EUMETSAT's possible contributions to the future radio occultation constellation

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Introduction: Radio Occultation Instruments

- GPS/MET
- Oersted
- SAC/C
- CHAMP
- SAC/D
- GRAS Instrument Development
- GRAS Processor Development
- Non-Operational/Research
- Operational
- GRACE
- COSMIC (6 Sat's)
- Metop-A
- Metop-B
- Metop-C
- TerraSAR-X
- OCEANSAT-2
- KOMPSAT-5
- SAC/D
- TanDEM-X
- COSMIC-2

COSMIC Workshop 2009
Boulder, USA
Slide: 2
EUMETSAT operates the only operational RO mission (GRAS on Metop-A) providing a highly reliable source for occultations in mid-morning orbit.

Metop-A is the first in a series of 3 Metops, that will cover the mid-morning orbit up to at least 2020. Within Post-EPS (>2020), a RO instrument is one of several important instruments considered.
Post-EPS Planning and Timelines

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Post-EPS: Follow-on and evolution of the current EPS system
Need date for RO (2020) driven by EPS continuity
Phase 0 ("Mission Analysis") now finalizing
Draft Post-EPS mission requirements defined
Within Post-EPS, the following performance level definitions are often used:

- **Threshold:**
  - minimum performance level useful for a particular application

- **Breakthrough:**
  - would give a significant delta impact on the targeted user service
  - would justify new instrument developments

- **Objective:**
  - level beyond which any improvement does not bring a clear advantage in a cost effective way
Post-EPS Requirements for RO (I)

Single instrument requirements:

- Different GNSS systems; at least GPS & Galileo
- Number of rising and setting occultations / day / instrument:
  - **1000** (threshold) / **1500** (breakthrough)
- Closed and open loop tracking, increased sampling rates (at least for CL)
- Tracking of a third frequency (for each system) considered
- Vertical coverage
  - Neutral atmosphere (higher priority): surface - 80 km
  - Ionosphere / space weather: 80 km - sat altitude
Post-EPS Requirements for RO (II)

Accuracy of RO sensor and ground segment processing:

- Expressed in terms of Bending Angle (BA).

- For GRAS it was set to 1 μrad or 0.4% of the BA (whichever is larger);

- The threshold RMS accuracy for Post-EPS shall be better than:
  - 1 μrad or 0.4% of the BA between 35 to 80 km (whichever is larger);
  - from 0.4% to 1% of the BA linearly in height between 35 km and 10 km;
  - from 1% to 10% of the BA linearly in height between 10 km and the surface.

- The breakthrough RMS accuracy for Post-EPS shall be better than:
  - 0.5 μrad or 0.2% of the BA between 35 to 80 km (whichever is larger);
  - from 0.2% to 0.5% of the BA linearly in height between 35 km and 10 km;

- For instrument design, more emphasis is given to requirements at heights equal and greater than 35 km. However, the receiver's performance shall remain stable over individual occultations down to the surface;
Standard deviation for low latitudes (left), mid (center), high (right) collocations between GRAS and COSMIC for different collocation criteria, ECMWF at GRAS locations is also shown.
Overall system requirements on coverage:

- Uniformity of sampling in space and time
- Threshold / Breakthrough / Objective:
  - 1000 / 4000 / 8000 / day
- Threshold and breakthrough targets based on input from operational NWP and mission planning simulations
- Objective target is TBC:
  - Driven by saturation of RO impact (particularly in NWP)
  - OSSEs planned by NCEP and J CSDA
EUMETSAT Contributions to the RO Community

Existing collaborations:
- NOAA: on-demand downlink, operational processing and dissemination of NOAA 19 ATOVS data
- CNES: operational downlink, processing and dissemination of Jason 2 data
- ISRO: operational downlink and dissemination of Oceansat 2 data in preparation; processing under discussion

Support to other RO missions:
- in-kind contribution of
  - GPS orbits / clocks
  - ground station data (requires inter-agency agreement; UCAR, NSPO)
  - navigation bit data (under discussion)
- cooperating with other RO operators, e.g. COSMIC, ROSA,...
- Additional contributions (downlink, processing, dissemination) similar to the above collaborations can be envisaged, but require detailed inter-agency discussion ahead of time

Looking ahead:
- aiming at multi-mission processing in the future, especially for re-analysis and climate purposes
- in contact with international committees, e.g. the Galileo Science Advisory Committee to ease use of Galileo signals for operational weather monitoring