GNSS Products for Radio Occultation Soundings
Present Use and Future Requirements

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with many thanks to S. Healy (ECMWF)

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IGS 2010 Workshop
Newcastle upon Tyne, UK

Agenda

- Radio occultations
- Their impact on NWP and Re-analysis
- Current and future timeliness constraints
- Antarctic Data Aquisition
- Advanced Retransmission Service
- Summary

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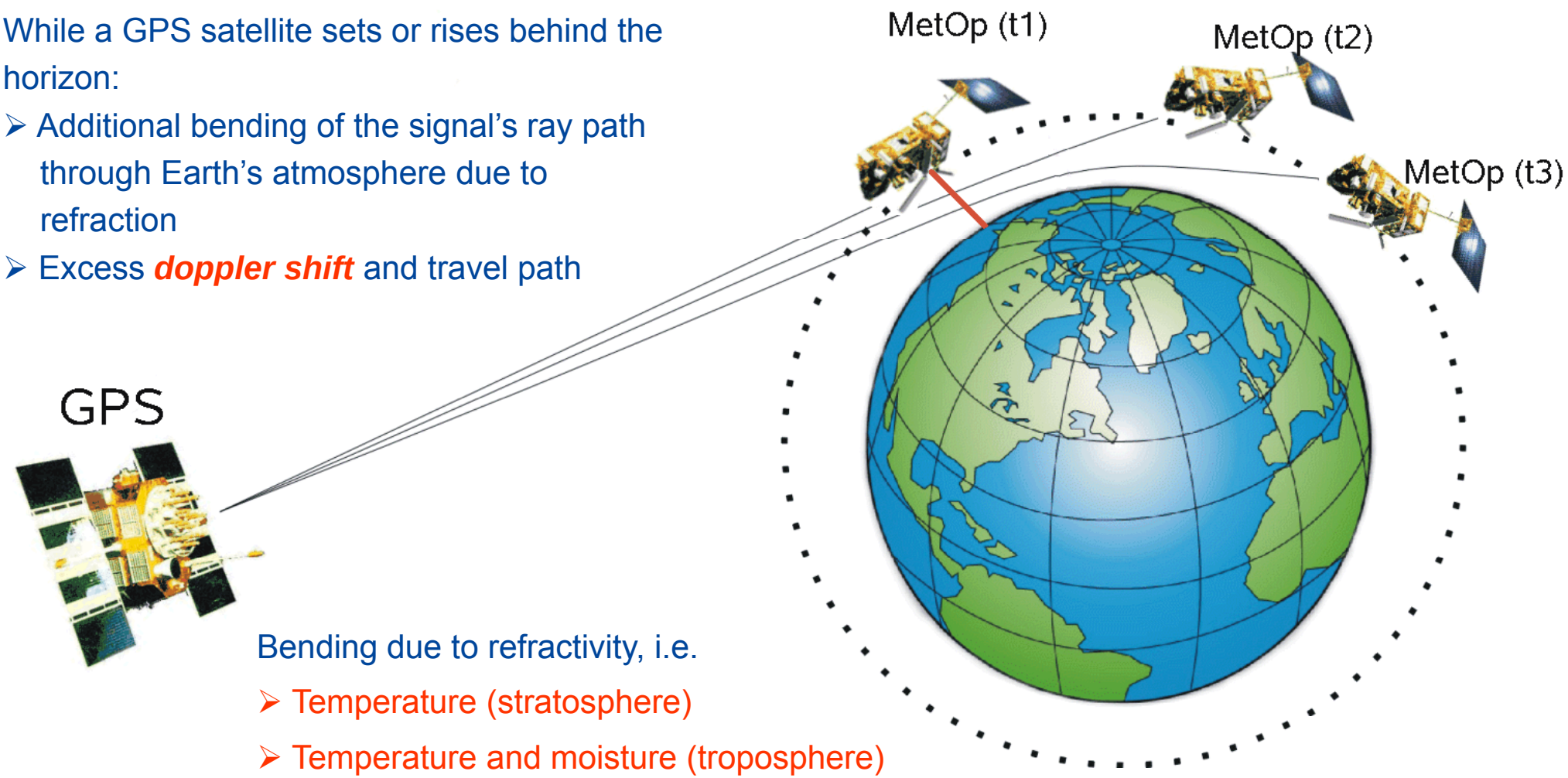
Radio Occultations

While a GPS satellite sets or rises behind the horizon:

- Additional bending of the signal's ray path through Earth's atmosphere due to refraction
- Excess ***doppler shift*** and travel path



Bending due to refractivity, i.e.

- Temperature (stratosphere)
- Temperature and moisture (troposphere)

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Radio Occultations (cont'd)

- Limb sounding:
  - High vertical resolution (~ 800 m in the tropopause region)
  - Horizontally integrating (and moving) over 200 – 400 km
  - Measurement of opportunity only
- GPS frequencies (wavelengths ~ 20 cm / 1.575 and 1.227 GHz):
  - Weather-independent (in the free atmosphere)
- Measurement principle:
  - No instrument degradation or drifts
  - Calibration free
  - Highly accurate temperature soundings (< 1 K) in the UTLS and lower stratosphere
- Applications:
  - NWP
  - Climate monitoring

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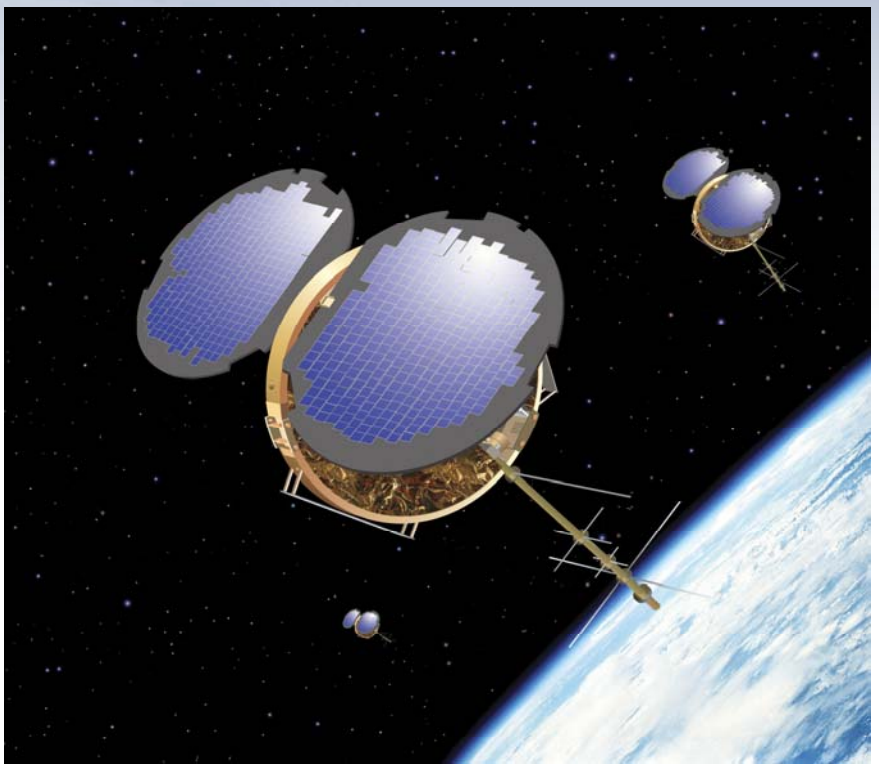
Radio Occultations (cont'd)



COSMIC / FORMOSAT 3

6 Microsatellites, 4 years+

IGOR; iono-beacon

GRAS on Metop / EPS

Sequence of 3 large satellites, 15 years+

GRAS; AMSU, AVHRR, HIRS, IASI, GOME, ASCAT

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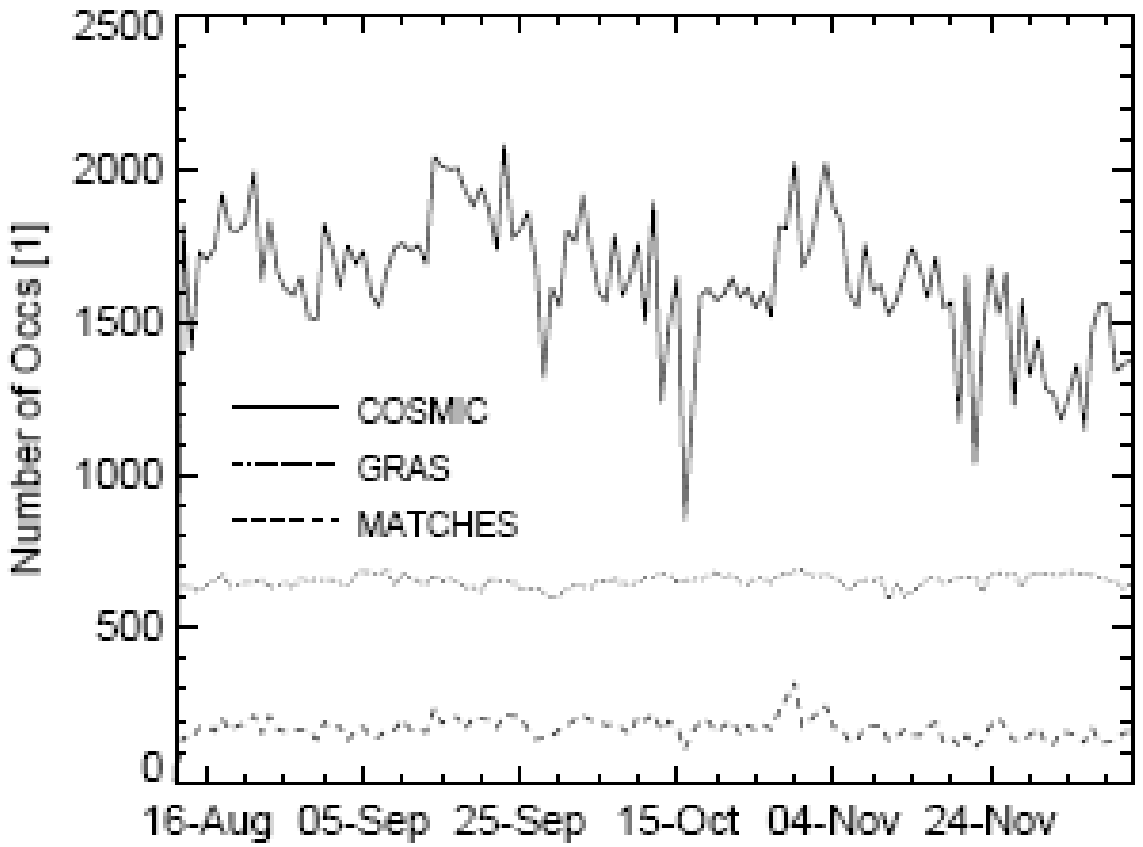
Radio Occultations (cont'd)



Number of daily occultations and matches (300 km / 3 hrs in 2009)

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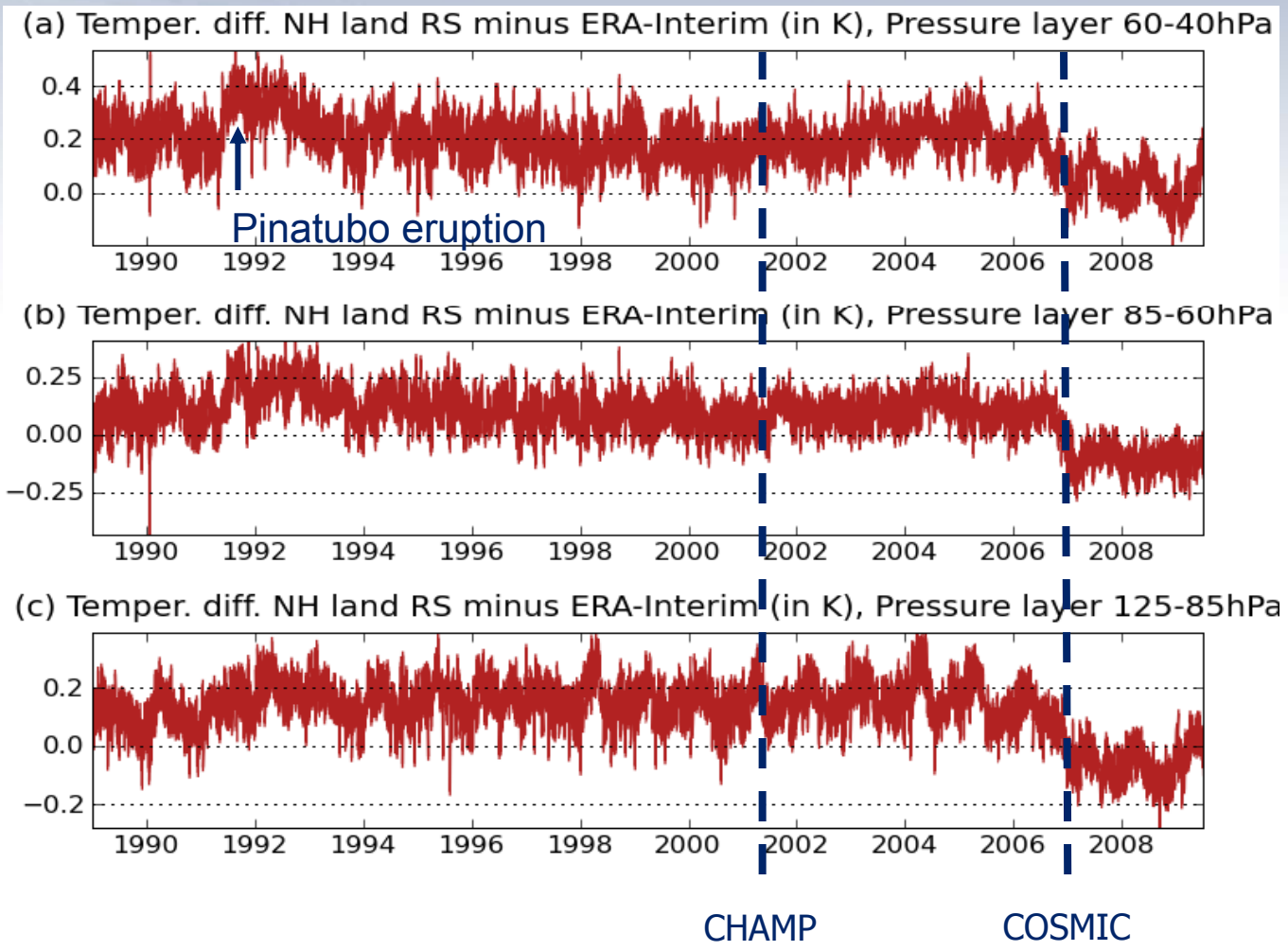
RO Impact – ERA Interim Reanalysis



RO impact:

- ECMWF Reanalysis
- Mean deviation against radiosondes in NH

(figure courtesy P. Poli, ECMWF)

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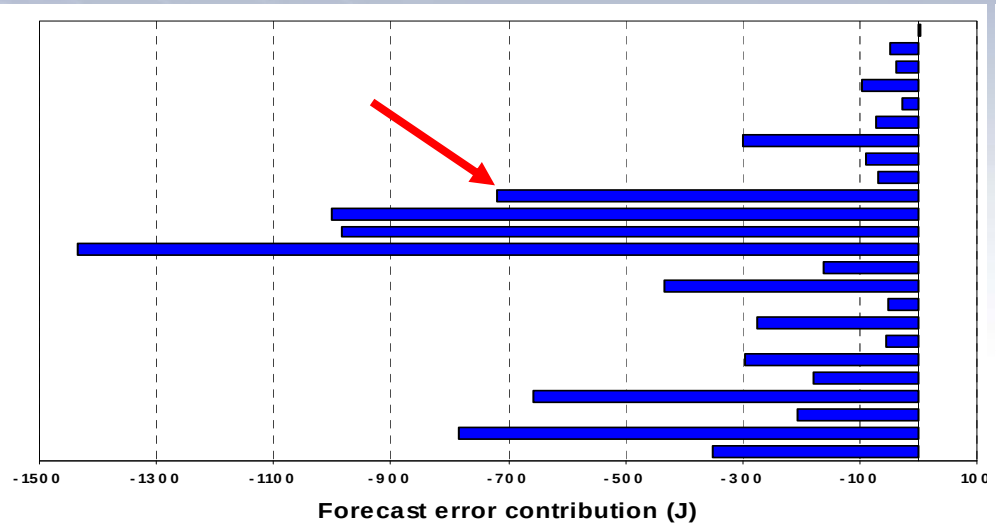
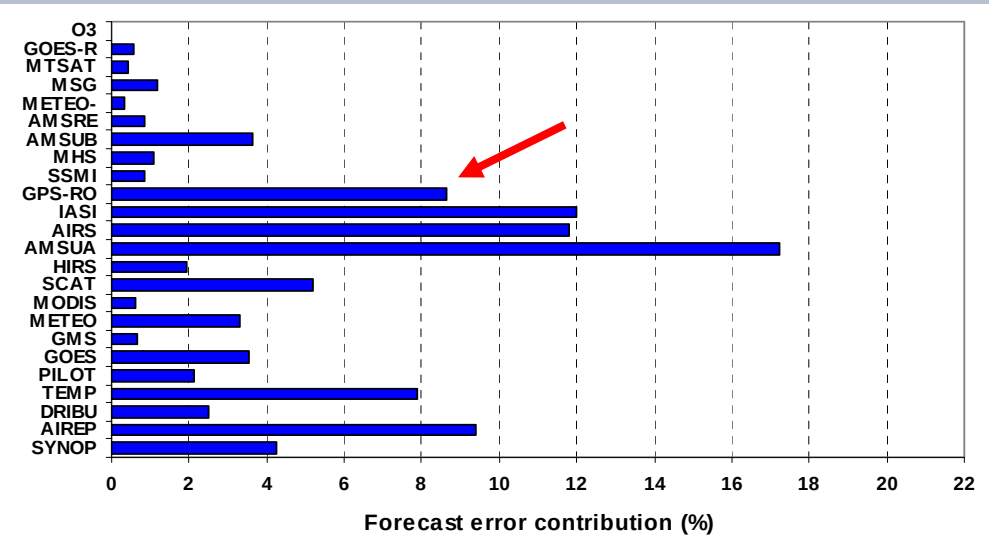
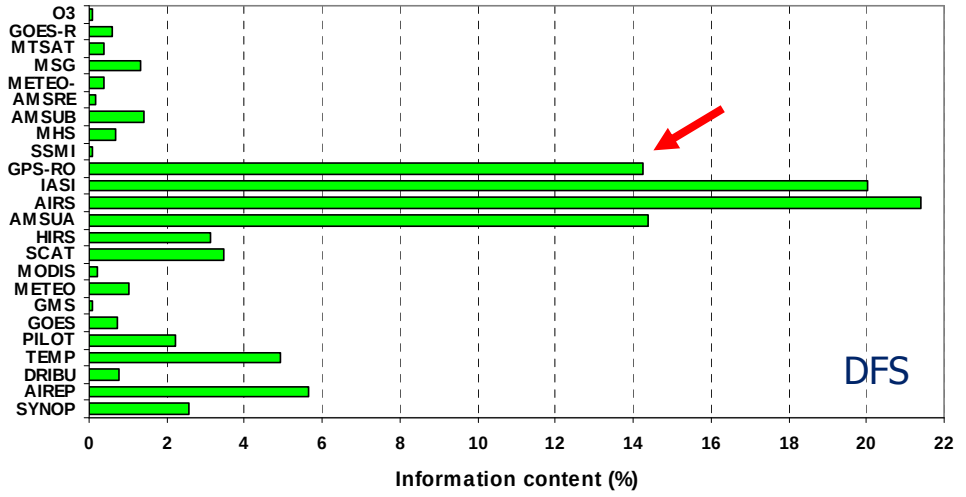
RO Impact – Information Content by Type





How much do various observation types contribute to ECMWF's forecasts, relative to each other?

- J measure of forecast error
- Reduction of 24 h forecast error
- ECMWF operational forecasts
- 09/2008 – 12/2008



(C. Cardinali et al., ECMWF)

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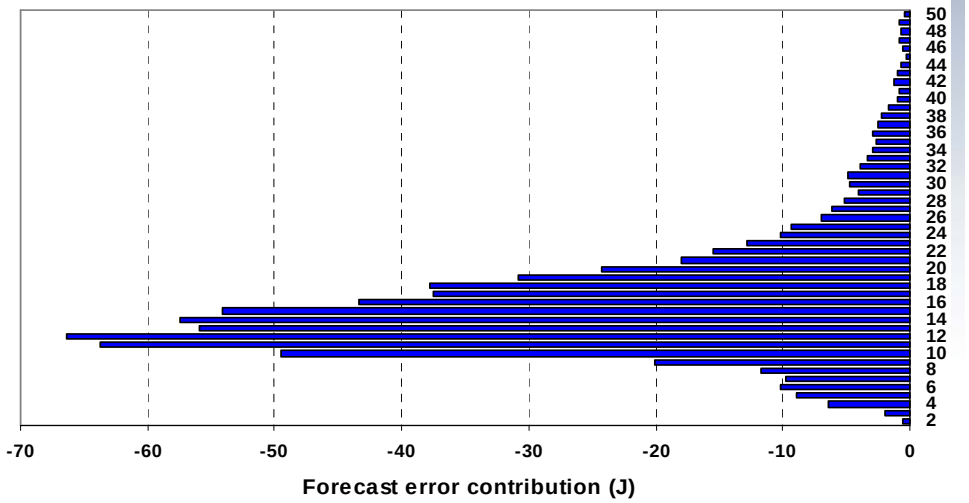
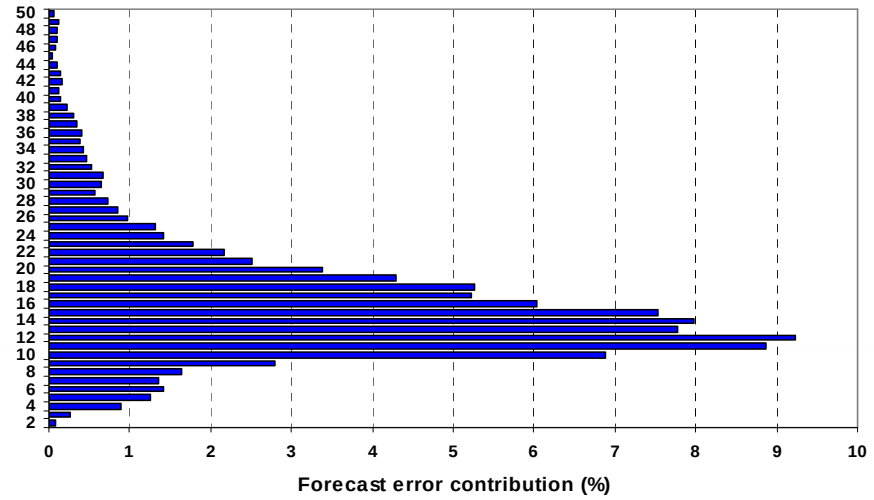
RO Impact – Information Content by Altitude





A which levels (altitude) do radio occultations contribute to ECMWF's forecasts?

- J measure of forecast error
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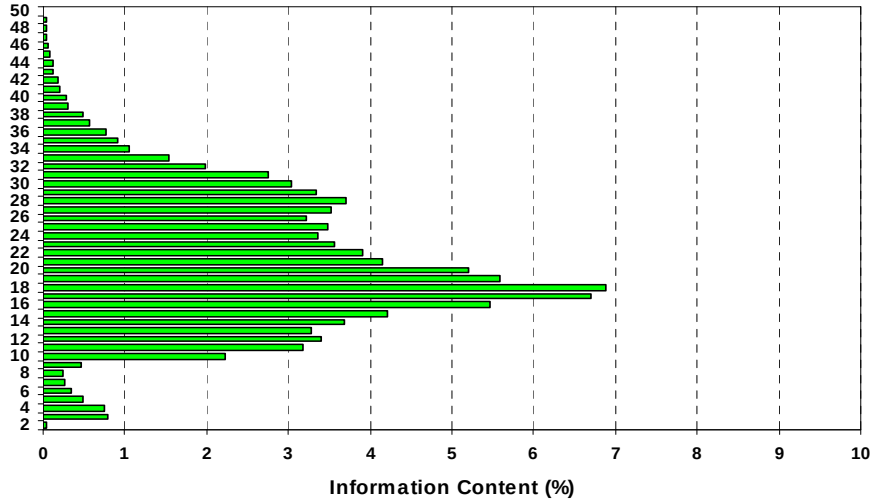

(C. Cardinali et al., ECMWF)

GPS-Radio Occultation

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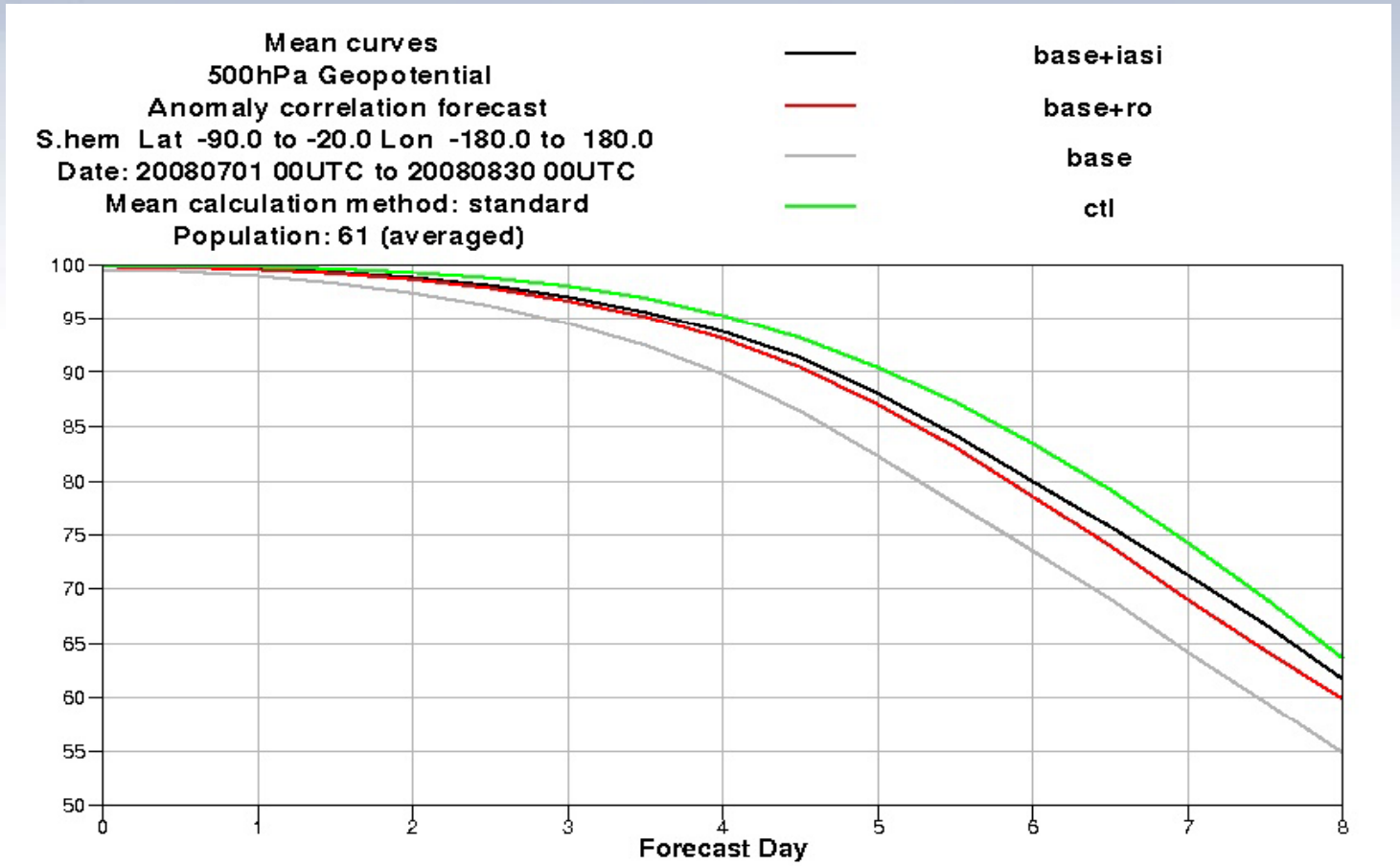
RO Impact – Poor Baseline & IASI



How many RO receivers would we need to equal the impact of IASI?

(courtesy S. Healy, ECMWF)

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RO in Operational NWP (and Re-Analysis / Climate)

- Radio occultations operationally used at ECMWF, Met Office, Meteo France, NOAA/NCEP, NRL Monterey, HMC (Moscow),…
- Synergistic impact: RO anchors stratospheric bias correction schemes for other instruments, which can then be used more efficiently
- Very low structural uncertainty between instruments and data providers in upper tropospheric and lower / mid stratospheric data

- RO has become mainstream and will stay
- Future receivers all plan to exploit Galileo (and maybe GLONASS)

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RO Requirements and Timeliness

- Orbit and clock accuracy requirements for RO processing driven by doppler accuracy: Δv and clock drifts < 0.2 mm/s
  - In practice, we get away with slightly poorer performance in NRT (but do reprocessing with better quality orbits for climate applications)
  - Well within reach of current POD systems for both GNSS and LEO satellites

- Timeliness requirements driven by data downlink capabilities, NWP analysis schedule and user needs
  - Currently: 3 hrs (GNSS orbits & clocks ~ 1 hr)
  - Future: < 1 hr (GNSS orbits & clocks ~ 30 – 45 min), mostly driven by regional modelling
  - Benefits in data quality if we would get GNSS orbits & clocks even earlier (TBC)

RO Requirements and Timeliness (cont'd)

- Reliability requirements for RO processing driven by 24/7 service and 95%+ reliability requirements
  - GPS orbit and clock products provided a GRAS Ground Support Network (GSN)
    - Run by Navigation Office at ESA/ESOC
    - High rate ground station data from various data providers (commercial and research, 15 mins)
    - Raw GSN data used for COSMIC processing at UCAR and in Taiwan
  - In the past, focus has been on reliability, 24/7 support and service level (agreements)
  - GSN will be upgraded to NAPEOS to close performance gap to IGS products over the next few weeks

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Antarctic Data Acquisition (ADA)

- Metop mission data downlink to be supported by NASA/NSF 10m antenna at McMurdo Sound (77°S)
- Mission data to be sent by combined satellite/land link to Darmstadt via Australia
- Phases :
  - Testing — starts Dec 2010
  - Demonstration — Feb 2011 to Feb 2014 — (average of 9 passes/day)
  - Operational — Feb 2014 onwards — (all passes of operational satellite)

- Focussed on prime Metop, with option to support backup Metop
- Level-1 product timeliness to improve from max. 135 to 65 mins (sensing time to product dissemination, current avg = 115 mins)

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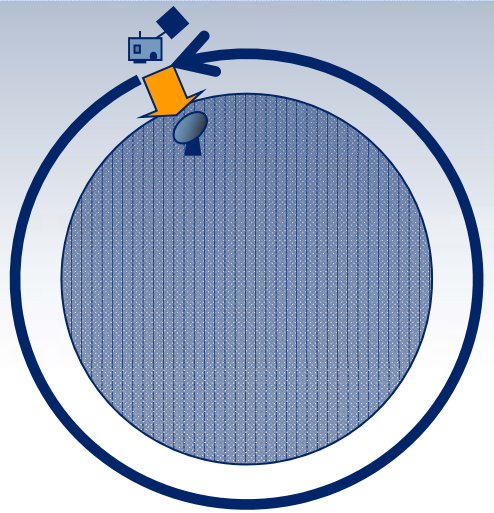
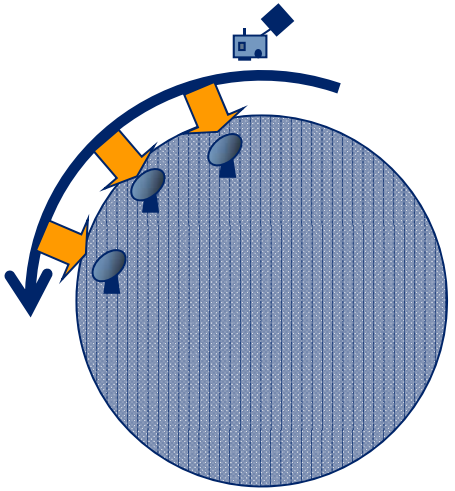
EUMETSAT Advanced Retransmission Service (EARS)

- Collect data from polar orbiting meteorological satellites via a selected set of HRPT (direct read-out) stations
- Process and retransmit the data to end users via GTS and EUMETCast
- Timeliness adequate for local and regional NWP (typically < 30 min)



- So far mostly focussed on AMSU, AVHR, IASI and ASCAT, with de-centralised processing
- Timeliness of individual raw data chunks ~ 10 - 20 mins
- Since a few weeks, a test data stream for GRAS level 0 is available internally at EUMETSAT



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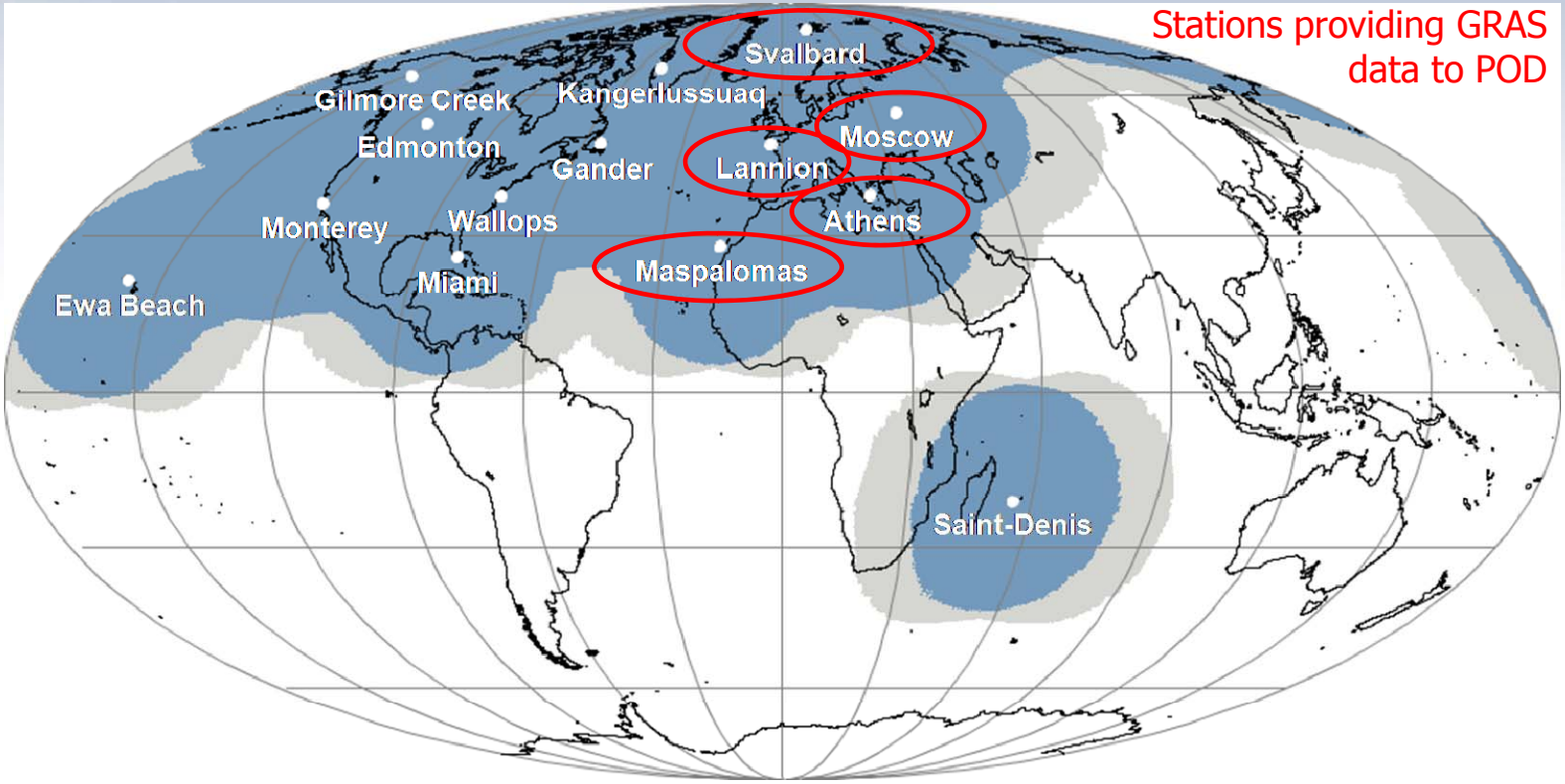
EARS Geographical Coverage



Ewa Beach ● Gilmore Creek ● Edmonton ● Monterey ● Kangerlussuaq ● Moscow ● Gander ● Miami ● Wallops ● Svalbard ● Lannion ● Athens ● Maspalomas ● Saint-Denis

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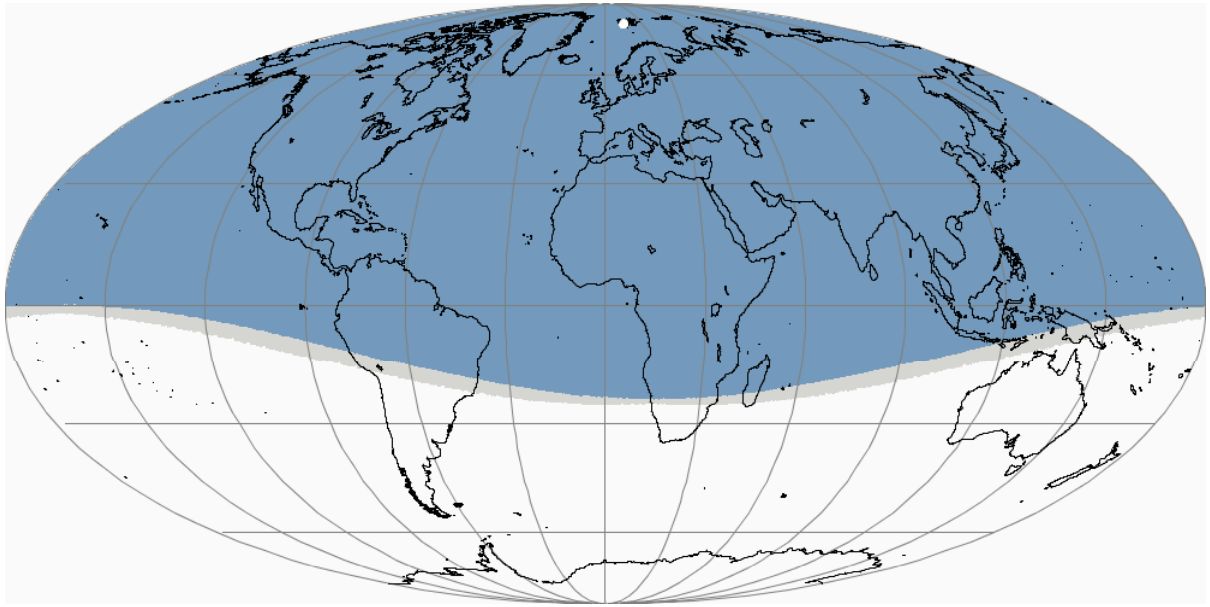
Fast Dump Extract Service (FDES)

- Complement "partial" EARS service and mitigate Metop HRPT issues
- Most recent part of the X-band global dump received at Svalbard + EARS
- Timeliness of EARS FDES products: 20 - 30 minutes



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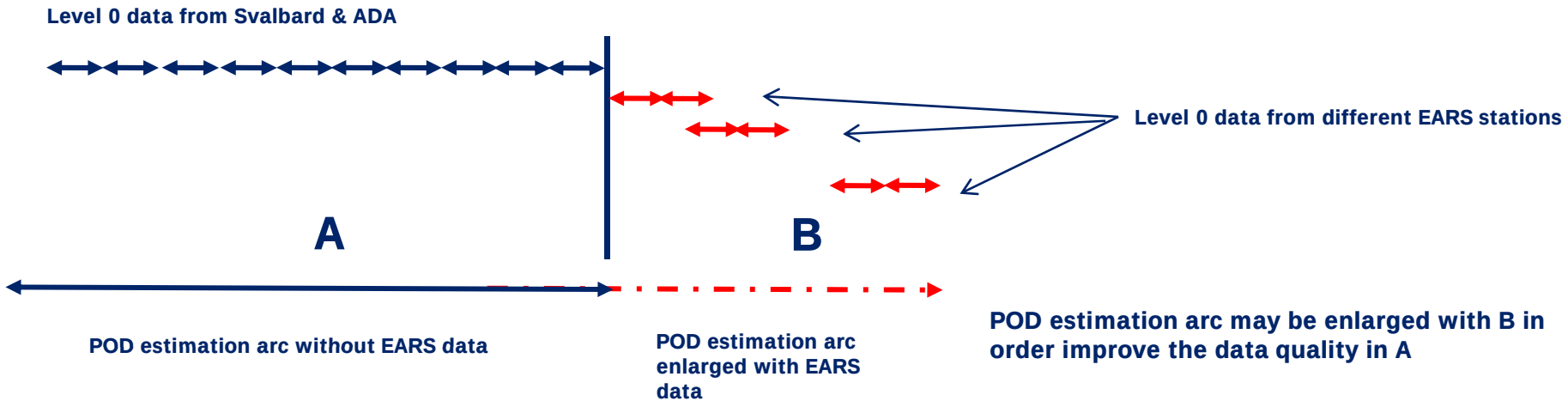
EARS Data for GRAS (we're thinking about it...)

- Level 0 data (continuous) from standard downlinks for level 1b production
- Level 0 data (intermittent) from EARS network for improving POD in the production interval (?)
- Level 0 data (continuous) from FDES for producing level 1b with smaller timeliness (??)
- Need of NRT auxiliary data (precise GPS orbits and clocks)
- Would have to demonstrate benefits in data quality and/or timeliness



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Summary

- Radio occultation soundings have become a mainstream data source in operational NWP, ranking high among other observation types
- Future missions will exploit Galileo and probably other (GLONASS, Compass?) GNSS systems
- Timeliness requirements for meteorological products are being reduced from 3 to 1 hrs or less upon user request; mainly driven by local and regional NWP
- Operational agencies like EUMETSAT undertake considerable efforts to meet them (ADA, EARS)
- We see some potential in the use of true NRT data for GNSS constellations in the processing of RO data, but have to provide evidence for actual benefits

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