Space Weather of the Heliosphere: Processes and Forecasts
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The Belgian space weather observatory in Dourbes

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Abstract. The paper outlines the space-weather-related observations, instrumentation, research and service developments carried out at the Geophysical Centre of the Royal Meteorological Institute (RMI) in Dourbes, Belgium.

Keywords. Space weather, solar-terrestrial relations, cosmic rays

1. Introduction

The Geophysical Centre (http://dourbes.meteo.be) of the Royal Meteorological Institute (RMI) was established in the 1940s in Dourbes (50.1°N, 4.6°E), a remote location in the south of Belgium, providing a suitable environment for accurate observations of the geomagnetic field, ionosphere, and cosmic ray activity. Regular observations started in the early 1950s, long before the term "space weather" was first coined, and continue to this day. Fundamental and applied research was carried out by several generations of scientists, who also develop services for users from the industry, academia, and public. This paper provides an overview of the observations, research and development activities.

2. Instrumentation and measurements

The geomagnetic observatory, in operation since 1953 and following on the previous century-old tradition of magnetic observations in the Brussels area, consists of variometers for measuring the variations of the field components about the baseline and magnetometers for the absolute measurements needed to establish the baseline values (Verhulst *et al.* 2014). The current data acquisition cadence is 1 s for time, with a precision of 0.1 nT for the induction and 0.001° for both, the declination and the inclination.

The main instrument utilised for ionospheric observations is the digital ionospheric sounder (a Lowell Digisonde-4D), a state-of-the-art equipment using high-frequency radar principles of remote sensing to evaluate, with high accuracy and precision, the local ionospheric plasma characteristics (Stankov *et al.* 2012). Ionospheric observations are also helped by several GNSS signal receivers providing high-resolution measurements of the total electron content (TEC) and the small-scale variability of the ionosphere.

Cosmic rays are observed with a 9NM-64 neutron monitor providing measurements of the secondary neutron component of the cosmic rays on the ground, which (after pressure correction) mirrors the primary cosmic ray intensity (Sapundjiev *et al.* 2014). Thus, one can reliably detect proton events (due to energetic solar flares) and Forbush decreases (due to the occurrences of strong solar winds).

RMI supports the Belgian Open Data policy, readily shares data, and provides (in real time) all measurements to international databases, such as the International Magnetic Observatory (http://www.intermagnet.org), Global Ionosphere Radio Observatory (http://giro.uml.edu), International Neutron Monitor Data Base (http://www.nmdb.eu).

3. Research

Research is focused on local and regional space weather, including ionospheric plasma structures and dynamics, ionospheric irregularities, geomagnetic disturbances (Jodogne & Stankov 2002; Stankov *et al.* 2010; Verhulst *et al.* 2014), and their effects on communications and navigation systems' performance (Warnant *et al.* 2007; Lejeune & Warnant 2008; Stankov *et al.* 2009; Warnant *et al.* 2009; Lejeune *et al.* 2012). Also designed, developed, and programmed are robust algorithms for nowcast and short-/long- term forecast of geospace plasma parameters by utilising ground-based (ionospheric incidence sounding, geomagnetic, cosmic rays) and space-based (GNSS, LEO satellite) measurements (Spits & Warnant 2008; Stankov & Warnant 2009; Spits & Warnant 2011; Stankov *et al.* 2011a; Stankov *et al.* 2011b; Stankov *et al.* 2012; Verhulst & Stankov 2013; Verhulst & Stankov 2014; Sapundjiev *et al.* 2014; Verhulst & Stankov 2015; Sapundjiev & Stankov 2016). RMI is also actively involved in the research activities of the Belgian Solar-Terrestrial Centre of Excellence (http://www.stce.be). For example, a joint recent multi-instrument observation campaign focused on the solar eclipse effects on the geospace environment (Verhulst *et al.* 2016; Stankov *et al.* 2017). Over the years, the team has participated in and managed several national and international research projects funded by the Belgian Government, European Commission, ESA, NATO, etc.

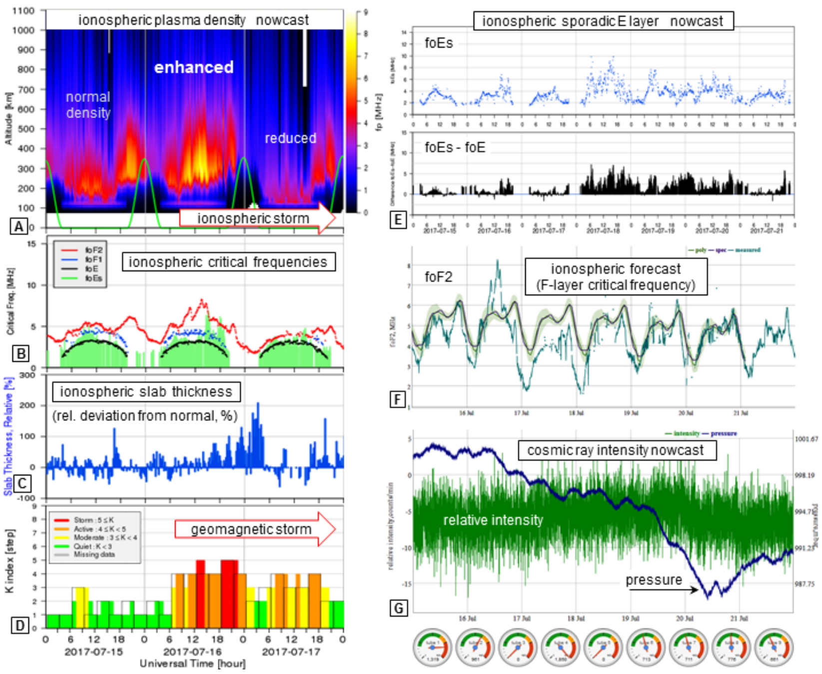

Figure 1. Space weather monitoring services (http://ionosphere.meteo.be): (A) ionospheric plasma density (plotted as plasma frequency) nowcast, (B) ionospheric critical frequencies, (C) ionospheric slab thickness, (D) geomagnetic activity nowcast, (E) ionospheric sporadic E-layer activity nowcast, (F) ionospheric forecast (climatological), and (G) cosmic ray intensity nowcast.

4. Services

All instruments, used as a finely-tuned observatory, yield high-resolution concurrent and collocated measurements of key characteristics of the space weather and its effects.

Several services (http://ionosphere.meteo.be) were developed and are now available to the users (Fig.1). A nowcast system for operational (1-hour cadence) calculation of a proxy K-type geomagnetic index (K-LOGIC) was installed (Stankov *et al.* 2011a), estimating the local magnetic field activity and issuing an alert when storm levels are indicated. The local ionospheric specification and visualisation system LIEDR (Stankov *et al.* 2011b) acquires and processes GNSS TEC and ionosonde measurements, and deduces the vertical electron density distribution in the local ionosphere. It provides nowcast of the critical frequencies, peak densities and heights of the ionospheric layers, and the ionospheric slab thickness. The ionospheric sporadic layer Es is also monitored and alert is issued when high levels of the Es critical frequency, foEs, are reached. Ionospheric forecast (climatological) is offered, based on long-term statistics of the local ionospheric critical frequency foF2 (Sapundjiev & Stankov 2016). For cosmic-ray monitoring, an automatic data quality control system for real-time correction of data from the neutron monitor was developed and implemented (Sapundjiev *et al.* 2014).

5. Future developments

Space weather research demands high accuracy and precision of instruments, high resolution of measurements, prompt and convenient dissemination of data, and continuous availability of services. Such demands necessitate regular upgrades of the instruments and become even more challenging when a service utilises different types of instruments. The NM64 neutron monitor proved to be a reliable tool for cosmic-ray monitoring, so a second 9-tube monitor is under construction. Initially, a producer-free concept will be exploited for verification of several theoretical simulations and investigation of the monitor's yield functions. A multi-directional muon telescope is being developed, which will improve the characterisation of interplanetary space conditions. Also planned is the installation of a radio telescope for solar activity monitoring. Research and developments will be focused on high-resolution nowcast and more reliable forecast of space weather.

References

Jodogne, J.C., & Stankov, S.M. 2002, *Ann. Geophys.*, 45, 5, 629

Lejeune, S., & Warnant, R. 2008, *J. Atm. Sol.-Terr. Phys.*, 70, 6, 889

Lejeune, S., Wautelet, G., & Warnant, R. 2012, *GPS Solutions*, 16, 1, 105

Sapundjiev, D., Nemry, M., Stankov, S.M., & Jodogne, J.C. 2014, *Adv. Space Res.*, 53, 1, 71

Sapundjiev, D., & Stankov, S.M. 2016, *Acta Geophys.*, 64, 3, 810

Spits, J., & Warnant, R. 2008, *J. Atm. Sol.-Terr. Phys.*, 70, 15, 1885

Spits, J., & Warnant, R. 2011, *Adv. Space Res.*, 47, 2, 296

Stankov, S.M., & Warnant, R. 2009, *Adv. Space Res.*, 44, 11, 1295

Stankov, S.M., Warnant, R., & Stegen, K. 2009, *Adv. Space Res.*, 43, 9, 1314

Stankov, S.M., Stegen, K., & Warnant, R. 2010, *Adv. Space Res.*, 46, 10, 1318

Stankov, S.M., Stegen, K., & Warnant, R. 2011, *Ann. Geophys.*, 54, 3, 285

Stankov, S.M., Stegen, K., Muhtarov, P., & Warnant, R. 2011, *Adv. Space Res.*, 47, 7, 1172

Stankov, S.M., Jodogne, J.C., Kutiev, I., & al. 2012, *Ann. Geophys.*, 55, 2, 283

Stankov, S.M., Bergeot, N., Berghmans, D. & al. 2017, *J. Space Weather Space Clim.*, 7, A19

Verhulst, T., & Stankov, S.M. 2013, *Adv. Space Res.*, 51, 11

Verhulst, T., & Stankov, S.M. 2014, *Radio Sci.*, 49, 3, 181

Verhulst, T., Stankov, S.M., & Rasson, J. 2014, *KBVE Rev. E Tijdschrift*, 30, 2, 1

Verhulst, T., & Stankov, S.M. 2015, *Adv. Space Res.*, 55, 8, 2058

Verhulst, T.G.W., Sapundjiev, D., & Stankov, S.M. 2016, *Adv. Space Res.*, 57, 11, 2407

Warnant, R., Lejeune, S., & Bavier, M. 2007, *J. Lilensten (ed.), Space Weather (Springer)*, 129

Warnant, R., Foelsche, U., Aquino, M., & al. 2009, *Ann. Geophys.*, 52, 3-4, 373