The troposphere is the lower part of the atmosphere and covers the region between the Earth´s surface to a height of about 50 km. Its strong spatial inhomogeneity and temporal variability continues to be a source of random and systematic errors in geodetic techniques. The major limitation is attributed to mismodelling ofthe water vapor component. Tropospheric path delay is a serious error in GPS measurements both through ray path bending and the modification of the electromagnetic velocity, and is especially critical for the GPS accuracy of the height component. Accurate estimation of atmospheric path delay in GPS signals is necessary for high-accuracy positioning (e.g., tectonics and sea-level change) and meteorological applications (climatology and weather forecasting). Due to their non-dispersive nature and smaller magnitude, the estimation of tropospheric delay is very hazardous and require a refinement in the processing techniques of GPS data. Furthermore, the high spatial and temporal variability of the troposphere demands a sufficient number of ground GPS receivers to beused. Dense GPS continuous networks provide therefore an opportunity to estimate the 3-dimensional state of the troposphere with a appropriate spatial and temporal resolution. Tomographic techniques are applied to obtain 3D images of the tropospheric refractivity using dense networks of GPS receivers in Japan (GEONET) and California (SCIGN). We show how GPS data are processed to obtain the tropospheric delays and discuss the validity of the processing, providing evidence that these techniques can yield horizontal and vertical structure of the atmospheric refractivity. The tomography can be used for the calibration of the other remote-sensing techniques (e.g. SAR) and in numerical weather prediction models as additional data.

JSM07/02P/D-019 Poster **1400-198**

TIME VARIATION OF PRECIPITABLE WATER VAPOR OBTAINED FROM GPS IN THAILAND

Mikiko FUJITA[1], Fujio KIMURA[2], Mikio SATOMURA[3], Tosiyuki NAKAEGAWA[4], Teruyuki KATO[5] ([1]Master's Program in Environment Sciences, University of Tsukuba, [2]Institute of Geoscience, University of Tsukuba, [3]Faculty of Science, Shizuoka University, [4]Meteorological Research Institute, [5]Earthquake Research Institute, University of Tokyo)

Observation using GPS receiver was performed to obtain Precipitable water Vapor (PWV) with high time resolution at six stations in Thailand by GAME-T (GEWEX Asian Monsoon Experiment - Tropics). Diurnal variation of PWV is examined using GPS data obtained in 1999 The results show that the diurnal variation is weak both in the dry season (from January to April, and November and December) and the wet season (from May to October) except in March in Thailand. In Bangkok, the amplitude of diurnal variation is less than 1 mm. Precipitable water vapor decreases in the morning showing clear minimum, but its peak is unclear. At neighboring GPS site near Jakarta in Indonesia (IGS station), however, PWV has clear diurnal cycle with the amplitude of about 6 mm and 3 mm in the dry and the wet season, respectively, while maxima appear at about 17 LST and 14 LST, respectively. On the other hand, prominent seasonal variation can be observed in PWV in Thailand and Indonesia. There is clear difference in change of PWV between dry and wet season. At Bangkok, variation of about 10 - 15 days cycle is prominent in PWV with large amplitude of about 40 mm in dry season. In case of the wet season, however, variation of PWV is smaller than that in dry season, while mean PWV keeps high value of between 50 mm to 60 mm. In general, diurnal variation of PWV in the dry season is clearer than that of the wet season. Variation of water vapor is small in the wet season because of nearly saturated water vapor in the atmosphere as the result of continuous supply by monsoon. Diurnal variation is not clear even in the dry season in Thailand, as contrast with Indonesia, Tibet and Japan, where clear diurnal variation of PWV is observed in calm and clear days in the warm season.

JSM07/02P/D-020 Poster **1400-199**

POSITIONING PRECISION EVALUATION OF GPS: COMPARISON BETWEEN GPS AND SONDE- PRECIPITABLE WATER VAPORS

Kazuya HATAMOTO, Akira TAKEUCHI (Department of Earth Science, Toyama University, Japan)

The hydrosphere delays a propagation speed of electric wave. A microwave from the GPS satellite to the ground, involves the delay, also has information about water vapor distribution in atmosphere. In short, the GPS technology can contribute to not only geodesy, but also meteorology. A difference between the precipitable water vapor estimated by GPS (GPS-PWV) and the precipitable water vapor estimated by radiosonde balloon for meteorological observations (Sonde-PWV) has been 4.0 mm with r.m.s on an average in Japan (Otani and Naito, 1999). This study has compared GPS-PWV with Sonde-PWV around the Northern Japan Alps. The using data were measured with the Jodo Mountain for GPS and the Kurobe Dam for the radiosonde on June 27-29, 1999. In addition, this study has used atmospheric data, quantity of water vapor every altitude measured radiosonde, and an airborne trajectory of radiosonde. In conclusion, a bias, value taking away Sonde-PWV from GPS-PWV, is 4.4 mm on an average. It is likely that two PWVs are harmonic. When trajectories of radiosonde are considered, an average of the bias is 5 mm more with 5 km more in horizontal separation, on the other hand is 3.1 mm with less than 5 km in horizontal separation, at the 6000 m in the sky. I think that the bias has been due to the heterogeneous atmosphere, because GPS-PWD is estimated from an average value of the diagonal and vertical microwave course in the atmosphere. Judging from the above, I think that GPS-PWD is able to estimate a quantity of water vapor of atmosphere. Conversely, if quantity of atmosphere delay calculated from the precipitable water vapor is used for a geodetic analysis, the GPS geodesy provides the higher accuracy positioning probably.

JSM07/02P/D-021 Poster **1400-200**

4-D TROPOSPHERIC TOMOGRAPHY BASED ON GROUND-BASED GPS OBSERVATION

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Before Precipitable Water Vapors (PWVs) are imputed into numerical weather prediction models, the three-dimensional water vapor fields with time often need to be recovered. This paper discusses the possibility of the tomographic technique of water vapor fields by ground-based GPS observation. The tomographic techniques are applied to obtain 4D images of the specific humidity in a local dense network. We adopted the specific Square-Root Information Filtering (SRIF) algorithm to solve the specific humidity based on slant wet delay derived from ground-based GPS observation. The SRIF algorithms have numerical stability and can handle singular state-transition matrices and perfect measurements. These are good to our recovery of the specific humidity because there are maybe some singular status happened. The results from our tomography technique are compared to the those of Radiosonde.

JSM07 Wednesday, July 2 - Thursday, July 3

APPLICATION OF GPS TECHNIQUES IN THE ATMOSPHERE (IAMAS [ICMA], IAGA, IAG)

Location: Site B, Room 23

Thursday, July 3 AM

Presiding Chairs: H. F. Tsai, A. Saito

JSM07/03A/B23-001 **0900**

SOUNDING THE IONOSPHERE BY GROUND AND SPACE BASED GPS MEASUREMENTS

Norbert JAKOWSKI[1], Andreas WEHRENPFENNIG[2], Stefan SCHLUETER[1], Stefan HEISE[3], Stanimir M. STANKOV[1] ([1]Deutsches Zentrum fuer Luft- und Raumfahrt (DLR), Institut fuer Kommunikation und Navigation, [2]Fachhochschule Neubrandenburg, Neubrandenburg, Germany, [3]GeoForschungsZentrum Potsdam (GFZ), Division 1, Telegrafenberg, Potsdam, Germany)

Due to the dispersive nature of the ionosphere, dual frequency navigation signals of Global Navigation Satellite Systems (GNSS) such as GPS and GLONASS provide integral information about the ionosphere. In a first order approximation the differential phase is proportional to the integral of the electron density along the ray path (Total Electron Content-TEC) between the transmitting GNSS satellite and the receiver.Taking into account the permanently growing number of GNSS receivers on ground, this technique is very effective in regional and global monitoring of the ionospheric state as it will be demonstrated in the talk. Whereas ground based GNSS measurements may provide dense information on the horizontal structure and dynamics of the ionospheric ionization, recently applied spaceborne GPS measurement techniques (e.g. onboard CHAMP) open a new dimension in exploring the vertical structure of the ionosphere. Consequently, combining ground and space based measurements, the three-dimensional distribution of the electron density can be reconstructed. Considering international efforts to launch multi-satellite systems carrying GNSS receivers onboard, complex reconstruction of the ionosphere/plasmasphere systems become possible. Since ionospheric perturbations may considerably degrade navigation signals, the ionosphere monitoring is not only important for improving our knowledge on solar-terrestrial relationships and modeling, but also for providing users of precise positioning applications with relevant information on accuracy and reliability of their measurements.

JSM07/03A/B23-002 **0935**

MONITORING THE RESPONSE TO GEOMAGNETIC STORMS USING GPS TOTAL ELECTRON CONTENT MEASUREMENTS

Richard Brian LANGLEY[1], Mariangel FEDRIZZI[2], Eurico Rodrigues DE PAULA[2] ([1]Department of Geodesy & Geomatics Engineering, University of New Brunswick, [2]Instituto Nacional de Pesquisas Espaciais)

Despite the fact that much has been learned about physical, dynamical and chemical processes that drive ionospheric storms, understanding the effects of geomagnetic storms on the neutral and ionized upper atmosphere is still one of the most challenging topics remaining in the physics of this atmospheric region. In order to investigate the magnetospheric and ionospheric-thermospheric coupling processes, many researchers are taking advantage of the dispersive nature of the ionosphere to compute total electron content (TEC) from Global Positioning System (GPS) dual-frequency data. In this paper, GPS data from the Brazilian Network for Continuous Monitoring by GPS (RBMC) have been used along with data from the International GPS Service (IGS) network and other independently operated networks to investigate the response of the ionosphere over the North and South American regions during geomagnetic storms. For this study, we are using the University of New Brunswick (UNB) Ionospheric Modelling Technique, which uses a spatial linear approximation of the vertical TEC above each station using stochastic parameters in a Kalman filter estimation to describe the local time and geomagnetic latitude dependence of the TEC. The utilisation of GPS data to monitor the ionosphere over the western hemisphere will provide more accurate and representative regional and global ionospheric models and help us to obtain, in particular, a better understanding of the physics and dynamics of the low-latitude and equatorial ionosphere during geomagnetically disturbed periods.

JSM07/03A/B23-003 Invited **0955**

ANALYSIS AND RESULTS OF GPS OCCULTATIONS COLLECTED FROM THE CHAMP, SAC-C AND GRACE MISSIONS

George A. HAJJ, Chi AO, Byron IIJIMA, Anthony MANNUCCI, Thomas MEEHAN (Jet Propulsion Laboratory)

Over 200,000 GPS occultations have been and will be collected from CHAMP, SAC-C and GRACE by the middle of 2003, each providing high resolution profiles of atmospheric parameters in the stratosphere and the troposphere. This unique dataset is used to assess the potential of GPS radio occultations of providing accurate, drift-free, and unbiased measurements of refractivity, temperature, pressure and water vapor at sub-kilometer vertical resolutions. Our presentation will examine various issues with data from these missions including: (1) Comparisons of refractivity, pressure, temperature and water vapor derived from GPS occultations to numerical weather prediction analyses, radiosondes and other passive instruments. (2) Assessment of the refractivity bias in the lower troposphere caused by tracking errors and super-refraction. This is done by use of simulations and real data and by examination of various retrieval schemes including the conical transform and radio optics. (3) Summarizing the status of open-loop tracking currently being implemented on SAC-C and its ability to eliminate tracking errors in the lower troposphere. (4) Intercomparisons of results from CHAMP, SAC-C and GRACE and implications on the precision and resolution of the technique.

JSM07/03A/B23-004 **1055**

WATCHING CLIMATE CHANGE: TOWARDS GLOBAL CLIMATE MONITORING USING GPS OCCULTATION DATA FROM CHAMP AND SAC-C

Gottfried KIRCHENGAST, Ulrich FOELSCHE, Andrea K. STEINER, Andreas GOBIET (IGAM/University of Graz)

GPS (Global Positioning System) radio occultation is a promising means for globally sounding atmospheric temperature and water vapor fields from space with an unique combination of high vertical resolution and accuracy, all-weather capability, and long-term stability due to intrinsic self-calibration. The latter property, long-term stability, is particularly crucial for climate change monitoring applications, as it enables a novel qualityof