off was well attended.

The EPO-officers triggered a poll for the logo based on the input of STCE-members. The result was a recognizable and interpretable logo shown in Figure 3.

- A dedicated website was created: http://www.stce.be. It serves in a way to pass easily information to the other STCE members but also to the outside world.

- We take care of the practical organisation of the seminars of STCE scientists or visitors: invitations, rooms, listing on the website.

2.2.3.1 Space Weather Show@planetarium

The planetarium is creating a Space Weather Show. STCE scientists, D. Berghmans, J. Dekeyser, R. Van der Linden, P. Vanlommel were member of the scientific panel that had the task to correct the scientific content of the scenario. There have been several iterations on the script.

- Info session and tour for the scenarist, ROB, Brussels, March 04
- Discussion of the scenario, Planetarium, November 27

2.2.3.2 Information given to the public

The Sunspot debate

Contrary to the level of solar activity, 2008 was filled with excitement about the absence of sunspots, the duration of the solar minimum, the observational differences between pores and sunspots, the treatment of the International Sunspot Index. Wrong interpretations of the International Sunspot Index about the calculation and about the content of the index itself, led to speculative remarks and unscientific statements with which the amateur astronomers were left. We tried to clarify those issues on amateur websites dedicated to sunspots. We published the text 'The sunspot number clarified'. Questions from Belgian observers were addressed during an oral presentation. We started with a gathering of a solar dictionary. The goal is also to have a scientific publication. When observers, scientists or simply interested people need information about sunspots, this publication can serve as a unique reference.

Publication

- *The sunspot number clarified*
  http://www.sidc.be/news/106/sunspotnumberclarified.pdf

Oral presentation

- *Alles wat je wilde weten over het zonnevlekkengetal (maar nooit durfde vragen)*
  Annual réunion VVS-werkgroep Zon, Grimbergen, Nov 08

Space Weather

A series of educative information sessions was given to amateur astronomers about Space Weather, as well as publications in popular science magazines: see [1], [2].
At the KULeuven, CPA, a whole day workshop for last year (high school) students was organized. The theme was the Sun and space weather. The STCE gave a workshop on space weather forecasting for students. The demo version is shown in Figure 4.

- P. Vanlommel, *How to become a space weather expert in 60 minutes*, KULeuven, Mar 10, 2009
- P. Vanlommel*, De Zon in het vizier*, Urania, Hove, Oct 21, 2008.
- P. Vanlommel*, De Aarde in de ban van de Zon*, Urania, Hove, Oct 07, 2008,
- P. Vanlommel and M. Krijger: *Space Weather: international affairs and beyond*, Utrecht, the Netherlands, Feb 16, 2008,

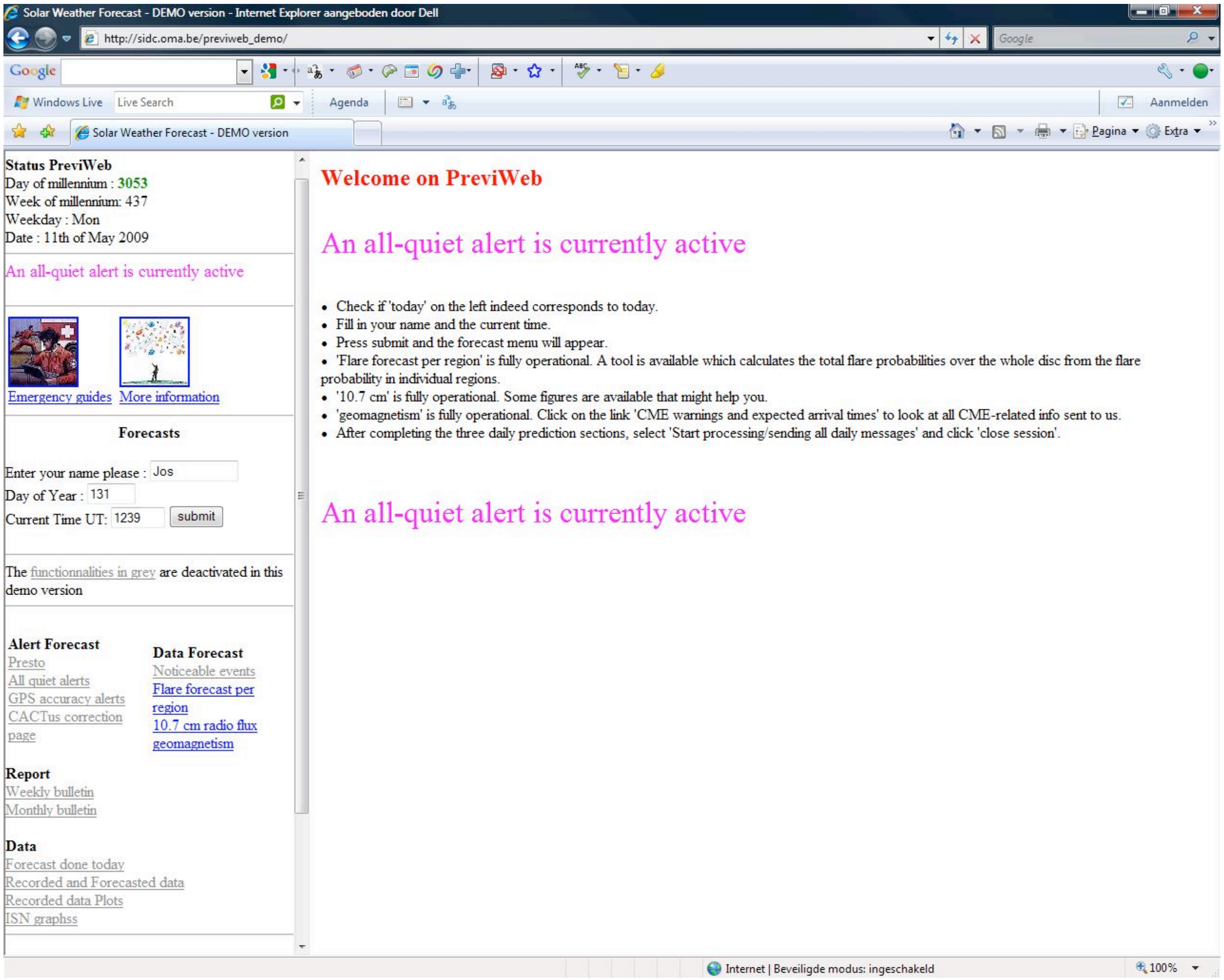


Figure 4 Snapshot of the demo version of previweb, the webpage for forecasting space weather by the Regional Warning Center for Western Europe. The RWC is a part of the STCE. The demo version is specially created for workshop. Students can do a space weather forecast without interfering with the real forecast. They immediately see their bulletin after pushing the submit button.

Information for the general public

The website www.ikhebeenvraag.be is an initiative of the Royal Belgian Institute of Natural Sciences with the support of the 'actieplan wetenschapsinformatie en innovatie' of the Flemish goverment. Scientists registered for it answer questions related to space, Sun and space weather.

We often respond to questions sent to us by mail. The hottest topic was the doom scenario linked with the date 20-12-2012.

Besides our presence on the web, we are always available for interviews.

- MIRA, Grimbergen, Mar 10, 2009
- 11 year old student, Feb 27, 2009

We paid special attention to the organization of The DREAM-day on Mar 13, 2008. This was a successful project for youngsters interested to learn about careers at a company of their choice. A French class visited the STCE. The purpose was to show the real-live working environment and the employees' perception of it. Technicians, scientists tried to answer several questions:

- Why working at a scientific institute?
- How a career looks like?

- What can trigger you to go into science?
- What skills are necessary to perform this job: education, language-knowledge?
- How combining a job with a family?
- Going abroad?
- What is the fun part of the job?

2.2.3.3 Information given to the media

Press releases

The press releases are distributed to journalists and published on the web.

- *Belgian GPS station on the South Pole,* Jan 22, 2009
- *European experts meet again in Brussels to predict the weather in space, A European answer to a threat from space,* Nov 12 2008
- *Belgian solar physicists win prizes, Scientific results thanks to a 12 years old space based telescope,* May 30 2008
- *A new center of Excellence,* Nov 20, 2007
- *European Space Weather Week,* Nov 05, 2007

Press interviews related to

- www.ikhebeenvraag.be: telephone radio interview (radio Donna), May 06, 2008.
- Press conference www.ikhebeenvraag.be: answer on questions from the Vlamish minister of science, Ceysens. May 06, 2008, KBIN, Brussels

2.2.3.4 Educational responsibilities

- KSB Gecertificeerde opleiding "Technisch deskundige"
    - *Concepten en methodologogieën vna de aard-en ruimtewetenschappen*
    - Deel 3: de Zon
    - Deel 5.2: Invloed van de zon op de technologie
    - Deel 5.3: De zon en het klimaat van de aarde
- The EPO officer, Dutch, took the responsibility for these parts: making of the syllabus, the exam question, translating, give the course on October 14 (full day, part 3) and on October 28 (part of the day, part 5.2 and 5.3)
- Thesis 'De Zon', Jasmine Van Regenmortel, sixth grade, Stella Matutina-Instituut Wuustwezel

2.2.3.5 Visits

Different tours where guided by the science communicators. The public gets information about the ration Sun-Earth and space weather. Special attention is given to the solar telescope from the WP concerning RWC + WDC space weather services.

- February 04, 2008, amateur astronomers
- March 04, 2008, scenarist
- March 18, 2008, VUB
- April 04, 2008, Skycom, science communicators.

On April 02, 2009, Students of the sixth grade visited the BIRA, the RMI and the ROB. Employees of these institutes talked about their job and their education.

2.2.3.6 Courses and Workshops

How to communicate with thirds is a skill that the outreach-officers have to become familiar with.

- Meeting sky communicators, Apr 04, 2008, ROB, Brussels
- Workshop wetenschapspopularisering, Feb 25, 2008, IMEC, Leuven

- Infonamiddag VRT, Feb 19, 2008, Brussels
- Workshop wetenschapspopularisatie, Feb 25, 2008 IMEC, Leuven
- OFO-training: media relations, Jan 2008, Brussels
- 2de Laboratorium voor Kennis en Wetenschap', Jun 25 2007, VRT, Brussels
- Laboratorium voor Kennis en Wetenschap', Dec 10 2007, VRT, Brussels

2.2.4 Perspective for next years

2.2.4.1 The sixth European Space Weather Week

ESWW6, which will be held on Nov 16-22, 2009 in Brugge will also give new occasions to broaden the scope of the conference. New ideas are brought in such that the space weather week becomes innovative. The new idea this time is to organize a debate on 'solar influences on climate'. This for sure will attract the attention of a community much broader then the space weather oriented one. Besides that, the 'Tutorial' will again be organized.

2.2.4.2 Participation to 'Le Bourget'

The STCE will have a stand at the 'International Paris Air Show' in 'Le Bourget', contributing to the international visibility.

2.2.4.3 Planetarium show

The Planetarium show about space weather will be finished by autumn of 2009.

2.2.4.4 Participation to the open doors weekend of the Space Pole

The STCE will present its main activities in a separate area at the occasion of the open doors weekend of the Space Pole

2.2.5 Publications

2.2.5.1 Publications on the web

- Solar radio silence ended, May 08, 2009
- Visit of the godfather of the solar wind, E. Parker, Feb 10, 2009
- A first radio burst at Humain, Dec 15, 2009
- The European Space Weather Week, the final result, Dec 11 2009
- The sunspot number clarified, Sep 18, 2008
- Partial Solar eclipse observed in Belgium, Aug 01, 2008
- Solar cycle 24 sunspot, Apr 14, 2008
- First light, Mar 17, 2008
- A first cycle 24 sunspot, Jan 08, 2008
- Start of solar cycle 24, Dec 13 2007

2.2.5.2 Publications in popular journals

[1] P. Vanlommel
Het weer in de ruimte
Zenit, 5, 223-226, 2008

[2] P. Vanlommel, M. Mierla, L. Rodriguez, A.N. Zhukov, D. Berghmans, R.A.M. Van der Linden, S. Gissot, O. Podladchikova, E. Robbrecht
STEREO: een dubbele dosis Zon
Heelal, 53, 396-408, 2008

3 STCE@ROB

3.1 SIDC space weather services

Responsible person: David Berghmans, email: David.Berghmans@sidc.be

This work package is related to

- B: providing space weather services,
- D: ground-based solar monitoring,
- E: developing advanced technology for solar observations,
- G: studying the interaction of corpuscular radiation with the terrestrial magnetosphere,
- H: studying the interaction of solar electromagnetic radiation with the terrestrial atmosphere,
- I: GNSS-based ionospheric monitoring in support of space weather services and GNSS applications.

3.1.1 Overall Description

The ROB/SIDC group hosts the World Data Center (WDC) for the Sunspot Index since 1981 and the Regional Warning Center (RWC) of the International Space Environment Service (ISES) for Western Europe since 2000. The ROB/SIDC group is actively involved in the ESA SWENET network. We monitor the solar and geomagnetic activity over time scales from the solar cycle (the sunspot index) down to real-time flaring alerts. Space weather messages are produced by a daily operator and by automated data processing.

In the past years we have built up considerable IT infrastructure for the monitoring of solar activity (http://sidc.be/SWB), for the automated detection of coronal mass ejections (http://sidc.be/cactus, http://sidc.be/nemo) as well as for the logistic handling of incoming/outgoing space weather messages over the ISES network ('previmaster', http://www.sidc.be/products/) and the collection of sunspot observations from stations worldwide ('WOLF interface', http://sidc.be/WOLF). The present work package deals with the maintenance, development and further expansion of the operational service of space weather monitoring, alerting and forecasting.

3.1.2 Long Term Goal

In the US, space weather services are significantly ahead of Europe. The *Space Weather Prediction Center (SPWC)* operated by NOAA in Boulder is the reference for space weather services, also for European users. Our long term ambition is to grow into a European equivalent of the SPWC with complementary and/or improved services.

3.1.3 Personnel involved

Following the arrival of funding in November 2007 and the kick-off meeting in Mach 2008 we have identified and selected the following key personnel in this work-package:

- Laurence Wauters (STCE staff). Specific responsibilities: database management and WDC (WOLF interface) maintenance/developments.
- Sarah Willems (STCE staff). Specific responsibilities: IT infrastructure and RWC (previmaster) maintenance/developments
- Bogdan Nicula (STCE staff, 50% shared with ROB WP A5). Specific responsibilities: advanced software technology, including development of "Solar Weather Browser".

Important contributions to this work-package are also made by

- Ronald Van der Linden (ROB staff). Specific responsibilities: SIDC RWC/WDC director, WDC support scientist, emergency support
- David Berghmans (ROB staff). Specific responsibilities: STCE work package responsible, space weather science support, emergency support
- Frederic Clette (ROB staff). Specific responsibilities: local data capture responsible, space weather science support, emergency support
- Petra Vanlommel (STCE staff, WP COMMON 2). Specific responsibilities: editing of review bulletins, updating of website news-bulletins
- Olivier Boulvin (ROB contractual), contributes monthly shifts as WDC operator; occasionally other ROB staff assume the same role.
- Several SIDC post-docs (ROB contractuals) contribute daily shifts as RWC forecaster.

3.1.4 Activities

RWC Belgium is a permanent service center specializing in solar monitoring and solar activity forecasting. It is run by the SIDC under the auspices of the ISES network. Its solid base is the solar physics research undertaken at the SIDC and our involvement in solar observations from space and ground, giving access to a large volume of solar and heliospheric data that can collectively span operational requirements. Building on insights derived from our scientific studies, the SIDC provides expert and timely information on and assessment of solar dynamics and its likely relevance for human technology.

3.1.4.1 Internal Management

Communication acts on two levels: internal and external. Good Internal communication is one of the necessities to perform well. A website, regular meetings, email contact, (in)formal live contacts, ... can contribute to a good internal communication. The RWC-performance is being guided by the RWCWDC-wiki (http://sol042.oma.be:8000:RWCWDC), regular internal meetings and a more general SIDC consultation meeting [22] open for the whole departement. With open communication in mind, the departement 4 days were organized. The RWC was presented as an operational service [16], [17], [18], [19], [20], [21].

3.1.4.2 External Management

The RWC Belgium was represented on several meetings and reunions relevant for the space weather business. R. Van der Linden introduced the RWC as a member of the International Space Environment Service (ISES) at a UN-COPUOS meeting [3]. UN-COPUOS is a UN committee for the Peaceful Use of Outer Space. These meetings are important for the visibility of the RWC broader then only the space weather community.
The RWC Belgium is also an important player in the ISES and FAGS structure ([4], [5], [6], [7], [11], [27],[28]), in the present COST activities [13] and the general Space Weather community [14],[15].
Being present at international level is one of the key issues to get involved in future projects like the European Space Situational Awareness program.

3.1.4.3 Routine operations

For the RWC activities, a continuous data stream from ground-based spacecraft instruments has to be analyzed and interpreted. The daily routine of RWC activities include different tasks:

- *Data distribution*. The RWC acts as a hub for further distribution of solar and geophysical data, mostly in the form of ISES encoded messages.
- *Monitoring solar activity and space weather*. To maintain a high standard in our activities as an RWC, we develop and use software that autonomously detects space weather events. This service is timely and assists the forecaster on duty in his monitoring and alerting task. Examples are CACTus (CME detector), B2X (flare detector), and NEMO (EIT-wave detector). These monitoring activities result in an alert service. Most of the warnings are sent out automatically in several alert-type messages, though some alerts need human intervention.

- *Forecasting solar activity and space weather*. Reports and forecasts of solar activity and space weather conditions are distributed every day (including weekends and holidays) at approximately 12:30 UT in the 'ursigram' messages. Weekly summaries are sent out in principle on Mondays, while more extensive monthly summaries of solar and geomagnetic activity are included in the Sunspot Bulletin of the SIDC. The latter also includes medium-term forecasts of the evolution of the sunspot cycle. This results in publications [25] and [26].

On the technical level, the monitoring, alerting and forecasting services of the RWC contain three main aspects: client database management, production of data/messages and delivery of data/messages. These activities are managed in a semi-autonomous way by the software package *PreviMaster*, which handles the solar data, the forecasts and alerts in conjunction with a database. The interface between the human operator and the *PreviMaster* package to receive the daily forecasts, manually triggered alerts and other subsidiary information, is a secured web-based tool called called *PreviWeb*. Continuous maintenance and upgrade of these two packages, and the SIDC website itself, is an important never-ending task.

The WDC is responsible for the Computation, publication and diffusion of the International Sunspot Number and additional indices:

- Total, hemispheric and central zone sunspot number
- Monthly provisional index
- Definitive sunspot index (quarterly)
- Additional indices: PPSI, sunspot areas
- Mid-term forecasts of the total sunspot number (Waldmeier and Cugnon-Denkmeier methods)

The calculation and production of the International Sunspot Number (the Estimated, the Provisional and the Definitive International Sunspot Number) is based on the collected wolfnumbers. The wolfnumbers of each observer are put into the database by the observers through a dedicated website, the WOLF-interface.

New Developments

The **Solar Weather Browser** (SWB) is a tool that allows easily displaying and combining solar images from different observatories together with solar metadata, without the need of data processing. For the forecast team, the SWB offers an easy tool to browse through solar data while performing the forecast and monitoring the sun. A renewed effort was done on the server side of the SWB. The daily maintenance of the tool became again a priority. This included also the storage of the downloaded Hα images from the Kanzelhohe Observatory and the preparation for inclusion of our own USET Hα and white-light data.

The **CACTus** software was developed originally to run on LASCO coronograph images. The software is although applicable on images obtained from the Sun Earth Connection Coronal and Heliospheric Investigation (SECCHI) aboard the Solar TErrestrial RElations Observatory (STEREO) Ahead and Behind. STEREO is a fleet of two identical spacecrafts. We have now the ability to watch coronal mass ejections from 3 points of view: STEREO Behind, SOHO and STEREO Ahead. Given the separation angle in 2008 between the two satellites, COR1 and COR2 from the SECCHI-package give us the possibility to give a more precise estimate of the speed of an earthward directed CME. Combining remote and in situ data of the three spacecrafts, we are able follow in some cases a CME on its path through space.

We illustrate this with an example in Figure 5 and Figure 6. On Apr 26, 2008, a prominence eruption took place. The event was associated with a B3.8 flare peaking at 14:08 UT. A CME was detected in the LASCO-images. CACTus, detected a partial halo CME in the LASCO-images. A solar surface EUV-wave, a 'solar tsunami' combined with a coronal dimming was clearly visible in the SOHO/EIT and STEREO/EUVI images. "NEMO" (Novel EIT wave Machine Observing) scans systematically the many thousands of images searching for EUV-waves as a proof of a CME. A structure preliminarily identified as an interplanetary shock was detected by ACE on Apr 30 around 15:00 UT. It marked the arrival of an interplanetary disturbance associated with a partial halo CME on Apr 26. The interplanetary CME (ICME) itself seemed to have missed the earth, and only the plasma Shock wave was detected. The interplanetary magnetic field went down to -8 nT in the aftermath of the shock. Disturbed geomagnetic conditions (K=5 reported by IZMIRAN and NOAA and K=4 by Dourbes) were registered. The complete STEREO/SECCHI instrument suite detected the CME: EUVI, COR1-2 and HI1-2. HI-2 onboard STEREO Ahead had a nice side-way view on the cloud traveling through space and pictured the moment the erupted prominence reached earth. In situ solar wind data made clear that one leg of the cloud passed STEREO Behind on Apr 29, the shock passed ACE on Apr 30, while STEREO Ahead measured only a minor change in the solar wind parameters early on Apr 30.

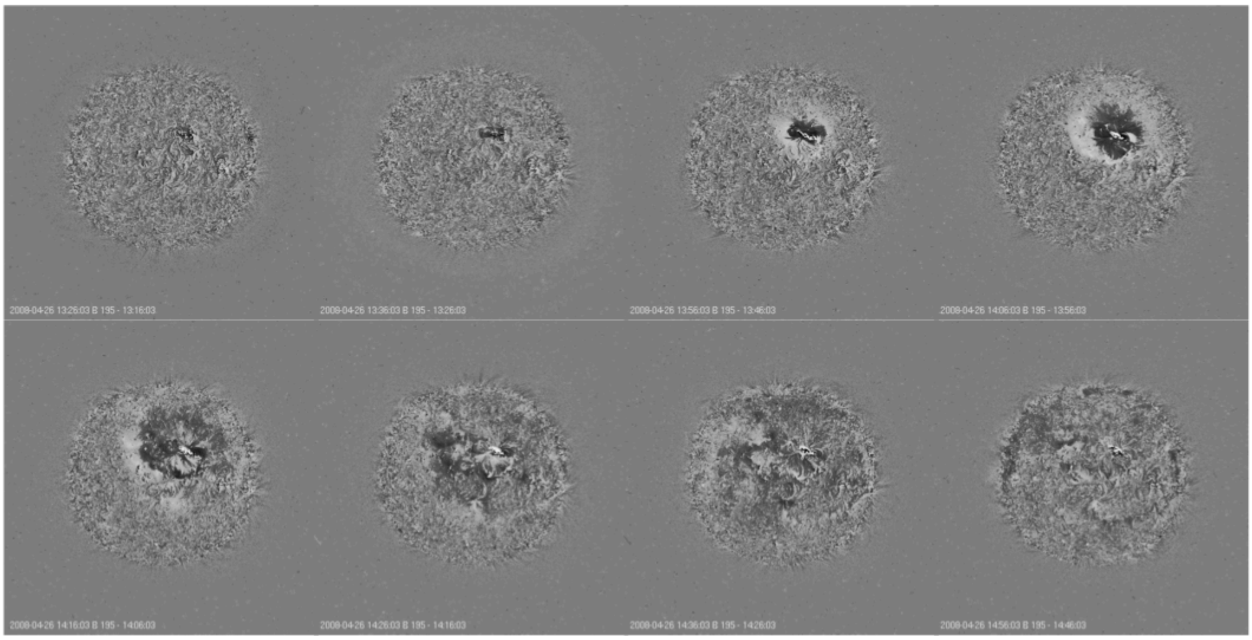


Figure 5. ***This is a sequence of difference images from the EUVI telescope aboard of the STEREO Behind. By taking the difference of two succeeding images, the changing's become visible. A solar tsunami or EUV-wave is visible. The tsunami runs over the solar disk. An EUV-wave is a signature of a CME.***

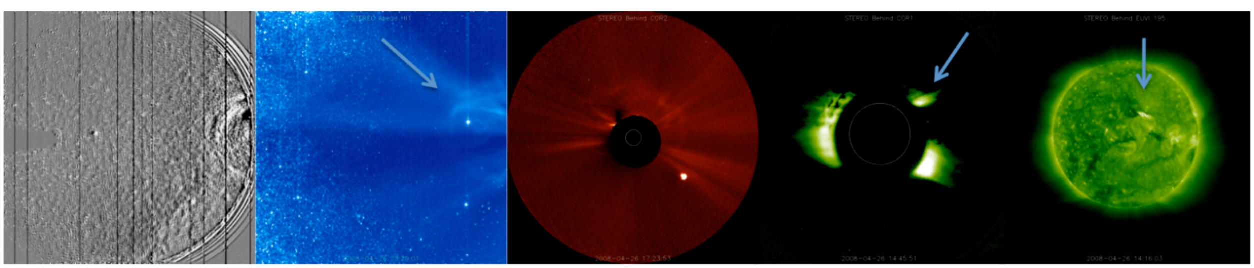


Figure 6 ***The eruption and the plasma cloud was seen by the complete SECCHI set of telescopes. From right to left: EUVI, COR1, COR2, HI1 and HI2. The first three images mentioned are taken by STEREO B. The last two images are taken by STEREO A and give a side view of the plasma cloud. On HI1 and HI2, the Earth on the left side of the image is behind the occulter. In EUVI, we see the post flare loops. The cloud passed COR1 and COR2 in which is appears as a halo CME, i.e. directed to the observer***

NEMO (Novel EIT wave Machine Observing), a new software package for detection of EIT waves forms one block of the Space Weather software package together with CACTus (the CME detector which works with coronograph data). NEMO consists of a series of high level image processing techniques especially developed to extract eruptive features from the EUV solar disk. This technique is based on the

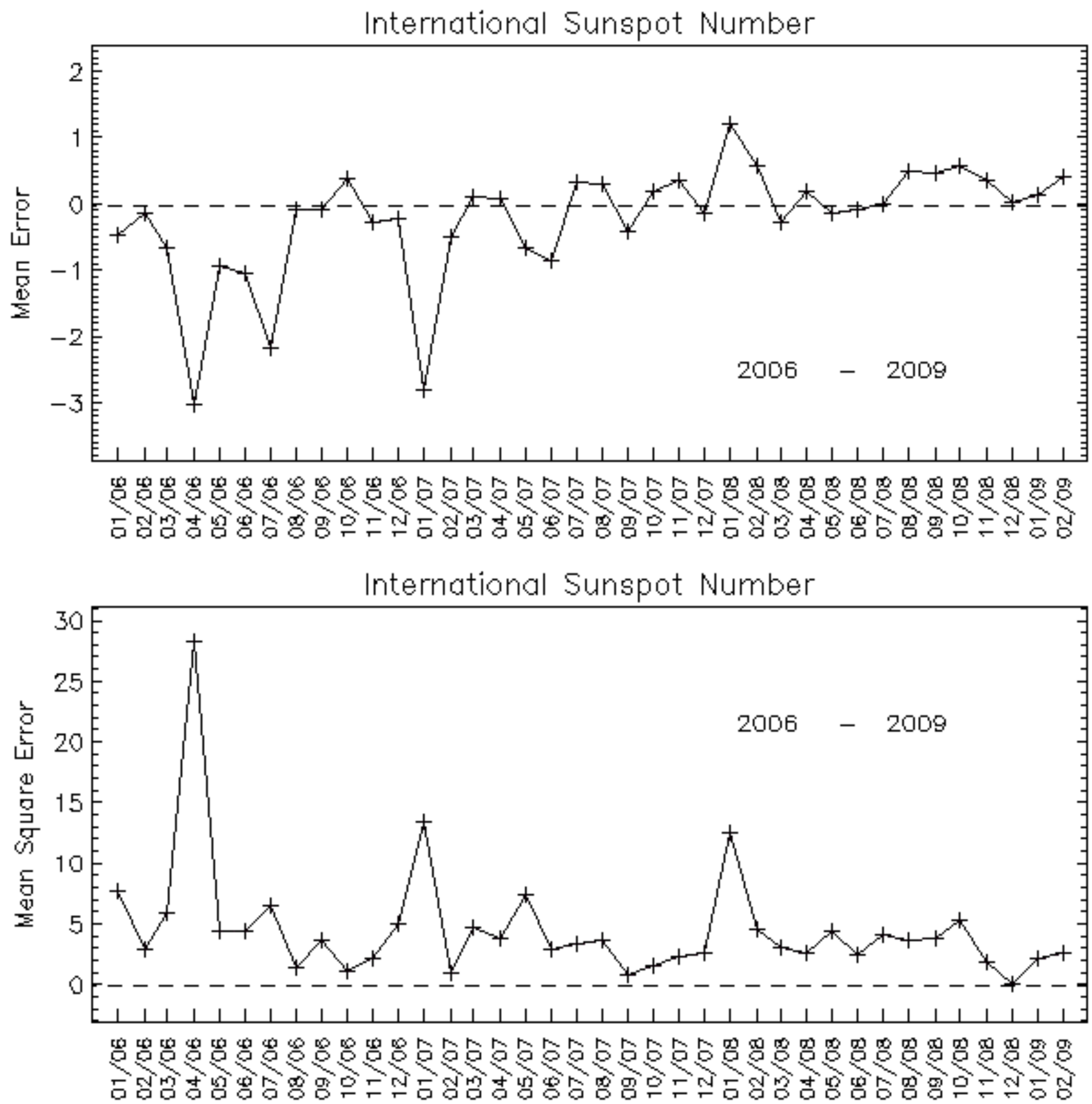


Figure 7 The monthly mean error and monthly mean square error of the Estimated International Sunspot Number is shown from Jan 2006 up to the present. The mean error is calculated as the mean of (PISN – EISN). Values below zero, indicate that the EISN underestimates the International Sunspot Index. The mean square error makes it easy to compare individual months: during Jan 2008, the EISN gave a almost perfect estimate of the PISN.

general statistical properties and underlying physics of eruptive on-disk events. Such events are tell-tale signs of coronal mass ejections that are not always seen by coronographs.

NEMO runs automatically on a daily basis. The real time results are made available online: http://sidc.be/nemo. If the CME is associated with a flare, the profile of the X-ray flux curve gives an indication of the fact that an eruptive plasma event occurred. The type of radio outburst is another way to identify CMEs. NEMO gives also a clear indication of the strength of the event. NEMO runs on EIT and STEREO data.

All **monthly reports** from 1981 **are archived** in a digital form and available online in pdf-format. From 1981, when the SIDC as Sunspot Index Data Center was founded, up to the end of 2000, the bulletin reported the Provisional International and hemispheric daily sunspot numbers: daily, monthly and the summary of the ursigrams. From Jan 2001 onwards, the report was extended with the section ‘Monthly Summary of Solar and Geomagnetic Activity’.

The evaluation of the **Estimated International Sunspot Number** (EISN) is updated. The EISN is a solar activity index calculated on a daily basis. This solar activity index is sent within the ursigrams. The sunspot counts that are inserted by the observer before 12:30 UT in the Wolf database are used as input. The monthly mean error and monthly mean square error are made internally available through previweb. We compare the EISN with the daily Provisional International Sunspot Number (PISN) in **Error! Reference source not found.**.

The SIDC was invited by Dr. M. Bianda, Director of the IRSOL (Locarno, Switzerland), to present a keynote lecture at the occasion of a workshop dedicated to Sergio Cortesi, main observer of the reference Locarno station for the last 50 years. This was also the occasion to announce officially the nomination of Sergio Cortesi as Correspondent Astronomer of the Royal Observatory of Belgium. Moreover, the bases for future collaborations were established, including the digitization of the Zürich-Locarno sunspot drawing collection, maybe already in the framework of the SOTERIA project. In that perspective, contacts were also established with the Library of the University of Zürich where the original paper drawings from the Zürich Observatory are preserved.

More detailed information was also exchanged about the sunspot observing practices at the Locarno station. This led for instance to the adjustment of the observing quality scale for the Locarno station in the spring of 2008. Moreover, the archive of original observing reports from the Zürich period of the WDC-sunspot was transferred from Locarno to the WDC in Brussels in April 2008. This archive is being digitalized.

A meeting with the company THALES was set up to investigate the possible common interests regarding space weather applications.

The following development activities are ongoing:

- Finalization of the transfer of the WDC observing network from the old mail/e-mail data collection system to the WOLF-interface
- Modernization of the sunspot index calculation from FORTRAN to SQL-database queries.
- First studies to migrate the different servers to a system of virtual servers for enhanced redundancy
- Discussions with the RMI, partners in the STCE, on the K-index alert services.
- Participation as external expert (R. Van der Linden) to the Solar Cycle 24 Prediction Panel set up by NASA/NOAA and ISES.

Organization of Meetings, Events and Public Outreach

The RWC concerns the involvement of the scientific space weather community, commercial and amateur organizations and the general public. Special attention is given to the users. This human aspect triggers necessarily *space weather education* and the awareness of the society. In view of this, the RWC pays special attention to publicity and promotion of space weather and related activities. Our **website** is the ultimate window to the space weather community and the public on which for example on a regular basis ‘News Items’ are posted: http://www.sidc.be/news/index.php.

E. Podladchikova got the internationally recognized Zeldovich medal pinned up during the COSPAR conference in Canada. The medal is conferred for excellence and achievements. D. Berghmans and his colleagues in the EIT-consortium were nominated for the prestigious European Descartes prizes for the unique and excelling contributions to solar physics and space research. A press release was written by the EPO-officers.

Contrary to the level of solar activity, 2008 was filled with excitement about the absence of sunspots, the duration of the solar minimum, the observational differences between pores and sunspots, the treatment of the International Sunspot Index. Wrong interpretations of the International Sunspot Index about the calcu-

lation and about the content of the index itself, led to speculative remarks and unscientific statements with which the amateur astronomers were left. We tried to clarify those issues on amateur websites dedicated to sunspots. We published the text 'The sunspot number clarified' [23], Questions from Belgian observers were addressed during an oral presentation. We started with a gathering of a solar dictionary. The goal is also to have a scientific publication. When observers, scientists or simply interested people need information about sunspots, this publication can serve as a unique reference.
The planetarium@Heizel is creating a Space Weather Show. Scientists of the SIDC were members of the panel that had to correct the scientific content of the scenario. The scenarist found his inspiration from the daily routine work done at our Regional Warning Center. There have been several iterations on the script.
A series of educative information sessions was given to local amateur astronomers about Space Weather, see section 3.1.7, as well as publications in popular science magazines: [29] and [30]. Besides the general public, the communication with the scientific community is also a goal: e.g. tutorials for PhD-students, scientists, see [10].
Several scientists of the RWC-WDC are involved in the project: 'www.ikhebenvraag.be'. This is an initiative of the Royal Belgian Institute of natural sciences with the support of the 'actieplan wetenschapsinformatie en innovatie', the Vlamish government. Space Weather Scientists answer questions related to the topic of solar physics: space, Sun, space weather.
During the fifth European Space Weather, a fair was organized. The fair was intended as a hands-on workshop to show products, services to the space weather community. The SIDC/RWC was present with a lively and, as I may say so, a nice stand. On a daily basis, the space weather was broad casted. Visitors could browse through solar data with the Solar Weather Browser while explanation was given by one of the forecasters. A radio antenna was installed measuring real-time the radio waves in the local environment. This was a reference to the ROB radio station in Humain, Belgium.

3.1.5 Partnerships

3.1.5.1 Existing non-STCE funding

- ROB personnel
- PRODEX Telescience
- FAGS support and subscription fees to the Sunspot Bulletin
- The SOTERIA project (EU FP7)

3.1.5.2 Opportunities and collaborations

- The new ESA program for Space Situational Awareness
- International Space Environment Service
- Federation of Astronomical and Geophysical Data Analysis Services
- Potential synergy with operational forecast and alert distribution of IRM
- The COST ES0803 action
- Links established through UNCOPUOS
- SWENET: http://esa-spaceweather.net/swenet/index.html
- Worldwide network of 89 solar observatories in 29 countries

3.1.5.3 National partners or collaborators having actively contributed to the project in the last year

- ROB Planetarium
- RMI and BISA

3.1.5.4 Visitors:

- David Boteler, ISES, 27/02/2008.
- Scenarist Planetarium Space Weather show, 04/03/2008.
- M. Vandenhove, THALES, 03/09/2008.

➢ Nilson Sant'Anna, RWC Brazil, 24-25/11/2008

3.1.6 Scientific outreach

3.1.6.1 Meeting presentations

[3] R. Van der Linden
Space Weather: an international affair – and beyond
UN-COPUOS, February 08, Paris, France

[4] R. Van der Linden
Annual report FAGS service: the SIDC
FAGS annual meeting, April 24, Paris, France

[5] R. Van der Linden
Annual RWC report
ISES annual meeting, July 10-11, Ottawa, Canada

[6] R. Van der Linden
UNCOPUOS activity report
ISES annual meeting, July 10-11, Ottawa, Canada

[7] R. Van der Linden
RWC Belgium@Solar Influences Data Analysis Center
COSPAR, July 13-20, Montreal, Canada

[8] F.Clette
Four centuries of sunspot index: from Wolf to the SIDC
Geological Survey of Canada, August 21, 2008 Ottawa, Canada

[9] F.Clette
L'indice des taches solaires sur 4 siècles: de Wolf au SIDC
Groupe de Recherche en Physique Solaire, August 25, 2008, Montreal, Canada

[10] D. Berghmans
Sun-Earth System: Space Weather
Lecture at the STFC Summer school « Intro to Solar & Solar-Terresterial Physics », Septembre 16, Sheffield, UK.

[11] R. Van der Linden
The Belgian Solar-Terrestrial Center of Excellence: Building Space Weather Capacity in Europe
IAASS3, October 21- 23, Rome, Italy

[12] P. Vanlommel
How to become a space weather specialist in 60 minutes
ESWW5, November 16-20, Brussels, Belgium.

[13] R. Van der Linden
COST ESO803 WG2: Space Weather Products and Services
COST ESO803 Kick-off meeting, November 16-17, Brussels, Belgium.

[14] R. Van der Linden
The SIDC at the Solar-Terrestrial Center of Excellence
ESWW5, November 16-20, Brussels, Belgium.

[15] R. Van der Linden
European Resources for Space Weather Applications: An Overview of Existing and Planned Data, Tools and Services.

ESWW5, November 16-20, Brussels, Belgium.

3.1.6.2 Seminars

[16] P. Vanlommel
External services based on data: Products and User-profile
Dep 4 Days, Februari 21, Brussels, Belgium.

[17] P. Vanlommel
Scientific-Educational Public Outreach/Inreach
Dep 4 Days, Februari 21, Brussels, Belgium.

[18] S. Willems
Server structure at the SIDC
Dep 4 Days, Februari 20-21, Brussels, Belgium.

[19] L. Wauters
Database management at the RWCWDC
Dep 4 Days, Februari 20-21, Brussels, Belgium.

[20] F. Clette
Sunspots: internal, historical and future aspects
Dep 4 Days, Februari 21, Brussels, Belgium.

[21] C. Marqué
The RWC: daily forecast
Dep 4 Days, Februari 20-21, Brussels, Belgium.

[22] R. Van der Linden
The future of Space Weather at SIDC
Internal SIDC team consultation, December 18, Brussels, Belgium.

3.1.6.3 Wikis and Websites

- Internal development wiki: http://sol042.oma.be:8000:RWCWDC
- Internal development wiki: http://pb2sc.oma.be:8000/ESWW/
- http://www.sidc.be/esww5
- http://www.sidc.be/esww6
- http://www.sidc.be/

3.1.7 Information given to the public

- P. Vanlommel and M. Krijger: *Space Weather: an international affaire and beyond*, Utrecht, the Netherlands, February 16
- P. Vanlommel, *De Aarde in de ban van de Zon*, Urania, Hove, Belgium, October 07
- P. Vanlommel, *De Zon in het vizier*, Urania, Hove, Belgium, October 21.
- P. Vanlommel, *Alles wat je wilde weten over het zonnevlekkengetal (maar nooit durfde vragen),* VVS, Grimbergen, Belgium, November 08.
- D. Berghmans, *PROBA2 satellite: pre-launch briefing*, Urania, Hove, Belgium, December 16.

3.1.8 Representation at international level

- R. Van der Linden: Representation in ISES Board.
- R. Van der Linden, D. Berghmans, P. Vanlommel: Space Weather Working Team.
- R. Van der Linden, P. Vanlommel: member of the scientific organizing committee of the fifth European Space Weather Week.
- R. Van der Linden: member of the Space Situational Awareness Users Group

3.1.9 Missions

Assemblies, symposia:	Fifth European Space Weather Week, Brussels, Belgium COSPAR, Montreal, Canada ISES annual meeting, Ottawa Canada FAGS annual meeting, Paris, France IAASS3, Rome, Italy UN-COPUOS, Paris, France UN-COPUOS, Glasgow, UK URSI General Assembly, Chicago, USA
Commissions, working groups (days):	Space Weather Working Team (Jun 04, Nov 19)

3.1.10 Perspective for next years

In general terms, we plan to consolidate the current RWC activities with similar activities of other partners in the STCE and to continually modernize and upgrade the WDC and RWC data processing. More specifically we plan to:

- Explore opportunities for new or better services on the basis of new solar data that will become available in 2009 (PROBA2/SWAP&LYRA, SDO, PICARD, Humain Radio data).
- Bring online new automated data analysis tools that have been developed in the ROB/SIDC group and that are ready to transition to an operational context (NEMO, SOFLEX, Velociraptor)
- Improve the redundancy and the error/warning reporting of the deployed IT-infrastructure. Experiments will be conducted with tools for inter-process communication in support of the solar feature recognition tools.
- Study (and optionally invest) in a system of virtual servers for increased redundancy
- Identify and develop well targeted new space weather services and products for specific user (groups)
- Improve the availability and the dataset served through the Solar Weather Browser (SWB). JPEG2000 functionality will be added and experiments with other (streaming video) compression schemes will be conducted
- Support will be given to the development of the PROBA2 Science Center (goal: ready by mid 2009)
- Statistical studies will be performed for the evaluation of the forecasts generated at RWC Belgium (quality control)
- The procedures for the calculation of the different solar indices will be revised
- The backlog of publication in the Quarterly Bulletin of Solar Activity will be at least partially cleared
- A new policy for the management of e-mail registration will be implemented
- New contacts will be established with satellite operators to try to gain their custom
- We will consider implementing RSS feeds.

3.1.11 Publications

3.1.11.1 Publications without peer review

[23] P. Vanlommel and the SIDC-team
The sunspot number clarified
Website: http://www.sidc.be/news/106/sunspotnumberclarified.pdf

[24] P. Vanlommel and the SIDC-team
News Items
Website: http://www.sidc.be/news/

3.1.11.2 Reports, Thesis, etc

[25] Van der Linden, R., Vanlommel P. and the SIDC-team,
SIDC Monthly Bulletin of Solar and Geomagnetic Activity, monthly issues
The Sunspot Bulletin

[26] The SIDC team
Outgoing messages from RWC Belgium: e.g. daily ursigrams, weekly bulletins, quarterly bulletins, Monthly Ri Reports, Monthly Ri_hemispheric Reports, all-quiet-alerts, presto alerts, halo CME alerts, GOES X-ray flare detection alert, reduced GPS accuracy alert, advance alert: enhanced geo-magnetic activity warning.
E-mail distribution. The alerts are sent when needed; the other bulletins are sent on a regular basis.

[27] R.A.M. Van der Linden and the SIDC team.
Annual report 2008 to the International Space Environment Service.
ISES Annual Report

[28] R.A.M. Van der Linden and the SIDC team.
Annual report 2008 to the Federation of Astrophysical and Geophysical data Analysis Services
FAGS Annual Report

3.1.11.3 Publications in popular journals

[29] F. Clette, D. Berghmans, P. Vanlommel, R.A.M. Van der Linden, A. Koeckelenbergh, L. Wauters
Du Nombre de Wolf a l'indice international des taches solaires: 25 ans de SIDC (1e partie)
Ciel & Terre, 124, 3, pp.66-75, 2008.

[30] F. Clette, D. Berghmans, P. Vanlommel, R.A.M. Van der Linden, A. Koeckelenbergh, L. Wauters
Du Nombre de Wolf a l'indice international des taches solaires: 25 ans de SIDC (2ème partie)
Ciel & Terre 124, 4, pp. 98-109, 2008.

3.2 Ground-based Solar Instruments

Responsible person: Frederic Clette, email: Frederic.Clette@sidc.be
This work package is related to the following research themes or objectives:

- B: Providing space weather services,
- D: ground-based solar monitoring,
- E: developing advanced technology for solar observations.

3.2.1 Objectives

The optical instruments of the Uccle Solar Equatorial Table (USET) are providing visual and CCD observations in support to the SIDC sunspot index determination and to the operational monitoring and forecast of solar eruptions within the STCE community but primarily at the international level. Those long-term continuous observations also provide base data for studies of the solar cycle and of irradiance variations. The USET activities thus follow two main axes:

- Optical observations of the Sun and characterisation of its activity:
  - Visual observations of sunspot, digitization and exploitation of drawings
  - White-light synoptic observations of the photosphere
  - Real-time flare patrol observations in the H-alpha line (chromosphere)
  - Near-UV chromospheric imaging in the CaII-K line for chromospheric irradiance proxies.
- Digitization and processing of the visual sunspot observations of the Uccle station:
  - Total, hemispheric and central zone sunspot number (raw and normalized)
  - Classification and history of individual sunspot groups
  - Study of new image-based sunspot indices

The above objectives imply the following developments of the USET instrumentation:

- Digital imaging systems in white-light (photosphere), in the Hα line (chromosphere) and in the CaII-K line (chromosphere)
- Telescope pointing system
- Telescope and dome automatization

The radio telescopes at the Humain station provide radio electric observations of the Sun for two primary purposes:

- The real-time monitoring and spectrographic study of radio bursts associated with solar flares and coronal mass ejections (CMEs) in support to flare alert services and solar flare research.
- The long-term recording of the absolute solar radio flux at discrete frequencies emitted in the upper chromosphere and low corona for the production of long-term solar activity indices and irradiance proxies, including 2,8Ghz (10.7 cm flux). This work builds on the expertise of the SIDC regarding long-term solar reference indices.

The new radio observations will also be complementary with the SWAP and LYRA data from the PROBA2 mission and will provide base solar data supporting the SIDC and STCE activities.

To achieve the above goals, major instrumental developments are undertaken as part of STCE Work Package 2 and proceed in the context of international collaborations. The following systems are now under development:

- New Generation Solar radio flux monitors at 6 discrete frequencies: including 2,8Ghz (10.7 cm flux) and the 600MHz.
- Radio spectrographs covering the 30MHz-3GHz frequency range (CALLISTO)
- Remote operation of the radio telescopes from Uccle: antenna control, data acquisition modes.
- Near-real time transmission and processing of the Humain data at the ROB-SIDC.

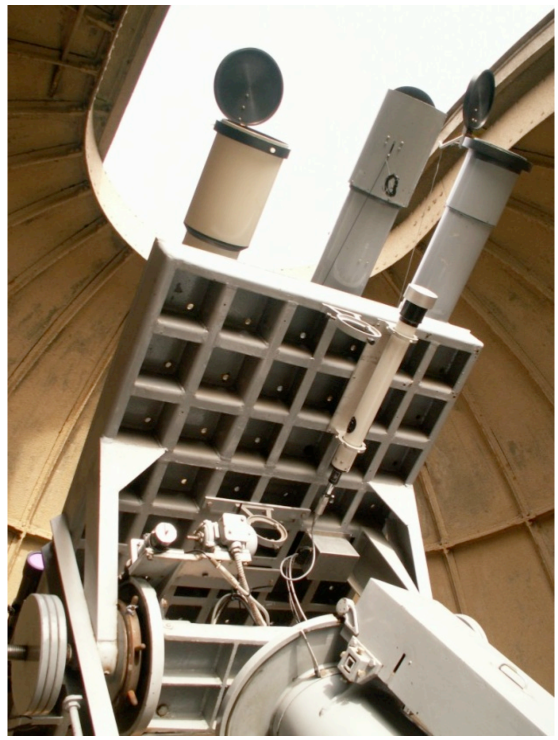


Figure 8 View of the underside of the Equatorial Table, showing the small pointer telescope with the sensor unit (4-quadrant photodiode) and electronic box.

3.2.2 Achievements

3.2.2.1 Solar Optical Observations

USET optical telescope upgrades

- Hα telescope: in January 2008, a new camera (QImaging RETIGA 4000R) was coupled with the new H-alpha optics, providing a 2-time increase in image resolution as well as more advanced controls (Figure 9).
- White-Light telescope: On June 25, 2008, a new camera identical to the Hα camera was installed on the white-light telescope. It also provides a doubling of the image resolution. In 2008, the image scale was not yet optimized for the larger CCD sensor dimensions. A new custom-made focal reducer was designed, built and installed in May 2009.
- CaII-K telescope: in December 2008, the telescope that will feed the system was selected and purchased (LOTTO budget): namely, an apochromatic refractor (Williams Optics) with a 132mm aperture. The design of the focal optics was undertaken in the spring of 2009.
- CCD software development: an entirely new camera control and image acquisition software, SUNCAP, was developed and implemented over the first half of 2008. This software features access to all control parameters of the new cameras but also special automated imaging modes allowing the sequential acquisition of synoptic images and of high-cadence images triggered by solar flares. The program is also built to accommodate future extensions like the remote control of the telescope focus and pointing. Due to the very low solar activity, the flare capture capability could not be tested yet.
- Independent motorized telescope pointing and focusing: by the end of 2008, high-precision linear translation stages were purchased (LOTTO budget). They will allow accurate independent centering of the images on the 3 telescopes as well as the motorized focusing. The system will be remote-controlled in order to integrate it with the image acquisition software and hardware located in the USET control room. One of the key capabilities of this mechanical setup will be to acquire easily and routinely controlled shifted image sequences necessary to extract the evolving camera flat-field correction, leading to photometrical calibrated images.

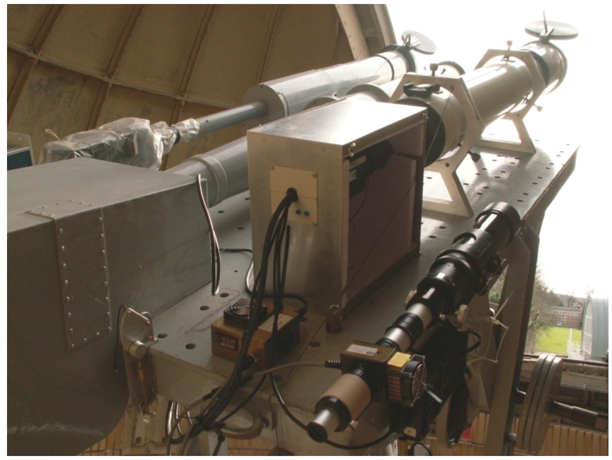


Figure 9: View of the new compact H-alpha telescope and Fabry-Pérot monochromator installed in a test configuration on the USET in 2007 (black optical tube on the lower right). The white-light and old H-alpha CCD telescopes in operation since 2002 can be seen on its left. The large enclosure in the center harbors the white-light CCD camera.

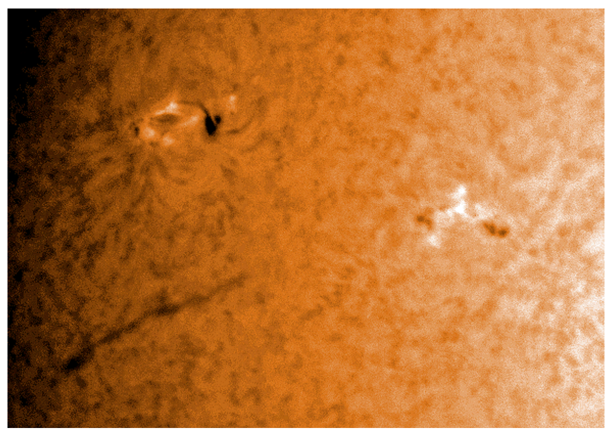


Figure 10: Close-up view of two small active regions and a filament extracted from a whole-disk Hα image produced with the new USET Hα telescope and QImaging Retiga 4000R camera (25/3/2008)

Data product	Nb. Days	Nb. Images
Visual sunspot drawings	246	297
CCD Photosphere	246	785
CCD Hα Chromosphere	246	1054
Total	**246**	**2146**

➢ Design and construction of a solar auto guider (Figure 9): in 2008, this development effort continued mainly as part of the 3-month training work of a graduate student in informatics.

Solar optical observations and data distribution

➢ Statistics for the USET observations produced in 2008 are given in the table below. Those data were made available in near real-time on the SIDC website as PNG images (Figure 9 and Figure 11) and archived in the global USET data archive (Figure 13). Those drawings and FITS images can be selected and downloaded through the dedicated database GUI (http://sidc.be/USET)

➢ 6 "core" observers did all observations. This marks the return to a normal observing team, following the recruiting of two vacant positions late in 2007.

➢ USET drawings were processed on a monthly basis in order to provide to the IAU WDC "sunspot", hosted at the ROB. The Uccle station is one of the reference stations of the WDC network. The resulting Uccle sunspot indices and sunspot group evolution data are published in the monthly SIDC "Sunspot bulletin".

➢ Daily operations involved the technical maintenance of the instruments and facility (no service interruption in 2008)

Drawing digitization and new photospheric activity indices

In the context of the SOTERIA project (SOLar-TERrestrial Investigations and Archives) funded by the European 7th Framework Program, we started to work on the following topics by the end of 2008:

➢ The global digitization of the Uccle collection of sunspot drawings: the existing DIGISUN program, already used routinely for the current drawing digitization and encoding, was rewritten and improved in 2008 (Fig. 6) and the development of an expanded version adapted to bulk digitization of large drawing collections took place in the first half of 2009. This application will be adaptable to other drawings collections in view of later digitization of other external collections.

➢ The study of new image-based activity indices derived from solar images of the photosphere (CCD, photographic): initial data sets (USET, SOHO/MDI). As this task requires the definition of common standards, by late 2008, we submitted an extensive list of all possible sunspot and sunspot group descriptors to the SOTERIA consortium in order to constitute a reference document and a common format that will facilitate the exploration of new solar activity indices.

Figure 11: Sample whole disk Hα image of a very quiet Sun with a fleeting intruder captured with the new USET Hα telescope and camera. The Sun was extremely quiet in 2008 with extended spotless time periods

Preliminary contacts were also established with the solar team of the Astronomical Institute in Tatranska Lomnica (J. Ribak) and with the Specola Solare Ticinense (M. Bianda, S. Cortesi) in order to prepare a coordinated digitization of other drawing collections, covering complementary time intervals next to the Uccle drawings.

3.2.2.2 Solar radio observations

The newly recruited radioastronomer, Christophe Marqué (Jan. 2008), allowed to start the actual redeployment of solar radio instruments at the Humain station in the context of the STCE. Most of the efforts are now concentrated into the construction of an entirely new set of instruments that will progressively be put in operation over the next 3 years.

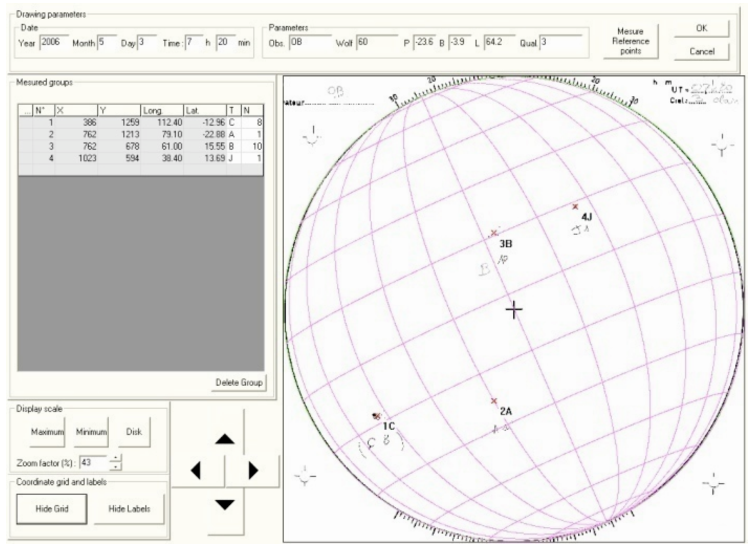


Figure 12: Graphical user interface of the DIGISUN application developed for the measurement and coding of the Uccle visual sunspot drawings. This software will be expanded in 2009 in order to digitize the full collection of the Uccle drawings and contribute one of the new WP2 sunspot catalogs.

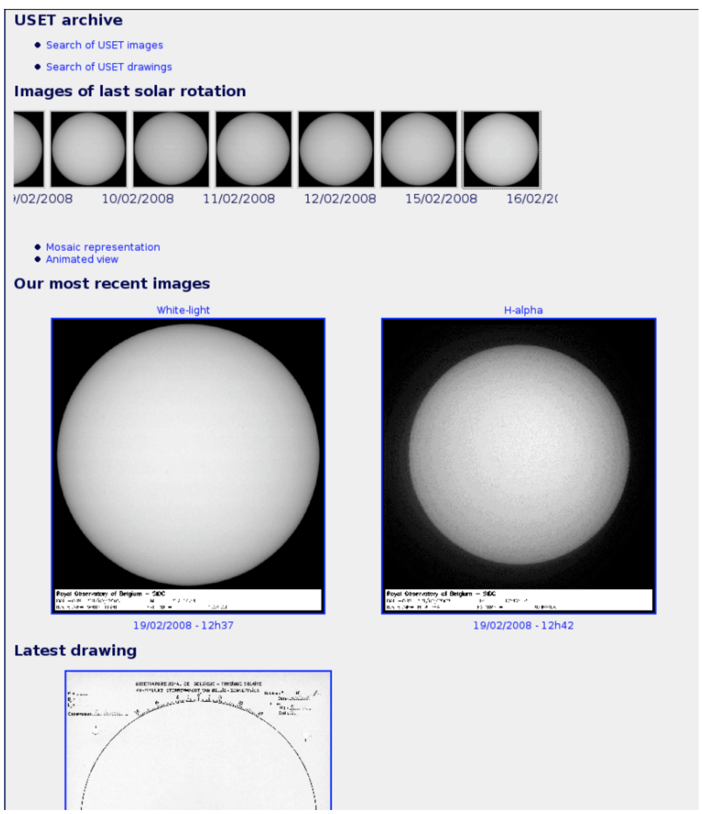


Figure 13: Section of the main USET data query Web interface, displaying the latest images in each channel and latest Uccle sunspot drawing, as well as an interactive panorama of the last 28 days (1 Carrington rotation). On top of the page, two links lead to query forms allowing to search and select datasets from the archive of past images and digitized drawings.

CALLISTO spectrograph

In 2008-2009, the collaboration with the ETH Zürich radio astronomy group flourished further and led to the actual rebirth of radio astronomy in the Humain station.

- A log-periodic antenna covering the range 50-1300MHz was mounted in parallel with the modernized 6m parabolic antenna (Figure 14). New HF cabling was installed between the antenna and the laboratory. A new version of the antenna pointing software was developed in view of the remote operation of the antenna from Brussels. This work will be completed in 2009.
- A first CALLISTO receiver was installed in May 2008. From May to mid-November, the receiver was tested and set up to monitor its whole frequency range. This revealed a degradation of radio interferences (RFI) only above 500 MHz compared to the spectrum monitoring campaign of 2006, as well as significant intermodulation due to the FM band (87-108 MHz; Figure 15). Since November, the receiver has been programmed to monitor only the very lower part of the spectrum (92-45 MHz) in order to avoid strong man-made emissions, before a filtering strategy is developed. In November, a second CALLISTO receiver was provided by the ETH collaborators.. It will be used for tests and RFI monitoring and should finally be converted to operate at higher frequencies (> 1GHz).

Figure 14: the new 50-1300 MHz log-periodic antenna mounted on the outer ring of a refurbished 6m parabola.

- Data transmission and remote control: A new control PC is now controlling the receiver control software and transmits the acquired data to the ROB in real time via the ADSL connection (downloads every 15 minutes). Since November, the receiver has been used in routine operation using only the lower part of the spectrum (45-82 MHz) until proper filters are installed for the range 100-500MHz in 2009. Due to the very low solar activity, it is only by Dec. 11, 2008 that a first minor radio burst occurred. This was a weak event but it was detected by the Humain radio telescope as well as by two other CALLISTO stations, confirming that the receiver works properly with sufficient sensitivity (Figure 16). More recently, in May 2009, a series of bursts linked to moderate flaring activity and a CME was also detected (see Figure 17).
- CALLISTO website: by November 2008, a dedicated Web page was implemented. It displays graphically the Humain radio spectra in near real time. In addition, the ETH Zürich downloads data from all CALLISTO receivers around the world (including Humain) when there is a solar event and makes them available on a dedicated website named DIRAC (http://pandora.ethz.ch:8080/frontend/). Following a request from the ETH, we agreed to take over this central data-distribution website in the course of 2009

Next-generation solar flux monitors (NGSFM)

In 2008, an actual collaboration was initiated with Dr. K.Tapping (Dominion Radio Astronomy Observatory, Penticton Canada) and Dr. D. Boteler (Geological survey of Canada, Ottawa) for the joint development and construction of new absolute solar radio flux monitors. It involves the design of new receivers based on state-of-the-art HF components but also on the extension of the frequency coverage by measuring 6 frequencies in parallel, including the historical 2.8GHz flux, in order to better characterize the slowly varying component (S component). Another goal is to implement a 24h/day coverage thanks to a worldwide network of at least 3 stations (Canada, Belgium, Japan).

The terms of this collaboration would attribute the design work to the DRAO, while the construction and testing of the final receivers would be carried out by the ROB. For the Humain instrument, it will be necessary to refurbish and adapt existing antenna or purchase a new dish and mounting. A preliminary study of the options was carried out late in 2008 and will continue in 2009. The first prototype of a single-frequency receiver will be produced in the course of 2009. In the current timeline, radio flux measurements will start to be produced only in 2010 or 2011.

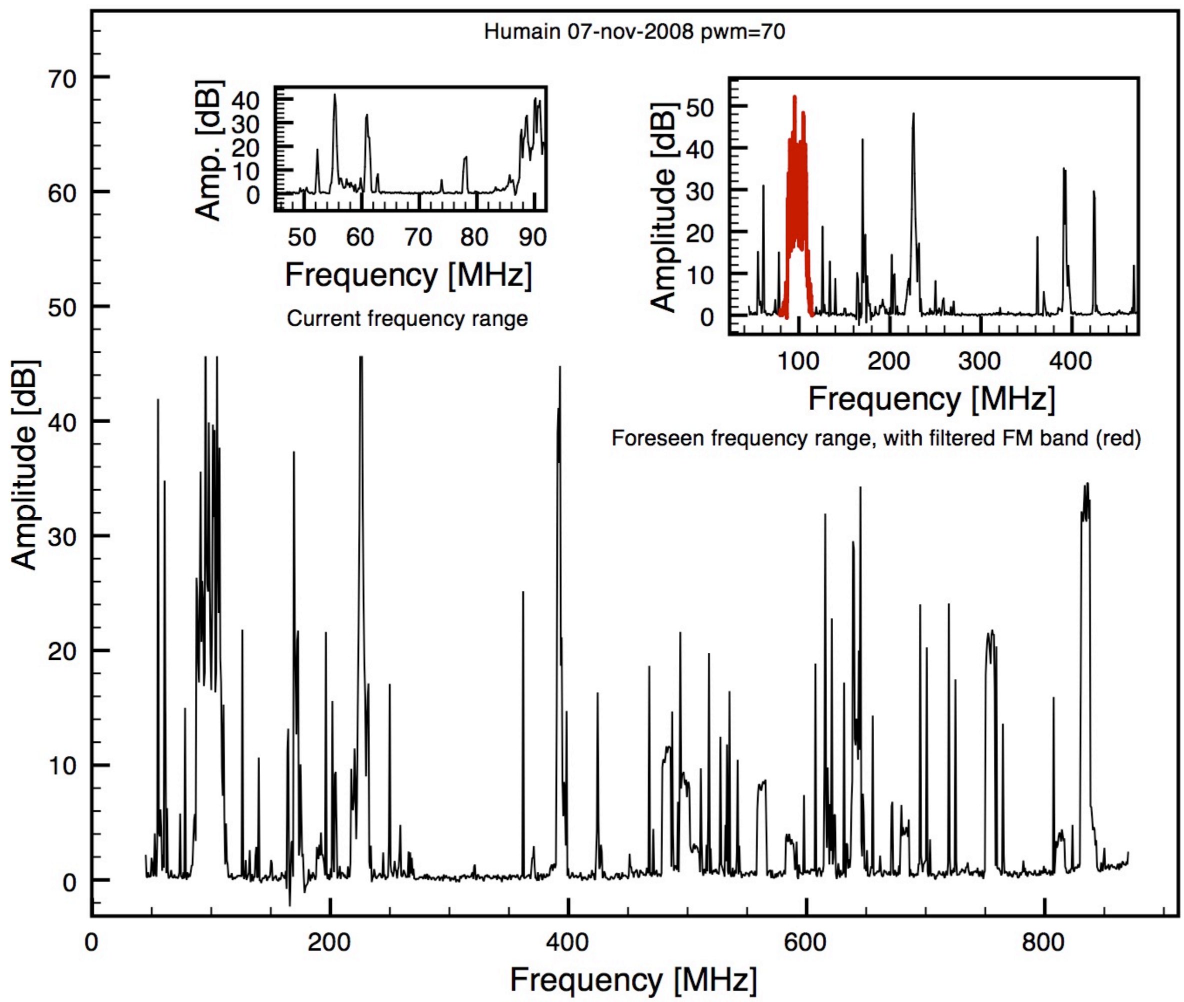
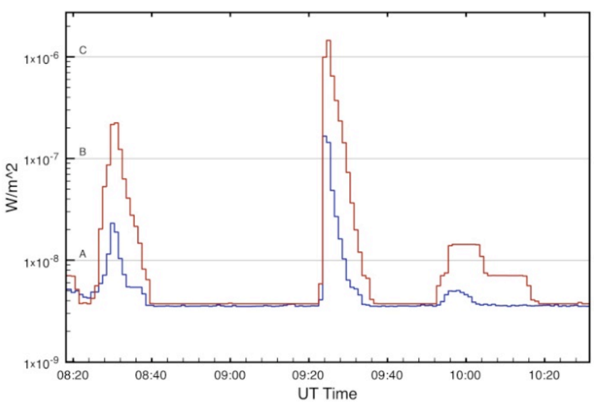


Figure 15: Measured spectrum at Humain between 45 and 870 MHz with the foreseen future spectral range (top right) and the current one (top left)

- Radiofrequency laboratory: in view of the abundant development, testing and maintenance work, the selection and purchase of HF laboratory equipment was initiated. Two primary components were ordered by April 2009: the spectrum analyzer and a frequency generator. These are the most expensive instruments needed for this laboratory (Initial investment of about 50000 euro)

Preservation of the site quality and protection of the radio electric spectrum

- CRAF (Committee on Radio Astronomy Frequencies, ESF): in 2008, we took an increasingly active role in this organization. In November 2008, we hosted the 47th CRAF meeting at the ROB on Nov. 12-14, 2008. During this meeting, a visit to the Humain station was organized on Nov.13 for all radio astronomers attending the meeting. Taking advantage of the location in Brussels, a special round table was organized at the end of the meeting to allow direct discussions with several EU officials.
- The links with the BIPT (Belgian Institute for Post and Telecommunication) were maintained as well as our participation to the URSI (Union Radio Scientifique Internationale), e.g. as URSI representative to the FAGS Council, which emphasizes the current connection between solar radio astronomy and operational space-weather services.



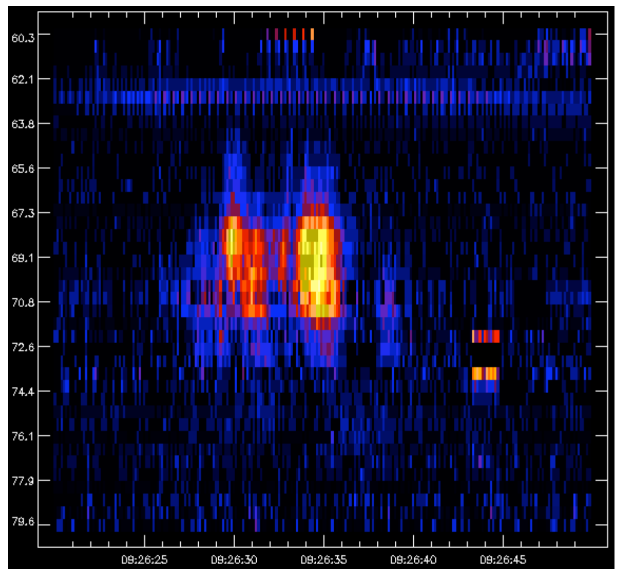


Figure 16: C-class flare of Dec. 11th 2008 (top) associated with the first radio burst (right) observed in Humain with the Callisto receiver

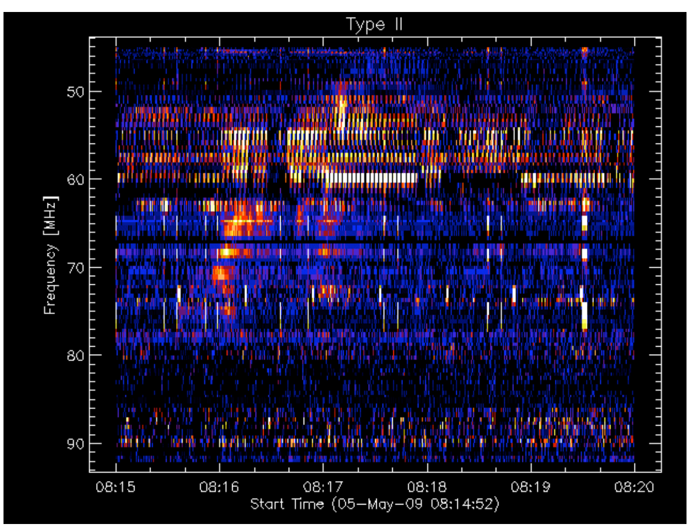
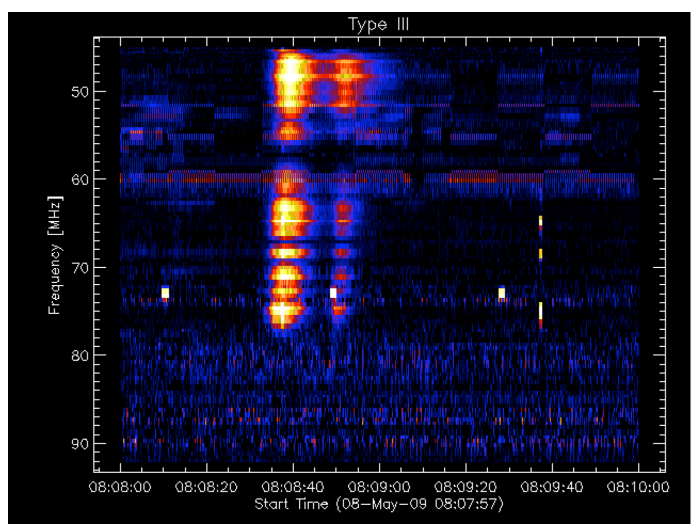


Figure 17: Example of Type II (a shock wave signature) observed on May 05th 2009.



Example of type III burst (linked to electron beams propagating along open field lines) observed at Humain on May 8th 2009

3.2.3 Perspective for next years

3.2.3.1 Solar optical observations

- Hardware development:
  - Design and construction of the CaII-K telescope and optics in connection with the Observatory of Rome (PSPT).
  - Design and construction of the motor-actuated mechanical support and focus systems for the new telescopes.
  - Completion of the solar auto guider:
  - Software: implementation of systematic procedures for the determination of the camera dark level and flat-field, which will be used in the routine observations of the new cameras.
- Software development:
  - Development of new programs for the selection and pre-processing of high-cadence images from the 3 new camera systems.
  - Implementation of systematic procedures for the determination of the camera dark level and flat-field, which will be used in the routine observations of the new cameras.
  - Upgrade and reorganization of the USET web pages (with O. Lemaître).
- Long-term sunspot data exploitation in the context of the SOTERIA project:
  - Systematic digitization and encoding of the Uccle sunspot drawing collection.
  - Development of a new program for group tracking, in order to feed a catalog of all sunspot groups with the individual evolution history.
  - Study of new image-based activity indices derived from solar images of the photosphere (CCD, photographic): initial data sets (USET, SOHO/MDI).

3.2.3.2 Solar radio observations

The upcoming tasks for 2009 will be:

- Recruiting of new staff (technician, ICT) in the framework of the STCE. The selection process is on going through SELOR.
- <u>CALLISTO spectrographs</u>:
  - Optimization of the first receiver by reducing intermodulation effects associated with strong radio transmitters (mainly the FM band) and by minimizing internal interferences due to the local electronic devices and PCs by the installation of RF notch filters.
  - Preparation of a second receiver operating at higher frequencies, which will first allow making a survey of RFI in the high frequency range 1-3 GHz.
  - Implementation of a remote control system allowing unattended operation of the radiotelescope directly from Brussels.
- <u>Absolute solar flux monitors</u>: in 2009, the development and testing of the new-generation solar flux monitors should make its actual start, once the Canadian team will secure its funding:
  - Construction and testing of a mono-frequency prototype designed by K. Tapping (DRAO).
  - In parallel, for the Humain implementation, the selection of an antenna and mount will be continued, followed by the installation and cabling of the new or refurbished antenna. For the high-frequency instruments, a comparative cost study will be completed between the refurbishing of existing hardware or the purchase of a new mount and HF parabola.
- <u>Radiofrequency laboratory</u>: the selection and purchase of HF laboratory equipment was made in April 2009 (spectrum analyzer and signal generator). Additionnal small equipment (filters, antennas, etc.) will be bought during the year. Work has started at the Observatory to create a fully equipped HF laboratory, including a Faraday cage, lended by the Royal Meteorological Institute.
- <u>Radioprotection of the Humain site</u> (CRAF, BIPT, etc.)

3.2.4 Personnel involved

Scientific staff:

- F. Clette (Lead scientist, instrument design & development, permanent ROB staff)
- C. Marqué (Lead radioastronomer, STCE)

Technical staff:

- J-L. Dufond (Engineer-technician: electronics, permament ROB staff)
- S. Vanraes (ICT, programmer, observer, permanent ROB staff)
- A. Ergen (Technician: electronics, permanent ROB staff)
- O. Boulvin (Operator-observer; permanent ROB staff)
- O. Lemaître (Operator-observer, permanent ROB staff)

3.2.5 Partnerships

3.2.5.1 External funding

- LOTTO equipment grant (attributed in November 2006)
- SOTERIA "SOlar-TERrestrial Investigations and Archives" project (EU 7th Framework Program, Nov.2008- Oct. 2010)

3.2.5.2 Opportunities and collaborations

- M. Bianda, IRSOL-Specola Solare Ticinense, Switzerland
- Dr Arnold Benz & Eng. Christian Monstein, Eidgenössische Technische Hochschule (ETH), Zürich, Switzerland.
- Dr Kenneth Tapping, Dominion Radio Astrophysical Observatory, Penticton (Ottawa), Canada.
- Dr. David Boteler, Geological Survey of Canada, Ottawa, Canada
- Dr Roberto Ambrosini, Instituto de Radioastronomia, Bologna, Italia

3.2.5.3 List of national partners or collaborators having actively contributed to the project in the last year

- ROB Planetarium
- RMI and BISA

3.2.5.4 Visitors:

- David Boteler, ISES, 27/02/2008.
- Scenarist Planetarium Space Weather show, 04/03/2008.
- M. Vandenhove, THALES, 03/09/2008.
- Nilson Sant'Anna, RWC Brazil, 24-25/11/2008

3.2.6 Scientific outreach

3.2.6.1 Meeting presentations

[31] F. Clette, C. Marqué
New solar radiotelescopes in Belgium
URSI Forum, 30/5/2008 (oral)

[32] F. Clette, C. Marqué, C. Monstein, J.-L. Dufond, A. Ergen
New solar radiotelescopes in Belgium
URSI General Assembly, 10-16/8/2008 (poster)

[33] F. Clette
SOTERIA WP2 Photosphere: ROB contribution

SOTERIA kick-off meeting, Work Package 2 session, 17-21/11/2008 (5th ESW Week, Royal Library, Brussels).

[34] C. Marqué, F. Clette, J.-L. Dufond, A. Ergen
New developments of solar radio observations in Belgium)
European Space Weather Week 5, Brussels, Belgium, 17-21/11/2008 (poster)

3.2.6.2 Seminars

[35] F. Clette
Four centuries of sunspot index: from Wolf to the SIDC
Geological Survey of Canada (D. Boteler, Ottawa), 20-21/8/2008.

3.2.6.3 Public conferences

- F. Clette, 19/4/2008: Société Royale Belge d'Astronomie, "Soleil et Terre: en liaison directe avec une étoile".

3.2.6.4 Wikis and Websites

- USET Web site: featuring visual data query tool (preview thumbnail images) and a whole-rotation navigator (mosaic, movie, sliding strip). Via an SQL database, it gives access to the whole USET archive of CCD images as well as the scans of USET drawings. (URL: www.sidc.be/USET)
- CALLISTO Web site: access to near-real time Humain observations as well as past archived data (quick-look and FITS files). URL: http://sidc.be/humain

3.2.7 Publications

3.2.7.1 Publications with peer review

[36] R. Brajsa, H. Woehl, B. Vrsnak, V. Ruzdjak, F. Clette, J.-F. Hochedez, G. Verbanac, I. Skokic, A. Hanslmeier
Proper Motions of Coronal Bright Points
Central European Astrophysical Bulletin 32, 165--190 (2008).

[37] M. Mierla, B. Inhester, C. Marqué, L. Rodriguez, S. Gissot, A.N. Zhukov, D. Berghmans, J. Davila
On 3D Reconstruction of Coronal Mass Ejections: I. Method description and application to SECCHI-COR Data
Accepted in Solar Physics 2009, in press

3.2.7.2 Publications without peer review

[38] Clette, F., 3/2008:
New prospects for solar radioastronomy in Belgium
CRAF Newsletter, N° 17, European Science Foundation.

[39] Clette, F., 11/2008:
Report on the CRAF visit to the Humain station
Summary report of the 47th CRAF Meeting

[40] SIDC sunspot bulletin (12 monthly issues): the Uccle-USET sunspot numbers, sunspot group table, returning group list.

3.2.7.3 Publications in popular journals

[41] Clette, F., Berghmans, D., Vanlommel, P., Van der Linden, R.A.M., Koeckelenbergh, A., Wauters, L.
Du Nombre de Wolf a l'indice international des taches solaires: 25 ans de SIDC (1ère partie)

Ciel & Terre 124, 3, 66-75 (2008).

[42] F. Clette, D. Berghmans, P. Vanlommel, R. Van der Linden, A. Koeckelenbergh, L., Wauters. *Du Nombre de Wolf a l'indice international des taches solaires: 25 ans de SIDC (2ème partie)* Ciel & Terre 124, 4, 98-109 (2008).

3.3 Energetic events in the solar corona; coronal heating

Responsible person: Elena Podladchikova, email: olenapo@sidc.be
This work package is related to the following research themes or objectives:

- F: Studying the solar atmosphere and solar activity,
- B: providing space weather services,
- J: Solar Cycle and irradiance studies and the 'solar constant'

3.3.1 Overall description

Since 2006, continuously improving performance of optical space diagnostics of the Sun (cadence, resolution, instrument sensitivity - variety of missions, improving telemetry), deliver us the exponentially growing flow of new data. They contain precious and unique information about fundamental physics in space, but cannot serve us as the indicator of plasma processes directly. First we have to develop tools able to:

- Handle exponentially growing data flow (data mining);
- Extract physical information from data and present it in simple compact format.

Already now, the first steps of our data analysis as well as elaborated earlier physical models for the solar corona, give us strong indication about small-scale processes playing unexpectedly important role in solar corona formation (e.g. turbulence generation in quiet sun; eruptive processes of active sun).

Thus, the final goal of this work package is to understand how the dynamic events of all scales contribute to coronal heating and solar wind formation near the Sun. The consecutive steps are to:

- Build the physical model of small-scale eruptive events, using three-dimensional MHD models. They will incorporate experimental parameters extracted from tools developed by us at ROB. This will be performed in collaboration with recognized specialists on plasma processes simulations. STCE contributes high expertise in experimental data as well to this task.
- Perform the global analysis of eruption ensemble using the combination of the available data and the relevant numerical codes developed before in order to understand their general contribution to corona formation and solar wind generation.

Peculiarities of STEREO spacecrafts, namely simultaneous observations by 2 spacecrafts of the 2 different solar hemispheres are particularly helpful for these studies. First the Full ensemble of events can be analysed. Already now the preliminary analysis of firstly available detailed spatial information of eruptive events demonstrates that at list the significant part of them initiated not in a sporadic way as it was considered before.

3.3.2 Long term goals

This work package constitutes a fundamental research project with direct operational outputs thanks to its long-term activities and heritage from previous projects. The following up to date tools and data provide fast connection between observational data and physical models to explain new phenomena discovered by STEREO mission flying since 2007.

3.3.2.1 Input data and analysis tools

- **EUV images of the solar corona from SECCHI/STEREO mission.** Temporal resolution (x 6 better), spatial resolution (x 2 better) with respect to the previous EIT/SOHO mission. Capacities of 3D view.
- **NEMO tool: Autonomous detector of solar disk Eruption from EUV solar corona** provides first fast and autonomous event extraction and catalog of coronal explosive events.

3.3.2.2 Numerical Codes

- **Reduced Hybrid code** modelling statistical behaviour of small-scale coronal explosive events in the low corona. (*Elena Podladchikova* development: 1998-2008 with *V. Krasnoselkikh, T. Dudok de Wit, N. Vilmer* – CNRS/France, *B.Lefebvre* - New-Hampshire University, US)
- **2-D and 3-D MHD codes modelling various modes of excitation of explosive events** (such as MHD modes excitation (Latest code upgrade by *Leon Ofman*-NASA and *Magda Selwa* - Naval Research Laboratory, US)

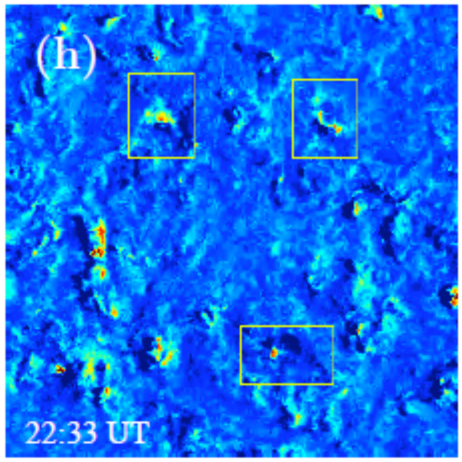
3.3.3 Achievements

3.3.3.1 Services

- The software package NEMO has been developed and tested for the detection of EIT waves in EUV images of the Sun (http://sidc.be/nemo).
- Real-time EIT wave detection with EIT/SOHO for space weather service.
- Beginning of STEREO EIT waves catalogue construction: 2007-2009. NEMO extraction technique application. Scientific events catalogue of slow large events with calibrated data due to their high priority for scientific study. Small set of events is due to the low activity due to the solar minimum. (*Pavel Lisnichenko responsibility:* http://sidc.be/nemo/events). =

3.3.3.2 Scientific research

- *Experimental:* Study of small-scale EUV eruptions with SECCHI (see Figure). The higher temporal and spatial resolution of data allowed us to detect and analyze micro-event to resolve their fine structure and to prove unambiguously their identity to large-scale eruptions discovered by the SOHO mission. These micro events differ from those on a large scale by having smaller geometrical sizes, a shorter lifetime, and the reduced intensity. Study of spatial distributions of eruptions.
- *Experimental:* Method development to define the 3D characteristics of eruptions with STEREO (collaboration with WP ROB A.4 *Andrei Zhukov, Luciano Rodriguez,* 3-D reconstruction of magnetic loops, see 3.4). 3D parameters of large scale eruption of 07/12/2007 event are computed.
- *Theoretical:* Incorporation of small-scale drivers to the Reduced Hybrid code of low corona simulations reproducing observed behaviour of small-scale eruptions.
- *Theoretical:* Setup of 2-D and 3-D MHD code to simulate large-scale solar eruptions, incorporate of observational data (magnetic field and emission measure). First meeting between scientists involved: ROB, NRL, CNRS (see 1st paragraph) and elaboration of detailed plan of future scientific interaction (collaboration with WP ROB A.4, see 3.4).



EUV corona image subtracted from the previous one.

Extracted eruptive micro dimming evolution.
The box is [50 *x* 80] arcsecs.

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Micro-eruption detected by SECCHI.
The box is [50 *x* 80] arcsecs.

Figure 18: Micro-eruptions detected by SECCHI

3.3.4 Partnerships

3.3.4.1 Opportunities and Collaborations

- Institut d'Astrophysique de Paris, France
- Meudon Observatory, Paris, France
- LPCE/CNRS, Univeriste d'Orleans, France
- Naval Research Laboratory, US
- Jet Propulson Laboratory, US
- Warwick University, UK
- Tel-Aviv University, Israel
- NASA, NSF/US solar waves working group
- Programme National Soleil-Terre (PNST), France

3.3.5 Perspective for next year

We intend to continue our current research and service activities. The goals to achieve in 2009:

3.3.5.1 Services

- Estimation of quality of NEMO automatic eruption detection for EUV solar corona EIT/SOHO data. Option A (best result): entire 1997-2009 period. Option B (secure result): 2 years 1997-1998 around solar minimum and 2 years 2002-2003 around solar maximum level activity.
- Study the performance of the STEREO mission for the operational eruption space weather fore-casting: Study of NEMO autonomous eruption detection application to EUVI/SECCHI data. First elaboration of software transition algorithm to apply on data coming from the different satellite, determination of time scale for such software adaptation for autonomous work with different type of data. Risk: different data properties may partially influence the detection algorithm adjusted for EIT/SOHO data.

The recently hired g scientist Pavel Lisnichenko passed his 3 months adaptation period at ROB and proved his capacities to perform these 2 specific tasks.

3.3.5.2 Scientific research

- Publication of the letter “Micro eruptions properties discovered by SECCHI/STEREO”. Collabo-ration with NRL/NASA. Ready for submission. Submission date: 25 May 2009.
- Publication of the paper “Distortion of the EIT wave rotation in the presence of ARs on the Sun”, after discovery of the EIT wave rotation. Ready for submisison.Submisison date: 10 June 2009, Solar Physics Topical issue, SIP conference 2009.
- Publication of the paper “Time-Distance relations between solar flares. The statistical studies of 5 years flare data given by SIDC catalog”. 80% ready for submission. Submission date: August 2009, Solar Physics Topical issue, SIP conference 2009.
- Publications of the Letter ‘The Geometrical 3D Properties of SECCHI EUV Eruptions”. 40% ready for submission. Submission date: 1 November 2009.

First results on 2D and 3D MHD simulations of EUV Eruptions. We move in 2 parallel directions with NASA group: - A- 2D General simulation of slow mode excitation in the solar corona with the eruption geometry (since 2009). –B- Data analysis of STEREO selected events detected and by NEMO (since 2009). Incorporation of observational data into simulation (August-November 2009). We plan 2nd joint summer meeting ROB-NASA in US.

3.3.6 Scientific Outreach

3.3.6.1 Meeting Presentations

[43] Podladchikova O., Koucthmy, S.
First Optical Observations Of Shock Waves Interaction With The Solar System Planets. The Prelimi-nary Analysis (Solicited talk)
Isradynamics - Dynamical Processes in Space Plasmas. 11-19 May, 2008, Dead Sea, Israel

[44] Podladchikova O.
New Diagnostics Techniques of Space (Invited Lecturer)
3rd Open Summer School-Seminar"Achievements and Applications of Contemporary Informatics, Mathematics and Physics - Neuromodelling" (AACIMP-2008), 11-21 August 2008, Kiev, Ukraine

[45] Podladchikova O.
Cellular Automata to describe turbulent plasma processes (Invited Lecturer)
3rd Open Summer School-Seminar"Achievements and Applications of Contemporary Informatics, Mathematics and Physics - Space Research" (AACIMP-2008), 11-21 August 2008, Kiev, Ukraine

[46] Podladchikova O.
*EUV Micro-Eruptions by SECCHI -.Discovery and Diganostic (*Talk)
7th SECCHI Consortium Meeting, 13-19, March, Meudon, Paris,

[47] Podladchikova O., Krasnoselskikh, V.
Turbulent Kinematic Dynamo Driver of Coronal Hetaing (Talk)
37 COSPAR Scientific Assemby, 13-12, July, Monréal, Canada

[48] Podladchikova O.,
EUV coronal wave recognition for SECCHI/STEREO:Problems and Achievments (Talk)
37 COSPAR Scientific Assemby, 13-12, July, Monréal, Canada

[49] Podladchikova O.
EUV Micro-Waves in the Solar Corona (Poster)
AGU, American Geophysical Union, Fall Meeting 2008, 15- 19 December, 2008, San-Francisco, USA

[50] Podladchikova O., Nicula, B., Willems, S., Berghmans, D
NEMO: Detection of CMEs without Coronographs in Real Time at SIDC (Poster)
ESWW5- *Fifth European Space Weather Week, 17-21 November, 2008, Brussels, Belgium*

3.3.7 Publications

3.3.7.1 Publications with peer review

[51] O. Podladchikova, A.Vourlidas, R Van der Linden, S.Patsourakos, J-P, Wuesler,
"SECCHI EUV Micro-Eruptions"
Submitted to APJ.

3.4 Solar Atmosphere Studies

Responsible person: Andrei Zhukov, email: Andrei.Zhukov@sidc.be
This work package is related to the following research themes or objectives:

- F: Studying the solar atmosphere and solar activity,
- D: ground-based solar monitoring,
- E: developing advanced technology for solar observations,
- J: Solar Cycle and irradiance studies and the 'solar constant'

3.4.1 Objectives

We deal with the fundamental physical research on the structure and dynamics of the solar atmosphere, in particular solar corona, including physics of potentially geo-effective eruptive events such as flares, coronal mass ejections (CMEs), solar energetic particles. It also includes linking solar and heliospheric phenomena (which is a part of the space weather science). A particularly important target is the development of a physical knowledge for predicting interplanetary plasma and magnetic field disturbances on the base of solar observations.
This research has important implications for several unsolved problems of the solar physics, in particular coronal heating and the mechanism of solar eruptions – flares and Coronal Mass Ejections (CMEs) – that have a potential influence on the space weather.

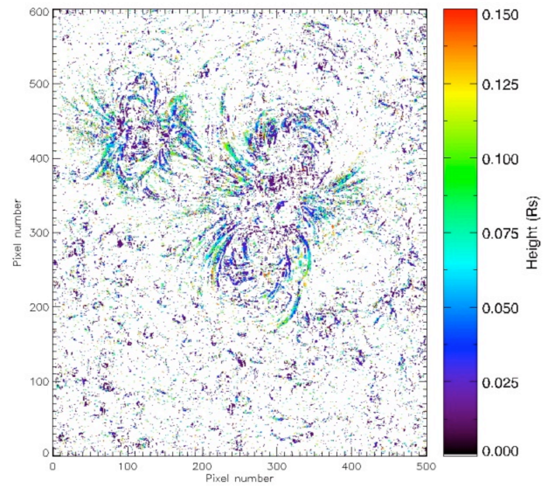


Figure 19: 3D configuration of the NOAA active regions 0953 (close to the centre of the image) and 0954 (in the top left corner of the image) as observed in the 171 Å bandpass of SECCHI EUVI onboard STEREO on 2 May 2007 at 01:01:30 UT. The colour shows the height above the solar surface, in solar radii (Rs).

3.4.2 Achievements

We give a summation

- Development of an automated technique for three-dimensional reconstruction of active regions observed by SECCHI/EUVI telescopes onboard STEREO, see Figure 19. We found that some coronal loops that look co-spatial in the 171 Å and 195 Å EUVI band passes have in fact different heights and thus occupy different volumes.
- Stereoscopic reconstruction of CME's on the base of SECCHI COR data was performed. Reconstruction results obtained from the application of four different algorithms were compared. Quantitative estimations of the coronal electron density in CME's were made through an iterative procedure of forward modeling.
- Three-dimensional structure of the coronal streamer belt was analyzed by forward modeling. It was found that polar streamers (observed during the epoch of high solar activity) are "classical" streamers (loops with the current sheet above them) associated with polar crown photospheric neutral line. During the solar cycle maximum the streamer belt therefore has a configuration drastically different from the one given by the potential field source surface model.
- The physical nature of EIT waves in the solar atmosphere was investigated. An event with a peculiar velocity profile (deceleration – constant speed – acceleration – deceleration) was identified and it was demonstrated that even EIT waves with a symmetric front can be produced by a magnetic field restructuring during the CME eruption.
- The origin of coronal shock waves was investigated. Several events in which the shock was probably not driven by the CME (as it is frequently assumed), but initiated by the flare, were identified and analyzed.
- Investigation of the link of coronal dimmings and the magnetic connection of CMEs with the Sun. It was demonstrated that dimmings may disappear (by shrinking of their outer boundaries but also by internal brightenings) whilst the magnetic connectivity of the CME with the Sun is maintained.
- Multispacecraft observations of interplanetary magnetic clouds (by ACE and Ulysses) were analyzed in order to understand how these structures develop in their cruise from the Sun to 5 AU.
- A study of spectroscopic diagnostics of CME counterparts in the low corona (EUV dimmings) has started (after the hiring of Dr. L. Dolla in October 2008).

- Scientific support was provided to the ROB-led consortium developing the EUI instrument for Solar Orbiter mission of ESA Cosmic Vision program.

3.4.3 Partnerships

3.4.3.1 Opportunities and collaborations

- International Space Science Institute (ISSI) working groups "The Stages of Sun – Earth Connection" and "From the Sun to the Terrestrial Surface: Understanding the Chain" (leader – C. Cid, University of Alcala, Spain)
- Mullard Space Science Laboratory, University College of London, UK (G. Attrill)
- Laboratoire d'Astrophysique de Marseille, France (P. Lamy, A. Llebaria, F. Saez)
- Institut d'Astrophysique de Paris, France (S. Koutchmy)
- NASA Goddard Space Flight Center, USA (G. Stenborg)
- Max-Planck-Institute for Solar System Research (Bernd Inhester)
- Skobeltsyn Institute of Nuclear Physics, Moscow State University, Russia (I. S. Veselovsky)
- STEREO/SECCHI consortium
- Consortium of EUI (Extreme-Ultraviolet Imager) for Solar Orbiter mission proposed for ESA Cosmic Vision program: Centre Spatiale de Liège (Belgium), Institut d'Astrophysique Spatiale (France), Institut d'Optique (France), Mullard Space Science Laboratory, University College London (UK), Max-Planck-Institute for Solar System Research (Germany).

3.4.4 Scientific outreach

3.4.4.1 Meeting presentations

[52] Zhukov A. N., Rodriguez L., de Patoul J.
STEREO/SECCHI Observations of the EIT Wave on December 8, 2007: Evidence against the Freely Propagating Wave Hypothesis of the EIT Wave Origin
STEREO/SECCHI Consortium meeting, April 23, Meudon, France

[53] Rodriguez L., Zhukov A. N., Gissot S., Mierla M., Marqué C.
Stereoscopy with EUVI Data
STEREO/SECCHI Consortium Meeting, Paris, April 2008

[54] Zhukov A. N.
EIT Waves and EUV Dimmings
Third Workshop for Young Researchers on Coronal Mass Ejections and Related Phenomena, May 30, Meudon, France (invited talk)

[55] Zhukov A. N., Veselovsky I. S.
Global Coronal Mass Ejections
COSPAR General Assembly, July 14, Montreal, Canada

[56] Rodriguez L., Zhukov A. N., Gissot S.
Automatic Extraction of Stereoscopic Information from STEREO – EUVI Images
37th COSPAR Scientific Assembly, Montreal, Canada, July 2008 (poster presentation)

[57] Magdalenić J, Marqué C., Zhukov A. N., Vršnak B.
On the Origin of Coronal Shock Waves Associated with Limb Events
12th European Solar Physics Meeting, September 8–12, Freiburg, Germany (poster presentation)

[58] Zhukov A. N.
Global Coronal Mass Ejections

Third International Symposium on KuaFu Project, September 15, 2008, Kunming, China (invited talk)

[59] Magdalenić J, Marqué C., Zhukov A. N., Vršnak B.
A Multiwavelength Study of the Origin of Coronal Shock Waves: Flares or CMEs?
IXth Hvar Astrophysical Colloquium, September 23, Hvar, Croatia

[60] Magdalenić J, Marqué C., Zhukov A. N., Vršnak B.
On the Origin of Coronal Shock Waves Associated with Limb Events
Fifth European Space Weather Week, November 17–21, Brussels, Belgium (poster presentation)

[61] Mierla M., Inhester B., Marqué C., Rodriguez L., Gissot S., Zhukov A. N., Berghmans D., Davila J.
3D Reconstruction of Coronal Mass Ejections Using SECCHI-COR Data
Fifth European Space Weather Week, November 17–21, Brussels, Belgium (poster presentation)

3.4.4.2 Referee reports

- Advances in Space Research, The Astrophysical Journal Letters, Annales Geophysicae, Astronomy and Astrophysics (2 papers), Solar Physics

3.4.5 Information given to the public

- interviews to the RTBF and RTL TVI TV channels related to the August 1, 2008 total solar eclipse (partial in Belgium)

3.4.6 Perspective for next years

- Publication of papers reporting results obtained in 2008 (5 papers are currently in press and one more is submitted).
- The research on CMEs and their low corona counterparts (EIT waves, coronal dimmings) will be continued. A special attention will be paid to multispacecraft observations (STEREO mission) and to the spectroscopic diagnostics (Hinode/EIS).
- We plan to investigate the link between CMEs observed by STEREO mission remotely and ICMEs observed in situ by STEREO, ACE and Wind. The collaboration with the ISSI team “From the Sun to the Terrestrial Surface: Understanding the Chain” will be pursued.
- The provision of the scientific expertise to the EUI consortium will be continued.

3.4.7 Publications

3.4.7.1 Publications with peer review

[62] Rodriguez L., Zhukov A. N., Dasso S., Mandrini C. H., Cremades H., Cid C., Cerrato Y., Saiz E., Aran A., Menvielle M., Poedts S., Schmieder B.
Magnetic Clouds Seen at Different Locations in the Heliosphere
Annales Geophysicae 26, 213-229, 2008

[63] Zhukov A. N., Saez F., Lamy P., Llebaria A., Stenborg G.
The Origin of Polar Streamers in the Solar Corona
The Astrophysical Journal 680, 1532–1541, 2008

[64] Attrill G. D. R., van Driel-Gesztelyi L., Démoulin P., Zhukov A. N., Steed K., Harra L. K., Mandrini C. H., Linker J.
The Recovery of CME-Related Dimmings and the ICME’s Enduring Magnetic Connection to the Sun
Solar Physics 252, 349–372, 2008

3.5 Advanced Technology for Solar Observations

Responsible person: Ali Ben Moussa, email: ali.benmoussa@oma.be
This work package is related to the following research themes or objectives:

- E: developing advanced technology for solar observations,
- C: exploiting the position as a centre of know-how on the management of space-missions in the context of solar-terrestrial relations

3.5.1 Objectives

One of the objectives is to consolidate and extend our technological expertise of high relevance to the hardware and software of solar instruments.
This WP addresses particularly the definition, development, and experimental characterization of photodetectors, with emphasis on single-pixel and imaging sensors, on their associated proximity electronics and optical filters. The application wavelengths can include the electromagnetic spectrum from the near-infrared to gamma rays, with special interest in the ultraviolet ranges. Novel imaging schemes will be explored, and the development of "smart camera" features will be supported.

3.5.2 Achievements

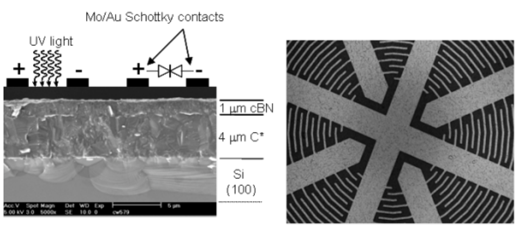


Figure 20: SEM image of the cross-sectional morphology of the c-BN/diamond composite film (a) and enlarged SEM view showing the circular interdigitated electrodes at the central region (b).

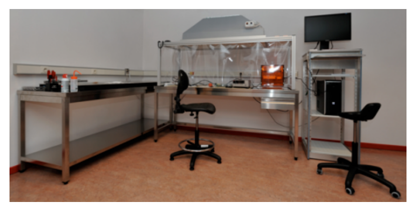


Figure 21: Photograph of the Detector Measurements Laboratory (DeMelab) facility.

We give a summation

- Development of blind to the visible light detectors based on the wide bandgap materials (cBN, AlN, and diamond),
- Detector studies for the EUI instrument onboard Solar Orbiter: preliminary translation of observational requirements into detector specifications,
- Support/coordinate with other partners in view of UV measurements, and physical modeling simulations. Planning of calibration measurements (PTB/Bessy, ESTEC, BIRA-IASB).

3.5.3 Partnerships

3.5.3.1 Opportunities and collaborations

- BIRA-IASB (Vacuum Ultra-Violet spectrometer),
- CSL, IMEC, IMO and CMOSIS, Belgium
- ESTEC, NL
- PTB-BESSY II, Germany (Synchrotron facilities),
- Dr A. Soltani, Institut d'Electronique de Microélectronique et de Nanotechnologie (Lille, France),
- Dr T. Saito, NMIJ : National metrology Insitute of Japan (Tsukuba, Japan),

- Prof Dr W. Zhang, Department of Physics and Materials Science (Hong Kong),
- Prof Dr H.X Jiang, Department of Physics (Kansas State University),
- Dr J. Morse, European Synchrotron Radiation Facility (Grenoble, France),
- S.O.-EUI partners (IAS in F, MPS in Germany, MSSL in the UK, SAO in the USA),
- Lebedev Physical Institute, Moscow, Russia (e.g. porous filters collaboration),
- SCK-CEN (Belgian Nuclear Research Center).

3.5.4 Scientific outreach

3.5.4.1 Meeting presentations

[65] BenMoussa A. (invited speaker)
Recent developments on wide bandgap based UV sensors
Diamond 2008, 19th European Conference, September 7-11, Stiges, Spain

3.5.4.2 Referee reports, expertise, audit

- Evaluators for the EU FP7 Strengthening Space Foundations (Space critical components),
- Evaluators for the French PNANO/ANR programme (Nanosciences and nanotechnologies),
- Referee for Optics communications.

3.5.5 Perspective for next years

- Design and assembly of a characterization set-up: the Detector Measurements Laboratory (**De-MeLab**). The primary purpose of the Demelab is to perform and interpret electro-optical measurements on imaging and non-imaging detectors of interest to solar physics in clean environment,
- Exploration and support to the development of "smart camera" features: Noise lowering via the exploitation of multiple non-destructive readouts (NDR), cosmic ray hits on-the-fly removal, SNR and higher dynamical range increases via multiple adaptive resets, etc. Relationships with image compression and its implementation,
- Design and implementation of an archival system for test data and their metadata,
- Design and implementation of a library of analysis software for detector electro-optical characterizations,
- Support to the other STCE partners (electro-optical characterization and analysis), e.g. tests of USET cameras.

3.5.6 Publications

3.5.6.1 Publications with peer review

[66] A. BenMoussa, A. Soltani, K. Haenen, U. Kroth, V. Mortet, H.A. Barkad, D. Bolsee, C. Hermans, M. Richter, J.C. De Jaeger , J.F. Hochedez
New developments on diamond photodetector for VUV Solar Observations
Semiconductor Science and Technology, 23, 035026 (2008)

[67] A. BenMoussa, J.F. Hochedez, R. Dahal, J. Li, J. Y. Lin, H. X. Jiang, A. Soltani and J.-C. De Jaeger, U. Kroth and M. Richter
Characterization of AlN metal-semiconductor-metal diodes in the spectral range 44-360 nm: Photoemission assessments
Appl. Phys. Lett. 92, 022108 (2008)

[68] A. Soltani, H.A. Barkad, M. Mattalah, B. Benbakhti, J.-C. De Jaeger, Y. M. Chong, Y. S. Zou, W. J. Zhang, S.T. Lee, A. BenMoussa, B. Giordanengo, J.-F. Hochedez
193 nm deep-ultraviolet solar-blind cubic boron nitride based photodetectors
Appl. Phys. Lett, 92, 053501 (2008)

[69] M. Dominique, A.V. Mitrofanov, J.-F. Hochedez, P. Apel, U. Schuehle, F.A. Pudonin, O.L. Orelovich, S.Yu. Zuev, D. Bolsee, C. Hermans and A. BenMoussa.
Track membranes with open pores used as diffractive filters for space-based X-ray and EUV solar observations.
Accepted to Applied Optics (2008).

[70] Pawel E. Malinowski, Joachim John, Anne Lorenza, Patricia Aparicio Alonso, Marianne Germain, Joff Derluyn, Kai Cheng, Gustaaf Borghs, Robert Mertens, Jean Yves Duboz, Fabrice Semond, Udo Kroth, Matthias Richter, J.-F. Hochedez and A. BenMoussa.
AlGaN photo-detectors for applications in the extreme ultraviolet (EUV) wavelength range. Proc SPIE, vol 7003, 70030N-N8 (2008).

3.5.6.2 Publications without peer review

[71] D. Berghmans, A. BenMoussa and A. De Groof
The PROBA2 satellite on the hunt for solar eruptions.
Physicalia Mag. 30, 2, 61-70 (2008)

[72] B. Giordanengo, A. Ben Moussa, J.-F. Hochedez, A. Soltani, P. de Moor, K. Minoglou, P. Malinowski, J.-Y. Duboz, Y. M. Chong, Y. S. Zou, W. J. Zhang, S.T. Lee, R. Dahal, J. Li, J. Y. Lin and H. X. Jiang.
Recent ROB developments on wide bandgap based UV sensors
To appear in the European Astronomical Society Publications Series

3.6 Atmospheric Effects on GNSS Applications

Responsible person: Pascal Defraigne, email: Pascale.Defraigne@oma.be
This work package is related to the following research themes or objectives:

- H: studying the interaction of solar electromagnetic radiation with the terrestrial atmosphere
- I: GNSS-based ionospheric monitoring in support of space weather services and GNSS applications

Introduction

When travelling from the GNSS satellites to the receiving antenna located on the Earth, the radio-frequency signals emitted by Global Navigation Satellite Systems (such as GPS, GLONASS and Galileo) cross and interact with the Earth's atmosphere. The two atmospheric layers that influence the most the propagation of GNSS signals are the troposphere and the ionosphere (see Figure 22). The troposphere is the lowermost Earth's atmospheric shell and it is the seat of all meteorological phenomena's (clouds, rain, hydrometeors...). It contains approximately 75% of the atmosphere's mass and almost all (99%) of its water vapour and aerosols. The ionosphere is stretching from a height of about 50 km to more than 1000 km; it is named so because it is ionized by the Sun's ultra-violet light. The ionosphere is thus a shell of free electrons, electrically charged atoms and molecules that surrounds the Earth. As most of the space weather starts at the Sun, also the Earth's ionosphere is undergoing the effects of space weather.

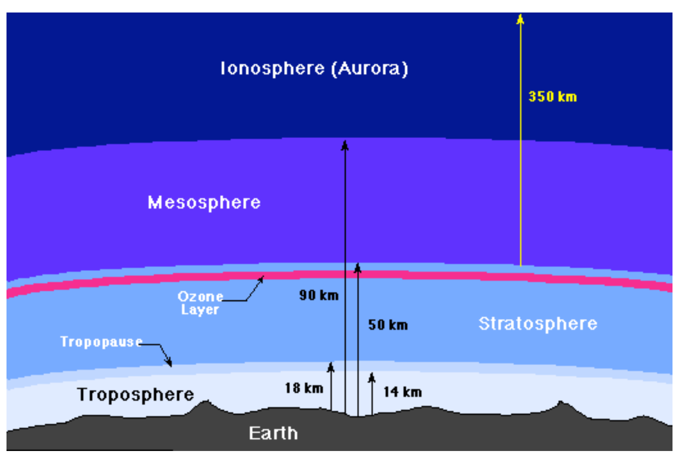


Figure 22: Subdivision of the Earth's atmosphere in different layers

Both the ionosphere and the troposphere refract the GNSS satellite signals and are error sources for GNSS applications. Tropospheric refraction causes errors of about 2-10 m on GNSS signals, while the errors caused by the ionospheric refraction can reach up to 50-150 m.

3.6.2 Objectives

To assess and mitigate the influence of the Earth's atmosphere on high precision GNSS applications (WP ROB B.1).

The effect of the tropospheric refraction on the propagation of GNSS signals can be corrected using several a priori models, which satisfy the less demanding GNSS applications, like cm-m level GNSS positioning and navigation. However, when high precision applications are targeted, the effect of the troposphere on the propagation of the GNSS signals is introduced as an additional parameter estimated simultaneously with the GNSS position of the receiver on the Earth.

As the ionosphere is a dispersive medium, GNSS applications can be corrected for first-order ionospheric effects by combining the different GNSS frequencies. However, as it will be shown below, during high ionospheric activity, higher-order ionospheric correction terms have to be taken into account when high precision GNSS applications (like e.g. earthquake monitoring) are targeted.

3.6.3 Progress and results

3.6.3.1 Positioning

GNSS allows computing positions on the Earth with precisions ranging from several meters down to a few mm, depending on the sophistication of the hardware and software used. When high precision GNSS applications are targeted, the Earth's atmosphere becomes a predominant error source. To illustrate this, we simulated an earthquake monitoring applications using GPS observations during the October 2003 geomagnetic storm, which affected the ionosphere above the Northern part of Europe. Earthquake monitoring typically requires positions with a precision better than 1 cm using just a few minutes of GPS observations. High-end GPS equipments as well as high-end software were used during the test. During the computation of the positions, both GPS frequencies (L_1 and L_2) were observed allowing to eliminate first-order ionospheric effects. The influence of the troposphere was corrected by introducing results from a state-of-the-art modelling technique. We computed 5-min kinematic GPS positions during 20 days around the October 2003 Halloween storm.

Figure 23 shows how the positions (north, east and up components) of two GPS stations (one located in Brussels, Belgium and another one in Vardo, Norway) computed each 5 minutes varies with time during the geomagnetic storm. When performing seismic monitoring in Central and Southern Europe, the obtained precision of a few mm in the east and north, and 1 cm in the height component satisfies the earthquake monitoring requirements. However, in Norway, the precision of the GPS positions is of the level of 4-7 cm in the east and north and even more than 33 cm in the height. Consequently, even when removing the first-order ionospheric effect, the ionospheric disturbances caused by geomagnetic storms dramatically degrade the precision of kinematic GPS positioning and a correction for higher-order ionospheric effects will be necessary. Moreover, the future increase of the solar activity related to the upcoming new solar cycle further enhances the need to improve the data processing techniques used for high precision GNSS applications such as earthquake monitoring. More details can be found in [9].

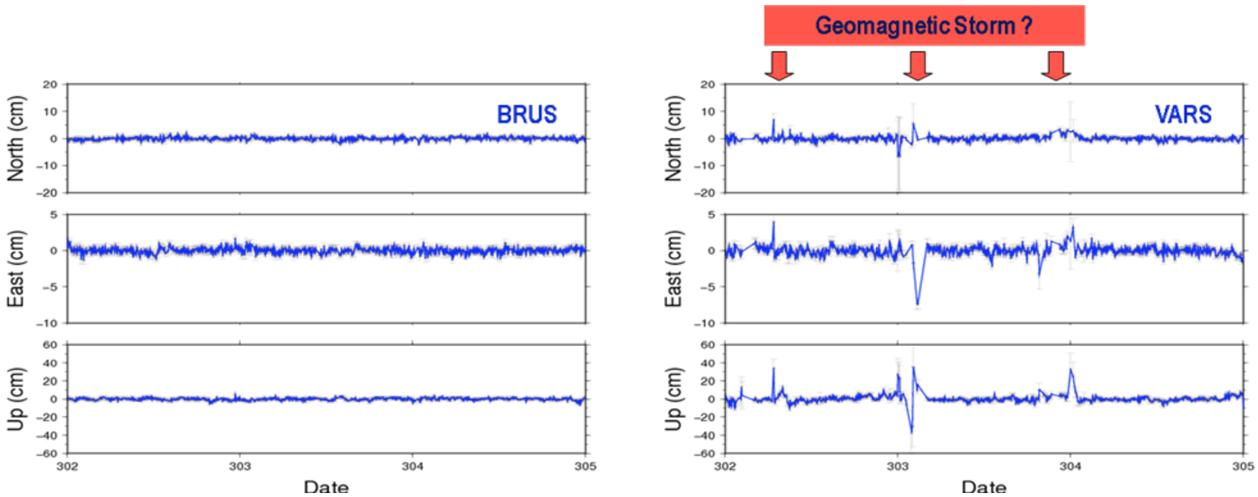


Figure 23: GPS-based positions (north, east, and up components) estimated each 5 minutes for BRUS (Brussels, Belgium) and VARS (Vardo, Norway) stations for days 302 to 305 days in 2003.

3.6.3.2 Time Transfer

The present requirement for the clocks participating to the generation of the International Atomic Time (TAI), which is the basis for our legal time, is at the level of the nanosecond over one day. The comparison of these clocks is done using GPS time transfer. The Atomium software has been developed at ROB to investigate the improvement of time transfer by using high-end GPS receivers. It aims at performing time transfer at the picosecond (psec) level and it is based on the GPS Precise Point Positioning (PPP) and Common View (CV) approaches. Similar to high-end GPS positioning, Atomium uses the "*ionospheric-free*" combination of GPS dual-frequency measurements to remove first-order ionospheric effects from the computations. We computed and quantified the second and third-order ionospheric perturbations on the GPS signals and their influence on time transfer, and have included this correction in the new version of the Atomium software [126], [131]. We showed that during a geomagnetic storm higher-order ionospheric effects on time transfer reach up to the 10 psec level (Figure 3), and probably even more due to the magnetic field perturbations at that time which are not included in the model, as they are not measured.

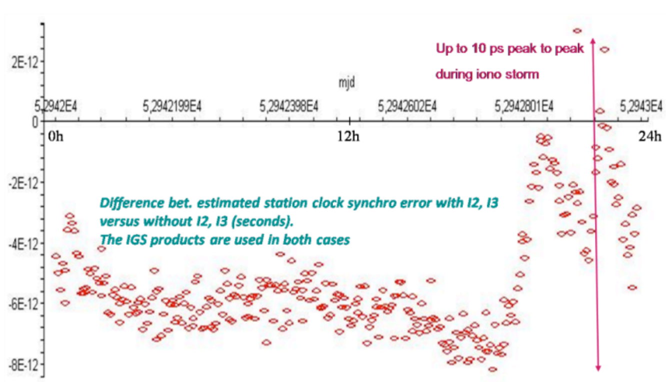


Figure 24: ***Effect of taking higher-order ionosphere effects, or not, into account in the ionospheric free GPS measurements for the Brussels-Onsala link during an ionospheric storm (October 30, 2003).***

3.6.4 Perspective for next years

- The effect of ionospheric storms on kinematic GNSS positioning applications (such as earthquake monitoring) has been evidenced. The focus will now be shifted to the modelling of the atmosphere using GNSS observations (WP ROB B.2). Once this modelling has reached enough maturity, it will be used to investigate the improvements it can induce on GNSS-based positioning during periods of high ionospheric activities.
- Finalise the implementation of the higher-order ionospheric correction in the Atomium software.

3.6.5 Personnel involved

Scientific staff: C. Bruyninx (head “GNSS” project, ROB)
P. Defraigne (head “Time and time transfer” project, ROB)
Q. Baire (Development of Atomium, BELSPO Suppl. Researcher (Jan.-Sept.), STCE (Oct.-Dec.))
N. Bergeot (Influence of the ionosphere in GNSS positioning, STCE)
S. Pireaux (Implementation of higher-order ionospheric effects in Atomium, STCE)
Technical staff: F. Coutereel (Technical support time laboratory, STCE)

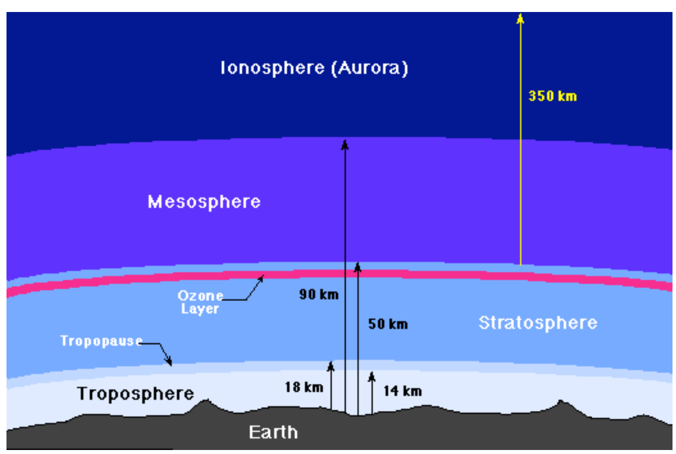
3.7 Modelling the Earth’s Atmosphere using GNSS

Responsible person: Carine Bruyninx, email: Carine.Bruyninx@oma.be
This work package is related to the following research themes or objectives:

- G: studying the interaction of corpuscular radiation with the terrestrial magnetosphere
- H: studying the interaction of solar electromagnetic radiation with the terrestrial atmosphere
- I: GNSS-based ionospheric monitoring in support of space weather services and GNSS applications

3.7.1 Objectives

To improve our knowledge of the spatial and temporal variations in the Earth’s atmosphere (troposphere and ionosphere) over the European region, with emphasis on Belgium (WP ROB B.2).



As the GNSS signals travel through the Earth’s atmosphere, they contain information on the ionospheric and the tropospheric state. To extract this information from the GNSS signals, networks of continuously observing GNSS stations, with well-known positions, are used. For that purpose, members of the ROB “GNSS project” maintain a network of continuously observing GNSS stations and contribute actively to the elaboration and extension of the European GNSS network, known as the EUREF Permanent Network (EPN). In a second step, the GNSS data from these networks are used to monitor the Earth’s ionosphere and troposphere.

3.7.2 Progress and results

3.7.2.1 Development of GNSS Observation Networks

We perform the daily management of the European Permanent GNSS network (EPN), a European network of continuously observing GNSS reference stations serving multi-disciplinary applications and covering 38 European countries. In that frame, we maintain and continuously update the EPN Central Bureau (CB) web site (http://epncb.oma.be/, see Figure 25). In 2008, the site received a total of about 2.7 million hits. Moreover,

- 22 new GNSS stations were added in the EPN, while 7 EPN stations were decommissioned, bringing the total of EPN stations to 217, see Figure 26.
- Several new codes and shell scripts were written to further develop the routine checks on the EPN data e.g. to improve the reliability of the real-time, hourly and daily data flow within the EPN (collaboration with G. Weber, BKG, Germany).
- We started investigating the usage of the Atomium software for monitoring the EPN site coordinates.
- The ROB, together with a number of groups involved in EUREF and WEGENER, replied to an FP7 call for "Deployment of e-Infrastructures for scientific communities" within the e-infrastructures activities of the capacities specific program of FP7. The name of the project is "PLEGG – Platform for European GNSS and other geo-products" and it aims at developing a European e-infrastructure to
    - Warrant optimal access so GNSS and SAR data.
    - Provide GNSS derived products for end-user communities
    - Foster research to anticipate new GNSS and SAR products

  The project was submitted on Sept. 11, 2008 but was finally just not selected and it was recommended to resubmit it.
- More details on these topics can be found in communications [79], [80], [82], [86], [87], [88], [89], and [91] and papers [112], [114], [121], [122], [123], and [132].

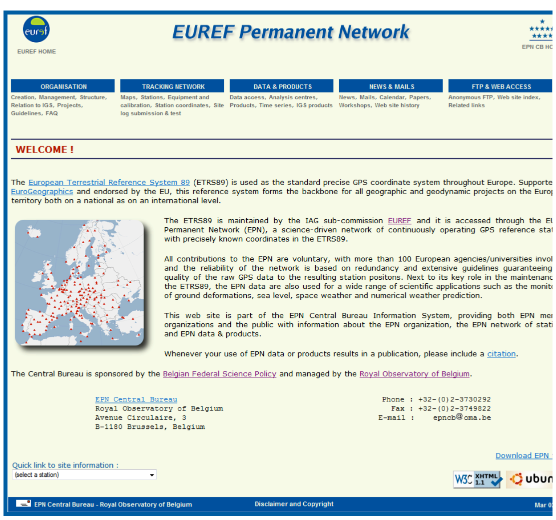


Figure 25: http://epncb.oma.be/ web site of the Central Bureau of the EPN hosted by the ROB

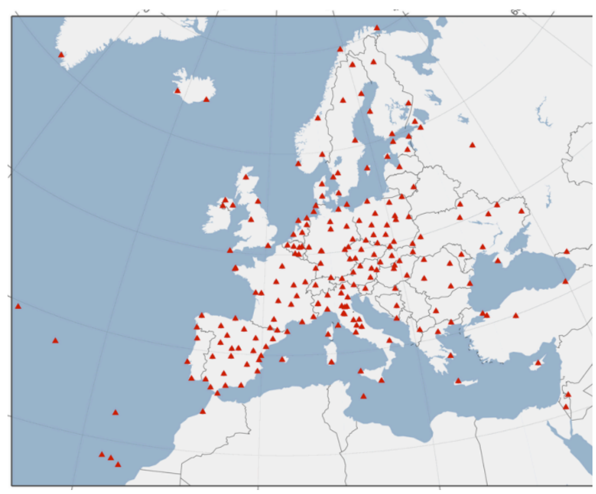


Figure 26: Map of the continuously observing GNSS stations in the EPN (Status: April 2009)

3.7.2.2 GNSS at the Princess Elisabeth base in Antarctica

We contributed to the preparation of the technical design of the GNSS receivers and antennas (one from ROB and one from the University of Luxembourg) that will be installed at the Princess Elisabeth I station in Antarctica, in collaboration with the Royal Military Academy. Once installed the GNSS equipment will allow monitoring the Earth's atmosphere above the Antarctic region.

3.7.2.3 Monitoring of the Earth's troposphere

Precise knowledge of the ionosphere from GNSS measurements cannot be obtained if the tropospheric delays are not properly corrected. This is the reason why some studies of the troposphere modelling in GNSS data must be developed in parallel.

- ➢ The EUMETNET E-GVAP project aims at using improved estimation techniques to provide meteorological agencies with GNSS-based troposphere Zenith Path Delays (ZPD) for assimilation in their operational Numerical Weather Prediction (NWP) models. The ROB E-GVAP analysis centre was re-established, (see communications [73], [77], [83], [84], [89], [90] and paper [128] - collaboration H. Vedel from the Danish Meteorological Institute DMI).
- ➢ We studied the influence of the reference frame definition, the GNSS antenna calibration and the ocean tide loading models on the modelling of the tropospheric delay error source, notably to improve the strategy used for E-GVAP, (see communications [73], [84] and papers [128], [130] - collaboration E. Brockmann, W. Söhne).
- ➢ We studied the incorporation of GLONASS observations, its near real-time and post-processing treatment and its influence on the modelling and mitigation of the troposphere delay error source, (see communications [73], [83], [84], [89], [90] and paper [128]).
- ➢ We contributed to the establishment of a Memorandum of Understanding between EUREF and EUMETNET and we demonstrated the benefits of this memorandum for EUREF, (see communications [83] and paper [130]- collaboration Swisstopo and BKG).
- ➢ We demonstrated that using observations from dense GNSS networks allows monitoring the structure, movement and variability of fine mesoscale atmospheric water vapour structures, providing valuable information for Numerical Weather Prediction and nowcasting applications, (see communications [73], [85] and paper [129] - collaboration S. de Haan, KNMI).
- ➢ We compared the GNSS-based troposphere ZPD against ZPD obtained from radiosonde observations and NWP models to validate the GNSS observation processing strategy developed in the frame of E-GVAP to monitor the troposphere. We demonstrated that the current precision and accuracy achieved by the method is at the level of 6 to 7 mm of ZPD, (see communication [84] and paper [128]).

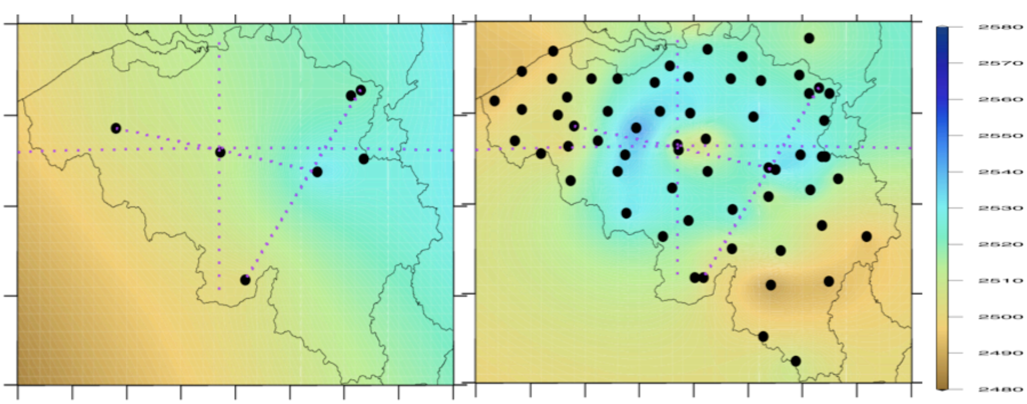


Figure 27: Tropospheric delay field reconstructed without (left) and with (right) the Belgian dense network

3.7.2.4 Monitoring of the Earth's Ionosphere

- We investigated the best way of estimating the Total Electron Content (TEC) over Europe using the EPN GPS data. For that purpose, we first used the Bernese software, but as this software is smoothing the TEC, we decided to develop ourselves the software to estimate TEC maps without performing any smoothing (in collaboration with S. Jin).
- We started the estimation of TEC (Total Electron Content) maps using our own software and based on the EPN GPS data. We demonstrated that the density of the EPN allows to estimate hourly V (vertical) TEC and its RMS on a 1°/1° grid over Europe (Figure 28). Thanks to their high resolution in time and space, these maps allow to better monitor small structures in the ionosphere than the standard global ionospheric maps.
- We demonstrated that the TEC maps estimated with our software agree with CODE Global Ionospheric Map (GIM) products at 0.1±1 TECU during normal ionospheric activity and 1.2±2.8 TECU during the geomagnetic storm period.
- An ESA project entitled "GNSS Contribution to the Next Generation Global Ionospheric Monitoring" (Proposal acronym: GIOMO) has been proposed. This proposal has been highly evaluated for the science content but not selected.

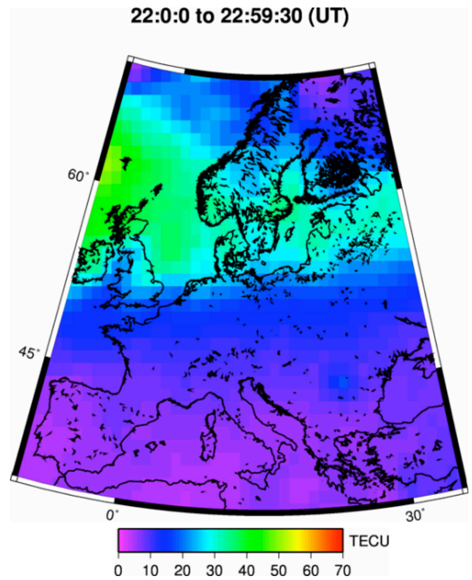


Figure 28: 1°/1° hourly TEC map over Europe from EPN GPS data between 22:00 and 23:00, day 303 of 2003 (Halloween geomagnetic storm)

More details are available in communications [81], [92], and [96] and papers [120], [121], and [133].

3.7.3 Perspective for next years

- Continue to maintain and modernise (GLONASS and GALILEO) the ROB network of permanent GNSS stations
- Continue to maintain, extend and improve the EUREF service centre (management of the EPN Central Bureau, EPN Data Centre, and EPN Analysis Centre)
- Continue to develop and maintain the E-GVAP service
- Continue to acquire, manage and distribute scientific knowledge within the frame of GNSS: improvement of the precision and reliability of the positioning, improvement of the knowledge of spatial and temporal variations of the atmosphere, and improvement of the knowledge of crustal deformations
- Continue to contribute to the GIANT project at the Belgian Antarctic Base
- Continue to monitor the European ionosphere concentrating on the improvement of the software, and automation of the generation of TEC maps
- Use the GNSS data from the Belgian dense network to improve the knowledge of spatial and temporal variations of the atmosphere

3.7.4 Personnel involved

Scientific staff: C. Bruyninx (head "GNSS" project – EPN Central Bureau, ROB)
P. Defraigne (head "Time and time transfer" project, ROB)
N. Bergeot (Monitoring of the ionosphere, STCE)
J. Legrand (BELSPO Action 1, EPN Central Bureau)

E. Pottiaux (Monitoring of the troposphere, STCE)
S. Pireaux (Implementation of higher-order ionospheric effects in Atomium, STCE)
Technical staff: F. Coutereel (Technical support GNSS equipment, STCE)
A. Moyaert (ICT, ROB)
D. Mesmaker (gestionnaire de dossiers techniques, ROB)

3.8 Synergy between GNSS-based and SW products

Responsible person: Veronique Dehant, email: V.Dehant@oma.be
This work package is related to the following research themes or objectives:

- G: studying the interaction of corpuscular radiation with the terrestrial magnetosphere
- H: studying the interaction of solar electromagnetic radiation with the terrestrial atmosphere
- I: GNSS-based ionospheric monitoring in support of space weather services and GNSS applications

3.8.1 Objectives

The synergy between GNSS-based and other SW products concerns fundamental research, outreach and development of future-oriented approaches.
To use GNSS-based ionospheric monitoring to learn more about the physics of the ionosphere and the interaction between SW and the ionosphere; to use GNSS-based tropospheric monitoring to learn more about the physics of the troposphere, intense weather phenomena and their applications; to indentify the synergies in the frame of the STCE (WP ROB B.3).

3.8.2 Progress and results

In the frame of identifying and assessing synergies between the measurement techniques used and the products provided by the different WPs of the STCE, a first domain of opportunity has been identified in the frame of space research: radio science. As the GNSS signals travel through the Earth's atmosphere, they contain information on the ionosphere and the troposphere state as established in STCE WP results. As the plasma variations can be characterized as a function of the solar activity as indicated in other STCE WPs, the plasma between the Sun and the Earth and around the Sun can be modelled. The effects of the neutral atmosphere and ionosphere on GNSS and the plasma changes induced by solar activity as determined by the STCE actors can be further used by other partners of the space pole working with radio science data. Indeed, radio science experiments using spacecrafts communicating with the Earth involve radio signals propagating within the interplanetary medium, in the atmosphere of the Earth, and possibly in the atmosphere of other planets. The expected instrument noise of transponders used in present and future radio science experiments onboard planetary space missions such as on ExoMars and MarsNEXT (AURORA program) are below the measurement noise due to the large perturbations on the radio signals induced by signal propagation, in the case of Mars' mission, in the atmosphere of Mars and (mainly) the Earth, the ionosphere of Mars and (mainly) the Earth, and the interplanetary plasma along the ray path (see Figure 29).

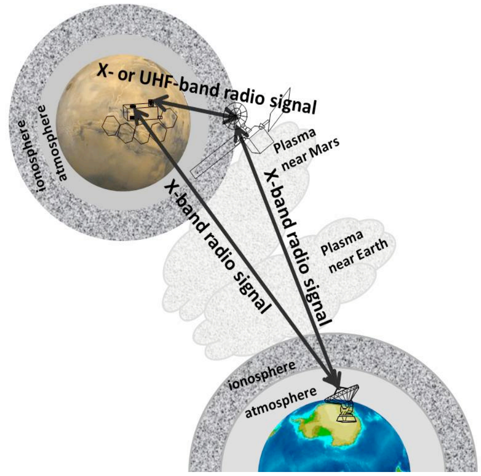


Figure 29: Schematic representation of the atmosphere and plasma effects on radio signals.

The Doppler measurements of the radio signal of these future missions will provide unprecedented information on the interior of the moons or planets through the observation of their orientation and their rotation (precession and nutations, librations, polar motion, and length-of-day variations). An example of the radio link between Mars and the Earth is presented in Figure 30.

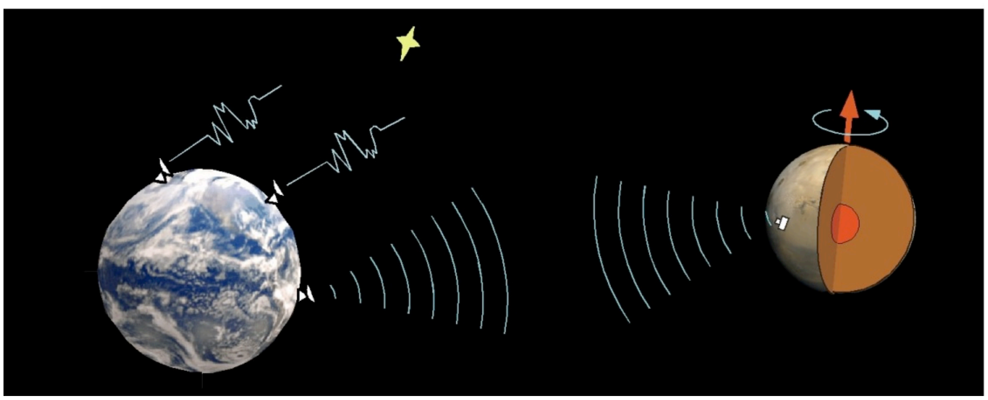


Figure 30: Rotation of Mars can be measured by radio range and Doppler, with the rotation of Earth measured relative to extragalactic radio sources with very-long-baseline interferometer.

The lower the signal to noise ratio is, the better the geophysical parameters can be determined. The STCE offers the opportunity to improve the propagation corrections in order to increase the measurement precision, and therewith, to increase the scientific return. The application of the STCE knowledge can improve the corrections on the signal at all levels along the propagation path. Models based on GNSS data of the neutral atmosphere and of the ionosphere of the Earth are and will be used to compute the corrections. The plasma between the planets or moons and the Earth will be computed for different solar activity indices. An FP7 proposal entitled "Atmospheric, ionospheric, and interplanetary plasma propagation corrections on Earth-Mars RAdio Link" (Proposal acronym: EMRAL) has been proposed in 2008 under a 'Collaborative Project' funding scheme coordinated by ROB. This proposal has been highly evaluated for the science content but not selected. It will be proposed for a next call.

3.8.3 Perspective for next years

- Continue to work within a synergetic approach on the radioscience corrections for plasma and atmosphere/ionosphere effects on radio signals;
- Propose a Collaborative Project in the frame of a future FP7 call.

3.8.4 Personnel involved

Scientific staff: C. Bruyninx (head "GNSS" project – EPN Central Bureau, ROB)
N. Bergeot (Monitoring of the ionosphere, STCE)
P. Defraigne (head "Time and time transfer" project, ROB)
J. Legrand (BELSPO Action 1, EPN Central Bureau)
E. Pottiaux (Monitoring of the troposphere, STCE)
V. Dehant (Radioscience experiment coordinator, ROB)
P. Rosenblatt (Radioscience experiment data analysis, PRODEX)
Ö. Karatekin (Planet atmosphere, PRODEX)
M. Mitrovic (Radioscience error budget, PRODEX)
E. Podladchikova (Solar activity and plasma model, STCE)
L. Rodriguez (Solar activity and plasma model, STCE)
A. Zhukov (Solar activity and plasma model, STCE)
R. Van der Linden (Solar activity and SIDC, ROB)

3.8.5 Scientific Outreach

3.8.5.1 Meeting presentations

The list below is related to 3.6, 3.7 and 3.8.

[73] Pottiaux E.
The Belgian contribution to the EUMETNET GPS water vapour program (E-GVAP): recent developments and applications
EGU General Assembly 2008, April 14-18, 2008, Vienna, Austria

[74] Defraigne P., Bruyninx C., Legrand J.
Continuous Frequency Transfer Using GPS Carrier-Phases
22nd European Frequency and Time Forum (EFTF), April 23-28, 2008, Toulouse, France

[75] Defraigne P., M.C. Martinez,
Combination of TWSTFT and GPS data for Time Transfer
22nd European Frequency and Time Forum (EFTF), April 23-28, 2008, Toulouse, France

[76] Baire Q., P. Defraigne,
Combining GPS and GLONASS for Time and Frequency Transfer
22nd European Frequency and Time Forum (EFTF), April 23-28, 2008, Toulouse, France

[77] Pottiaux E.
The Belgian contribution to E-GVAP: current status and developments
E-GVAP joint expert team meeting, May 6-7, 2008, Potsdam, Germany

[78] Pottiaux E.
The Belgian Active Geodetic Network
E-GVAP joint expert team meeting, May 6-7, 2008, Potsdam, Germany

[79] Bruyninx C., Legrand J., Roosbeek F.
GNSS Network Management Procedures: Application to the EPN
IGS Analysis Centers Workshop, June 2-6, 2008, Miami, US

[80] Weber G., Bruyninx C.
Monitoring of the Real-time IGS NTRIP Interfaces
IGS Analysis Centers Workshop, June 2-6, 2008, Miami, US

[81] Bergeot N., C. Bruyninx, E. Pottiaux, S. Pireaux, P. Defraigne, J. Legrand
Detection of Abnormal Ionospheric Activity from the EPN and Impact on Kinematic GPS Positioning
EUREF Symposium, June 18-21, Brussels, Belgium

[82] Bruyninx C., Legrand J., Roosbeek F.
Status and Performance of the EUREF Permanent Tracking Network
EUREF Symposium, June 18-21, Brussels, Belgium

[83] Pottiaux E., Brockmann E., Söhne W., Bruyninx C.
The EUREF - EUMETNET Collaboration: First Experiences and Potential Benefits
EUREF Symposium, June 18-21, Brussels, Belgium

[84] Pottiaux E.
GNSS Near Real-Time Zenith Path Delay Estimations at ROB: Methodology and Quality Monitoring
EUREF Symposium, June 18-21, Brussels, Belgium

[85] Pottiaux E.
Detecting Small-scale Tropospheric Phenomena Using GNSS Observations from Dense National Networks
EUREF Symposium, June 18-21, Brussels, Belgium

[86] Bruyninx C.
The EUREF Permanent Network: Design and Objectives
ASG-EUPOS Conference, June 24, 2008, Warsaw, Poland

[87] Ihde J., C. Bruyninx, H. Habrich, A. Kenyeres, M. Poutanen, M. Sacher
EUREF's Reference Networks EPN, UELN, and ECGN – Basis for Tectonic Monitoring and Investigations in Europe
WEGENER General Assembly, September 15-18, 2008, Darmstadt, Germany

[88] Bruyninx C., J. Legrand, F. Roosbeek
EPN Coordination Status and Plans
EUREF Local Analysis Centers Workshop, October 22-23, 2008, Frankfurt, Germany

[89] Legrand J., Q. Baire, N. Bergeot, C. Bruyninx, P. Defraigne, S. Pireaux, E. Pottiaux
Current activities and research at ROB LAC
EUREF Local Analysis Centers Workshop, October 22-23, 2008, Frankfurt, Germany

[90] Pottiaux E.
The Belgian Contribution to E-GVAP: current status and developments
E-GVAP joint expert team meeting, 7 November 2008, Copenhagen, Denmark

[91] Ihde J., C. Bruyninx, H. Habrich, A. Kenyeres, M. Poutanen
Development of EUREF's GNSS Reference Network EPN
Int. Symp. On GNSS, Space-based and Ground-based Augmentation Systems and Applications, 11-14 November 2008, Berlin, Germany

[92] Bergeot N., C. Bruyninx, S. Pireaux, P. Defraigne, J. Legrand, E. Pottiaux
Impact of a Geomagnetic Super Storm on Kinematic GPS Positioning
5th European Space Weather Week, 17-21 November 2008, Brussels, Belgium

[93] Pireaux S., P. Defraigne, N. Bergeot, C. Bruyninx
Correction Second Order and Third Order Ionospheric Perturbations in GPS Time and Frequency Transfer Based on PPP

5th European Space Weather Week, 17-21 November 2008, Brussels, Belgium

[94] Pireaux S., P. Defraigne, N. Bergeot, C. Bruyninx
Influence of Ionospheric Perturbations in GPS Time and Frequency Transfer
PTTI2008, 1-4 December 2008, Reston, Virginia, US

[95] Defraigne P., M.C. Martinez, Z. Jiang
Time transfer from combined analysis of GPS and TWSTFT data,
PTTI2008, 1-4 December 2008, Reston, Virginia, US

[96] Bergeot N., C. Bruyninx, E. Pottiaux, S. Pireaux, P. Defraigne, J. Legrand
Detection of Ionospheric Scintillations and Impact on Kinematic GPS Positioning
AGU Fall Meeting, 15-19 December 2008, San Francisco, US

[97] Dehant V.
Geodesy with multiple lander radioscience
NEXT Science Payload Definition Team Meeting, ESTEC, ESA, Noordwijk, the Netherlands, 10-11 January 2008

[98] Dehant V.
Gravity from Orbiter
Mars-NEXT Science Definition Team meeting, ESA ESTEC, Noordwijk, the Netherlands, 10-11 January 2008

[99] Dehant V.
Radioscience onboard landers and orbiters
AURORA-NEXT Science Definition Team (SDT), ESTEC, ESA, Noordwijk, the Netherlands, 10-11 January 2008

[100] Dehant V.
Lander Interior and Geodesy Payload
AURORA-NEXT Science Definition Team (SDT), ESTEC, ESA, Noordwijk, the Netherlands, 31 January-1st February 2008

[101] Dehant V., Orban D., Renotte E., Mitrovic M., and the LaRa Team (including Van Hoolst T., Rosenblatt P.)
The LaRa experiment, requirements and interfaces
TAS-I interface meeting, Thales Alenia Space, Roma, Italy, 3-4 March 2008

[102] Dehant V.
The LaRa experiment
ExoMars Science Working Team (ESWT), ESTEC, Noordwijk, the Netherlands, 7-9 April 2008

[103] Dehant V., Folkner W., Orban D., Renotte E., Le Maistre S., Mitrovic M., Chicarro A., and the LaRa Team (including Van Hoolst T. and Rosenblatt P.)
The geodesy experiment LaRa (Lander Radioscience, onboard ExoMars) and future radioscience experiments
EGU 2008 General Assembly, Vienna, Austria, 14-18 April 2008

[104] Rosenblatt P., Le Maistre S., Marty J.C., Dehant V.
Numerical simulations of a geodetic orbital experiment for future mission to Mars
EGU 2008 General Assembly, poster, Vienna, Austria, 14-18 April 2008

[105] Le Maistre S., Rosenblatt P., Marty J.C., Dehant V., Karatekin Ö., Rivoldini A.
Improvement of Mars orientation and rotation model from the LaRa experiment onboard ExoMars
EGU 2008 General Assembly, poster, Vienna, Austria, 14-18 April 2008

[106] Dehant V.

The geodesy experiment using radioscience within ExoMars and Mars-NEXT
Mars-NEXT 4th Science Definition Team meeting, ESA HQ, Paris, France, 24-25 April 2008

[107] Dehant V.
Clarifications on Radio Science links
Mars-NEXT 4th Science Definition Team meeting, ESA HQ, Paris, France, 24-25 April 2008

[108] Dehant V.
LaRa versus enhanced LaRa
Mars-NEXT 5th Science Definition Team meeting, ESA ESTEC, Noordwijk, the Netherlands, 23-24 July 2008

[109] Dehant V., Le Maistre S., Mitrovic M., Rosenblatt P., Chicarro A., Fisackerly R., and the LaRa team and the SDT of Mars-NEXT
Rotation and internal dynamics from future geodesy experiment
European Planetary Science Congress 2008, Munster, Germany, 21-24 September 2008

[110] Dehant V., Folkner W., Chicarro A., and the LaRa team and the SDT of Mars-NEXT
Rotation and internal dynamics from future geodesy experiment
Journées Systèmes de Référence Spatio-temporels, Dresden, Germany, 21-23 September 2008

[111] Dehant V., Le Maistre S., Mitrovic M., Rosenblatt P., Rivoldini A., Folkner W., Orban D., Renotte E., and the LaRa team
Rotation and internal dynamics of Mars from the LaRa experiment in ExoMars
AGU Fall Meeting, Session: P14: Landed Measurements on Mars: Ground Truth for Orbital Data, San Francisco, USA, 15-19 December 2008

3.8.6 Publications

We give an overview of the publications related to 3.6, 3.7 and 3.8

3.8.6.1 Publications with peer review

[112] Torres J.A., Z. Altamimi, C. Boucher, E. Brockmann, C. Bruyninx, A. Caporali, W. Gurtner, H. Habrich, H. Hornik, J. Ihde, A. Kenyeres, J. Mäkinen, H. v d Marel, H. Seeger, J. Simek, G. Stangl and G. Weber
Status of the European Reference Frame (EUREF)
"Observing our Changing Earth", IAG Symposia Series, Vol. 133, pp. 47-56, DOI: 10.1007/978-3-540-85426-5

[113] Defraigne P., Guyennon N., and Bruyninx C.
GPS Time and Frequency Transfer: PPP and Phase-only analysis
Intern. Journ. of Navigation and Observation, Volume 2008 (2008), Article ID 175468.

3.8.6.2 Publications without peer review

[114] Bruyninx C., Roosbeek F.
The EUREF Permanent Network: Recent Achievements
Mitteilungen des BKG, Band 40, EUREF Publication No. 16, Ed. BKG, Frankfurt am Main, pp. 105-112

[115] Bruyninx C.
GPS and GLONASS Data Analysis using Stations from the EUREF Permanent Network
Mitteilungen des BKG, Band 40, EUREF Publication No. 16, Ed. BKG, Frankfurt am Main, pp. 377-383

[116] Defraigne P., Bruyninx C., Legrand J.

Continuous Frequency Transfer Using GPS Carrier-Phases
Proc. EFTF 2008 (on CD)

[117] Baire Q. and Defraigne P.
Combining GPS and GLONASS for Time and Frequency Transfer
Proceedings of the 28th EFTF, 2008 (CD-rom).

[118] Defraigne P. and Martinez M.C.
*Combination of TWSTFT and GPS data for Time Transfe*r
Proceedings of the 28th EFTF, 2008 (CD-rom).

3.8.6.3 Publications in press, submitted

[119] Bergeot N, M-N. Bouin, M. Diament, B. Pelletier, M. Régnier, S. Calmant, V. Ballu
Horizontal and vertical interseismic velocity fields in the Vanuatu subduction zone from GPS measurements: evidence for central Vanuatu locked zone.
Journal of Geophysical Research, Solid Earth, in press

[120] Bergeot N., C. Bruyninx, E. Pottiaux, S. Pireaux, P. Defraigne, J. Legrand
Detection of abnormal ionospheric activity from the EPN and impact on kinematic GPS positioning
Proc. EUREF2008 Symposium, July 2008, Brussels, in press

[121] Bergeot N., C. Bruyninx, J. Legrand, E. Pottiaux, F. Roosbeek, P. Voet
National Report of Belgium
Proc. EUREF2008 Symposium, July 2008, Brussels, in press

[122] Bruyninx C., Carpentier G., Roosbeek **F.**
The EUREF Permanent Network: Monitoring and On-line Resources
"Geodetic Reference Frames", IAG Symposia Series, Springer, in press

[123] Bruyninx C., Legrand J., Roosbeek F.
Status and Performance of the EUREF Permanent Tracking Network
Proc. EUREF symposium, July 2008, Brussels, in press

[124] Dehant V., Folkner W., Renotte E., Orban D., Asmar S., Balmino G., Barriot J.-P., Benoist J., Biancale R., Biele J., Budnik F., Burger S., de Viron O., Häusler B., Karatekin Ö., Le Maistre S., Lognonné P., Menvielle M., Mitrovic M., Pätzold M., Rivoldini A., Rosenblatt P., Schubert G., Spohn T., Thomassen L., Tortora P., Van Hoolst T., Witasse O., Yseboodt M.
Lander Radioscience for obtaining the rotation and orientation of Mars
Planet. Sp. Sci, DOI: 10.1016/j.pss.2008.08.009, in press

[125] Dehant V., Folkner W., Chicarro A., the LaRa team, and the MarsNEXT team
Rotation and internal dynamics from future geodesy experiments
In: Proc. Journées Systèmes de Référence spatio-temporels 2008 and X. Lohrmann-Kolloquium, Ed. M. Soffel, in press.

[126] Defraigne P., M.C. Martinez, Z. Jiang,
Time transfer from combined analysis of GPS and TWSTFT data
Proc. PTTI2008, 1-4 December 2008, Reston, Virginia, US, in prerss

[127] Pireaux S., P.Defraigne, N.Bergeot, Q.Baire, C.Bruyninx
Influence of Ionosphere Perturbations in GPS Time and Frequency Transfer
Proc. PTTI2008, 1-4 December 2008, Reston, Virginia, US, in press

[128] Pottiaux E.
GNSS Near Real-Time Zenith Path Delay Estimations at ROB: Methodology and Quality Monitoring
Bulletin of Geodesy and Geomatics, in press

[129] Pottiaux E.
Detecting small-scale Tropospheric Phenomena Using GNSS Observations from Dense National Networks
Proc EUREF2008 Symposium, July 2008, Brussels, in press

[130] Pottiaux E., Brockman E., Söhne W., Bruyninx C.
The EUREF - EUMETNET Collaboration: First Experience and Potential Benefits
Bulletin of Geodesy and Geomatics, in press

[131] Pireaux S., Defraigne P., Wauters L., Bergeot N., Baire Q., Bruyninx C.,
Influence of ionosphere perturbations in GPS time and frequency transfer
Advances in Space Research, submitted

3.8.6.4 Reports, etc

[132] Bastos L., and the PLEGG team including N. Bergeot, C. Bruyninx, E. Pottiaux
PLEGG: Platform for European GNSS and other Geo-products
Reply to FP7-INFRASTRUCTURES-2008-2 call, 176 pages

[133] Seybold J., Aichhorn K., Wasle E., Weber R., Hausleitner W., Stangl G., Bruyninx C., Bergeot N., Teferle N.
GIOMO: GNSS Contribution to Next Generation Global Ionospheric Monitoring
Reply to ESA call OPS-MGT-SOW-0009-OPS-GN, 61 pages

[134] Dehant V., and the EMRAL team including N. Bergeot, C. Bruyninx, Ö. Karatekin, M. Mitrovic, E. Podladchikova, E. Pottiaux, P. Rosenblatt, A. Zhukov
Atmospheric, ionospheric, and interplanetary plasma propagation corrections on Earth-Mars RAdio Link: EMRAL
Reply to FP7-SPACE-2009-1 call, 75 pages

[135] Le Maistre S., Dehant V.
Geophysical contribution to Doppler measurements & Parameter sensitivity
LARA-TN-ROB-00007, 24 pages

[136] Le Maistre S., Dehant V.
Retrieval of the geophysical parameters from the LaRa Doppler measurements
LARA-TN-ROB-00008, 20 pages

[137] Mitrovic M., Dehant V.
Error budget for LaRa radio link
LARA-TN-ROB-00001, 16 pages

[138] Mitrovic M., Dehant V.
Modelling of LaRa for our understanding of the thermal noise
LARA-TN-ROB-00010, 108 pages

[139] Rivoldini A., Van Hoolst T.
What can we obtain as information on the interior of Mars from Mars rotation and orientation parameters?
LARA-TN-ROB-00011, 16 pages

4 STCE@RMI

4.1 Study of the solar constant

Responsible person: Steven Dewitte, email: Steven.Dewitte@oma.be
This work package is related to the following research themes or objectives:

- E: developing advanced technology for solar observations,
- J: solar cycle and iradiance studies and the "solar constant".

4.1.1 Overall Description

The goal is to perform a long term monitoring of the solar irradiance for climate change studies.

4.1.2 Composite total solar irradiance series

At international level the RMIB is one of the groups who maintain a composite of the measurements of the Total Solar Irradiance (TSI), see Figure 31. The red curve is our composite, the green curve is the composite of our Swiss PMOD colleagues, and the blue curve is the one of our American ACRIM colleagues. We agree on the 'short' term (short compared to climate timescales) variations of the TSI with the eleven-year cycle, which is known from the observation of sunspots. The eleven year variations of the TSI are of the order of one per thousand, and they cause temperature variations on earth of the order of 0.1 °C. Although these temperature variations are small, they are not negligible, and they have to be taken into account in order to study the temperature increase due to increasing greenhouse gases or decreasing aerosols.

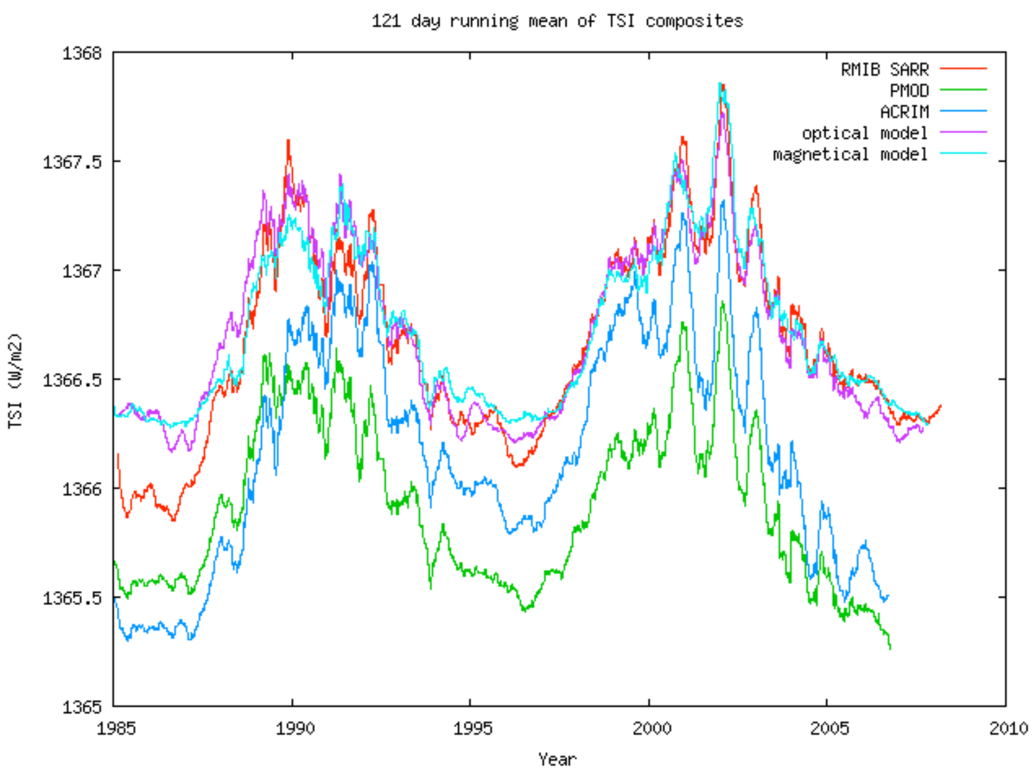


Figure 31: Composite measurements of the variations of the Total Solar Irradiance for the last two eleven year solar cycles compiled by three international groups

Differences among the three composites exist for what concerns the variation of the TSI in between the minima of the eleven-year cycles. If they exist, these variations are the most relevant for climate change. For the previous solar cycle we have found an increase of 0.15 W/m², however this increase was not significant compared to an uncertainty of +/- 0.35 W/m². The ACRIM group found an increase of 0.8 W/m², the PMOD group found no change. For the current solar cycle, which started in 1996 and which is now ending, we find no change with an uncertainty of +/- 0.14 W/m². The uncertainty has been more than halved; for a large part this is due to the stability of our DIARAD/VIRGO instrument. The ACRIM and PMOD groups find a decrease for the current solar cycle. These deviating results can be explained by the use of the ACRIM 3 instrument with incomplete ageing correction by the ACRIM group, and by the use of subjective instrument corrections by the PMOD group.

4.1.3 Construction of the SOVAP space radiometer for flight on the PICARD satellite

The RMIB builds its own space instruments for the measurements of the incident solar irradiance. Figure 32 shows the team that is responsible for building these instruments with the prototype SOVAP radiometer. In June 2008 the team finished the flight model of the SOVAP radiometer for flight on the PICARD satellite in 2009. After instrument qualification SOVAP was integrated on the PICARD satellite. Currently (April 2009) our instrument construction team is participating to the thermal balance testing of the entire PICARD satellite. During the thermal balance testing the SOVAP electrical reference voltages are measured in order to maximise the in-flight accuracy of SOVAP. The PICARD launch is foreseen for November 2009. We are completing the SOVAP flight software to be run at the Picard scientific mission control center (Centre de Mission Scientifique Picard) that will be hosted by Busoc.
The SOVAP instrument contains a Bolometric Oscillation Sensor (BOS), which is developed by the ROB.

Figure 32: The RMIB team for the construction of space radiometers with the protoype of the SOVAP radiometer for the PICARD project.

For a connection of the space and ground value of the solar irradiance we plan to have a measurement with the SOVAP prototype radiometer in the new Belgian Antarctica research station Princess Elisabeth during the next Antarctic summer season (end 2009 – begin 2010). From a first series of measurements with a sun photometer in Antarctica during Feb. 2009 as part of the Belatmos project (cooperation RMIB-BISA-University of Gent), it appeared that both the water vapor and the aerosol content of the atmosphere near the station is very low. Therefore the atmospheric transmission is high, and the conditions for accurate measurements of the ground solar irradiance are favorable.

4.1.4 DIARAD/SOVIM space radiometer launch and scientific results

On 7 February 2008 our DIARAD/SOVIM instrument was launched as part of the European Columbus module on the International Space Station. The RMIB now has two working TSI radiometers in space, our first one is active on the SOHO satellite since 1996. This strengthens our leading role at the international level for the measurement of the TSI from space.

Unfortunately, due to a hardware failure beyond our control, our DIARAD/SOVIM instrument stopped working on 4 October 2008. The available DIARAD/SOVIM data was analysed and a journal paper on the results is under review.

The DIARAD/SOVIM results are important concerning the controversial open issue of the absolute level of the TSI. The debate on the absolute level of the TSI was opened with the launch of the American TIM/SORCE instrument in 2003. This instrument measures a value which is 5.2 W/m^2 lower than our DIARAD/VIRGO instrument which is making measurements in space since 1996. The difference between TIM/SORCE and DIARAD/VIRGO is larger than what can be explained from the claimed instrument accuracies.

Due to the controversy on the absolute level we have – before the launch of DIARAD/SOVIM - paid extra attention to the different elements that have an influence on its absolute accuracy. These elements are the measurement of the precision aperture areas, the optical and thermal characterisation, and the measurement of the reference voltages. A quality control of the DIARAD/SOVIM absolute accuracy is given by the difference between its two independent channels, which is as low as 0.25 W/m^2. This is lower than what we obtained with our previous instruments, so we can confirm that DIARAD/SOVIM is our best instrument in terms of absolute accuracy. The measurements of DIARAD/SOVIM are 1.2 W/m^2 lower than DIARAD/VIRGO and 4 W/m^2 higher than TIM/SORCE. These results are possible within the claimed DIARAD/VIRGO uncertainty and are not possible within the claimed TIM/SORCE uncertainty.

Besides an interest in basic radiometric meteorology, i.e. how accurate can we measure radiative energy, the absolute level of the Total Solar Irradiance is also crucial for the challenging measurement of the Earth Radiation Imbalance.

4.1.5 First measurement of the Earth Radiation Imbalance

The measurements of the TSI, see Figure 31, can be well reproduced by regression models. Two regression models are shown by the purple curve, labeled 'optical model' and the light blue curve, labeled 'magnetical model'. The regression models describe the TSI variations by sunspot darkening and facular brightening. Within the measurement uncertainty of +/- 0.14 W/m^2 for the last solar cycle, the models describe the measured TSI variations completely. Therefore it seems that we can consider the measurement of the TSI variations as a 'solved issue'. It has taken the RMIB 25 years since the launch of its first space radiometer on Spacelab 1 in 1983 to reach this success. For the future we want to enlarge the application of our space radiometers to the even more demanding measurement of the Earth Radiation Imbalance.

The Earth Radiation Imbalance is the driver behind global climate change. The small radiation imbalance is the difference between the two large and nearly equal opposite energy fluxes of heating incoming solar radiation and cooling terrestrial radiation lost to space. If these two opposite fluxes are measured by independent instruments with independent calibration their calibration errors are added and they overwhelm the climate imbalance. By reanalysing data obtained with the Wide Field Of View (WFOV) radiometers from the Earth Radiation Budget Experiment (ERBE) for the year 1987, we were able for the first time to measure the small radiation imbalance directly. For 1987, we find a net heating of the earth of 0.88 +/- 0.29 W/m², which agrees well with the expected value around 0.85 W/m², see Figure 33.

For the future we want to develop a new generation of WFOV space radiometers based on our TSI radiometer design. These measurements should continue the ERBE WFOV measurements, which stopped in 1999, and improve their accuracy.

A design on paper of the required instrument has been carried out. The instrument has been baptised SIMBA, standing for Sun-earth IMBAlance radiometer. After completion of the SOVAP instrument work, and in parallel with the support to the Picard launch and commissioning, our instrument team will work on the development of a SIMBA prototype instrument. A ground testing of this prototype SIMBA in Antarctica during the season 2009-2010 is envisaged.

A collaboration with the University of Liege for flying SIMBA as a nanosatellite is being set up, and practical work will start during the next academic year. The goal is to fly SIMBA-1 as the OUFTI-2 nanosatellite. OUFTI-2 could than stand for Orbital Utility For True Imbalance measurement.

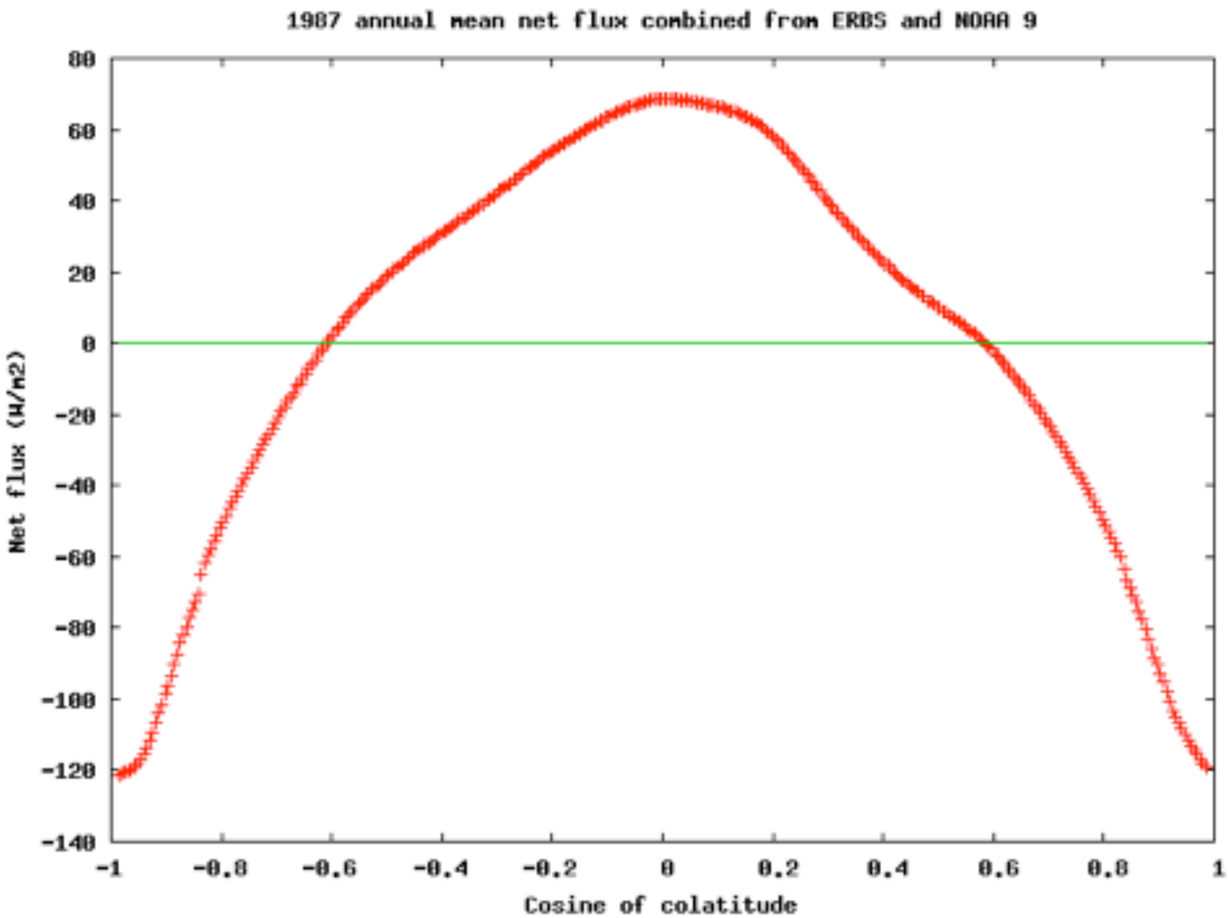


Figure 33: Latitudinal distribution of the net fluxes heating/cooling the earth. Near the equator there is a strong heating, near the poles there is a strong cooling. The differential heating/cooling is driving the general circulation in the oceans and in the atmosphere. There is a small positive radiation imbalance driving global climate change.

4.1.6 Perspective for the next years

- Launch preparation of SOVAP radiometer for flight on PICARD with foreseen launch in November 2009 – February 2010 time frame.

- After SOVAP launch: SOVAP instrument testing during commissioning activities, first validation SOVAP flight processing software, first validation scientific results. A first journal paper with the basic validation results is expected to be submitted for review one year after the first solar observations.
- Processing and analysis of measurements of DIARAD radiometer on SOHO.
- Refurbishment of SOVAP QM radiometer.
- Temporary integration of SOVAP QM radiometer in "Picard-Sol" at CERGA for safe non-standard flight instrument operation testing and for ground solar measurements
- Measurement campaign with SOVAP QM radiometer at Princess Elisabeth Antarctica station during 2010-2011 Southern Hemisphere summer season.
- Refurbishment and re-characterisation of SOVA1 radiometer which has flight heritage from 1992 Eureca space flight.
- Contribute to international radiometer comparison for resolving absolute scale difference between TIM and other radiometers. Laboratory comparison of SOVA 1 with cryogenic radiometer at LASP.
- Continue SIMBA instrument design, feasability and optimisation studies.
- Built prototypes of SIMBA instrument and make laboratory tests of critical elements for instrument accuracy.
- Start SIMBA-OUFTI cubesat satellite integration study.

4.1.7 Partnerships

4.1.7.1 Existing non-STCE funding

- PRODEX SOVAP/PICARD Instrument Development. The funding in 2009 covers only limited equipment and travel.
- PRODEX Solar Constant Data Exploitation. The funding has been stopped end of 2007.
- PRODEX Centre de Mission Scientifique PICARD. No funding goes to RMI.
- RMI personnel

4.1.7.2 Opportunities and collaborations

- Collaboration with international Total Solar Irradiance radiometer community.
- Foreseen collaboration with CSL for development of a new generation of radiometers

4.1.8 Publications

4.1.8.1 Journal publications with peer review

[140] G. Thuillier, S. Dewitte, W. Schmutz
Simultaneous measurement of the Total Solar Irradiance and Solar Diameter by the PICARD mission
Adv. Space Res., Vol. 38, pp 1792-1806, 2006.

[141] Dewitte, S., L. Gonzalez, N. Clerbaux, A. Ipe, C. Bertrand, B. De Paepe
The Geostationary Earth Radiation Budget Edition 1 data processing algorithms
Advances in Space Research, doi:10.1016/j.asr.2007.07.042, 2007.

[142] Mekaoui, S., S. Dewitte
Total Solar Irradiance measurement and modelling during cycle 23
Solar Physics, vol 247, Number 1, pp 203-216, January, 2008.

[143] Mekaoui, S., S. Dewitte
Cycle 23 TSI measurements from DIARAD/VIRGO with improved shutter temperature determination
submitted to Adv. Space Res.

[144] Mekaoui, S., S. Dewitte
Total Solar Irradiance absolute level from DIARAD/SOVIM on the International Space Station
submitted to Adv. Space Res.

4.1.8.2 Conference proceedings

[145] Buisson, F., M. Meissonnier, J.M. Mouret, P. Samson, G. Tuillier, S. Dewitte, W. Schmutz
Sun observation with a micro satellite: the Picard project
Proceedings of the 4S Satellite Symposium, 2006.

[146] Dewitte, S., Vermeulen, N., Mekaoui, S.
The Sun-earth IMBAlance radiometer for a direct measurement of the net heating of the earth
Eumetsat user conference, 2009.

4.1.8.3 Technical documents

The following documents have been written by the RMI techical team working on the Picard project. Only the documents since the delivery in October 2008 are given. Only short references are given:

PIC-PRAS-S-7-001-IRMB	Mise on MQ
PIC-PRAS-S-7-003-IRMB	Bit LAUP
PIC-PRAS-S-7-004-IRMB	Distribution de l'horloge à des circuits non-alimentés
PIC-PRAS-S-7-005-IRMB	Test modification logicielle PICO11.3
PIC-PRAS-S-7-007-IRMB	Isolation MQ
PIC-PRAS-S-7-008-IRMB	Equilibrage des sensibilités MV
PIC-PRAS-S-7-009-IRMB	Distribution horloge MV
PIC-PRAS-S-7-010-IRMB	Oscillation du courant BNR
PIC-PRAS-S-7-011-IRMB	Niveau des signaux de données digitales
PIC-PRAS-S-7-012-IRMB	Mesure des tensions de références in situ
PIC-PRAS-S-7-014-IRMB	Correction du traitement de surface
PIC-PRAS-S-7-015-IRMB	Actions en vue de la réduction du bruit sur canal 4
PIC-PRAS-S-7-016-IRMB	Topologie de la dissipation de l'électronique
PIC-PRAS-S-7-018-IRMB	Modification du pilotage du servo
PIC-PRAS-S-7-019-IRMB	Mesures d'isolation MV
PIC-PRAS-S-7-020-IRMB	Lecture de statut obturateur G
PIC-PRAS-S-7-021-IRMB	Lecture de statut obturateur D
PIC-PRAS-S-7-022-IRMB	Comportement de Udg
PIC-PRAS-S-7-023-IRMB	AGSE
PIC-PRAS-S-7-024-IRMB	Gamme de fonctionnement des obturateurs
PIC-PRAS-S-7-025-IRMB	Consommation à Vmin et Vmax

PIC_FA_S_7_SOV_6151_IRM Ed1R1 _Vref mercure1_
PIC_FA_S_7_SOV_6152_IRM Ed1R0 _Obtu Gauche mercure1_
PIC_FA_S_7_SOV_6153_IRM Ed1R0 _Obtu Droit mercure1_
PIC_FA_S_7_SOV_6154_IRM Ed1R1_susceptibilité CEM_
PIC_FA_S_7_SOV_6155_IRM Ed1R0 _Bruit sur canal 4_
PIC_FA_S_7_SOV_6157_IRM Ed1R0 _gradient température gauche…
PIC_FA_S_7_SOV_6158_IRM Ed1R0 _Obtu Gauche mercure2_
PIC_FA_S_7_SOV_6159_IRM Ed1R0 _Erreur d'asservissement_
PIC_FA_S_7_SOV_6161_IRM Ed1R0 _comportement étrange Udg_
PIC_FA_S_7_SOV_6162_IRM Ed1R0 _Obtu Droit mercure2_
PIC_FA_S_7_SOV_6163_IRM Ed1R0 _Connecteur Structure_
PIC_FA_S_7_SOV_6164_IRM Ed1R0 _Implémentation connecteurs_…

PIC_FA_S_7_SOV_6165_IRM Ed1R0 _Connecteur de test_
PIC_FA_S_7_SOV_6166_IRM Ed1R0 _Circuits de protection_
PIC_FA_S_7_SOV_6167_IRM Ed1R0 _Isolation AGSE_
PIC_FA_S_7_SOV_6168_IRM Ed1R0 _di_dt_
PIC_FA_S_7_SOV_6169_IRM Ed1R0 _rampe 1V_sec_
PIC_FA_S_7_SOV_6171_IRM Ed1R0 _Serial link_
PIC_FA_S_7_SOV_6172_IRM Ed1R0 _Continuité électrique SSM_
PIC_FA_S_7_SOV_6173_IRM Ed1R0 _Résistance entre les masses…
PIC_FA_S_7_SOV_6174_IRM Ed1R0 _Isolation sous 30V_
PIC_AQ_S_7_SOV_6113_IRM_Ed1_R0(Matrice Spec CU)
PIC-AQ-S-7-SOV-6104_E1R1_PQ_SovaP
PIC_AQ_S_7_SOV_6160_IRM_Ed1R1_IRMB_Mesures_Physiques
PIC-SP-S-7-SOV-6003-IRM(SpecIF_SOVAP)Ed2Rev0
PIC-CI-S-7-SOV-6111-IRMEd2Rev1(EICD_SOVAP)
PIC_AQ_S_7_SOV_6112_IRM_ED2R1_(Matrice_E_SovaP)
PIC_RP_S_7_SOV_6137_IRM Ed1R0(BS issue Vib)
PIC_PE_S_7_SOV_6136_IRM_Ed1_Rev2_Ther_Vac_MV_
PIC-IE-S-7-SOV-6190-IRM_Ed1R2(SERVO)
PIC_IE_S_7_SOV_6146_IRM_Ed1R0_(SovaP_MV&Harnais)
Recette_MV_Logique
PIC-IE-S-7-SOV-6144-IRM_Ed1R0_(MV_L&G)
PIC-IE-S-S-7-SOV-6145-IRM_Ed1R3_(BOS)

4.1.8.4 Presentations without paper

- S. Dewitte, “SOVAP scientific objectives”, Picard science team meeting, Oct. 2006.
- S. Dewitte, “SOVAP instrument design”, Picard science team meeting, Oct. 2006.
- A. Chevalier, “SOVAP instrument development status”, Picard science team meeting, Oct. 2006.
- S. Mekaoui, “TSI measurement and modelling during cyclme 22 and 23”, Picard science team meeting, Oct. 2006.
- S. Dewitte, “Measurement of the Total Solar Irradiance: status after 20 years of measurements and outlook for the future”, RMIB conference, May 2007.
- S. Dewitte, “SOVAP: measurement of the Total Solar Irradiance”, PICARD scientific committee, June 2007.
- S. Dewitte, “”, AGU meeting, Dec. 2007.
- S. Dewitte, “Long term TSI changes: status of our knowledge at the end of solar cycle 23”, SORCE science meeting, Feb. 2008.
- S. Dewitte, “Earth Radiation Imbalance measurement”, joint GERB/CERES science team meeting, October 2008.
- S. Mekaoui, “Total Solar Irradiance measurements from DIARAD/SOVIM on the ISS”, RMIB conference, Oct. 2008.
- N. Vermeulen, “Wide Field of View Measurement of the Earth Radiation Imbalance with Wide Field of View Radiometers”, joint GERB/CERES science team meeting, October 2008.
- S. Dewitte, “SOVAP science status”, PICARD scientific committee, May 2009.

4.2 Study of ozone and aerosol and their influence on climate and UV radiation

Responsible person: Hugo de Backer, email: Hugo.DeBacker@oma.be
This work package is related to the following research themes or objectives:

- H: studying the interaction of solar electromagnetic radiation with the terrestrial atmosphere,

- K: studying the influence of aerosols on climate.

4.2.1 Long term goals

With this study, we try to extend the high quality data set of the vertical distribution of ozone and ozone columns, which started in 1969 and UV spectral irradiation measurements, which started in 1989. We extract the additional information on aerosol available in the ozone and UV observations from the ground with spectrophotometers and from space using satellite images. The study allows us to maintain and improve/update the UV index prediction system. Another goal is to inform the public about the state of the ozone layer and the UV radiation.

Exploitation of the data:

- Use of ozone profile data in the study of tropospheric ozone events;
- Use of aerosol information to investigate the effect of aerosol on the UV radiation reaching the ground;
- Effect of the aerosol properties on the accuracy of broadband UV observations;
- Study of the interactions between changes in aerosol and ozone content of the atmosphere and climate changes;
- Study of the ozone budget over mid-latitudes.

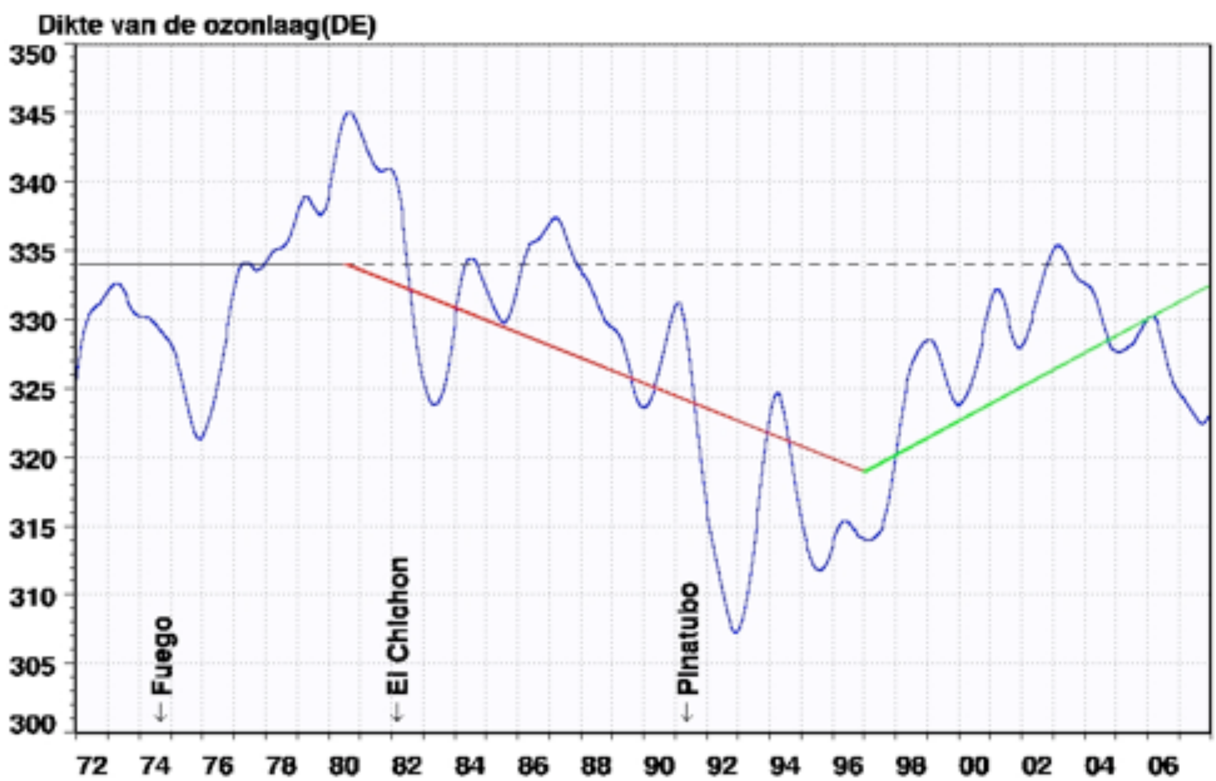


Figure 34: The running yearly mean values of the thickness of the ozone layer in Dobson units.

4.2.2 Ozone observations

The Royal Meteorological Institute of Belgium has a long tradition in the observation of ozone in the atmosphere. Since 1971 regular (almost daily) observations of the total ozone column at Uccle are avail-

able. The observations started with a Dobson instrument. In 1983 and 2001 the observations were expanded with Brewer instruments, which are more state-of-the art. The time series of the ozone observations from the different instruments are combined and can be used to study changes of the ozone layer on different time scales. Figure 34 shows the running yearly mean values of this time series. Ozone is depleted by Chlorine and Bromine compounds, which came in the stratosphere where the ozone layer resides in the early 1980s. Through the regulations of the Montreal protocol their concentration started to decrease in the second half of the 1990s. Therefore the piecewise trend line is drawn through the data. The time series also shows the influence of some large volcanic eruptions.
In order to maintain the quality of the observation the Brewer instruments were calibrated against a travelling world standard instrument in May 2008. These calibrations normally take place every two years.
Besides the ozone column the vertical distribution of ozone is also observed. This is done by radio soundings launched approximately three times a week. During such a sounding, an electrochemical ozone sensor, coupled to a meteorological radio sonde is attached to a balloon. The balloon ascents to about 30-35 km and gives a detailed profile of ozone, temperature, humidity and wind. An example is shown in Figure 35 . This time series started in 1969 and belongs to the longest records of ozone profiles in the world, together with Payerne in Switzerland and Hohenpeissenberg in Germany who started around the same period.

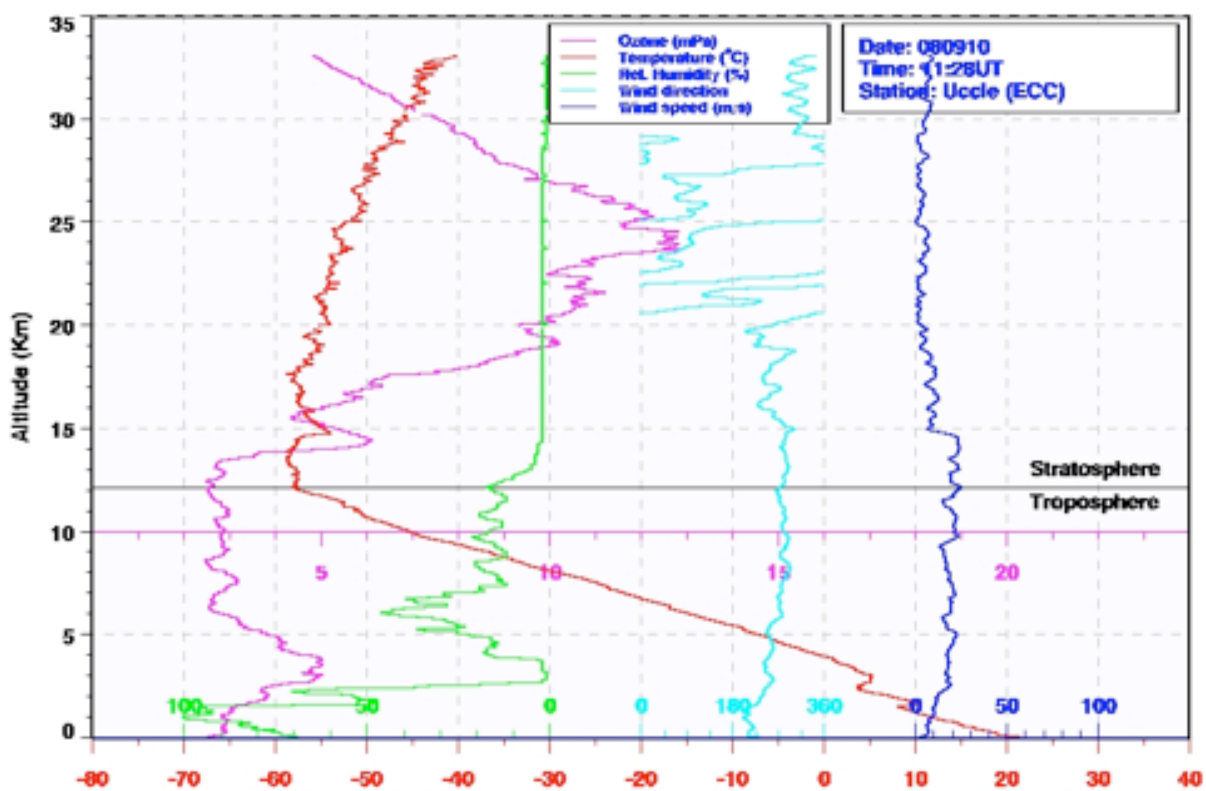


Figure 35: Example of the results of an ozone sounding, giving detailed profiles of ozone, temperature, relative humidity wind speed and wind direction.

In 2007 new ground equipment for radio soundings was installed to ensure the continuity of the observations.
The time series of ozone soundings can also be used to derive trends as function of the altitude. Indeed the behavior of ozone in the stratosphere is totally different from that in the troposphere.
Uccle is a complementary station for ozone in the Network for the Detection of Atmospheric Composition Changes (NDACC). All the ozone data are stored in international databases and can be used for stud-

ies of changes in the composition of the atmosphere and the relation with climate changes. The routine ozone soundings (about 140-150 per year) of Uccle are also used for the validation of ozone products from satellites (eg KMI-IRM is part of the O3M SAF of EUMETSAT for the validation of GOME-2 profiles). ECMWF is planning to integrate also reactive gases in the numerical weather forecast system. In this context, ozone soundings are very useful, either to validate model results, or to assimilate in the system, as they are the only detailed source of profile information in the troposphere. Therefore it is of high priority to continue the long time series of observations. In 2009 a new analyses of the long-term variation of atmospheric ozone will be initiated.

The ozone sounding data contain besides the ozone profiles also profiles of temperature, humidity and wind speed and direction. From the point of view of climate changes water vapour is also very important. Humidity changesaround the tropopauze, where the ozone gradient is large, may reflect an important impact on the climate. Therefore the humidity data from the soundings have been reviewed. It comes out (see Figure 36) that the troposphere above Uccle shrinks between January 1990 and September 2001, so that the upper tropospheric (UT) layers are descending, warming up and moistening. After September 2001, the troposphere expands, hence the UT layers are lifting, cooling down and drying. Other authors also pointed to a change in the strength of the Brewer-Dobson circulation around this period to explain a similar water vapour change in their observations.

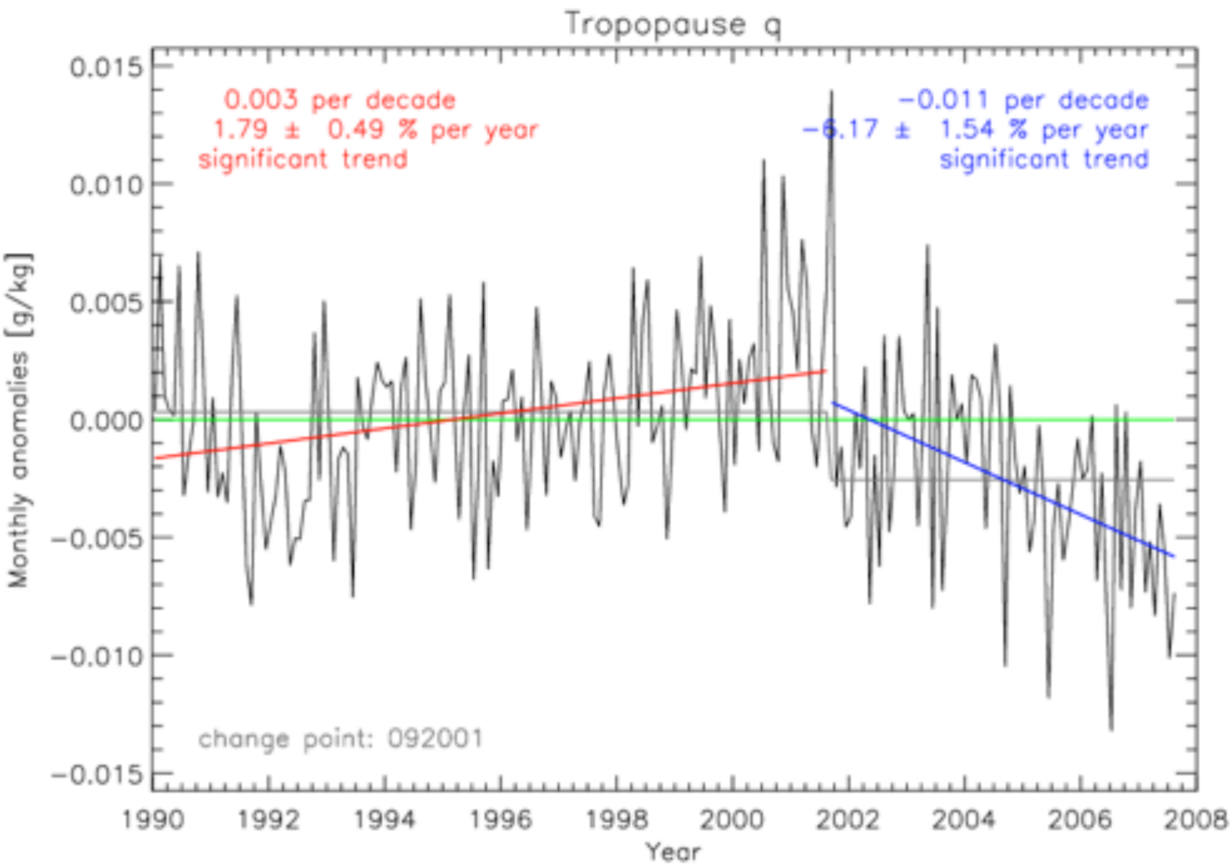


Figure 36: Time series of the monthly anomalies of the specific humidity at the tropopause for the 1990-2007 period.

4.2.3 Aerosol observations

An algorithm has been developed to derive aerosol information from the observations of the Brewer instruments. By now we have a time series of aerosol optical depths (AOD) at 320 nm (in the UV). It is the aim to make this algorithm operational so that the observations are available in near real time. Another aim is to start analysing the AOD at 340 nm and to compare the data with data from instruments in other networks. Observations at 340nm with the double Brewer have been collected during 2008, and are ready for analysis. This will be done in 2009-2010 and the results can be directly compared with the observations of the CIMEL instrument operated at BIRA.

The aerosol information is important for climate studies because of their impact on the radiation budget. During the next year, new efforts for observations of aerosols will mainly be done in the frame of BelAtmos for the monitoring at the Belgian station in Antarctica.

4.2.4 UV irradiance

The Brewer instruments also make spectral measurements in the UVB range of the solar radiance reaching the surface. From these data the UV index is derived and shown on the worldwide web (Figure 37, www.meteo.be).

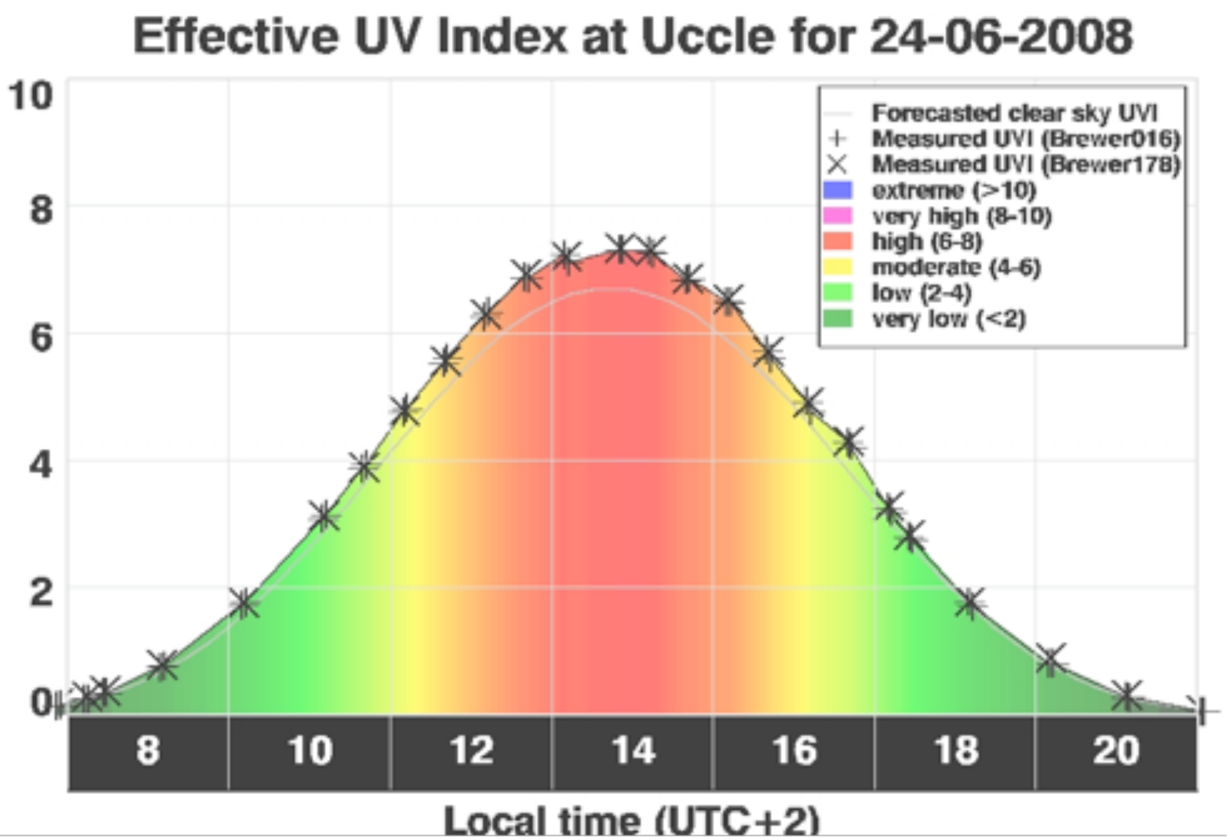


Figure 37: Forecasted and measured UV index for 24 June 2008 at Uccle.

At the same place a forecast of the UV index is available. This is to warn the public for the possible dangers of the UV radiation.

The intensity of UV radiation depends, besides the elevation of the sun, on the ozone and aerosol content of the atmosphere and the cloudiness. To improve the reliability of the forecast the relation between the UV radiation measurements and the aerosol observations will be studied. A method will be developed to estimate for Uccle the contribution of the aerosols to the attenuation of the UV irradiance.

A study in 2008 comparing ozone column forecasts from the statistical model at RMI, results from the ECWF, the BASCOE model and DWD forecasts revealed that the best results on day + 1 and day +2 were obtained with the DWD model. With these data the UV-index forecast is extended to day+1 and day +2. It is also aimed at including aerosol information in the UV forecast. To that aim the method to derive

AOD in the UV (at 320nm) from the standard direct sun observations of total ozone from the Brewer Instrument will be made operational. Another study, in collaboration with a Master student of the Department of Physics of the University of Antwerp learned that other optical properties (single scattering albedo) is related to the AOD itself. This relation will be further elaborated to implement it in the operational forecasts.
Further in future (2010) it is envisaged to investigate the possibility to produce UV-index forecasts for different areas in Belgium. A first choice would be the seashore. In order to assure the quality of the forecasts they will be first compared to the measurements made with a broadband instrument at Oostende by members of the team at BIRA.

4.2.5 Remote sensing tropospheric aerosols using SEVIRI (Meteosat Second Generation - MSG-).

The use of the SEVIRI visible channels allows monitoring aerosols over the oceans. **Error! Reference source not found.**Figure 38 shows the seasonal mean aerosol optical depth (AOD) during spring 2006.

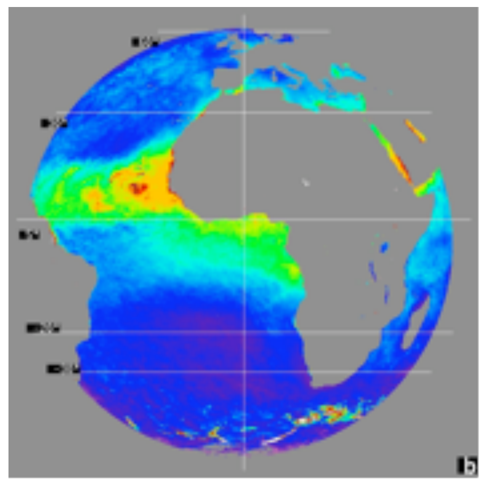


Figure 38: mean AOD at 0.83µm from 21 March until 20 June 2006.

We observe that the region in front of the coast of West Africa has high AOD. That corresponds to the presence of increased concentrations of dust aerosols that spread from the Sahara Desert over the subtropical northern Atlantic towards the Amazon basin. Similar dust events are responsible for the high AOD over the Red Sea and the Persian Gulf. On the other hand, the increased AOD over the Gulf of Guinea is due to intens biomass burning activities on the land.
Due to its observation of the Sahara with high time resolution, MSG is particularly interesting to study dust aerosols. However, over bright surfaces such as desert we can not use the visible channels. Instead we will use the thermal channels, which allow monitoring both at day and at night. Figure 39 shows the false color composite (RGB) using the thermal infrared channels on 8 March 2006 at 12:00 UTC over the Sahara that was characterized by a dust storm (pink areas). The combination of the differences of the brightness temperature (BT) between several thermal infrared channels allows to detect the dust aerosols (pink areas), high clouds (red), low clouds (green) and the surface (light blue and white).

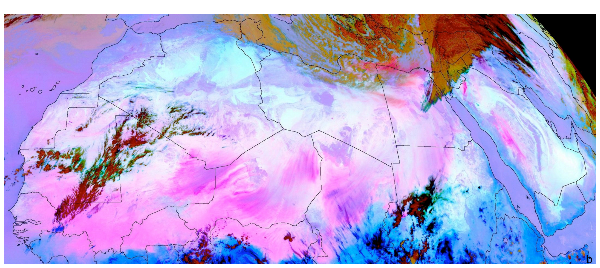


Figure 39: RGB (BT12.0µm-BT10.8µm , BT10.8µm-BT8.7µm , BT12.0µm)

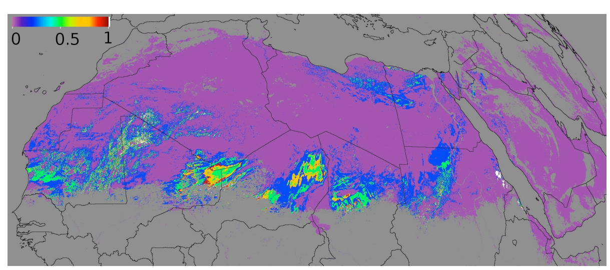


Figure 40: AOD at 8.7µm on 8 March 2006 at 12:00 UTC

On Figure 40 we show the corresponding AOD at 8.7µm. The grey pixels lie outside the Sahara region and therefore are not processed. We observe that the dust areas have an AOD between 0.2 and 0.8. Similarly, the clouds from Fig 2 are also characterized by high AOD. Therefore we should apply a cloud mask to our results. Further, the main area of the image has only a small background concentration of aerosols that can not be estimated accurately by our method.

4.2.6 Perspective for the next years

- Analysis of long term ozone series at Ukkel
- Implementation of SEVIRI aerosol retrieved over land, Hygeos algorithm developed in the context of the Eumetsat Climate Monitoring SAF

4.2.7 Partnerships

4.2.7.1 Existing non-STCE funding

- Action 1, contract MO/34/006, Aerosol Optical depth derived from ground based spectral observations of solar radiation.
- Action 1, contract MO/34/016, Assimilation of vertical ozone profile data in the chemical transport model CHIMERE coupled to weather prediction models of RMI.
- Action 2, contract WI/34/E02, Remote tropospheric aerosols from SEVIRI data.
- PODO III, contract SD/AT/01A, Advanced exploitation of ground-based measurements for chemistry and climate applications.
- European Commission: contract SIP4-CT-2004-516099 GEMS, Global and regional Earth system monitoring using Satellite and in-situ data
- A demand has been made for financing new ground equipment for ozone soundings by LOTTO via BELSPO.
- Belspo Action 2 for PhD Bart De Paepe until Sep. 2008.
- Eumetsat Climate Monitoring SAF
- Eumetsat Gerb ground segment
- RMI personnel

4.2.7.2 Opportunities and collaborations

- Collaboration with Eumetsat and European meteorological community for climate monitoring purposes
- Input to climate change related organisations like IPCC, UNFCCC, WMO GCOS etc.

4.2.8 Publications

4.2.8.1 Publications with peer review

[147] Solberg, Sverre, Ø. Hov, A. Søvde, I. Isaksen, P. Coddeville, H. De Backer, C. Forster, Y. Orsolini and K. Uhse
European surface ozone in the extreme summer 2003
J. Geophys. Res., 113 D07307, 2008

[148] Delcloo, Andy and H. De Backer
Five day 3D backward trajectories clusters and trends analysis for the Uccle ozone sounding time series in the troposphere (1969-2001),
Atm Env, 42, 4419-4432, doi:10.1016/j.atmosenv.2008.01.72, 2008.

[149] Cheymol, Anne, L. Gonzalez Sotelino, K.S. Lam, J. Kim, V. Fioletov, A.M. Siani and H. De Backer
Intercomparison of Aerosol Optical Depth from Brewer Ozone Spectrophotometer and CIMEL Sunphotometer measurements,

Atmos. Chem. Phys., 9, 733-741, 2009. http://www.atmos-chem-phys.net/9/733/2009/acp-9-733-2009.pdf

[150] De Backer, H.
Time series of daily erythemal doses at Uccle, Belgium,
International Journal of Remote Sensing, accepted, 2009.

[151] Mangold, Alexander, J.-U. Grooß, R. Ruhnke, H. De Backer and R. Müller,
Modelling the January 2006 low ozone episode over Western Europe and comparison with ozone sonde data,
Atmosph. Chemistry and Physics, Atmos. Chem. Phys. Discuss., 9, 6003–6060, 2009, http://www.atmos-chem-phys-discuss.net/9/6003/2009/acpd-9-6003-2009.pdf

[152] Schnadt Poberaj, Christina, J. Stähelin, D. Brunner, V. Thouret, H. De Backer and R. Stübi,
Long term changes in UT/LS ozone between the late 1970s and the 1990s deduced from GASP and MOZAIC aircraft programs and from ozonesondes,
Atmos. Chem. Phys. Discuss, 9, 2435-2499, 2009, **in preparation** for ACP, 2009. http://www.atmos-chem-phys-discuss.net/9/2435/2009/acpd-9-2435-2009.pdf

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Dust AOD retrieval over desert surface, using the SEVIRI window channels,
Journal of Atmospheric and Oceanic Technology, Vol. 26, No. 4, pages 704–718, 2009

[154] B. De Paepe et al.,
Aerosol retrieval over ocean from SEVIRI for the use in GERB Earth's radiation budget analyses,
Remote Sensing of Environment, Vol. 112, pages 2455-2468, 2007

4.2.8.2 Technical notes

[155] Köpke, Peter, H. De Backer, A. Bais, A. Curylo, K. Eerme, U. Feister, B. Johnsen, J. Junk, A. Kazantzidis, J. Krzyscin, A. Lindfors, J.A. Olseth, P. den Outer, A. Pribullova, A. Schmalwieser, H. Slaper, H. Staiger, J. Verdebout, L. Vuilleumier, P. Weihs,
Modelling solar UV radiation in the past: Comparison of algorithms and input data,
COST Office, 94pp., ISBN 978-92-898-0043-3, EUR 23338, Luxemburg, 2008.

4.2.8.3 PhD thesis

[156] B. De Paepe,
Remote Sensing Tropospheric Aerosols using the SEVIRI Radiometer (MSG),
PhD thesis, 130 pages, 2009

4.2.8.4 Abstracts of conference:

[157] Van Malderen Roeland and H. De Backer,
Trend analysis of the radiosonde relative humidity measurements at Uccle, Belgium,
EGU assembly, Vienna, Austria, 13-18 April 2008.

[158] Smit Herman, H. De Backer, G. Braathen, H. Claude, J. Davies, T. Deshler, B. Johnson, E. Kyro, R. Kivi, S. Oltmans, T. Sasaki, F. Schmidlin, J. Staehelin, R. Stubi, D. Tarasick, A. Thompson, P. Viatte, J. Witte,
Assessment of the performance of ECC-ozone sondes and the need for standardization of operating procedures,
EGU assembly, Vienna, Austria, 13-18 April 2008.

[159] Smit Herman, H. De Backer, G. Braathen, H. Claude, J. Davies, T. Deshler, B. Johnson, E. Kyro, R. Kivi, S. Oltmans, T. Sasaki, F. Schmidlin, J. Staehelin, R. Stubi, D. Tarasick, A. Thompson, P. Viatte, J. Witte,
Assessment of the performance of ECC-ozone sondes: Improvements through standardization of operating procedures,
Quadrennial ozone symposium, Tromso, Noorwegen, 29 Juni-5 Juli 2008.

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Linking aerosol optical depth from the NIR to the UV-B with aerosol composition,
EAC conference, Thessaloniki, Greece, 24-29 Augustus 2008.

[161] Van Malderen, R. and H. De Backer,
Trend analysis of the radiosonde relative humidity measurements at Uccle, Belgium,
SPARC General Assembly, Bologna, Italy, 31 August - 5 September 2009

[162] Delcloo Andy, R. Lemoine, H. De Backer,
Validation of GOME2 ozone profiles for mid- and Nordic latitudes, using balloon sounding data
EUMETSAT meteorological satellite conference, Darmstadt, Gemany,8-12 September 2008

[163] Van Malderen R., H. De Backer, and A. Delcloo,
Revision of 40 years of ozone measurements in Uccle, Belgium
EGU 2009, Vienna, Austria, 19-24 April 2009

[164] De Paepe, B., and S. Dewitte
Dust aerosol optical depth retrieval over desert surface using the SEVIRI window channels
In Remote Sensing of Clouds and the Atmosphere XII, A. Comeron, R.H. Picard, K. Schafer, J. R. Slusser, and A. Amodeo (Eds.), Proceedings of SPIE Vol. 6745, 67450B, (2007) . 0277-786X/07/$18 . doi: 10.1117/12.731734.

4.3 Monitoring, modeling and forecasting the ionospheric activity

4.3.1 Objectives

The goal of this WP is to develop techniques allowing to monitor, to model and to forecast ionospheric and Space Weather activity "parameters" which have an influence on the performances of technological systems based on radio waves (electron concentration, Total Electron Content (TEC), geomagnetic activity, …).

The electron concentration in space and time is the main parameter, which describes the state of the ionosphere. The ionospheric activity strongly depends on solar activity. Indeed, extreme UV and X rays emitted by the Sun are the main source of ionization in the ionosphere. For this reason, Space Weather is the main driver of ionospheric disturbances. In particular, geomagnetic storms are often the cause of strong variability in the ionosphere electron concentration.

The ionosphere Total Electron Content or TEC is another parameter of interest. Indeed, the influence of the ionosphere on GNSS measurements depends on GNSS wave frequency and on TEC. The TEC is the integral of the electron concentration on the GNSS receiver-to-satellite path. It is measured in TEC Units (TECU): 1 TECU=10^{16} electrons m^{-2}.

4.3.2 Progress and results

In 2007-2008, the goals of the WP were:

- To characterize ionospheric small-scale variability that affects GNSS real time applications.

- To improve the existing techniques allowing to compute (in near real time) and to forecast the Dourbes K geomagnetic index.

4.3.2.1 Characterization of ionospheric small-scale variability

As already mentioned, local variability in the TEC (scale of a few km) is the origin of degraded GNSS positioning conditions. Therefore, we performed a detailed study of the main ionospheric phenomena which can induce local variability in TEC.
GNSS carrier phase measurements can be used to monitor local TEC variability. At any location, several GPS satellites can simultaneously be observed at different azimuths and elevations. Every satellite-to-receiver path allows to "scan" the ionosphere in a particular direction. The more satellites are simultaneously observed, the "denser" the information on the ionosphere is. In particular, small-scale structures in the ionosphere can be detected by monitoring TEC rate of change (time derivative) between consecutive measurement epochs at a single station; indeed, as ionospheric disturbances are moving, we can expect that such structures will induce TEC temporal variability which can be detected at a single station (ref.[165], [166], [167]). We applied this method (called "single station" method) to the GPS data collected at the permanent (mid-latitude) station of Brussels from 1994 to 2006. On this period which covers more than one solar cycle, two main types of structures have been observed: Travelling Ionospheric Disturbances (TID's) and so-called noise-like structures. We have performed a climatological study of these phenomena on the period 1994-2006. We found that TID's have strong seasonal and solar cycle dependence when noise-like structures are "ionospheric variability" which is usually observed during geomagnetic storms. In addition, we have analyzed the "worst case" events identified during the period of our study: the most powerful solar flare ever observed in EUV on October 28^{th} 2003 and the extreme geomagnetic storm which followed this event on October 30^{th} 2003 where TEC variability reached the level of 9.8 TECU/min.
The single station method allows to measure variability in time but GNSS differential applications are affected by variability in space between the user and the reference station (see WP RMI-C2). Therefore, in a second step, we measured TEC differential variability (i.e. TEC variability in space) using double differences of the geometric free combination of phase measurements collected in the permanent GPS stations. From this study, we can conclude that:

- TEC differential variability depends on baseline length (i.e. the distance between the user and the reference station) and baseline orientation (with respect to ionospheric disturbance propagation).
- TEC differential variability is significantly larger when the single station method detects disturbed conditions than during "quiet days" where the single station method does not detect any disturbances. Therefore, the output of the single station method can be considered as a valuable indicator of TEC variability in space on scales of a few km.

From this study, we found that the combination of the single station method with the double difference method can be used as a tool to send warning to users when degraded positioning conditions are expected (ref. [15]). In the frame of WP RMI C2, we have analyzed in more details the relationship which exists between disturbed ionospheric conditions and positioning error.

4.3.2.2 Dourbes K geomagnetic index

The study outlined in the previous paragraph and the results obtained in WP RMI-C2 (see next paragraph) demonstrated that the strongest degradations in GNSS positioning are produced by severe geomagnetic storms (ref. [166], [167], [179], [180]). For this reason, we started the development of an operational procedure to now- and forecast local geomagnetic activity in Belgium. The main goal is to send warnings to GNSS users when we expect the occurrence of geomagnetic conditions which could be the origin of degraded positioning conditions.

Geomagnetic activity characterizes the degree of disturbance of the Earth magnetic field and the level of this disturbance is quantified by a number of indices, each of which characterizes the origin and the time scale of its variations. The mid-latitude magnetic disturbances are quantified by a number of indices *A* and *K*, depending on the method for deriving them. Each of the abovementioned indices is derived from a specific number of magnetic stations and represents the global (planetary) geomagnetic activity. It is well accepted that the planetary 3-hour *K* (*Kp*) and the daily *A* (*Ap*) are the best representatives of the large-scale mid-latitude ionospheric disturbances. Nevertheless, the 3-hour Kp index is too inaccurate to represent disturbances that may potentially degrade the GPS positioning accuracy. The small-scale disturbances are localized phenomena and the local K index derived from the nearest magnetic station better fits these disturbances than the planetary Kp.

Based on these considerations, a new model for predicting the geomagnetic K index has been developed based on the combined use of solar wind parameters and ground-based magnetic data. The present approach implements the previously developed solar wind based MAK model by calibrating its values with magnetogram-derived K index. The new model has been applied to the K index issued at the Dourbes Centre of Geophysics of the Royal Meteorological Institute where magnetometer data are available and is named Hybrid Dourbes K (HDK) model. The HDK model combines the advantages of predicting the sudden changes of geomagnetic activity induced by solar wind with the longer term predictability of the K index.

The MAK model coefficients were recalculated by fitting the model expression to IMF Bz, solar wind velocity and dynamic pressure and Dourbes K index data. The database used for modelling consists of the hourly values of solar wind parameters and the hourly interpolated 3-hour Dourbes K index (Kd), collected in the period 1998-2004. The HDK model output, the quantity Kdf, is obtained by MAK model output Ksw, corrected with the average difference between several past values of Kd and Ksw. The model error of the new quantity Kdf is found to be 0.38 KU, or nearly twice less than that of the MAK model. Kdf has a good predictability. Prediction made by weighted extrapolation 6 hours ahead carries an error of 1.0 KU, while for the first 1 hour the error is 0.58 KU only (ref. [172])

This now- and forecasting model which has been validated on past data will be implemented on our operational web site in 2009.

4.3.3 Perspective for next years

In 2009, the goals of this WP are:

- To improve TEC reconstruction techniques based on GNSS data.
- To develop an operational technique for real time reconstruction of electron concentration at Dourbes by combining GNSS and ionosonde data
- To develop an operational procedure for real time reconstruction of the ionospheric slab thickness at Dourbes (the slab thickness is a good indicator of the ionosphere dynamics; it can be used in real time as indicator of an up- or ongoing ionospheric storm).
- To further validate the Dourbes K now- and forecasting model on real time data and to implement the necessary corrections/improvements

4.3.4 Personnel involved

Prof. René WARNANT, Project Leader, statutory staff.
Dr. Stanimir STANKOV, Assistant, FP6/GALOCAD, STCE.
Dr. Hugues BRENOT, Assistant, FP6/GALOCAD, ESA/PRODEX 9.
Ms. Justine SPITS, Attaché, Belspo/Action 2.
Mr. Koen STEGEN, Attaché, STCE.

4.3.5 External funding sources

Part of the 2007-2008 activities reported above and part of the activities foreseen in 2009 have been or will be funded by external sources:

- GALOCAD: Galileo Local Component for the nowcasting and the forecasting of atmospheric disturbances affecting the integrity of high precision Galileo applications (2006-2008), EU 6th Framework program, in reply to Galileo Joint Undertaking call for proposal 2423, 236 000 EUR (RMI part; RMI = Coordinator).
- SIDC Telescience (2008-2010), ESA/PRODEX 9, contract C90317, 210 000 EUR (RMI part).
- Modélisation de l'effet ionosphérique affectant les systèmes de positionnement Galileo et GPS modernisé pour des applications de haute précision en géodésie et en géophysique (2005-2009), Belspo/Action 2, 152 000 EUR.
- Modelling and forecasting Space Weather and ionospheric disturbances which degrade the accuracy of GPS and Galileo applications (2007-2008), Belspo/Bilateral Collaboration "Belgium-Bulgaria", 10 000 EUR.
- Modélisation de l'erreur ionosphérique qui affecte les systèmes de positionnement par satellites (2007-2011), Belspo/Action 2, 156 000 EUR.
- Magnetic Valley (2009-2011), Belgian Federal Government, 1 000 000 EUR in 2009 for the whole project (not only for the SW part).

4.3.6 Publications

4.3.6.1 Publications in peer reviewed international journals

[165] Warnant R., Lejeune S., Bavier M. (2007)
Space Weather influence on satellite based navigation and precise positioning.
Space Weather - Research towards Applications in Europe, Astrophysics and Space Science Library series, Vol. 344, pp. 129-146, Ed. J. Lilensten, Springer.

[166] Warnant R., Kutiev I., Marinov P., Bavier M., Lejeune S. (2007)
Ionospheric and geomagnetic conditions during periods of degraded GPS position accuracy : 1. Monitoring variability in TEC which degrades the accuracy of Real Time Kinematic GPS applications.
Adv. Space Res., Vol. 39, 5, pp. 875-880.

[167] Warnant R., Kutiev I., Marinov P., Bavier M., Lejeune S. (2007)
Ionospheric and geomagnetic conditions during periods of degraded GPS position accuracy : 2. RTK events during disturbed and quiet geomagnetic conditions.
Adv. Space Res., Vol. 39, 5, pp. 881-888.

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A novel method for the quantitative assessment of the ionosphere effect on high accuracy GNSS applications which require ambiguity resolution.
J. of Atmospheric and Solar-Terrestrial Physics, Vol. 70, pp. 889-900,
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[169] Spits J., Warnant R. (2008)
Total Electron Content monitoring using triple frequency GNSS data: a three-step approach.
J. of Atmospheric and Solar-Terrestrial Physics, Vol. 70, pp. 1885-1893,
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J. of Atmospheric and Solar-Terrestrial Physics, Vol. 71, pp. 589-596,
doi:10.1016/j.jastp.2009.01.005.

[171] Stankov S., Warnant R., Stegen K. (2009)
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Modeling medium-scale TEC structures observed by Belgian GPS receiver network
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Mitigation of ionospheric effects on GNSS
Annals of Geoph., in press.

[174] Stankov S., Warnant R. (2009)
Monitoring the ionospheric slab thickness over mid-latitude Europe – analyses and applications.
Adv. Space Research, accepted.

4.3.6.2 Publications in proceedings

[175] Bidaine, B., Warnant, R. (2007)
Assessment of the NeQuick Model at Mid-latitudes using GPS TEC and Ionosonde Data.
Proceedings of the First Colloquium Scientific and Fundamental Aspects of the Galileo Programme [CD-Rom], Toulouse, France, 1- 4 October 2007.

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[177] Stankov S., Warnant R. (2008)
Ionospheric slab thickness: analysis and monitoring applications.
Proceedings of the 12th International Ionospheric Effects Symposium (IES2008), May 13-15 2008, Alexandria, USA, pp. 159-164.

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Proceedings of the 4th ESA Workshop on Satellite Navigation User Equipment Technologies NAVITEC 2008 (CD-ROM), Noordwijk, Netherlands, 10 -12 December 2008.

4.3.6.3 Technical reports

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GALOCAD User Interface
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4.3.6.4 Ph. D. Thesis

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Influence de l'ionosphère sur le positionnement différentiel par GNSS.
Ph. D. Thesis, University of Liège, 14 May 2009.

4.3.6.5 Presentations during international scientific meetings

[183] Kutiev I., Marinov P., Fidanova S., Warnant R. (2007)
Modelling the medium-scale TEC structures, observed by Belgian GPS receiver network.
Presented at COST296/IRI Meeting, Prague, 10-14 July 2007.

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Real time TEC monitoring using triple frequency GNSS data : a three step approach.
Presented at COST296/IRI Meeting, Prague, 10-14 July 2007.

[185] Lejeune S., Warnant R. (2007)
Effect of small-scale variability in TEC on high accuracy GNSS applications which require ambiguity resolution.
Presented at COST296/IRI Meeting, Prague, 10-14 July 2007.

[186] Wautelet G., Warnant R. (2007)
Statistical study of ionospheric small-scale irregularities at mid-latitudes using GPS measurements.
Presented at COST296/IRI Meeting, Prague, 10-14 July 2007.

[187] Bidaine B., Warnant R. (2007)
Assessment of the NeQuick model at mid-latitudes using GPS-TEC and ionosonde data.
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Hybrid Model for Kp prediction, combining solar wind and magnetometer data.
Presented at the 4th European Space Weather Week, Royal Library, Brussels, 5-9 November 2007.

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Total Electron Content monitoring using triple frequency GNSS data: a three-step approach
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Modelling the ionosphere over Europe : Investigation of NeQuick formulation.
Presented at 5th European Space Weather Week, Brussels, Belgium, 17-21 November 2008.

[196] Kunches J., Terkildsen M., Stanislawska I., Dabas R., Van der Linden R., Warnant R. (2008) *Ionospheric Products and Services from the Regional Warning Centers of the International Space Environment Service (ISES) for GNSS Users.*
Presented at 3rd International Committee on GNSS, Pasadena, California, December 8-12 2008.

4.4 Development of products and services for the users of real time GNSS applications

4.4.1 Objectives

Nowadays, Global Navigation Satellite Systems are widely used to measure positions in real time with a few cm precision. Such a level of precision can be obtained in "differential mode". In this positioning mode, mobile users make use of so-called "differential" corrections broadcast by reference stations in order to improve their positioning precision. At the present time, the ionospheric effect on GNSS radio signals remains the main factor which limits the accuracy and the reliability of differential positioning. Indeed, GNSS differential applications are based on the assumption that the measurements made by the reference station and by the mobile user are affected in the same way by the different error sources, in particular, by the ionospheric effect. The validity of this assumption depends on the distance between the user and the reference station which is called "baseline": on shorter baselines, ionospheric residual effects are smaller than on larger baselines. In practice, these applications will not be affected by the "absolute" TEC but by gradients in TEC between the reference station and the user. For this reason, local variability in the ionospheric plasma can be the origin of strong degradations in positioning precision. Strong variability in the ionospheric electron concentration (and in TEC) is mainly due to Space Weather events such as geomagnetic storms. GNSS real time users who undergo degradations of their measurement accuracy are not necessarily aware about this problem: this is an important limitation to the reliability of GNSS, in particular, in the frame of so-called "safety-of life" applications such as landings of planes. Therefore, it is important to develop services allowing to monitor GNSS "integrity" with respect to ionospheric threats and to warn GNSS users against such events.

Therefore, the goals of this WP are:
- To develop operational techniques to assess, to model and to forecast Space Weather effects on real time GNSS applications;
- To develop a web site which provides information about Space Weather activity and about Space Weather effects on real time GNSS applications.

4.4.2 Progress and results

In 2007-2008, the goals of the WP were:
- To study the influence of ionospheric small-scale variability on real time positioning techniques based on GNSS;
- To develop a web site which provides information about ionospheric and geomagnetic activity and about ionospheric effects on real time positioning techniques based on GNSS.

4.4.2.1 Influence of ionospheric small-scale variability on real time positioning

In 4.3, we characterized small-scale structures in the ionosphere which can pose a threat for real time GNSS applications. In 4.4, we started a study of which the goal is to assess in a quantitative way the effect of such structures on precise real time positioning applications, in particular, on the Real Time Kinematics technique which usually reaches a nominal accuracy of the order of a few cm in real time.
In order to have a realistic quantitative assessment of the ionospheric influence on RTK accuracy, we decided to develop software based on the technique used in RTK to compute real time positions on the field.

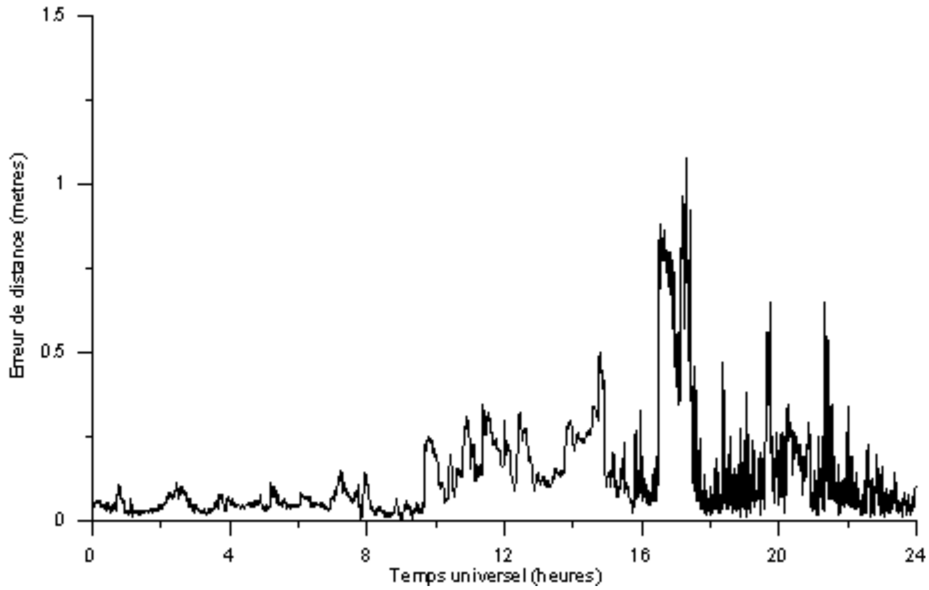


Figure 41: Error on the distance Tienen-Sint Truiden (18 km) due to the ionosphere on November 20th 2003 as computed by SoDIPE-RTK software.

This software is called SoDIPE-RTK (Software for Determining the Ionospheric Positioning Error on RTK). The idea is to reproduce as close as possible the "positioning conditions" that RTK users undergo on the field. Nevertheless, it is very clear that each observation site is different and that it will never be possible to reproduce exactly the conditions encountered by each user. This software uses permanent GPS stations to play the role of the reference station and of the user. The position of these stations is known at a few mm level. As the "nominal" RTK accuracy is a few cm, we will consider that the position of these permanent stations is perfectly known and we will refer to it as the "true" station position.

The direct comparison between the computed user position and the true station position does not give the positioning error due to the ionosphere but the error due to all the error sources. The most difficult point is to be able to isolate the part of the user position error budget which is due only to the ionosphere and not to the other error sources. A data processing technique allowing to reach that goal has been developed and validated with success on a few test cases which are representative of typical ionospheric conditions (quiet day, medium and large amplitude TID's, severe geomagnetic storm). These typical ionospheric conditions were identified based on the single station software. The largest effects were observed during the occurrence of a severe geomagnetic storm (November 20th 2003) where the positioning error due to ionosphere reached about 1 m on 20 km baselines.

As an illustration, Figure 41shows the positioning error due to the ionosphere on baseline Tienen-Sint Truiden (18 km) as given by SoDIPE-RTK. More details can be found in ref. [168], [180], [182].

At the present time, SoDIPE-RTK cannot process data automatically in real time: further developments are necessary to reach real time capability.

4.4.2.2 Space Weather web site for GNSS users

We started the development of a web site in order to provide users with real time information about:

- ionospheric activity.
- geomagnetic activity.
- ionospheric effects on GNSS applications.

As a first step, the development of real time web services requires real time availability and processing of the data which are necessary to produce the different services. At the present time, GNSS data, geomagnetic and ionosonde data from Dourbes Geophysical Observatory are available in (near) real time at Brussels. Several real time data processing procedures are under test, in particular the HDK model for Dourbes K now- and forecasting. First real time services will be available on line during summer 2009.

4.4.3 Perspective for next years

In 2009, the goals of this WP are:

- To analyze and characterize TEC gradients which can affect GNSS-based (aircraft) navigation.
- To develop an empirical model to forecast the occurrence of ionospheric disturbances which affect GNSS.
- To further develop SoDIPE-RTK software.
- To implement web pages which contain real time information about:
    - ionospheric activity at Dourbes (TEC, f0F2, electron concentration, slab thickness).
    - geomagnetic activity at Dourbes (Dourbes K now- and forecasting).
    - ionospheric effects on real time positioning with GNSS (qualitative assessment of positioning error using the single station software).

4.4.4 Personnel involved

Prof. René WARNANT, Project Leader, statutory staff.
Dr. Stanimir STANKOV, Assistant, FP6/GALOCAD, STCE.
Mrs. Sandrine LEJEUNE, Attaché, FP6/GALOCAD, STCE.
Mr. Koen STEGEN, Attaché, STCE.
Mr. Gilles WAUTELET, Attaché, Belspo/Action 2.

4.4.5 External funding sources

See 4.3.5

4.4.6 Publications

See 4.3.6

5 STCE@BISA

Similar to the ROB and RMI, the STCE-activities at the BISA are split in various subfields or “themes”. In each of these fields we have defined lines of research that complement our pre-existing strengths: see Table 2.

We report on the BIRA-IASB STCE activities for 2007-2008 per theme. We also discuss and motivate our future plans.

A distinction is made between *recurrent activities* and *punctual initiatives*. With the term *recurrent activities* we designate long-term themes of research, in which we will invest a multi-year research effort with STCE financial support. The reports for the themes and tasks below emphasize the continuity that is needed for such work. The *punctual initiatives* are one-time investments that serve to boost our activities in a particular field of solar-terrestrial physics, with the aim of accelerating progress there.

In view of the late start-up time in 2007, and with the overall aim of continuity in our work, the (recurrent) tasks for 2008 were the same as those for 2007. We refer to them with the notation 2008X.N: task N for theme X during 2007 and 2008.

Table 2: Themes and lines of research for the STCE at BIRA-IASB in 2007 and 2008

Themes	**Lines of research**
Atmosphere	*Measurement of solar UV* *Radiative transfer* *Solar UV index* *VUV spectrometer*
Space Physics	*Observations and models of the magnetosphere* *Participating in space experiments* *Fundamental Science*
Valorisation & Exploitation: Data & Mission Centre	*Data Centre* *Mission Centre* *Infrastructure*
Valorisation & Exploitation: Space Weather	*Space Weather services* *(SPENVIS, European Space Weather Portal, …)*
Valorisation & Exploitation: Chemical Weather	*Chemical Weather services* *(BACCHUS)*
ICT support	*Data and HPC support* *Hardware and Software* *F.3: Informatics infrastructure*

5.1 Atmosphere: Measurement of solar irradiance

Responsible person: Didier Gillotay, email: Didier.Gillotay@aeronomie.be

5.1.1 Overall description

The measurement of the solar UV radiation is essential in the Sun-Earth interaction with the atmosphere. As a long term goal, BIRA-IASB will continue and expand its activities concerning UV measurement techniques.

5.1.2 Ground-based UV-Visible solar irradiance monitoring

5.1.2.1 Objectives

Exploit, upgrade, and/or make publicly available the existing UV measurements at the 3 stations of the IASB-BIRA network (at Uccle, Redu and Oostende) and IASB-BIRA calibration facilities. Potential installation of 2 new stations (Kempen and Gaume).
Outputs: Regional UV database including ancillary data as ozone column, aerosols, cloud cover …

5.1.2.2 Achievements

During 2007-2008, additional stations have been installed in Virton (Gaume), Mol (Kempen), and Diekirch (Gr. D. Luxembourg) to improve the geographical coverage over Belgium. They have been fully integrated in the UV-Visible monitoring network. The stations (Uccle, Redu, Oostende, Virton, Mol, Diekirch) provide UV-B, UV-A, and Visible sets of data of the solar irradiance reaching the Earth's surface. Ancillary meteorological data (temperature, relative humidity, pressure, wind speed and direction, pluviometry, cloud cover) complete the data set.

5.1.3 UV-Visible calibration and characterization facilities

5.1.3.1 Objectives

The objective is to develop the present calibration and characterization facilities at IASB-BIRA, taking into account specific users requirements, into a service. Outputs: The instrument calibration facilities will be accessible to members of the STCE. At a later stage, we will extend this accessibility to external users.

5.1.3.2 Achievements

The different dark rooms of the Optical laboratory have been refurbished, and are operational since September 2008. Various optical setups are available for characterization and calibration of ground-based or space instruments.
In particular, SOLSPEC (now on the ISS) has been calibrated in the Optics lab. The instrument has been installed on the external pallet of Columbus onboard the International Space Station in February 2008. The first data were presented at the COSPAR meeting in Montreal, Canada. The total length of the mission will be 3 years.

5.1.4 Partnerships

5.1.4.1 Collaborations

- ROB
- PTB, Braunschweig, Germany
- Observatory of Heidelberg (Landessternwarte Heidelberg), Germany
- Service d'Aéronomie, CNRS, France

5.1.5 Perspective for the future

5.1.5.1 Ground-based measurements

We will continue to support/expand our ground network for measurement of the solar irradiance in UV-VIS-IR.

5.1.5.2 Space-based measurements

We will measure the solar irradiance in UV-VIS-IR using SOLSPEC on ISS. This is a new task that follows up on our SOLSPEC characterization work in the optics lab.

5.1.6 Publications and output

5.1.6.1 Publications with peer review

[197] G. Thuillier, T. Foujols, D. Bolsée, D. Gillotay, M. Hersé, W. Peetermans, W. Decuyper, H. Mandel, P. Sperfeld, S. Pape, D. R. Taubert and J. Hartmann
SOLAR/SOLSPEC: Scientific objectives, instrument performances and its absolute calibration using a blackbody as primary standard source.
Solar Physics, 2009 (accepted)

5.1.6.2 Meeting presentations

[198] G. Thuillier, D. Bolsée, D. Gillotay and Foujols
SOLSPEC measurement of the solar absolute spectral irradiance from 165 to 3080 nm on board the International Space Station, paper C12-0003-08
COSPAR meeting, Montreal Canada, June 16, 2008

5.1.6.3 Hardware

- Hardware for additional stations in Virton (Gaume), Mol (Kempen), and Diekirch (Gr. D. Luxembourg).
- Launch and installation of SOLSPEC on an external pallet of the Columbus module onboard the International Space Station in February 2008.

5.2 Atmosphere: Radiative Transfer

5.2.1 Overall description

Radiative transfer (RT) determines how much solar light is absorbed, transmitted or scattered in the atmosphere. Radiative transfer models are therefore essential for the interpretation of optical measurements of trace gases, aerosols, and of course radiative fluxes (e.g. UV fluxes at the Earth's surface). They are also key components in both atmospheric chemistry and climate models. The general long-term goal is to develop advanced modelling tools and to enhance our expertise in the field of radiative transfer. Specific goals:

- Improve the description of the interaction of light with clouds and aerosols in radiative transfer models. Include these descriptions in inversion codes for optical remote sensing of the atmospheric composition.
- Provide model estimates of the radiative fluxes reaching the Earth's surface, based on available distributions of gases, aerosols and clouds.
- Develop efficient parameterizations for the impact of clouds and aerosols on photolysis frequencies of chemical compounds in a chemical/transport model.

5.2.2 Short term goals

Assess existing datasets that are necessary for the modelling of the impact of aerosol and clouds. Study the UV radiation reaching the surface, in the presence of clouds and aerosols. Initiate development of specific applications.

5.2.3 Assessment of the state-of-the-art in radiative transfer modelling

5.2.3.1 Objectives

- Assess existing expertise in radiative transfer and the availability of RT codes applicable to the UV, VIS and IR parts of the spectrum.
- Assess the specific needs from the different research groups working on the measurement of trace species and of UV radiation, and on chemical-transport modelling, and establish a suitable working strategy to satisfy the needs.
- Outputs: Inventory and evaluation of existing tools and their specifications, inventory of existing parameterizations of aerosol and cloud optical properties, results of comparisons between existing datasets related to the global distribution of clouds and aerosols, an assessment of the impact of clouds and aerosol on UV measurements at the surface.

5.2.3.2 Achievements

Dr. P. Stammes from KNMI (the Netherlands) has given a series of 4 lectures of 2 hours each and associated workshops (a full morning each) concerning the principles of radiative transfer in the earth atmosphere, and applications. The lectures and workshops have been tailored to the needs of the scientists of the STCE dealing with RT problems. The material from the lectures and the workshops is available (password protected) on the STCE Web pages. The lectures have also been archived as video recordings, for future use.

5.2.4 Applications of radiative transfer modelling

5.2.4.1 Objectives

Initiate the development of specific radiative transfer applications. Evaluate and possibly improve the modelling of the impact of aerosol on IASI measurements in the thermal infrared.

5.2.4.2 Achievements

The selection of the candidate to work on this task at BIRA-IASB was finalized by the end of 2008. The selected candidate is Dr. S. Kochenova; she works full-time at BIRA-IASB since January 2009.
Work performed up to now:

- Overview of the RT applications at BIRA-IASB
- Study of the LIDORT and VLIDORT codes (in collaboration with RT Solutions) for implementation in a line-by-line radiative transfer and inversion code ASIMUT.
- Coupling between (V)LIDORT and ASIMUT is in progress. The goal is to have a better RT model in ASIMUT, better than the simple one that was available up to now and that had only limited applicability.

5.2.5 Partnerships

5.2.5.1 Collaborations

- GEOMON: NDACC-FTIR and NDACC-UVVis partners (see http://www.ndacc.org), in particular INSU/CNRS (France), IMK/FZK (Germany), and EMPA (Switzerland); ACE, Envisat, GOME, METOP, UARS and Aura satellite teams.

- AGACC: ULB, Univ. Liège (ULg), KMI-IRM
- NOVAC: Chalmers Univ. (Sweden), Uni-Heidelberg (Germany) + 15 volcanic observatories
- AMFIC: KNMI (The Netherlands), DUTH (Greece), TNO (The Netherlands), NSMC (China), IAP-CAS (China), VITO (Belgium), IFE-Bremen (Germany), NOA (Greece), LAP-AUTH (Greece)
- GODFIT-2/GDP5: RT-Solutions (USA), SRSS (Germany)
- SECPEA: RMI, U. Liège, BAS/NERC (United Kingdom), CAO (Russia), CNRS/SA (France), DMI (Denmark), DWD (Germany), ETHZ (Switzerland), FMI-ARC (Finland), IAP-Moscow (Russia), IFE/IUP-Bremen (Germany), IFU (Germany), IMK/FZK (Germany), INTA (Spain), ISAC-CNR (Italy), IUP-Heidelberg (Germany), KSNU (Kyrgyzstan), KTSU (Ukraine), MCH (Switzerland), MGO (Russia), MSC (Canada), NASA/JPL (USA), NILU (Norway), NIWA (New Zealand), NOAA/CMDL (USA), SPbSU (Russia), STIL-Bulgarian Academy of Science (Bulgaria), U. Chalmers (Sweden), UNESP (Brazil), U. Réunion (France), U. Toronto (Canada), U. Wales (United Kingdom), and U. Wollongong (Australia), ULB (Belgium), Univ. Liège (ULg, Belgium), CNRS-SA/IPSL, Univ. Toronto (Canada), Univ. Waterloo (Canada)
- Multi-TASTE: RMI, CNRS (France), FMI-ARC (Finland), IFE/IUP (Germany), IFU (Germany), IMK/FZK (Germany), INTA (Spain), KNMI (Netherlands), NIWA (New Zealand), U. Saint Petersburg (Russia)

5.2.6 Perspective for the future

5.2.6.1 Ray tracing and inversion code

Implementation of LIDORT and VLIDORT in ASIMUT, a line-by-line RT and inversion code used at BIRA-IASB for the inversion of high-resolution planetary atmospheres spectra (from the UV to the IR, in different observation geometries); verification of the results.

5.2.6.2 Radiative transfer support

Support to other applications of RT in atmospheric forward modelling and inversion problems – the priorities will be decided in the course of the year.

5.2.7 Output

5.2.7.1 Software

The following KNMI software packages have been installed at BIRA-IASB:

- DAK (Double-adding RT code)
- SPEX: raytracing code
- MIE: Mie scattering code

5.2.7.2 Other

- Videos have been made with the 4 lectures by Piet Stammes on Radiative Transfer

5.3 Atmosphere: Solar UV index

5.3.1 Overall description

The solar UV index has practical consequences. A long term goal is to monitor the UV index and to produce warnings; there is a synergy with the RMI in this domain. The short term goal is to develop a web service offering near-real-time solar UV measurements and short-term prediction of the UV index locally for Belgium (in synergy with RMI).

5.3.2 UV index web service

5.3.2.1 Objectives

Exploitation of UV measurements to produce a near-real-time UV index at the various measurement sites. Develop a web service offering near-real-time solar UV measurements and short-term prediction of the UV index locally for Belgium (interface to be developed in interaction with personnel in Theme 2008C.3.3).

5.3.2.2 Achievements

The web service is available at the internet address http://www.aeronomie.be/uv/. It offers access to the real-time measurements at the six stations (Uccle, Redu, Oostende, Virton, Mol, Diekirch). Ancillary data, such as basic meteorological data (temperature, relative humidity, pressure, wind speed and direction, and pluviometry, as well as the measurement of the cloud cover) are made available too. A color coding is used to highlight elevated levels of UV radiation.
Preparations are being made for implementing software to predict the UV index in realistic conditions.

5.3.3 Long-Term UV climatology

5.3.3.1 Objectives

Build a long-term UV climatology for Belgium.

5.3.3.2 Achievements

Data are being gathered for constructing such a climatology.

5.3.4 Perspective for the future

5.3.4.1 UV index web service

We will continue to offer and improve our web service.

5.3.4.2 Long-term UV climatology

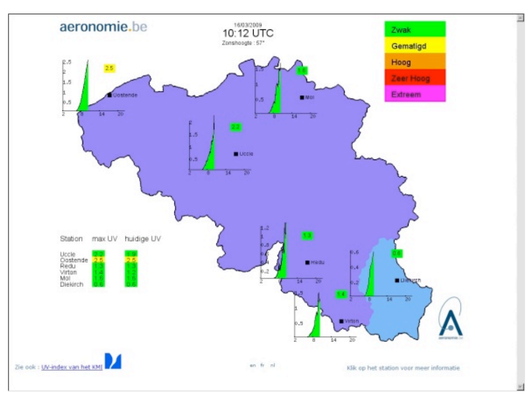
This activity is really a multi-year effort. Data are acquired continuously.

5.3.5 Publications and output

5.3.5.1 Software & web services

- The UV index web service is available at http://www.aeronomie.be/uv/.

5.4 Atmosphere: VUV spectrometer



5.4.1 Overall description

The optical laboratories of BIRA-IASB have developed an expertise for the radiometric characterization of optical instruments since more than thirty years. This expertise covers

- Use of standards of spectral irradiance for the absolute calibration of spectroradiometers.
- Use of spectral light sources for any wavelength calibration of instruments.

- Using a laboratory monochromator: characterization of optical sub-systems as filters, lamps …
- Using a laboratory monochromator coupled with a light source: production of a monochromatic and tuneable light beam for the characterization of the diffuse light of spectrograph, the transmission of filters or the measurement of detector response.

The characterizations are performed on commercial instruments or dedicated instruments developed at BIRA-IASB for ground-based instruments or space projects. Up to now the spectral range was limited to 200 nm for the shorter wavelengths. This range should be extended at least to 100 nm especially for space instruments dedicated to the measurement of the solar irradiance. For this, a monochromator working under vacuum must be used at the laboratory.

The goal is to put this expertise and the optics lab facilities at the disposal of other research teams in Belgium and abroad (see Task 2008.A.1.2) and therefore the VUV spectrometer should be refurbished.

5.4.2 VUV spectrometer refurbishment

5.4.2.1 Objectives

BIRA-IASB is equipped with a B225, 1 meter McPherson VUV (Vacuum Ultra-Violet) spectrometer. The objective is to refurbish this instrument with new electronic and optical accessories and to provide a complete characterization facility as a service for vacuum radiometry, for IASB instruments or external collaborations (ROB, universities …).

5.4.2.2 Achievements

The major part of the equipment needed for the refurbishment has been ordered. The new electronic and optical accessories will be delivered within 2 or 3 months.

5.4.3 Partnerships

5.4.3.1 Collaborations

- ROB
- PTB, Braunschweig, Germany
- Observatory of Heidelberg (Landessternwarte Heidelberg), Germany

5.4.4 Perspective for the future

5.4.4.1 Optics lab facilities

This activity covers the optical characterization and calibration services that BIRA-IASB offers through making available its optics lab expertise and instrumentation. This is the successor of the 2008A.1.2 sub-task.

5.4.4.2 VUV spectrometer refurbishment

The ordered hardware still has to be delivered and installed. This is the successor of the punctual 2008A.4.1 task.

5.4.5 Publications and output

5.4.5.1 Hardware

The order for the refurbishment of the B225, 1 meter McPherson VUV (Vacuum Ultra-Violet) spectrometer has been placed. Delivery is expected before summer 2009.

5.5 Space Physics: Observations and models of the Earth's magnetosphere

5.5.1 Overall description

Science-based prediction of the effects of the solar wind on the Earth's magnetosphere requires both visualization of observations and numerical simulation of magnetospheric dynamics based on a physical model. Our long-term goal is to maintain and expand our data processing and model visualization tools (MIM software) and to develop an operational simulation tool based on a kinetic approach (go beyond the existing huge but not-so-physical MHD simulations used elsewhere).

Short term goals:

- Maintain and expand the MIM software and its distribution
- Simulation proof of principle. Build and demonstrate a (non-operational) simulation for the acceleration region above aurora.

5.5.2 MIM software

5.5.2.1 Objectives

Maintenance of the MIM software and its distribution web pages. The aim is to make the software freely available through a web page with downloadable software, documentation, successive releases …

5.5.2.2 Achievements

The MIM software (Manager of Interactive Modules), developed at BIRA-IASB in the course of the past years, has reached a fairly mature state. STCE activities intend to further expand, maintain, and distribute the software. A capable software engineer has been hired to perform this work. MIM is written in Matlab and creates an interactive and user-friendly environment for the visualization of spacecraft data, for applying data interpretation algorithms, and for performing simulations and comparing their output against observed data.

A first version of the MIM Software has been released in February 2008 via the European Space Weather Portal (http://www.spaceweather.eu/en/software/mim). This release includes scientific modules to process multi-point data, such as gradient computation and magnetopause reconstruction and modules to model the chemistry of the cometary coma.

A second version, for the moment still being tested internally, will include the new gradient algorithms developed by BIRA-IASB in the context of the Cluster mission, and a module for analyzing turbulence.

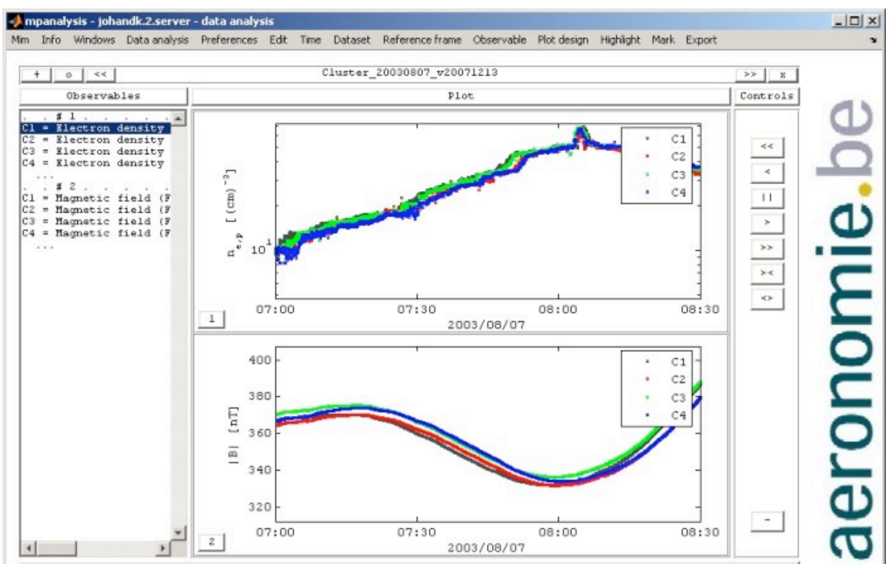
To support an efficient maintenance of the software, the source code was placed under control of the Subversion source code control system.

In addition to deploying MIM as a Matlab package, we have also created a compiled version (for the moment only on Unix platforms; a Windows version is underway). This allows people to run MIM even if they do not own a MATLAB license, which potentially increases the audience interested in the application.

We have presented the MIM software at the Cluster Workshop / Cluster Active Archive symposium in Tenerife in March 2008, and written a paper on the software rationale behind MIM data access (retrieval and formatting) for the proceedings of this workshop. We have also presented a poster at the 5th European Space Weather Week comparing different ways of deploying space weather software, using various options in MIM as an example.

Work in 2007 included extending the set of reference frames available (you can now transform between GSE, GSM, GEO, and SM), improving the graphics substantially (especially allowing the user to interactively modify graphics properties), adding scripts (programs for the MIM programming language), and adding documentation. We have also implemented the concept of "channels" through which MIM accesses local or remote data sources. MIM uses a local cache; if information is not found there, MIM relies on an FTP or HTTP-based protocol to access the relevant data repository on-line (e.g. the Cluster Active Archive). MIM can automatically convert the raw data files to its own preferred format, which is then stored in cache. This establishes a pipeline that allows us to import in a flexible manner the output from spacecraft or from various types of simulation.

Various extensions and refinements have been made in 2008 concerning MIM's graphical interface; new functionality has been added for formatting plots. Steps are being taken to integrate the routines for turbulence modelling into the MIM software. A thorough revision has been done of the software module for modelling tangential discontinuities, to improve the numerical precision, the ODE integration routine, and the DAE solver. Efforts have been made to improve the robustness and efficiency of the optimization routines, including a study of the effects of discretisation and round-off. Much attention has also been paid to the least-squares multi-spacecraft gradient computation routines available in MIM.



5.5.3 Object-oriented parallel computing environment

5.5.3.1 Objectives

The aim is to select a proper development frame for initiating the construction of a Vlasov simulation code. Get acquainted with object-oriented parallel computing environment.

5.5.3.2 Achievements

A technical and performance study of different parallelism libraries has been made for the numerical solver. The decision has been made to use C++ as the language for this software project. Familiarity with C++ has been established.

As a first step towards the development of kinetic plasma simulations, we are reviving our old software for the doing highly parallel computations of MHD wave phenomena. A source code repository has been created, and the object code generation mechanism is being updated for the new computer systems that we have available. A study is being made as to the best development environment.

5.5.4 Plasma distribution functions, solver, boundary conditions

5.5.4.1 Objectives

Develop classes to represent plasma distribution functions.
Construct parallel numerical solver.
Provide boundary conditions with typical high- and low-altitude data (data from Cluster, ground-based instruments, literature …) and demonstrate that the simulation works.

5.5.4.2 Achievements

Some preliminary study work has been performed. A list of interesting velocity distribution function representations has been compiled.
The young Romanian scientist Gabriel Voitcu that worked with us at BIRA-IASB for one month in 2007 won the prize for the Young Scientist Outstanding Poster at the 2008 EGU meeting ("Investigation of anisotropic velocity distribution functions using numerical solutions of the stationary Vlasov equation"). The results presented were obtained in close collaboration with M. Echim, who has moved from an Action 1 project to start working on this task at the beginning of 2009.

5.5.5 Partnerships

5.5.5.1 Collaborations

- The Cluster Active Archive team
- The Cluster Science Data System personnel
- The BIRA-IASB SPENVIS team

5.5.6 Perspective for the future

5.5.6.1 MIM software

We intend to continue to support the MIM software. We foresee additional features to make working with MIM even easier (command history, redo/undo commands …), further extensions to the graphical interface, and handling of additional types of input data. We will also continue to investigate how MIM can be coupled to virtual observatory-style data providers. An additional aspect will be to isolate algorithms from the MIM software so as to offer them as routines that could be used with other software packages, e.g. extracting the least-squares gradient calculation so as to link it to QSAS.

5.5.6.2 Kinetic simulation software for auroral physics

In view of the specific qualifications of the scientist that we have hired, we want to steer the development of kinetic simulation software towards auroral physics applications. (regroups activities 2008C.1.2-5).

5.5.7 Publications and output

5.5.7.1 Publications with peer review

[199] Lemaire, J., Echim, M.
Kinetic and Hydrodynamic Models of the Solar Wind and Polar Wind
EOS Transactions of AGU, 89(9), 86, 2008.

[200] Gamby E., De Keyser J., and Roth M.
Flexible tools to access the Cluster archives.
In Proceedings of the Cluster CAA workshop, Tenerife, 2008. In press.

5.5.7.2 Meeting presentations

[201] Crosby N. B. and De Keyser, J.
Interactive Software for Processing and Visualizing Multipoint and Multi-Instrument Data.
Geophysical Research Abstracts, Vol. 9, EGU General Assembly, Vienna, Austria, 2007.

[202] De Keyser, J. and Gamby, E
Flexible tools for integrating observations and models,
Fourth European Space Weather Week, Brussels, Belgium, 5-9 November 2007. Invited talk.

[203] Pierrard V., Stegen, K. Cabrera, J. and Lemaire, J.
Effects of space weather on the inner magnetosphere
Fourth European Space Weather, Brussels, 5-9 November 2007.

[204] Crosby, N.
A Space Weather Strategy for Europe
Meeting, 3 October 2007, ESA HQ, Paris, France.

[205] Crosby, N.
Heliospheric Exploration: Obstacles and Solutions (poster)
Fourth European Space Weather Week, Brussels, Belgium, 5-9 November 2007.

[206] Gamby, E., De Keyser, J. and Roth, M.
Flexible tools for accessing the Cluster archives
15th Cluster workshop, Tenerife, Canary Islands, March 2008.

[207] De Keyser, J., Gamby, E., and Roth, M.
Flexible tools for studying the magnetospheric boundary with Cluster and Themis
Geophysical Research Abstracts, Vol. 10, EGU General Assembly, Vienna, Austria, April 2008.

[208] De Keyser, J., Darrouzet, F. and Gamby, E.
Multi-spacecraft data analysis techniques
BPS General Assembly 2008, ULB, Brussels, Belgium, 21 May 2008.

[209] Voitcu, G., Bunescu, C., and Echim, M.
Solutions of the stationary Vlasov equations based on numerical integration of its characteristics: application to space plasma dynamics
45th Culham summer physics school, Culham, England, July 2008.

[210] Voitcu, G., and Echim, M.
Test-kinetic modelling of non-gyrotropic velocity distribution functions experimentally observed in the terrestrial magnetosphere
National Physics Conference, Bucuresti, September 2008.

[211] De Keyser, J., Gamby, E. and Kruglanksi, M.
Deployment of Interactive Space Weather Services
Fifth European Space Weather Week, Brussels, Belgium, November 2008.

5.5.7.3 Software & web services

- The MIM (Manager of Interactive Modules) Software package, available via the European Space Weather Portal (http://www.spaceweather.eu/en/software/mim)

5.6 Space physics: Participating in experiments

5.6.1 Overall description

Space environment monitoring begins with the availability of data. At the start of the STCE, the Institute was not actively participating in the construction of any specific terrestrial space physics related instrument. The long-term goal is to harbour a baseline expertise for initiating participation to experiments and performing initial feasibility studies, while specific proposals remain under the umbrella of GSTP (*General Support Technology Program*) or PRODEX programs of ESA. First efforts are expected to demonstrate that three Xylophone Bar Magnetometers of different frequencies can operate in close proximity. A first prototype, a three-axis sensor, would represent the final stage in the "proof of concept" development of a miniaturized magnetometer using one of the many available micro-electromechanical system (MEMS) technologies. Eventually, a fleet of micro-satellites, each carrying such a magnetometer, would be able to map large-scale and spatial changes in the near-Earth magnetic field. Such spacecraft constellations are needed to forecast space weather.

5.6.2 Prospecting for experiment oppportunities

5.6.2.1 Objectives

Newly hired scientist/engineer will get acquainted with the local environment, and with current/future missions on which space plasma instrumentation could be located.

5.6.2.2 Achievements

We have not yet found a scientist or engineer with the appropriate qualifications for this job; the search continues.

We have identified a number of possible options for instrumentation. In view of our scientific interests, we have also pursued the possibility of ground-based experiments.

In particular, we have been looking at the possibilities to work on experiments for measuring the polarization of auroral emissions. A meeting has been organized at BISA on 19 November 2008 to establish a long-term collaboration between the institute and the LPG de Grenoble (Dr. Jean Lilensten) on this subject, in the framework of the SEPAGE proposal. This collaboration will take various forms including a coordinated campaign with simultaneous observations of ALIS, EISCAT and POLARLIS, planned for December 2009. POLARLIS is an instrument dedicated to the measurement of the polarization of the red auroral line. Several meetings have been planned.

Another goal is to study the feasibility to carry out polarimetric observations with the current ALIS cameras (ALIS network of optical cameras for auroral tomography). A visit to Kiruna is planned for April 2009. In the long-term, we plan to build dedicated cameras to measure the polarization of the upper atmosphere. These cameras could possibly be located in existing empty ALIS stations. We have looked at how polarization measurements could contribute to improve tomographic reconstruction of auroral emissions.

Another option that we are examining is a participation in the ASIM detectors (T. Neubert, Danish Meteorological Institute) that would look at transient light emission from the Earth's atmosphere from an external platform on the ISS. We would be interested there in emissions from lighting and sprites, and from meteors.

An interest in radio detection of meteors is also growing in our team.

5.6.3 Feasibility of a Xylophone Bar Magnetometer

5.6.3.1 Objectives

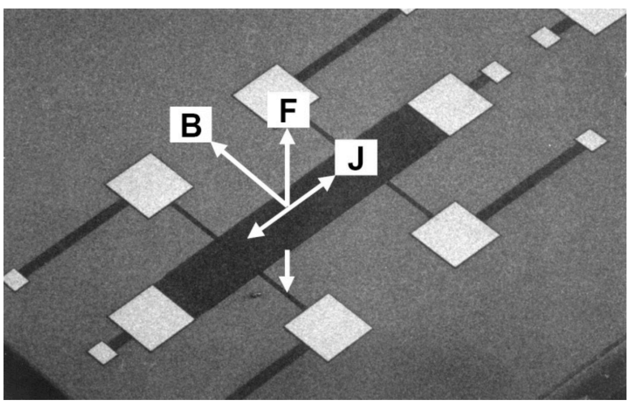
Study feasibility of a Xylophone resonating Bar Magnetometer with sub-nanotesla sensitivity and large bandwidth to detect time-varying magnetic fields.

Exchange information between CSL, LTAS, UCL, and BISA about existing spatial applications of the Johns Hopkins Xylophone Bar Resonating magnetometer. Study the micro-electromechanical system (MEMS) technology of the instrument (CSL). Test the replacement of the optical part of the instrument (this part suffers from strong constraints for spatial applications of this new type of magnetometer) by a tension measurement technique at both ends of the bar (LTAS). Internal feasibility study between CSL, LTAS, UCL Microwave lab, and BISA.

5.6.3.2 Achievements

Upon the exchange of information between the partners, Belgian Institute of Space Aeronomy has initiated collaboration with the CSL (Centre Spatial de Liège) and the LTAS (Aerospace & Mechanical Engineering Department of the University of Liège) for the study of the feasibility, design and manufacture of a MEMS magnetometer for future space missions, possibly on nano- or pico-satellites. Six working meetings have been organized in CSL on 21/05/08, 16/01/09 and 20/02/09, in BIRA-IASB on 08/07/08, in LTAS on 30/01/09 and in the Microwave Laboratory of UCL in 07/11/08.

BISA has written a requirements document, defining the scientific objectives of the space missions and the requirements needed for the sensitivity of the magnetometer as well as for its time resolution. The initial idea is to miniaturize a xylophone bar magnetometer although other type of magnetic sensors could be also considered.



Dr. H. Lamy and M. Roth of BIRA-IASB have written a working document summarizing the principles of the previous types of magnetometers used in space missions (mainly search-coil, flux-gate and vector helium magnetometers) and describing in detail the principle of a xylophone bar magnetometer (published in Physicalia Magazine).

A mask has been designed by Innocent Nyonzima and Dr. Véronique Rochus for the creation of a MEMS XBM prototype in the Microwave Laboratory of UCL. The prototype should be operational by the end of March. Optimal dimensions of the bar as well as factors influencing the quality factor have been modelled. Preliminary tests will be carried out at the LTAS with a Hall sensor provided by the CSL.

Preliminary results of this feasibility study will be presented by Lamy et al in the Space Technology Conference meeting, Thessaloniki, Greece, 24-26 August 2009.

Various missions have been considered as possibilities to embark this MEMS magnetometer. A decision has been made to request ESA GSTP funding for this work.

5.6.4 Partnerships

5.6.4.1 Collaborations

- Centre Spatial de Liège (CSL, Dr. P. Rochus, Nicolas Martin)
- Laboratoire de Techniques Aéronautiques et Spatiales (LTAS) of ULg (Prof. J.C. Golinval, Dr. V. Rochus, and Innocent Nyonzima, étudiant ingénieur civil)
- Microwave Laboratory of UCL (Prof. Raskin)
- Laboratoire de Planétologie de Grenoble (LPG) (Dr. Jean Lilensten and Dr. Mathieu Barthélemy)
- Swedish Institute of space Physics, Kiruna, Sweden, ALIS team (Auroral Large Imaging System)
- Danish Meteorological Institute, Denmark (T. Neubert)

- Vereniging voor Sterrenkunde (F. Verbelen)

5.6.5 Perspective for the future

5.6.5.1 Prospecting for experiment opportunities

We will keep on prospecting for new space or ground experiment opportunities.

5.6.5.2 Xylophone Bar Magnetometer

BIRA-IASB will take the lead in this project. Apart from trying to arrive at a prototype as soon as possible, we hope to verify that the design requirements for space applications can be met. In addition, we will study the possibility to eliminate stray fields by means of combining the measurements of several magnetometers on a spacecraft.

5.6.5.3 Instrumentation for observing polarized auroral emissions

Through the collaborations that we have established with the ALIS team and the LPG group, we see a clear scientific rationale for pursuing polarization measurements of auroral emissions, in view of its input to tomographic inversion. This task is a spin-off of the activities that we developed under 2008C2.1.

5.6.5.4 Instrumentation for meteor observations

We have a healthy interest in meteors for several reasons: They are part of the natural space environment, their re-entry is a plasma phenomenon and reveals clues about the upper atmosphere, and they are related to comets. We believe it is worthwhile to invest in particular in radio observations of meteors. This task is a spin-off of the activities that we developed under 2008C2.1.

5.6.6 Publications and output

5.6.6.1 Publications with peer review

[212] Neubert. T., M. Rycroft, T. Farges, E. Blanc, O. Chanrion, E. Arnone, A. Odzimek, N. Arnold, C.-F. Enell, E. Turunen, A. Mika, C. Haldoupis, R. Steiner, T. Bösinger, O. van der Velde, S. Soula, P. Berg, F. Boberg, P. Thejll, B. Christiansen, M. Füllekrug, M. Ignacollo, P. Veronen, J. Montanya, and N. Crosby
Recent Results from Studies of Electrical Discharges in the Mesosphere
Surveys in Geophysics, Vol. 29, 2008.

5.6.6.2 Publications without peer review

[213] Lamy H. and Roth M.
Magnetic sensors for space applications: towards miniaturization
Physicalia Magazine, 2008.

5.6.6.3 Technical reports

- Lamy H. and M. Roth, Magnetic Field Sensors for Space and Ground Applications: Emphasis on MEMS technology (Introductory part for a future GSTP project on a MEMS magnetometer as payload on a Cubesat)
- Roth, M. and Lamy, H., MEMS magnetometers: background and overview, internal report (introductory part of a GSTP project for a MEMS Resonating Bar Magnetometer).

5.6.6.4 Other

- H. Lamy organized a meeting at BIRA-IASB for developing methods and instruments to detect meteors with radio techniques in 2007, and a second meeting was held on "Radio detection of meteors and wavelet analysis" at the UCL in collaboration with Prof. J.-P. Antoine in 2008.

5.7 Space Physics: Fundamental Science

5.7.1 Overall description

Science underlies understanding and predicting the space environment. Our long-term goal is that STCE scientists would perform first-class science in various domains related to solar-terrestrial science (solar wind, auroral physics, solar-terrestrial relationships …) in close collaboration with the Institute science staff.

- Fundamental processes governing solar wind entry into the magnetosphere must be understood to improve space weather predictions. Modelling the structure of small scale boundary layers like rotational discontinuities will help to reveal the nature of some of these fundamental processes.
- Up to now, the influence of the Sun on climate change is not clearly evaluated. It seems nevertheless that it is not negligible, as evidenced by the very cold period observed in Europe in the 17th century, associated with a lack of sunspots. The influence of solar activity on climate has been linked to solar irradiance variations and the modulation of cosmic rays (and then of cloud formation).

It should be noted that other fundamental science topics relevant to solar-terrestrial physics will continue to be studied in the context of other projects. Work on those topics is not reported here.

5.7.2 Hiring physicist & Training phase

5.7.2.1 Objectives

Newly hired physicist with knowledge of plasma kinetic theory, space physics, computational methods … will get acquainted with the space plasma physics problems BIRA-IASB is working on (training).

5.7.2.2 Achievements

After a long and exhaustive search process during 2008, we hired Yuriy Voitenko as scientist for fundamental space science. He is working with us since mid January 2009. He has a lot of expertise concerning kinetic waves, which will be beneficial for us in the domain of solar wind – magnetosphere interaction, auroral physics … Because of this background, it did not take much time to get acquainted with what we are doing. In fact, in November 2008 he already participated in an Info Day that was held at BIRA-IASB, where we presented our activities.

5.7.3 Solar wind-magnetosphere interaction

5.7.3.1 Objectives

Study the solar wind and the solar wind-magnetosphere interaction. E.g. Modelling of rotational discontinuities.

5.7.3.2 Achievements

In the field of solar wind and exospheric modelling, we have improved the Fortran 90 code for the exospheric modelling of the acceleration of the fast solar wind. This code is now available on the Space Weather Portal. It is also available on the CCMC website from NASA. V. Pierrard is developing kinetic models for the ion exosphere of Jupiter and Saturn, in addition to the models developed for the Earth. The results of our kinetic models were compared to those obtained with Monte Carlo simulations. In such

Monte Carlo simulations, we collaborated with Prof. Barghouthi to introduce the effects of wave-particle interactions in the simulations for the escape of the polar wind. Conics were obtained at high altitude for the positive ions in the polar wind when a velocity and altitude-dependent diffusion coefficient is introduced to simulate the effects of wave-particle interactions. The effects of suprathermal particles on the current-voltage relationship were also studied.
Concerning the solar wind-magnetosphere interaction, we have continued our work on empirical reconstruction techniques. We have published a review paper, and we have also applied the technique to Themis observations of the dayside magnetopause.

5.7.4 Study of the influence of the Sun on the climate

5.7.4.1 Objectives

Contribute to the study of the influence of the Sun on the climate, including the role of corpuscular radiation. Comparisons of long-period observations of terrestrial parameters (magnetospheric characteristics, temperature at the surface of the Earth, cloud coverage…) and solar or external parameters (sunspots, solar wind velocity, solar wind density, cosmic ray flux …).

5.7.4.2 Achievements

In the area of solar effects on climate, N. Crosby is studying atmospheric electricity: sprites, jets and elves, also referred to as Transient Luminous Events (TLEs). In this context she has participated in the creation of the European research network (GDRE) entitled "Electromagnetic Coupling of the Atmosphere with near-Earth Space (E-CANES)". She has edited, together with T.-Y. Huang and M. Rycroft, a volume of the AIP Conference Proceedings, for the "Workshop on Coupling of Thunderstorms and Lightning Discharges to Near-Earth Space".
Some work has also been done concerning energetic corpuscular radiation to support other ongoing Space Weather activities at BIRA-IASB. Many of the currently used standard models of the solar energetic particle environment were developed based on results published more than 15 years ago. Modern user requirements, as well as recent observational data and scientific advances mean that these standards are currently in need of review and updating. Incorporating recent scientific results and a complete set of well calibrated data the ESA Solar Energetic Particle Environment Modelling (SEPEM) project is working towards creating new engineering models and tools to address current and future needs, e.g. both mission integrated fluence statistics and peak flux statistics, and other outputs suitable for SEU rate prediction and radiation background calculations. We have also contributed to the Martian Radiation Environment Models (MarsREM) project to provide detailed, extendible and easy-to-use radiation models and engineering tools to predict the Martian radiation environment. BISA has specifically been responsible for a review of existing data and models of energetic particles in interplanetary space, the creation of a radiation database, and the development of new models. In collaboration with the Center for Space Radiations (UCL), V. Pierrard analyzed satellite observations and developed statistical models to determine the flux variations of the energetic particles during geomagnetic storms and substorms and their influence on the high atmosphere.

5.7.5 Partnerships

5.7.5.1 Collaborations

- CLUSTER community, in particular M. Dunlop (Rutherford Appleton Lab, Oxford, UK), P. Decreau (LPCE/CNRS Orléans, France), N. Cornilleau (CETP/CNRS, France), C. Owen (MSSL, UK), H. Rème and I. Dandouras (CESR, Toulouse, France)
- Université Catholique de Louvain: Institut d'Astronomie et de géophysique Georges Lemaître (Prof. A. Berger) and Center for Space Radiations (mainly S. Benck ad J. Cabrera)
- Katholiek Universiteit Leuven (Dr. M. Lazar)

- Observatoire de Paris-Meudon (Pr. N. Meyer-Vernet)
- University Dunarea de Jos, Galati, Romania (Dr. Voiculescu)
- Institute for Space Sciences, Magurele-Bucaresti, Romania (Interball mission)
- Swedish Institute of Space Physics, Uppsala, Sweden (Viking mission)

5.7.6 Perspective for the future

5.7.6.1 Wave phenomena in the solar wind and the magnetosphere

The expert that we have hired is especially knowledgeable in the domain of plasma waves. It is therefore natural to study the role of waves in various regions: in the solar wind, near the magnetopause, in auroral acceleration regions, …

5.7.6.2 Exospheric models for the solar wind and for planets

We have a significant activity in the use of exospheric models, especially for modelling the solar wind and its acceleration, but also for the polar wind and the exospheres of the planets.

5.7.6.3 Study of space weather causes and effects

This task aims to look at various aspects of space weather research, including the effects of ionizing radiation, effects on health, on atmospheric electricity, on climate, …

5.7.7 Publications and output

5.7.7.1 Publications with peer review

[214] Barghouthi I.A., Doudinn N.M., Saleh A. A. and V. Pierrard
High-altitude and high latitude O+ and H+ outflows: The effect of finite electromagnetic turbulence wavelength
Annales Geophysicae, 25, 2195-2202, 2007.

[215] Chanrion O., Crosby N.B., Arnone E., Boberg F., Van der Velde O., Odzimek A., Mika A., Enell C.-F., Berg P., Ignaccolo M., Steiner R., Laursen S. and Neubert T.
The EuroSprite2005 Observational Campaign: an example of training and outreach opportunities for CAL young scientists
Advances in Geosciences, 13, 3-9, 2007.

[216] Crosby N.B. and Rycroft M.
Solar, heliospheric and external geophysical effects on the Earth's environment: scientific and educational initiatives
Advances in Geosciences, 13, 1-1, 2007.

[217] Crosby N., Krasotkin S., Haubold H.
University Satellites and Space Science Education Symposium
Eos Trans., AGU, 88(15), 172, 2007

[218] Pierrard V., G. V. Khazanov, and J. F. Lemaire
Current-voltage relationship,
J. Atmosph. Sol. Terr. Phys., Special issue on the polar wind, 2048-2057, doi: 10.1016/j.jastp.2007.08.005, 2007.

[219] Tam S. W. Y., T. Chang, and V. Pierrard
Kinetic modelling of the polar wind
J. Atmosph. Sol. Terr. Phys., Special issue on the polar wind, 1984-2027, doi: 10.1016/j.jastp.2007.08.006, 2007.

[220] Barghouthi I. A., N. M. Doudin, A. A. Saleh and V. Pierrard
The effect of altitude and velocity dependent wave-particle interactions on the H+ and O+ outflows in the auroral region
Journal of Atmospheric and Solar - Terrestrial Physics, 70, 1159-1169, doi:10.1016/j.jastp.2008.01.005, 2008.

[221] Crosby N.B., V. Bothmer, R. Facius, J.-M. Griessmeier, X. Moussas, M. Panasyuk, N. Romanova, and P. Withers
Interplanetary Space Weather and its Planetary Connection, meeting report
AGU Space Weather Journal, Vol. 6, No. 1, S01003, 2008.

[222] De Keyser, J.
Empirical Reconstruction
Multi-spacecraft Analysis Methods Revisited (eds. G. Paschmann and P. Daly), ISSI Scientific Report SR-008, chapter 10, pages 91-97, ESA Communications, Noordwijk, and ISSI, Berne, 2008.

[223] R. Maggiolo, J.A. Sauvaud, I. Dandouras, E. Luceck, H. Rème
A case study of dayside reconnection under extremely low solar wind density conditions
Annales Geophysicae 26(11), 3571-3583, 2008.

[224] Magnus A. P. and V. Pierrard
Formulas for recurrence coefficients of orthogonal polynomials related to Lorentzian-like weights
Journal of Computational and Applied Mathematics, 219, 431-440, doi: 10.1016/j.cam.2007.05.011, 2008.

[225] Neubert T., M. Rycroft, T. Farges, E. Blanc, O. Chanrion, E. Arnone, A. Odzimek, N. Arnold, C.-F. Enell, E. Turunen, A. Mika, C. Haldoupis, R. Steiner, T. Bösinger, O. van der Velde, S. Soula, P. Berg, F. Boberg, P. Thejll, B. Christiansen, M. Füllekrug, M. Ignacollo, P. Veronen, J. Montanya, and N. Crosby
Recent Results from Studies of Electrical Discharges in the Mesosphere
Surveys in Geophysics, Vol. 29, 2008.

[226] Crosby N.
Solar extreme events 2005-2006: effects on near-Earth space systems and interplanetary systems
Special Issue of Advances in Space Research, 2008. In press.

[227] Crosby, N.
Space Weather: Science and Effects
Proceedings of the IAU257 Symposium on Universal Heliospherical Processes, Cambridge University Press, 2008. In press.

[228] Babayev E. S., Crosby N. B., Obridko V. N. and Rycroft M. J.
Potential Effects of Solar, Geomagnetic and Cosmic Ray Variability on Biological and Ecological Systems
Recent Advances on Solar and Solar-Terrestrial Physics, Eds. Maris G. and Popescu M. D., Research SignPost Ed. House, India, 2008. Submitted.

[229] Maris O. and Crosby N. B.
Space Environment Effects on Space- and Ground-Based Technological Systems
Recent Advances on Solar and Solar-Terrestrial Physics, Eds. Maris G. and Popescu M. D., Research SignPost Ed. House, India, 2008. Submitted.

5.7.7.2 Publications without peer review

[230] De Keyser J. and Pierrard V.

Wat heeft de heliosfeer te maken met de aarde? Magnetosferisch onderzoek op het Belgisch Instituut voor Ruimte-Aeronomie. / Le lien entre l'héliosphère et la Terre: Recherche magnétosphérique à l'Institut d'Aéronomie Spatiale de Belgique
Space Connection, 61, 8-11, 2007.

5.7.7.3 Meeting presentations

[231] Lamy, J., Pierrard, V., and Lemaire, J.
Exospheric models of the solar wind
STIMM2 meeting, Sinaia , Romania, 11-15 June 2007. (invited)

[232] Crosby, N.
Solar Extreme Events 2005-2006: Effects on Near-Earth Space Systems and Interplanetary Missions
Solar Extreme Events 2007 - Fundamental Science and Applied Aspects, International Symposium, 24-27 September 2007, Athens, Greece. (invited)

[233] Echim, M.
Kinetic description of energetic plasmoids and their decoupling from background magnetic field and plasma
Conference on Earth Sun System Exploration (ESSE), Hawaii, USA, January 2008 (invited).

[234] Lemaire, J, Lamy, H., Pierrard, V., Barakat, A., Tam, S., Blelly J.-L., Lie-Svendsen, O., Echim, M.
Hydrodynamic and Kinetic models of the solar and polar wind: argument and summary of an inter-disciplinary focus group
Conference on Earth Sun System Exploration (ESSE), Hawaii, USA, January 2008 (invited)

[235] Lamy H. & Lemaire J.
Accretion of matter by the Sun : influence on the solar corona
National Radio Science Meeting of URSI at the University of Boulder, Colorado, January 2008

[236] Lamy H., Lemaire J.
Accretion of matter by the Sun: influence on the solar corona,
EGU Annual Meeting, Vienna, 13-18 April 2008 (oral presentation).

[237] Slominska, E.; Voitcu, G.; Echim, M.; Lamy, H.; Pierrard, V.; Lemaire, J.
Collisionless transport equations in the solar wind with Kappa distribution
EGU, Vienna, April 2008.

[238] Pierrard V.
The effects of the solar cycle on the space environment of the Earth
Scientific meeting of the Belgian Physical Society, ULB, Brussels, 21 May 2008.

[239] Pierrard V.
The influence of the solar cycle on the climate, Climate change: from the geological past to the uncertain future
UCL symposium in honour of André Berger, Louvain-la-Neuve, 26 to 29 May 2008.

[240] Pierrard V.
Fokker-Plank modeling of the solar and polar wind flow
STIMM2 meeting (Solar-Terrestrial Interactions from Microscale to Global Models), Sinaia (Romania), 11-15 June 2007. (invited)

[241] Glover, A. and N. Crosby
Advances in Solar Energetic Particle Statistical and Physical Modelling as part of the SEPEM Study
COSPAR 2008, Montreal, Canada.

[242] Mazzino, L.; Pierrard, V.; Cyamukungu, M.; Benck, S.; Cabrera, J.
Development of a statistical dynamic radiation belt model: Analysis of storm time particle flux variations
COSPAR, Montreal, Canada, 13-20 July, 2008. (oral).

[243] Crosby, N.
Space Weather: Science and Effects
IAU257 Symposium on Universal Heliospherical Processes, Sept. 15-19, 2008, Ioannina, Greece. (invited)

[244] Pierrard V.
Kinetic models of the Solar wind: achievements and fundamental questions
12th European Solar Physics Meeting in Freiburg, Germany from 8.-12. September, 2008. (invited).

[245] N. Crosby
Creation of a Standard Solar Energetic Particle Dataset as part of the SEPEM Project, SEENoTC
Workshop on Data Sharing, Experiments, Flight Opportunities and Lessons Learned, Toulouse, France, 13-15 October 2008.

[246] N. Crosby
Mission to Mars: Space Radiation and Related Obstacles
8th European Mars Conference, Antwerp, Belgium, 17-18 Oct. 2008 (Invited presentation).

[247] Benck S., L. Mazzino, V. Pierrard, M. Cyamukungu and J. Cabrera
Towards the development of a statistical dynamic radiation belt model
Fifth European Space Weather Week, 17-21st November, Brussels 2008.

[248] N. Crosby and L. Eliasson
Space Tourism - An Emerging Space Weather Market
Fifth European Space Weather Week 5, Brussels, Belgium.

5.7.7.4 Software and web services

- The solar wind model and plasmaspheric model can be run on the European Space Weather Portal (ESWEP) : www.spaceweather.eu
- The solar wind model can be run on the NASA Community-coordinated modeling center website: http://ccmc.gsfc.nasa.gov//models/models.shtml

5.7.7.5 Other

- N. Crosby was co-convener of the session “ST13 Solar, heliospheric and atmospheric coupling with near-Earth space”, European Geosciences Union, General Assembly 2007, Vienna, Austria, 15-20 April 2007.
- N. Crosby was convener of the Session “M3 Hazards in Interplanetary Space and on Other Planets: Science, Engineering and Health”, European Planetary Science Congress 2007, Potsdam, Germany, 19 – 24 August 2007.
- N. Crosby organized the “Workshop on Coupling of Thunderstorms and Lightning Discharges to Near-Earth Space”, 23-27 June 2008 at the University of Corsica, Corte, France: http://www.oma.be/TLE2008Workshop/
- J. De Keyser has participated in the scenario-writing for a new show at the Planetarium, which will deal with Space Weather (coordination: A.-L. Kochuyt). Meeting on 27 November 2008.
- N. Crosby created a flyer advertising the ongoing Mars related research activities at BISA including the SEPEM and MarsREM projects.

5.8 Data Centre

5.8.1 Overall description

To sustain STCE activities RMI, ROB and BISA are developing a data centre. Building that data centre will be a matter of acquiring equipment, connecting this equipment to existing and new networks, and developing services in order to satisfy end user's needs. Essentially the data centre will provide the following services:

- Collect, store and process data;
- Distribute data by FTP or HTTP;
- Distribute data by automatic forward;
- Give some users direct access to dedicated file servers;
- Guarantee service 7/7, 24/24.

To realize these services, we will have to collect requirements from all the data centre stakeholders and design the data centre. The designed data centre will be integrated in the existing IT infrastructure of STCE partners. It should be based on an architecture that can grow and adapt to new requirements and technologies.

A close collaboration is necessary between the BUSOC (data centre sub-project leader) and the IT services of RMI, ROB and BISA. This is the only way to make sure that the data centre will respond correctly to the end user's needs while taking into account the necessary interoperability with the existing IT infrastructure.

5.8.2 Requirements capture within BIRA-IASB

5.8.2.1 Objectives

Identification of the data centre resource requirements within BISA, bearing in mind that the requirements capture is an iterative process. The output of this process should be a top level design document, and detailed design documents for specific requirements. These documents should allow the design of an initial data centre setup. That first trial should cope with BISA internal requirements and remain open to the incorporation of requirements from other STCE partners.

5.8.2.2 Achievements

An analysis of the BIRA-IASB STCE data requirements has been carried out. The data requirements have been used as input in the infrastructure definition process. A dialogue has been maintained with BIRA-IASB general ICT services team to ensure compatibility of the design with existing facilities.

5.8.3 Requirements capture with STCE partners

5.8.3.1 Objectives

Requirements capture from ROB and RMI. Update of the top level design and the detailed design documents. Start negotiation with equipment and software providers. The output of this process should be the final top level design and detailed design documents, laying out a stable and cost-effective architecture of the data centre.

5.8.3.2 Achievements

Some preliminary discussions have taken place.

5.8.4 Order data storage system

5.8.4.1 Objectives

Order hardware items (storage processors, rack, console …) and software (licenses, service agreement …). Install and operate the data centre. This should result in a continuous data storage and distribution, and development and operation of specific applications.

5.8.4.2 Achievements

Ordering of hardware has been initiated, see theme 2008B.3.

5.8.5 Partnerships

5.8.5.1 Collaborations

- RMI
- ROB

5.8.6 Perspective for the future

5.8.6.1 Requirements capture within BIRA-IASB

These tasks will of course continue as the needs evolve.

5.8.6.2 Requirements capture with STCE partners

These tasks will of course continue as the needs evolve.

5.8.6.3 Accept and install data storage system

The data storage system has been ordered. We are awaiting delivery and installation. Then we can actually start the implementation of our data storage plans.

5.8.6.4 Participation to an international Data Centre Network

As Data Centre activities take place in an international context, we will be participating to the ULISSE project, which is focused on defining the optimal strategy for the exploitation of the ISS and other space science data for all stakeholders**.**

5.8.7 Publications and output

5.8.7.1 Publications

[249] G. Pradels, T. Guinle, G. Thuillier, A. Irbah, J.-P. Marcovici, C. Dufour, D. Moreau, C. Noel, M. Dominique, T. Corbard, M. Hadjara, S. Mekaoui, C. Wherli
The PICARD Payload Data Centre
AIAA Proceedings, 2008.

5.8.7.2 Meeting presentations

[250] C. Muller
Space exploration and Belgian society, 1911-2006.
EGU General Assembly 2007 Vienna, Austria, 15 – 20 April 2007

[251] C. Muller, D. Moreau, A. Michel, X. Stockman, K. Litefti and J. Wisemberg
Distributed Users Support and Operation Centres in the exploration programme as supporting infrastructure for virtual observatories

European Planetary Science Congress 2007 Potsdam, Germany, 19 – 24 August 2007.

5.8.7.3 Technical reports

BIRA-IASB B.USOC technical reports describing data storage system

- IASB-BUS-SERV-DSAT-AUG_v1.1
- IASB-BUS-SERV-DSAT-NF_v1
- IASB-BUS-SERV-DSAT-RED_v1.1

5.8.7.4 Software and web services

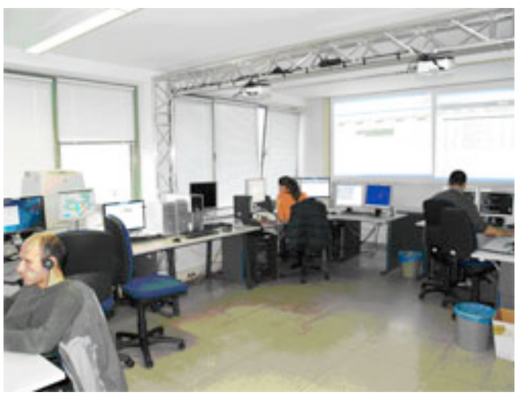
- General data centre access via website http://www.busoc.be

5.8.7.5 Hardware

- Order of the hardware. Delivery foreseen for June 2009 until November 2009 (three phases). See theme 2008B.3 for more details on the actual system that has been ordered.

5.9 Mission Centre

5.9.1 Overall Description



BIRA-IASB is involved in infrastructure management and operations & communication for space missions. Apart from specific funding for this purpose, we rely on the STCE to support the creation of generic infrastructure and an environment to operate payloads in the frame of Solar Physics and Space Physics, and to support the ISS Solar Monitoring Observatory.

The ISS/SOLAR observatory was launched in February 2008. The launch marked the start of the operational phase. SOLAR is a combination of instruments designed to monitor the solar radiation as it is received on the Earth. SOLAR is one of the first external payloads of the ISS. Its operations are entirely led from the Belgian Institute for Space Aeronomy where the operation centre, the B.USOC is located. Three instruments are deployed:

- SOL-ACES is a far UV monitor from the Fraunhofer-Institut für Physikalische Messtechnik from Freiburg in Germany.
- SOLSPEC measures the spectral repartition of solar radiation on the UV, the visible and the infrared. This instrument implies the Belgian Institute for Space Aeronomy and is led by the Service d'Aéronomie of the CNRS in France.
- SOVIM monitors the total energy output of the sun which was formerly known as the solar constant. This instrument implies the Royal Meteorological Institute of Belgium and is led by the radiation climate institute of Davos in Switzerland.

Older versions of SOLSPEC and SOVIM flew on various space platforms since the SPACELAB-1 flight of 1983. They were both present also at the ATLAS-1 flight of Dirk Frimout in 1992 and the existing data series honors both the Belgian Institute for Space Aeronomy and the Royal Meteorological Institute.

5.9.2 ISS SOLAR mission centre

5.9.2.1 Objectives

Continuation of implementation of the ISS SOLAR Mission Centre and installation of the ESA related HW and SW.

5.9.2.2 Achievements

The implementation of the SOLAR mission centre has finished. This centre is operational since February 2008, the launch of SOLAR, and works on a 24/24 and 7/7 basis. During the mission, B.USOC assumes different tasks:

- Operations coordination, i.e., control of the experiment;
- Coordination and control of activities in the UHB (scientific laboratories);
- Management of the control room.

These activities are made in close collaboration with the European Space Agency.
Another operational important role for the B.USOC is managing and receiving the scientific data from the experiments, as well as archiving the data and distributing them in real time to the scientific teams.

5.9.3 Establish real-time connectivity to operate as ESA operational centre

5.9.3.1 Objectives

We want to achieve the status of an ESA Operational Centre. For that, we must be connected to the ESA/IGS Network for real-time operations.

5.9.3.2 Achievements

The SOLAR mission centre is connected to the ESA IGS network and therefore potentially available for all real time operations of ESA payloads.

5.9.4 Generic mission centre definition

5.9.4.1 Objectives

Definition and preparation of implementation of a generic mission centre infrastructure.

5.9.4.2 Achievements

As an example of the generic mission centre infrastructure, a first version of the PICARD mission centre has been installed. It is currently in a testing phase. It has been designed with an emphasis on possible future expansion and extension. It follows the operating rules for payloads for CNES micro-satellites.

5.9.5 Generic mission centre implementation

5.9.5.1 Objectives

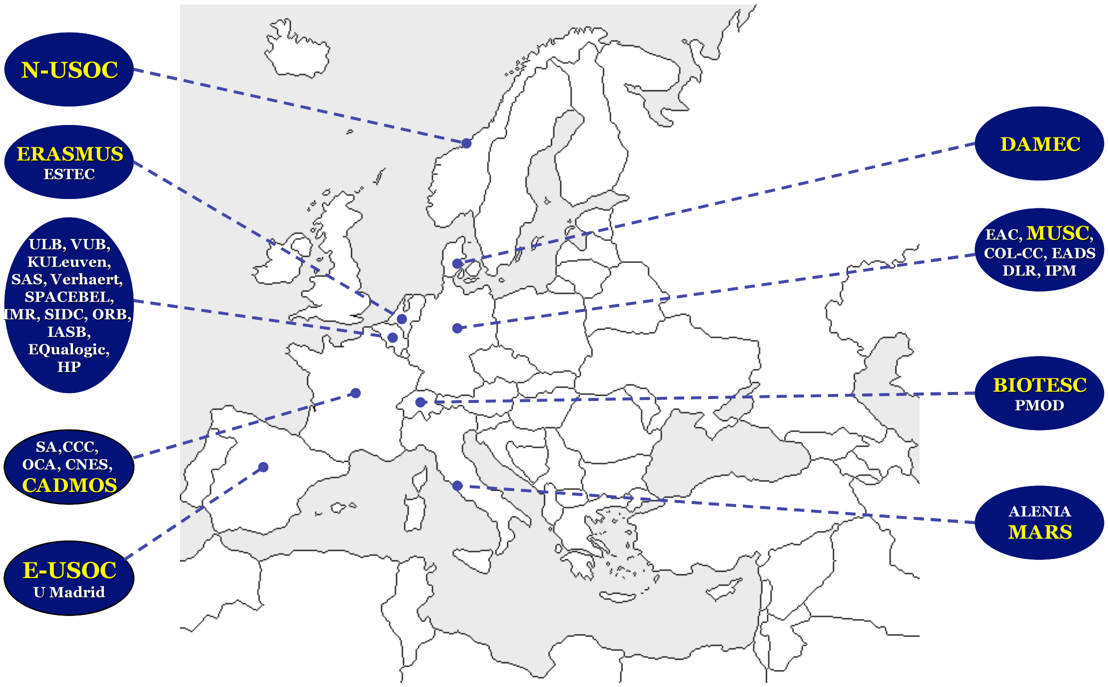
Prepare the installation of a generic mission centre infrastructure.

5.9.5.2 Achievements

Training of future operators of the PICARD mission centre has begun in September.

5.9.6 Partnerships

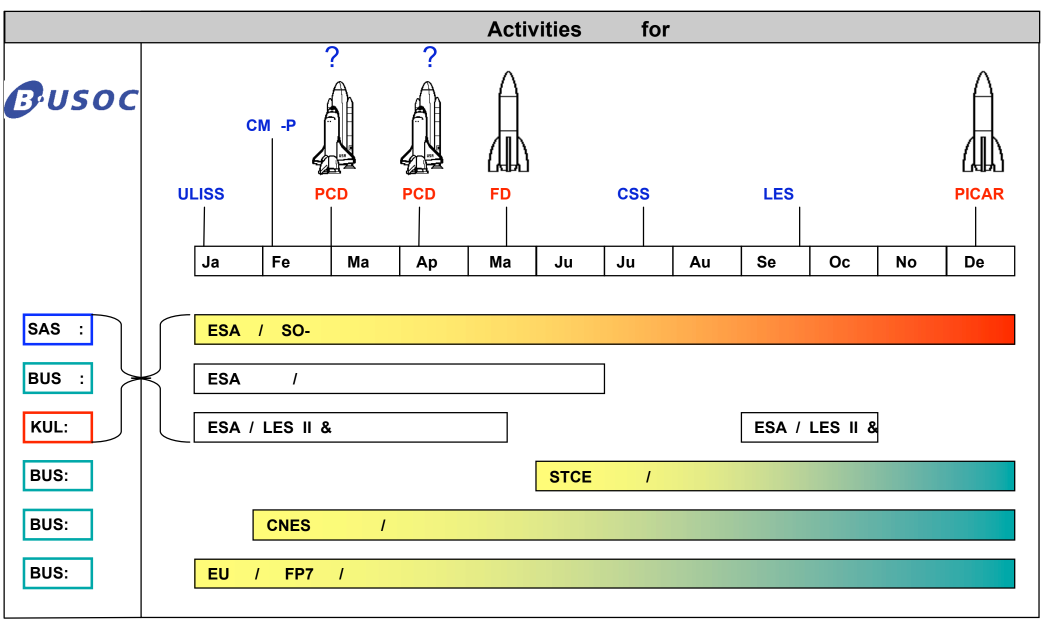
5.9.6.1 Collaborations



5.9.7 Perspective for the future

5.9.7.1 ISS SOLAR mission centre

We will continue to operate as the mission centre for SOLAR on ISS.



5.9.7.2 Explore options to operate as ESA operational centre

As we have now achieved the status of an ESA operational centre, we will further explore how we can best capitalize on our investments and play an active role towards ESA.

5.9.7.3 PICARD mission centre

We will operate as the mission centre for the CNES PICARD mission. This task follows up on task 2008B.2.3 and 2008.B.4.

5.9.8 Publications and output

5.9.8.1 Meeting presentations

[252] C. Muller, D. Moreau, X. Stockman, K. Litefti and J. Wisemberg
Role of distributed Users Support and Operation Centres in the exploration programme
ESA consultation meeting on the exploration programme, Edinburgh., January 8-9 2007.

[253] J. Wisemberg, D. Moreau, C. Muller, P. Olamba, E. Haumont, X. J. Stockmans and K. Litefti
The support of scientific experiments by B.USOC on the ISS since the Odissea Flight.,Experiments in Space and beyond
International congress Brussels, April 12-13, 2007.

[254] C. Muller, A. Michel, K. Lifteti, D. Moreau and J. Wisemberg
The support to the SOLAR payload on COLUMBUS:an external payload in the frame of a manned mission
European Planetary Science Congress 2007 Potsdam, Germany, 19 – 24 August 2007

[255] C. Muller, D. Moreau, A. Michel, X. Stockman, K. Litefti and J. Wisemberg
Distributed Users Support and Operation Centres in the exploration programme as supporting infra-structure for virtual observatories
European Planetary Science Congress 2007 Potsdam, Germany, 19 – 24 August 2007.

5.9.8.2 Software & web services

- General operation centre access via website http://www.busoc.be
- Columbus access website http://columbus.busoc.be
- Service offering data access to the SOLAR scientists: For this purpose a special UHB software terminal (archive browser) has been developed. This terminal allows scientists to retrieve their data through a VPN over internet.

5.9.8.3 Hardware

- Connection to the ESA/IGS Network for real-time operations

5.9.8.4 Other

- SOLAR mission centre
- Preliminary PICARD mission centre
- Achieved the status of an ESA Operational Centre

5.10 Infrastructure – Data storage

5.10.1 Overall description

In view of our aim to kick-start the implementation of the data centre, we inserted this punctual activity, backed up by a substantial amount of funding, for the provision of a sufficiently capable fail-safe data storage solution. This punctual activity supports task 2008B.1.3.

5.10.2 Data storage system acquisition

5.10.2.1 Objectives

Buying and installing a sufficiently capable data storage system, as defined by task 2008B.1.

5.10.2.2 Achievements

The required infrastructure has been defined and the ordering process has been initiated. The infrastructure will comprise:

- A data storage unit (Enterprise Virtual Array) of 12,5 TB that can evolve into 100 TB by end December 2009.
- 2 servers (minimum)
- A data replication utility.
- A backup utility.

5.10.3 Partnerships

5.10.3.1 Collaborations

- ROB
- RMI

5.10.4 Perspective for the future

Handling of the delivery and installation will be covered by task 2009B.1.3.

5.10.5 Hardware

Order of the hardware. Delivery foreseen for June 2009.

- A data storage unit (Enterprise Virtual Array) of 12,5 TB that can evolve into 100 TB by end December 2009.
- 2 servers (minimum)
- A data replication utility.
- A backup utility.

5.11 Space Weather: services

5.11.1 Overall description

Space Weather describes the conditions in space affecting Earth and human activities. It is mainly driven by the solar activity and is associated to phenomena such as geomagnetic storms, the Van Allen radiation belts, ionospheric disturbances, aurora and geomagnetically induced currents at Earth's surface. Several models and data sets have been produced (and are still being produced) by the scientific and engineering community to understand, evaluate and forecast the phenomena and their effects on technological systems. The access to this information is not always straightforward in particular for a broader public. Web accessible services should educate, inform and provide user-friendly tools to different communities (general public, space engineers and policy makers,…). Our long-term goal is to provide a number of human and machine readable services which expose the scientific and technical expertise that has been and will be acquired on the space environment and its effects.

We will do this by

- Operating the European Space Weather Portal initiated during the COST 724 action;
- Developing an integrated user-friendly framework tool to archive, access and manage scientific or engineering data sets used by other BISA projects;

– Establishing a functional link between the two preceding points and the SPENVIS interface.

5.11.2 European Space Weather Portal (ESWeP)

5.11.2.1 Objectives

- Maintenance of the ESWeP Content Management System.
- Support of the ESWeP Content Management System.
- Resolve intellectual property issues.

5.11.2.2 Achievements

The ESWeP portal is an integrated website providing a centralized access point to the space weather community to share their knowledge and results. A large section is devoted to education and outreach as a service for the general public. The portal provides also cross-links to existing websites.

A first prototype of the portal has been developed, based on the *TikiWiki* content-management system. But due to several drawbacks, this solution has been abandoned. After a survey of the existing content-management systems, the *Drupal* system has been selected based on its features relative to multi-lingual content, database independence, extensibility and open source. This system is still used in the current implementation of the portal.

The ESWeP portal includes about 50 articles, 150 images and 5 audio files in the galleries, contributed by 28 different people, refers about 60 external web pages or sites, and access to 6 models. While most articles are published in English, some are accessible in Armenian, Danish, Finnish, French, Greek or Slovene. The portal has also been presented during scientific meetings, e.g.

- European Geosciences Union, General Assembly 2007, 15 – 20 April 2007, Vienna, Austria
- Space Weather Working Team, Meeting # 23, 4 June 2008, ESTEC, The Netherlands

5.11.3 Space physics data repository

5.11.3.1 Objectives

- Data and metadata database system definition.
- Database population for existing static data sets.
- Prototype of near-real-time database update.

5.11.3.2 Achievements

We are doing a short survey of the possible implementations of such repository. Some early conclusions have been applied in the project SEPEM (Solar Energetic Particle Environment Modelling).
Note that there is a relation with Task 2008B.1

5.11.4 Space Environment, Effects, and Education System (SPENVIS)

5.11.4.1 Objectives

Interface definition.

5.11.4.2 Achievements

The SPENVIS system is a web-based interface for assessing the space environment and its effects on spacecraft systems and crews. The system is used by an international user community for various purposes, e.g. mission analysis and planning, educational support, and running models for scientific applications. Most of the users are based in ESA member states (35%) or the US (30%). The rest is based in China, Japan and Eastern European countries. Half of the users are affiliated in universities or research centres. A third of the users are commercial ones. The rest is governmental or military users. About 15 new users per week register in the SPENVIS system.
The system is currently upgraded in the framework of an ESA GSTP contract.

Activities during 2007-2008:

- We have installed and configured the new SPENVIS virtual machine on the server institute. Especially, a bug tracker (Mantis) has been installed and a new site 'http://dev.spenvis.oma.be', dedicated to the development and management of the SPENVIS project, has been created.

- The SVN repository with the source code has been reorganized towards a more rational and easy to use structure. Especially, all makefiles have been rewritten using standard conventions and the Fortran code has been ported to the latest version of GNU Fortran.
- The CGI script has been updated and several blocking bugs like segmentation faults and buffer overflows have been fixed.
- A new registration procedure for the SPENVIS users has been implemented. Compared to the old procedure, this procedure is:
  - Fully automatic. So it works also on week-ends and holidays!
  - More secure: email validity is checked against different methods and the registration form makes use of CAPTCHA.
  - Single sign-on (SSO). The user registers and logs in once. After that, it gains access to all systems (SPENVIS, Forum, Tracker, etc) without being prompted to log in again at each of them.
- We have fixed the old database that was corrupted, and migrated this database to the new registration system.

5.11.5 Partnerships

5.11.5.1 Collaborations

- ESA's Space Environments and Effects section (ESTEC/TEC-EES, http://space-env.esa.int/), in particular E. Daly and H. Evans
- UCL's Center for Space Radiation (CSR, http://www.spaceradiations.be/), in particular J. Cabrera

5.11.6 Perspective for the future

5.11.6.1 European Space Weather Portal (ESWeP)

In the frame of the STCE we want to maintain and continuously update and upgrade the ESWeP web portal.

5.11.6.2 Space physics data repository

The data requirements are changing. Several existing services or tools allow to access existing repositories, such as SWENET or the Cluster Active Archive. Instead of duplicating such repositories, we plan to design a common framework providing an overview of the available data and a mechanism of access. This progress could be a first step in the development of a virtual observatory (VO) for the space environment and its effects.

5.11.6.3 Space Environment, Effects, and Education System (SPENVIS)

The SPENVIS system has to be actualized permanently. In the near future we foresee, for instance, the adaptation of several models to non-Earth planetary environments and the addition of new models based on the GEANT4 Monte Carlo code. The system will also be enhanced in order to allow interoperability with other service application such as virtual observatories.

5.11.7 Publications and output

5.11.7.1 Meeting presentations

[256] M. Kruglanksi, N.B. Crosby
European Space Weather Portal
Fifth European Space Weather Week, Brussels, Belgium, November 2008

[257] K. Stegen, J. Wera, N.B. Crosby and the COST 724 Team

European Space Weather Portal
Geophysical Research Abstracts, Vol. 9, 07452, 2007

[258] J. De Keyser, E. Gamby, M. Kruglanksi
Deployment of Interactive Space Weather Services
Fifth European Space Weather Week, Brussels, Belgium, November 2008.

[259] N. Crosby and J. Wera
BISA in General and BISA Space Weather Services
RADECS 2007 Conference, 10-14 September 2007, Deauville, France.

[260] N. Crosby
Participation in a business meeting regarding the European Space Weather Portal (ESWEP) and co-chaired the splinter session "ESWEP Improvements"
Fourth European Space Weather Week, Brussels, Belgium, 5-9 November 2007.

5.11.7.2 Technical reports

- D. Heynderickx, K. Stegen, J. Wera, *Development of the European Space Weather Portal*, in COST 724 final report (*Developing the scientific basis for monitoring, modelling and predicting*), pp. 385—388, 2007.
- M. Kruglanski, SPENVIS-3 Final Report, ESTEC Contract No. 11711/95/NL/JG(SC) WO 1, November 2008

5.11.7.3 Software and web services

- ESWeP web site, URL http://www.spaceweather.eu/
- SPENVIS web site, URL http://www.spenvis.oma.be/

5.11.7.4

5.12 Chemical Weather: Development of BACCHUS services

5.12.1 Overall Description

Forecasting the effects of solar radiation on the chemistry of the neutral atmosphere, and the effect of chemical processes on the amount of solar UV radiation reaching the ground, is an important part of "Chemical Weather" applications. Prediction requires numerical simulation of photochemistry and radiative transfer in a 3-D model of the neutral atmosphere, using an operational Global Chemistry-Climate Model (GCCM) used operationally for Numerical Weather Prediction (NWP) and extended to atmospheric chemistry.
IASB-BIRA has participated to the development of such an advanced model as co-PI of the ESA/ESTEC study contract "Coupled Chemical-Dynamical Data Assimilation". This study was based on the extension of the Canadian NWP model "GEM" to stratospheric chemistry, resulting in the "GEM-BACH" model. The excellent results obtained by this project led to a long-term collaboration between Environment Canada (EC) and a consortium of Belgian research institutions, led by IASB-BIRA, named BACCHUS (Belgium And Canada for Chemical weather User-oriented Services). The main objective of BACCHUS is to improve the forecasting capability for chemical weather applications on the global and continental scales. The focus is Air Quality in the troposphere (global and continental scale) and ozone depletion in the stratosphere (global scale). The method consists in developing an assimilation/forecasting system based on the NWP GCCM developed by Environment Canada (named "GEM") and extended to tropospheric and stratospheric chemistry.

GEM-BACH is an excellent basis for chemical weather research and services, but

- GEM-BACH currently runs only in Canada. Its installation on the Space Pole supercomputers is a large IT task, currently ongoing.
- GEM-BACH does not include any tropospheric chemistry process at the present time. The extension to tropospheric chemistry requires the implementation into GEM of the tropospheric photochemistry module developed for the IMAGES Chemistry-Transport Model.
- The stratospheric photochemistry modules developed at IASB-BIRA, and implemented in the BASCOE model/assimilation system and in the GEM-BACH model, do not currently include any parameterization for the production of nitric oxides (NOx) in the mesosphere/lower thermosphere (MLT) by photoelectrons, energetic electron precipitation and solar proton events. These processes are a major source of variability for stratospheric chemistry because they depend primarily on the solar activity level and the resulting NOx enter the stratosphere through the polar vortices, where they destroy ozone.

A short-term goal was to allow a fast startup of the BACCHUS collaboration through the installation at IASB-BIRA of the Canadian NWP model "GEM" enhanced with atmospheric photochemistry modules. Start to implement into these modules the processes missing for useful chemical weather prediction (tropospheric chemistry; upper atmospheric production of NOx related to solar activity). In view of the relative urgency, we decided to launch this activity as a punctual task in our STCE activities.

5.12.2 Set up collaboration tools

5.12.2.1 Objectives

Set up web-based tools allowing easy collaboration between the participating institutions:

- Set up a web site allowing interactive documentation of the system development and project planning
- Set up a Revision Control Software with a Web front-end, i.e. Subversion, to allow collaborative programming.

5.12.2.2 Achievements

Is completed. Being an international collaboration, BACCHUS requires web-based tools to allow easy communication and management of the different tasks. This necessity has been fulfilled through the creation of a restricted-access website (http://wiki.bacchus-ext.info). Thanks to the "wiki" technology, this site allows to all participants a dynamic documentation of planning and technical progress. It already contains 55 pages. This documentation effort also led to the creation of an internal wiki for BIRA-IASB as a whole (http://wiki-ae.oma.be).
Revision control of the source codes for the models (GEM-BACH, BASCOE) and accompanying tools is done separately on the servers of Environment Canada and BIRA-IASB, due to network security issues. At BIRA-IASB, two separate SubVersion repositories have been created: the repository named BACCHUS contains all the code maintained primarily at Environment Canada and can be accessed only by the scientists involved in the project; the repository named COMMON contains all the code created at BIRA-IASB w.r.t. stratospheric modelling, including BASCOE, and can be accessed by all BIRA-IASB staff. The repository COMMON is being developed as a central platform for code exchange and development for all multi-project activities at BIRA-IASB (e.g. processing of ECMWF data).

5.12.3 Installation of GEM-BACH

5.12.3.1 Objectives

Install on the Space Pole supercomputers the existing GEM-BACH model, respecting IT standards for operational use of the model. Get acquainted with local development environment, Fortran programming, and operational data production (ECMWF live data stream). Do a local installation of GEM-BACH and accompanying software libraries, with help of IT experts from EC. Debugging and implementation of latest BASCOE CTM improvements. Adapt pre-processing, submission and post-processing scripts.

5.12.3.2 Achievements

This task is completed. Thanks to a two-week mission to Montreal (June 2008), the latest GEM-BACH version has been successfully installed and compiled on the supercomputer of the Space Pole (zeno).
We have performed a 3-month free run of the last GEM-BACH version (GEM 3.3.0 + PHY 4.5 + CHEM2.1) on zeno.oma.be.

5.12.4 Implement processes from IMAGES CTM

5.12.4.1 Objectives

Implement in GEM the processes from the IMAGES CTM allowing a realistic representation of tropospheric chemistry, at the global scale. Test the transport mechanism in the troposphere, using an ideal tracer behaving as radon. Implement the chemical solver itself, with photo-dissociation but no emission fluxes or other processes specific to the troposphere. Implement the climatological emission datasets.

5.12.4.2 Achievements

The implementation of tropospheric chemistry has started with the insertion in GEM-BACH of climatological datasets for the surface emissions of CO and NOx. The Canadian partners have advanced on their own side with an extension to the global scale of their continental-scale tropospheric configuration (GEM-MACH global). Hence this task has been modified to a validation of GEM-MACH global with the IMAGES CTM.

5.12.5 Improve stratospheric chemistry

5.12.5.1 Objectives

Improve the stratospheric chemistry module, using the BASCOE CTM as a test bed. Prepare the advection algorithm used in BASCOE for transfer to EC and potential implementation in GEM-BACH. Implement simple parameterizations for the NOx productions by solar processes and downward fluxes from MLT.

5.12.5.2 Achievements

An improved and up-to-date stratospheric photochemistry module has been obtained.
As for any 3D atmospheric model, the core component of GEM-BACH is the calculation of transport by the winds (advection). We showed that the algorithm used by Environment Canada has serious flaws in the stratosphere. Since BASCOE uses a different algorithm that performs much better, the corresponding code was cleaned, optimized and transferred to Environment Canada for testing and potential implementation in GEM-BACH.
In the framework of the European project GEMS, BIRA-IASB has also set up BASCOE to deliver real-time forecasts of stratospheric ozone at the global scale, with high horizontal resolution. This product is delivered on the web.

This activity is closely related to the "Chemical Weather" theme of STCE, with our senior IT invested a few weeks in the implementation of this new service. STCE can expect from this great benefits for future applications of radiative transfer calculations.

5.12.6 Partnerships

- Meteorological Research Branch and Air Quality Reasearch Branch, Dorval and Toronto, Canada

- Institute for Meteorology and Climate Research, Forschungszentrum Karlsruhe, Germany
- Integrated Environmental Studies, VITO, Belgium
- Stratospheric Dynamics and Chemistry Group, McGill University, Montreal, Canada
- "Global Atmospheric Chemistry Modeling" at the ICG-II, Research Center Jülich (FZJ), Germany
- Dept. of Physical and Inorganic Chemistry, University of Bologna, Italy

5.12.7 Perspective for the future

The chemical weather activities, while being boosted by the STCE in 2008, will be financed differently in the future. Although driven by Sun-Earth interactions, there is an important human impact on chemical weather. Other funding mechanisms will allow us to further develop these services, and turn them into operational activities in the future.

5.12.8 Publications and output

5.12.8.1 Publications with peer review

[261] Theys, N., Van Roozendael, M., Errera, Q., Hendrick, F., Daerden, F., Chabrillat, S., Dorf, M., Pfeilsticker, K., Rozanov, A., Lotz, W., Burrows, J. P., Lambert, J.-C., Goutail, F., Roscoe, H. K. and De Mazière, M.
A global stratospheric bromine monoxide climatology based on the BASCOE chemical transport model.
Atmos. Chem. Phys., 9, 831-848, 2009.

[262] de Grandpré J., Ménard R., Rochon Y., Charette C., Chabrillat S. and Robichaud A.
Radiative impact of ozone on temperature predictability in a coupled chemistry-dynamics data assimilation system.
Monthly Weather Review, 137, 679-692, 2009.

[263] Errera, Q., F. Daerden, S. Chabrillat, J. C. Lambert, W. A. Lahoz, S. Viscardy, S. Bonjean and D. Fonteyn
4D-Var assimilation of MIPAS chemical observations: ozone and nitrogen dioxide analyses
Atmos. Chem. Phys., 8, 6169-6187, 2008

[264] Sioris, C., S. Chabrillat, C. McLinden, C. Haley, Y. J. Rochon, R. Ménard, M. Charron and C. McElroy
OSIRIS observations of a tongue of NOx in the lower stratosphere at the Antarctic vortex edge: comparison with a high resolution simulation from the Global Environmental Multiscale (GEM) model
Canadian Journal of Physics, 85, 1195–1207, 2007.

5.12.8.2 Meeting presentations

[265] Strong, K., Adams, C., Batchelor, R., Drummond, J.R., Daffer, W., Fogal, P.F., Fraser, A., Kolonjari, F., Lindenmaier, R., Manney, G., Walker, K.A., Wolff, M.A., Manson, A., Meek, C., Chshyolkova, T. , Polavarapu, S., Reszka, M., Neish, M., Robichaud, A., de Grandpré, J., Roch, M., Chabrillat, S. et al.
Trace Gas Measurements at the Polar Environment Atmospheric Research Laboratory (PEARL) at Eureka, Canada
International Polar Year. AGU Fall Meeting, San Francisco, December 2008

[266] Batchelor, R., Strong, K., Lindenmaier, R., Manson, A., Meek, C., Chshyolkova, T., Polavarapu, S., Reszka, M., Neish, M., Robichaud, A., de Grandpré, J., Roch, M., Chabrillat, S., et al.
Characterizing the Arctic stratosphere using a combination of ground-based FTIR trace gas measurements, dynamical variables and models
International Arctic Change 2008 Conference, Quebec City, December 2008

[267] Ryzhkov, A., Bourqui, M. and Chabrillat, S.
FASTOC II : Further development of the FAst STratospheric Ozone Chemistry scheme
Fourth SPARC General Assembly, Bologna, Italy, September 2008

[268] Chabrillat, S., Y.J. Rochon,Y. Yang, R. Ménard, T. von Clarmann et al.
Assimilation of MIPAS data with the Canadian NWP system extended to stratospheric chemistry.
IMK Seminar Series (on invitation), Karlsruhe, Germany, 1 July 2008

[269] Sioris, C. E., C. A. McLinden, C. T. McElroy, S. Chabrillat, C. S. Haley, R. Menard, et al.
OSIRIS observations of a tongue of NOx in the lower stratosphere at the Antarctic vortex edge: comparison with a high resolution simulation from the Global Environmental Multiscale (GEM) model
IVth International Atmospheric Limb Workshop, Virginia Beach, U.S.A., 29 October – 2 November 2007

5.12.8.3 Technical reports

➢ Ménard, R., S. Chabrillat, J. McConnell, P. Gauthier , D. Fonteyn, J. Kaminsky, A. Robichaud, Y. Rochon, J. de Grandpré, T. von Clarmann, P. Vaillancourt, A. Robichaud,Y. Yang , C. Charrette, Y. Rochon, M. Charron and A. Kallaur. Coupled chemical-dynamical data assimilation. Final Report of ESA/ESTEC Study Contract 18560/04, December 2007.

5.12.8.4 Software & web services

- http://macc.aeronomie.be
- http://wiki.bacchus-ext.info
- http://svn-ae.oma.be/ae/COMMON
- http://svn-ae.oma.be/ae_bacc/BACCHUS

5.13 ICT Support: Data and HCP

5.13.1 Overall Description

The goal of this package is to offer specialized ICT support for specific tasks that are common to most STCE research themes involving data & computation intensive research. The primary aim is to reduce the number of IT-related task for the research staff and to offer them assistance in the use of the existing IT infrastructure.
One of the resulting bonuses is an increased efficiency in the use of the infrastructure, which should lead to an optimization of future needed investments and a reduction in the load on the remaining IT staff.

We offer support in 2 domains:

1. Data-management in the broad sense of the term: data reception, data storage and data lifecycle management.
2. HPC Computing assistance to maintain a user-friendly and effective computing environment on which the different STCE project groups can execute their codes, and to assist them in the development of their HPC codes.

5.13.2 Provide data management support

5.13.2.1 Objectives

Provide data management in the broad sense of the term: data reception, data storage and data lifecycle management.

5.13.2.2 Achievements

A new IT specialist was hired Q2 of 2008. His first tasks included the identification of the immediate needs, assuming the data management tasks for the research groups and streamlining them on the existing infrastructure in order to come to a coherent and integrated management policy across the different projects.
A website is being developed containing all relevant information concerning the data being stored on the central BIRA-IASB data servers (STCE related and other). This should give the users a good visibility on the available data, the storage infrastructure status and general guidelines on data collection, storage and usage.
All data transfers coming in and going out are being centralised to ensure a coherent management. This is necessary to guarantee data availability and to permit efficient space management on the servers and data lifecycle management.
Ongoing tasks are the continuous dialogue with the users concerning their current and future data storage needs as well as the permanent task of data management on the servers.

5.13.3 Provide high performance computing support

5.13.3.1 Objectives

- Provide assistance with high performance computing support by a dedicated IT specialist.

5.13.3.2 Achievements

After a long recruitment phase, an IT specialist has been hired in Q4 2008. This person maintains a user friendly and effective computing environment on which the different project groups can execute their codes, and assists the scientists in the development of their HPC codes.
A series of seminars has been set up to review the computing infrastructure, including the specific high performance computing environments needed by STCE applications.
Assistance is being given to users in the development of their codes and in porting existing or external codes to our computing infrastructure for more efficient execution.

5.13.4 Perspective for the future

5.13.4.1 Provide data management/ high performance computing support

- This is a permanent activity

5.13.5 Publications and output

5.13.5.1 Meeting presentations

- A series of internal seminars giving an introduction to the existing computing environment was planned. The seminars have started Q1 2009.

5.13.5.2 Software & web services

- Realization of a software framework for the automatic retrieval and storage of external data sets (near real-time data streams)

5.14 ICT Support: hard- and software

5.14.1 Overall description

This is a general support package with the aim of offering the needed basic IT tools to each member of the STCE, as there are: software, workstations, and small hardware.

5.14.2 Hardware

5.14.2.1 Objectives

- Provide hardware for STCE activities.

5.14.2.2 Achievements

- Provision of hardware (laptops, PC, X-terminals), installation, network access, to all new STCE personnel.

5.14.3 Software

5.14.3.1 Objectives

- Provide software for STCE activities.

5.14.3.2 Achievements

- Provision of software and licences to all new STCE personnel.

5.14.4 Perspective for the future

5.14.4.1 Hardware/Software

- This is a permanent activity

5.14.5 Publications and output

5.14.5.1 Software & web services

- IDL Software licences were purchased for web applications.

5.14.5.2 Hardware

- Hardware was configured and installed for new users (PC's & terminals)

5.15 ICT Support: Additional informatics infrastructure

5.15.1 Overall Description

The aim of this package is to add some necessary backbone infrastructure in function of the needs of the different work packages and to integrate them with the existing infrastructure of the institute. As these needs became manifest during the STCE startup, we have added this punctual investment to accelerate the establishment of proper IT infrastructure. This task strengthens 2008F.2.

5.15.2 Additional hardware

5.15.2.1 Objectives

Provision of additional hardware, installation, access.

5.15.2.2 Achievements

Servers (classic Intel x86 servers) and storage infrastructure (iSCSI raid array) were purchased for the configuration of a VMware cluster for running virtual machines.
In view of the additional STCE activities a capacity extension of the general purpose data storage infrastructure and related backup systems was realised.

5.15.3 Additional software

5.15.3.1 Objectives

- Provision of additional software, installation, access.

5.15.3.2 Achievements

VMware licenses and support were purchased and a VMware ESX cluster was installed and configured. This permits the flexible deployment of new services in combination with an efficient use of the hardware infrastructure. Web services were deployed on this infrastructure (European Space Weather portal, SPENVIS).

5.15.4 Perspective for the future

5.15.4.1 Storage facilities

The current infrastructure is at present able to cope with the existing demands. But in view of new STCE activities, in particular the radio meteor observations database that will be set up in 2009 (see Task 2009C.2.4), we foresee an extension of our storage requirements by the end of the year. Depending on the requirements assessment, the relative needs for on-line and archival storage will be determined.

5.15.5 Publications and output

5.15.5.1 Software & web services

- VMware software for a virtual machine cluster.
- Deployment platform for several STCE services (SPENVIS, European Space Weather Portal, …)

5.15.5.2 Hardware

- Servers (classic Intel x86 servers) and storage infrastructure (iSCSI raid array)
- Additional disk space (35TB) and corresponding tape-library for backup

5.16 Public Outreach

Public outreach for the STCE activities is managed at the KSB-ORB on behalf of the three Institutes. A major public outreach effort was done on the occasion of the International Heliospheric Year 2007-2008. In this context, BIRA-IASB has

- set up and maintained the IHY2007 website (http://www.oma.be/ihy2007);
- participated with KSB-ORB and KMI-IRM in the organization of the Open Doors Day held in Uccle 6-7 October 2007, which had a special emphasis on Space Weather;
- organized a special session at the Belgian Physical Society meeting, where we had an invited oral presentation (J. De Keyser, F. Darrouzet, and M. Roth. Magnetosphere exploration in the IHY and beyond. Session “Astrophysics, geophysics and plasma physics”, BPS General Assembly, Antwerpen, Belgium, 2007);
- J. De Keyser and V. Pierrard represented BIRA-IASB in the steering committee;
- N. Crosby was the Belgian IHY2007 National Coordinator for Education and Public Outreach.
- J. De Keyser and V. Pierrard contributed the article “Wat heeft de heliosfeer te maken met de Aarde? Magnetosferisch onderzoek op het Belgisch Instituut voor Ruimte-Aëronomie – Le lien entre l’héliosphère et la Terre: Recherche magnétosphérique à l’Institut d’Aéronomie Spatiale de Belgique” in de speciale editie van Space Connection uitgegeven ter gelegenheid van het IHY.

At present, Viviane Pierrard is member of the steering committee for IYA2009 (International Year of Astronomy).

In order to broaden the collaborations of BIRA-IASB, including the STCE activities, with institutes in Belgium, we organized a well-attended University Info Day on 28 November 2008, where we had several presentations and a lot of posters relevant to our STCE objectives.
Other public outreach activities in the frame of the STCE included the organization of the dedicated sessions "ES3 Integrating Activities in Environmental Science Education - Approaches and Perspectives" and "ES4 Sharing Education and Outreach Experiences in the Earth- and Space Sciences" at the European Geosciences Union General Assembly in Vienna, Austria, in April 2007 by N. Crosby. N. Crosby is the spokesperson for the "Education, Outreach and Defining Users" ESA Space Weather Topical Group (2003 – present). Together with Ms. Rosalyn Pertzborn and Dr. Sanjay Limaye from the University of Wisconsin–Madison, U.S.A., she organized a workshop "Comparing Earth and Venus" aimed at Belgian school teachers, which was held at the Planetarium of the Royal Observatory of Belgium on 25 April 2007.

5.17 Personnel Involved

As a general comment, it should be said though that attracting people from abroad was not an easy task. A number of people were interested, but finding people who fill in missing but complementary expertise, and who can live with the practicalities of changing jobs, is hard to do. Prospecting for international candidates and organizing job interviews has often been combined with attendance at international scientific conferences.
A fundamental choice has also been to strengthen our Institute's ICT team with specific competences that support the particular activities of the STCE. We have therefore hired a person responsible for managing the large data sets that are involved in many of the STCE tasks, and a person for high performance computing support to facilitate and improve exploitation of the already existing common computing infrastructure (AMABEL project).
An overview of the personnel is given in Table 3.

Table 3: Personnel currently foreseen on the nominal STCE budget

Themes	Personnel
Atmosphere	*2 scientists*
Space Physics	*2 scientists* *1 engineer* *1 IT specialist*
Valorisation & Exploitation: Data & Mission Centre	*1 engineer* *2 IT specialists*
Valorisation & Exploitation: Space Weather	*1 scientist* *3 IT specialists*
Valorisation & Exploitation: Chemical Weather	-
ICT support	*2 IT specialists*
Total	*5 scientists* *2 engineers* *8 IT specialists* *15 people*