GPS Validation: Validation of Near Real Time GPS Occultation Data Products for Meteorological Services.

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Introduction

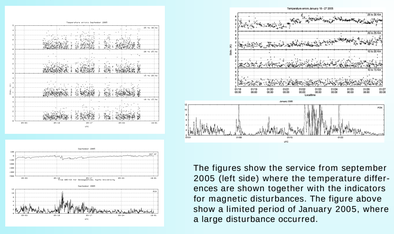
The GPS validation project is a joint effort between the Danish Meteorological Institute (DMI) and Terma A/S. The aim is to study the effects of space weather on the atmospheric products retrieved from GPS radio occultations. The project is conceived to be a service development activity based originally on the precise GPS data delivered by the Danish Ørsted satellite. In the project TERMA Space is the basic service provider by managing the Ørsted satellite and by developing the software to derive the scintillation indices of the individual measurements. The DMI is responsible for the processing of telemetry data to provide the GPS occultation data products in a useful form for the meteorological services and also to identify and analyse the impact of space weather in terms of accuracy on the individual atmospheric products.

The main user of the results from this service will be the coming operational missions, GRAS on the Metop satellite where profiles of refractivity, temperature and humidity are delivered from the GRAS SAF project hosted at DMI, and the American COSMIC mission consisting of a six-satellite constellation. As the GPS data availability from Ørsted has been very limited the current service is based on the radio occultation measurements from the CHAMP satellite. This data has been used for the identification and analysis of the space weather effects.

Acknowledgements:
To GFZ for the use of CHAMP data and to the COSMIC team at UCAR for providing excess phases for the CHAMP measurements.

Description of Service

The SDA is defined to monitor and identify the occurrence of space weather effect on GPS radio occultation measurements. The retrieved temperature profile is a suited measure to use for this identification and we have selected this as the primary indicator in this service. The data used is GPS radio occultation measurements from the CHAMP satellite. The error is estimated as the standard deviation from the ECMWF analysis data at the same location. For each occultation an average error is determined in each of the four altitude bins of 10-15, 15-20, 20-25, and 25-30 km. These error plots are used to identify possible effects of space weather, which will show up at sudden increases in the standard deviation of the temperature. Each plot cover one half month of measured radio occultations.

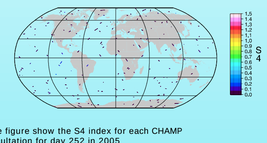


The figures show the service from september 2005 (left side) where the temperature differences are shown together with the indicators for magnetic disturbances. The figure above show a limited period of January 2005, where a large disturbance occurred.

The magnetic disturbances are shown as the near real-time Dst index (QL-Dst) obtained from the World Data Center for Geomagnetism, Kyoto, and the Northern Polar Cap index (PCN), obtained from the World Data Center for Geomagnetism, Copenhagen.

The Dst index was proposed by Sugiura and co-workers. It is primarily a measure of the intensity of the axi-symmetric part of the magnetospheric ring current flowing from east to west. The magnetospheric ring current is a large-scale current system (concentrated in the geomagnetic equator plane), which is strongly enhanced during magnetic storms and tends to reflect quantitatively its intensity. Dst dips into large negative values at the begin of the storm, reaches its minimum within a few hours and then recovers to quiet time values (which can take several days).

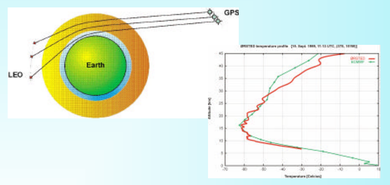
The PC index was proposed by Troshichev and co-workers. It is based on a statistical analysis of the relationship between the interplanetary merging electric field and geomagnetic perturbations observed at a near-polar ground station. Such a station is typically located under the sunward directed trans-polar Hall current which is part of the two-cell DP2 current system. The PC index reflects changes in the solar wind and embedded interplanetary magnetic field and is thus the most direct ground-based monitor of geomagnetic activity in response to variations in the solar wind and their effect on the magnetosphere-ionosphere current system



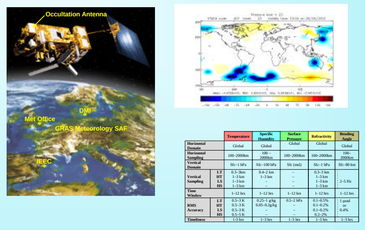
The figure show the S4 index for each CHAMP occultation for day 252 in 2005

Measurement technique

The meteorological services all over the world are about to employ a new and revolutionary globe-spanning satellite-based system with the capability to furnish round-the-clock weather data by using signals transmitted from satellites of the existing US Global Positioning System (GPS), and/or the planned European navigational satellite system: Galileo. The satellites carrying the GPS receivers are Low Earth Orbiting (LEO) satellites like the Danish Oersted satellite. These satellites may probe the atmosphere using the occultation technique (limb sounding) where the changes in phase and amplitude of signals transmitted from the high-altitude GPS satellites are monitored as the signal path decends toward or rises from the horizon.



Such a sequence of paths brings the signal through a deep cross-section of the atmosphere. Variations in electron density, air density, temperature and moisture can change the amplitude and phase of the probing signals and bend their paths. Measuring and analyzing these signal changes enables the detection of the atmospheric conditions that produces them. The total sequence of signal samples received during a completed occultation event can, for instance, be inverted by Abel transform into vertical profiles for atmospheric electron content, density, temperature and moisture. An example is shown in the figure presenting a temperature profile from Oersted. The profile is compared to ECMWF analysis at approximately the same location (37 S, 151 W) and time (12:00 UTC).



		Temperature	Specific Humidity	Surface Pressure	Refractivity	Bending Angle
Horizontal Resolution		Global	Global	Global	Global	Global
Horizontal Sampling Distance		100–200Km	100 (200)Km	100–200Km	100–200Km	100–200Km
Vertical Domain		50(~1 hPa	10(~100 hPa	50 (mid)	50(~1 hPa	50(~80 km
Vertical Sampling	0.5	0.1–1km	0.2–1 km	-	0.2–1 km	-
	1.0	0.1–1km	-	-	0.1–1 km	2–5 Hz
	2.5	1–3 km	-	-	1–3 km	
Time Relative		1–12 hrs	1–12 hrs	1–12 hrs	1–12 hrs	1–12 hrs
Accuracy	0.5	0.1–1 K	0.1–1 g/kg	0.1–1 hPa	0.1–0.5%	1 µrad
	1.0	0.1–1 K	0.01–0.5 g/kg	-	0.1–0.5%	0.5–1 µrad
	2.5	0.1–1 K	-	-	0.1–0.2%	0.4%
	20	0.1–1 K	-	-	0.1–2%	-
1 Confidence		1–3 hrs	1–3 hrs	1–3 hrs	1–3 hrs	1–3 hrs

Users and use of GPS radio occultations

The identified user of this service is the EUMETSAT GRAS SAF project, which will provide atmosphere products based on GPS radio occultation data from the GRAS instrument onboard the Metop satellite. The GRAS SAF is designed to be an operational service and will deliver atmosphere products such as profiles of temperature and humidity in near real time for NWP users and also reprocessed data for climate monitoring.

The GRAS SAF also develop software modules to enable 3D/4DVAR data assimilation of the retrieved bending angle or refractivity profiles. This software is developed by the Met Office. The figure shows the 3D increments in height at a fixed pressure level corresponding to approximately 10 km in height above surface. The software modules will be combined in a software package (Radio Occultation Processing Package) ROPP, which will be provided by the GRAS SAF to the users.