GRAS SAF AND RADIO OCCULTATION DATA

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The EUMETSAT Network of Scientific Application Facilities

GRAS SAF — GRAS Meteorology

www.grassaf.org

ABSTRACT...

The GRAS SAF is part of EUMETSATs network of Satellite Application Facilities (SAFs) under the EUMETSAT Polar System (EPS). The objective of the GRAS SAF is to deliver operational radio occultation products from the GRAS instruments onboard the three MetOp satellites, of which the first was launched in 2006. The second MetOp satellite is scheduled for launch in 2012 and the third in 2016. Another objective of the GRAS SAF is to deliver the Radio Occultation Processing Package (ROPP) that contains modules for processing and assimilating radio occultation data. The Leading Entity of the GRAS SAF is the Danish Meteorological Institute (DMI) and this is also the physical location of the operational GRAS SAF Processing and Archiving Center. The other project partners are ECMWF (European Center for Medium-range Weather Forecasts, Reading, UK), IEEC (Institut d'Estudis Espacials de Catalunya, Barcelona, Spain), and Met Office (Exeter, UK).

Radio occultation products are vertical profiles of meteorological variables like refractivity, temperature, humidity and pressure. The GRAS SAF currently receives level 1 radio occultation phase and bending angle data processed by EUMETSAT. These data are further processed to vertical profiles of refractivity (level 2a) using state-of-the art inversion algorithms. The level 1b and level 2a products are formatted as BUFR files and disseminated over the Global Telecommunication System network to NWP users worldwide within 1:41 hours (average value), 1:48 hours (90% of the profiles), and close to 100% of the profiles within the Near Real-Time (NRT) timeliness of 3 hours from observation time.

Currently the data received from EUMETSAT are based on so-called phase-locked loop tracking. Preliminary open loop tracking (also known as raw sampling mode) data are now also available. Such data allows for improved bending angles and refractivity profiles that extend deeper into the lower parts of the troposphere in the tropics. In order to further process the data into vertical profiles of temperature, humidity, and pressure an approach based on a one-dimensional variational (1Dvar) retrieval algorithm is used. The 1DVar approach needs as input error-covariance matrices for the observations and a background model. As background, profiles extracted from global ECMWF short-range forecasts fields are used.

An important feature of radio occultation data is that they are calibration free. Thus, radio occultation data are also well suited for climate investigations and monitoring, and the GRAS SAF will provide improved offline products and dedicated climate products to the research user community. We are investigating how to best exploit the GRAS data, both for construction of an accurate single-source climate database with known error characteristics of the data, and for provision of global climate monitoring. Climate data are provided in the form of global grids of bending angle, refractivity, temperature, humidity, and geopotential heights.

RADIO OCCULTATION METHOD...

Bending angle (BA) & vertical profile of:
- N (refractivity)
- T (temperature)
- P (pressure)
- q (humidity)

METOP

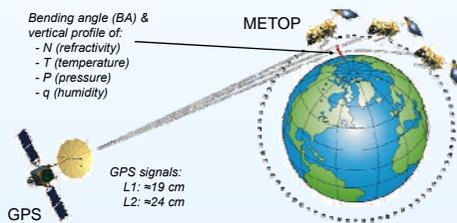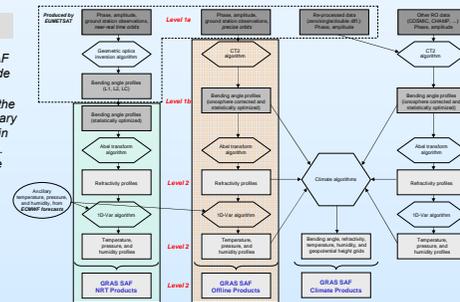GPS signals:
L1: ≈19 cm
L2: ≈24 cm

GPS

Figure 1. Principle of radio occultation measurements. A polar Low Earth Orbit satellite (here: EPS/Metop) observes the phase delay and amplitude of the navigation signal from a GPS satellite, rising or setting behind the Earth. The bending angle of the refracted ray path can be converted into a near-vertical profile of refractivity, temperature, pressure and humidity. Metop has one antenna for rising and setting occultations, respectively, and currently records approximately 700 profiles per day, distributed across the entire globe.

PROCESSING CHAIN...

Figure 2. Simplified processing chart of the GRAS SAF system, showing the way from the phase and amplitude measurement of the GNSS signal to the released meteorological products. Left: Schematic showing of the NRT processing steps to SAF Level 2 products. Ancillary temperature and humidity profiles are used to constrain the statistically optimal retrieval in the 1D-Var scheme. SAF Level 2 products include a thinned bending angle profile derived from the EUMETSAT Level 1b profile. Middle & Right: Offline and climate data processing steps.

DATA FLOW AND TIMELINESS...

EPS/Metop *Measurement*

GRAS SAF *Level 1b -> Level 2 Processing, Dissemination, Archiving, ...*

< 3 HRS. End Users

Level 2 Data: Refractivity, pressure, temperature, and humidity profiles, Validation Data ...

< 2 HRS. 15 MIN.

Level 1b Data: Bending Angles, Impact Parameters, Auxiliary Data, ...

Raw Data Downlink

High-latitude Downlink Site *Demultiplexing, Quality check*

Level 0 Data: Phase and Amplitude Data, Tracking and Ancillary Data, Ground Site Data, ...

Level 1a Data: Phase Delays, Doppler Shifts, SNR, Earth Location Data, ...

EPS Core Ground Segment *Level 0 -> Level 1a Processing Level 1a -> Level 1b Processing*
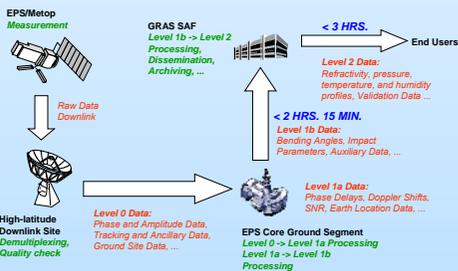
Figure 3. Simplified product and data flow diagram, showing the way from the measurement onboard Metop to end user product dissemination. The 3 hours constraint is for NRT products, suitable for NWP purposes.

PRODUCTS OVERVIEW...

Product	Characteristics
Bending Angle	Bending angle as a function of impact parameter (only offline)
Refractivity Profile	Neutral Refractivity as a function of height and location
Temperature, Humidity, and Pressure Profiles	Temperature, specific humidity, and pressure as a function of height and location of the occultation
Climate Data	Offline profiles (reprocessed data), and grids of bending angle, refractivity, temperature, humidity, and geopotential height
ROPP Software	Statistically optimal 1D-Var refractivity & BA retrieval code; Modules for pre-processing and processing of RO data; Forward models for NWP data assimilation: - Plane-averaged refractivity forward model - Direct assimilation of bending angle (1D or 2D)

CLIMATE DATA...

Climate data product	2D zonal grid: climate + errors	Time resolution	Spatial resolution	Format, graphical	Format, numerical	Time plan
CBA: bending angle	yes	Monthly	5 deg latitude	PNG, JPG	ASCII, netCDF	Q4 2010
CRO: refractivity	yes	Monthly	5 deg latitude	PNG, JPG	ASCII, netCDF	Q4 2010
CTE: temperature	yes	Monthly	5 deg latitude	PNG, JPG	ASCII, netCDF	Q4 2010
CHU: specific humidity	yes	Monthly	5 deg latitude	PNG, JPG	ASCII, netCDF	Q4 2010
CZG: geopotential height	yes	Monthly	5 deg latitude	PNG, JPG	ASCII, netCDF	Q4 2010

Process the RO profile data into climate data products, consisting of:
- standard climate variables: temperature, humidity, geopotential heights
- non-standard climate variables: RO bending angle, RO refractivity
- estimates of errors (sampling + observational)

Develop and study relevant climate data sets, including:
- investigations of the joint use of CHAMP / COSMIC / MetOp RO data
- comparisons of RO based climate data with data sets based on radio-sondes, MSU/AMSU, and reanalyses

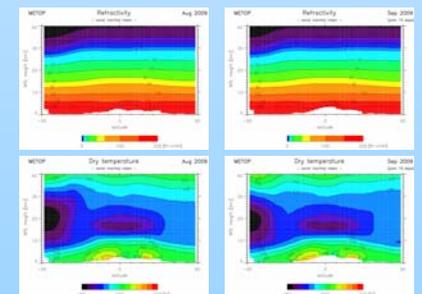Provide climate data as a user service for climate research and monitoring.

Figure 6. GRAS SAF prototype climate data products based on Metop RO data. These prototype data consist of zonal monthly mean refractivity and the so-called dry temperature. Note, above 10 kilometers dry temperature is essentially identical to the ordinary temperature.
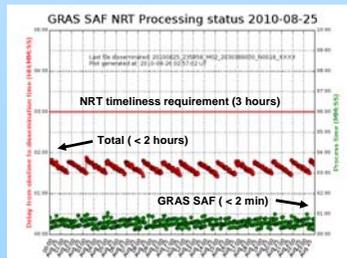
DISSEMINATION STATUS...

GRAS SAF NRT Processing status 2010-08-25

NRT timeliness requirement (3 hours)

Total (< 2 hours)

GRAS SAF (< 2 min)

Figure 4. Occultation processing times for one day of GRAS data.

ROPP SOFTWARE...

To provide users with a comprehensive software package, containing all necessary functions to pre-process RO data from EUMETSAT Level 1b files or GRAS SAF Level 2 files, plus RO-specific components to assist with the assimilation of these data.

Latest release: ROPP-4.1 formally released on 20 July 2010

Currently about 130 registered users

GRAS Level 1b (CGS)

eps2netcdf
netCDF
ropp_pp
netCDF

NWP User

EPS PFS

ropp2bufr (Thin Level 1b)

BUFR

ropp2bufr (Thin or Full Level 1b/2)

ropp2bufr (Thin Level 2)

ropp_1dvar (for Q/C)

ropp_1dvar

ropp_fm (as part of 3/4-D Var)

GRAS Level 2 (SAF)

netCDF

NWP VAR system

REFRACTIVITY STATISTICS...

Mean and stdev of (OBS–MOD)/MOD

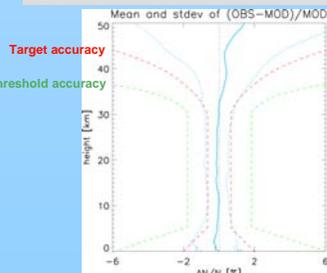Target accuracy

Threshold accuracy

Figure 5. Refractivity statistics for GRAS data (April 2009).

Data status:
- Operational level 1b GRAS bending angle data since 17 April 2008
- Refractivity level 2 data operational since 1 February 2010
- Available as: 1) BUFR file over GTS; 2) BUFR/netCDF over EUMETCast
- Refractivity data currently assimilated or used at Met Office, Environment Canada, NRL, Météo-France, and NCEP
- Archived GRAS SAF data are obtainable at our website www.grassaf.org

GRAS SAF MONITORING...
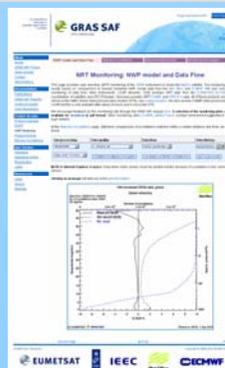
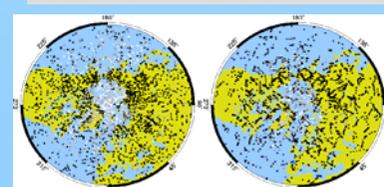## GRAS RAW SAMPLING EXAMPLE...
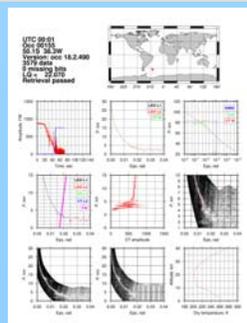
RO SURFACE REFLECTIONS...

Figure 7. North pole region: Feb (left) and Sept (right) 2004+2005.

EUMETSAT   IEEC   ECMWF