Overview of EUMETSAT RO Activities, with a focus on Reprocessing and Sentinel-6

A. von Engeln, C. Marquardt, Y. Andres, S. Paolella,

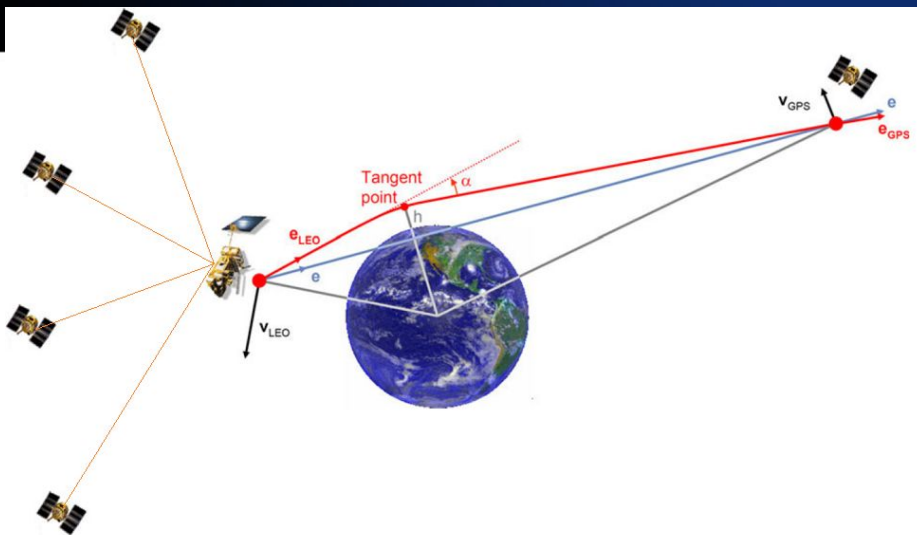S. Padovan, V. Oommen John, K. Petraityte

12th April, IROWG-8, Virtual

Overview

- Sentinel-6 / Jason-CS Results
- EUMETSAT reprocessing v2 of CHAMP, Grace, COSMIC, GRAS
- Summary of other EUMETSAT Activities

Sentinel-6 / RO Overview

Principle:

- Observation of GNSS (e.g. GPS) signals propagating through the atmosphere
- changing refractivity leads to bending of rays
- Bending / refractivity depends on pressure, temperature, and water vapour
- based on time measurement, thus long term stable across instruments (weather forecasting, climate applications)
- Observation of opportunity: 500 – 700 profiles / day / GNSS constellation, quasi randomly scattered (no land/sea, day night impact), rising or setting
- Observation of GNSS (e.g. GPS) signals above the satellite for precise orbit determination

EUMETSAT RO Missions/Activities:

EPS/GRAS (GNSS Receiver for Atmospheric Sounding, GPS):
- since 2006, provision of Near-Real-Time data for weather forecasting, several reprocessing campaigns for climate applications

Sentinel-6/TriG (Tri-GNSS, GPS and GLONASS):
- Instrument switch-on / first data 28 Nov 2020 at 09:25, first GPS occultation data at 13:39, first GLONASS occultation at 13:56

   NASA/JPL (Chi's talk): responsible for Near-Real-Time (3h)
   EUMETSAT: responsible for Non-Time-Critical (~16d)

EPS-SG/RO (GPS, Galileo and BeiDou):
- Launch mid-2020, continuation of EPS/GRAS

Reprocessing:
- Majority of EUMETSAT and 3rd Party RO instruments

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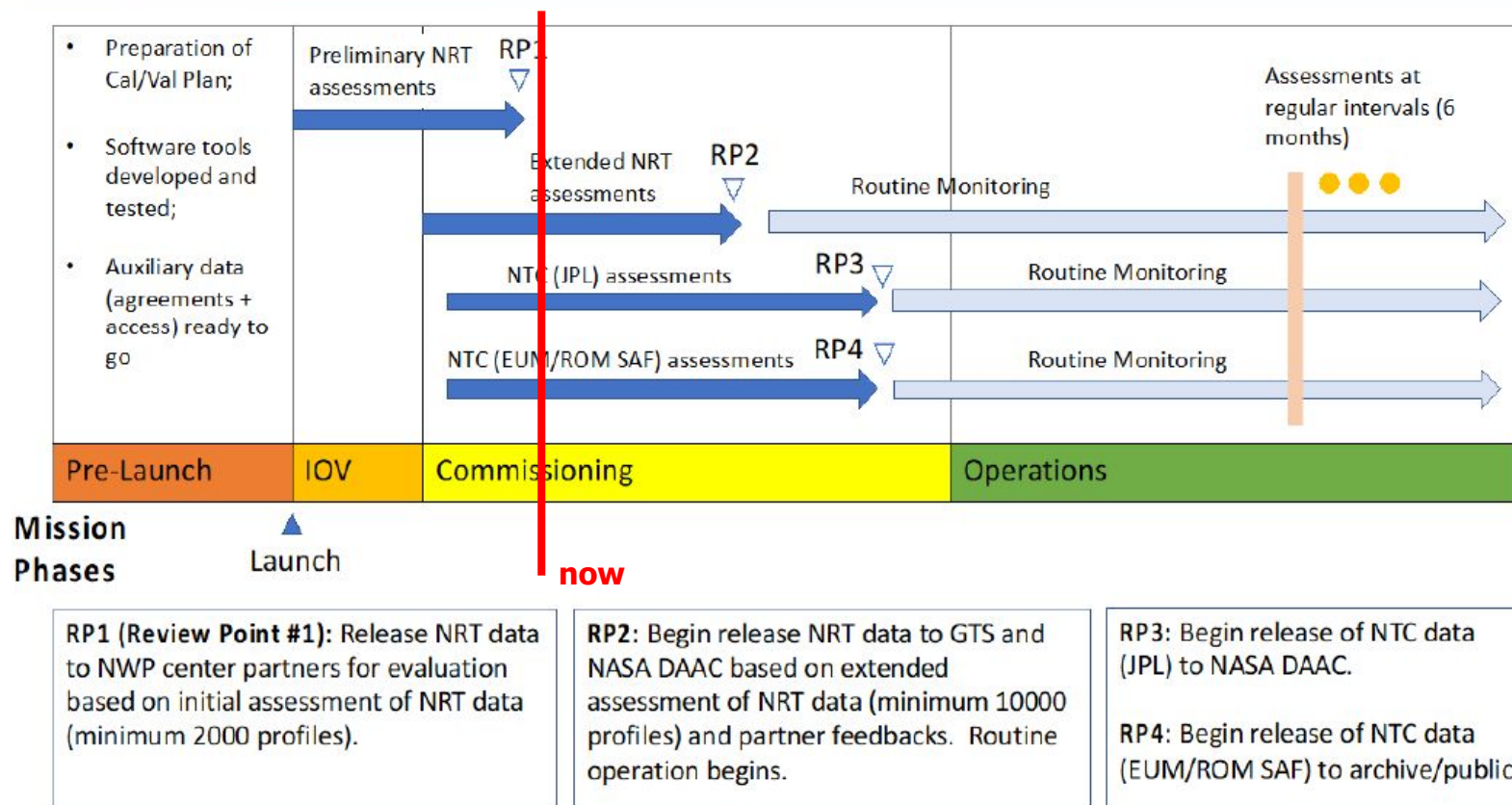# Sentinel-6: Commissioning / Cal/Val

Figure 1: RO Cal/Val activity timeline relative to mission phases and key "Review Points (RP)" where NRT and NTC products have been validated and recommended for release. It is expected that RO Cal/Val activities would be completed earlier than the mission commissioning phase for altimetry (5–12 months planned [RD.11]).

GNSS-RO Performance Status

Core End User Product Performance Requirements:

- GNSS-RO shall track radio occultations from at least two of the following constellations: GPS, GLONASS, Galileo;

- GNSS-RO shall make occultation measurements for ray path tangent heights between the Earth's surface and 80 km altitude;

- RO-NRT service shall be capable to provide 770 profiles per day;

- Neutral bending angle RMS measurement uncertainty: < 2 µrad for 30km-60km, interval 1.5 km; < 3 µrad for 20km-30km, interval 1.5 km; < 30 µrad for 10km-20km interval 0.15km

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Level 0 Data Analysis up to 31 March 2021:

- GPS and GLONASS observations are continuously acquired

- Average number of GPS occs/day (31 satellites available):

  545 (providing 65% of all occultations)

- Average number of GLONASS occs/day (24 satellites available):

  292 (providing 35% of all occultations)

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Sentinel-6 Performance Status

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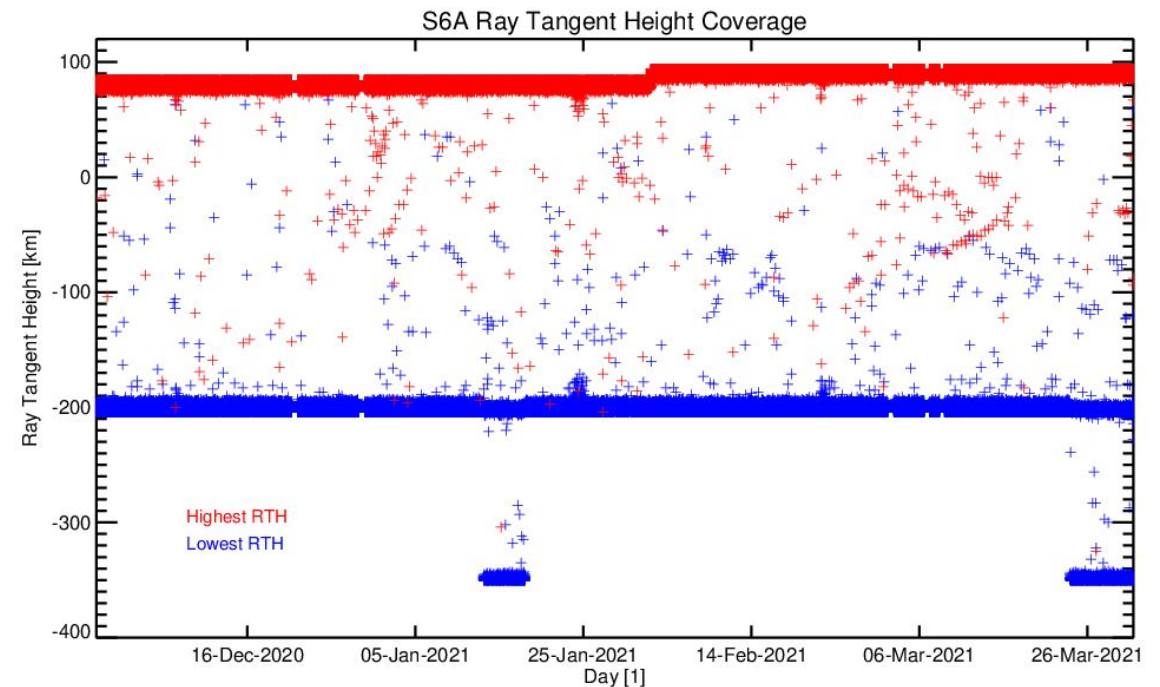
Scatter plot of the start and end ray tangent height of all occultations up to 30 March 2021. Period of extended tracking to -350km (only low latitudes) visible in mid-January, will remain default from 24 March onwards.

Sentinel-6 Performance Status

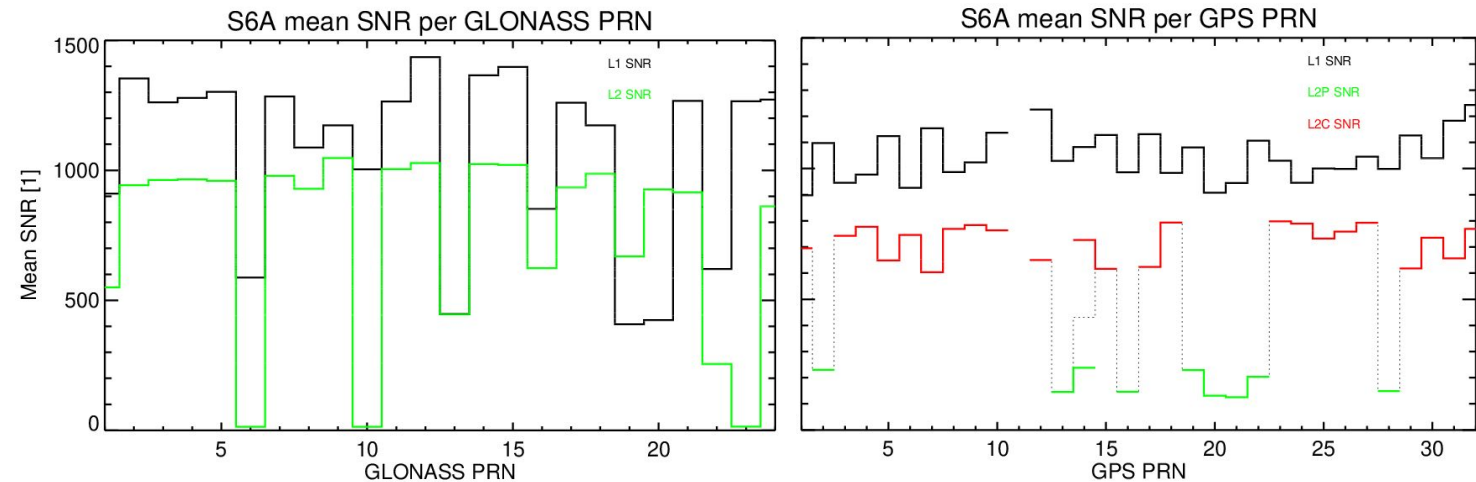## Core End User Product Performance Requirements:

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Level 0 Data Analysis up to 31 March 2021:
- 837 occultations/day (Caveat: not all occultations can be processed to quality controlled profiles);

Level 1B Data Analysis:
- about 730 profiles/day, reduced for various reasons:
  - some commissioning activities are included;
  - Instrument rebooting frequently (on average 0.7 gaps/day, 5% loss);
  - GLONASS issues (in total, about 9% underperforming for GLONASS):
    - Instrument sometimes not acquiring GLONASS after re-boot;
    - Instrument falling short of possible RO-NRT occultations;
    - several GLONASS satellites not fully functioning.

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Sentinel-6 Performance Status (1)

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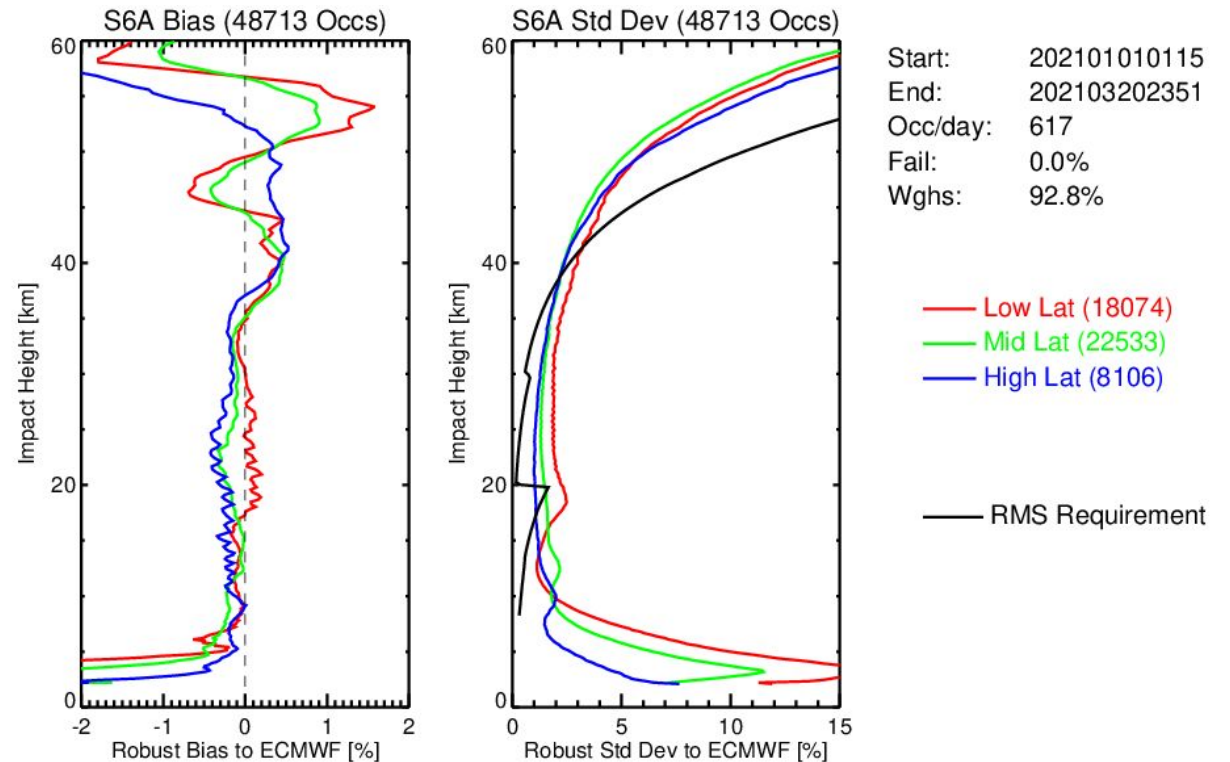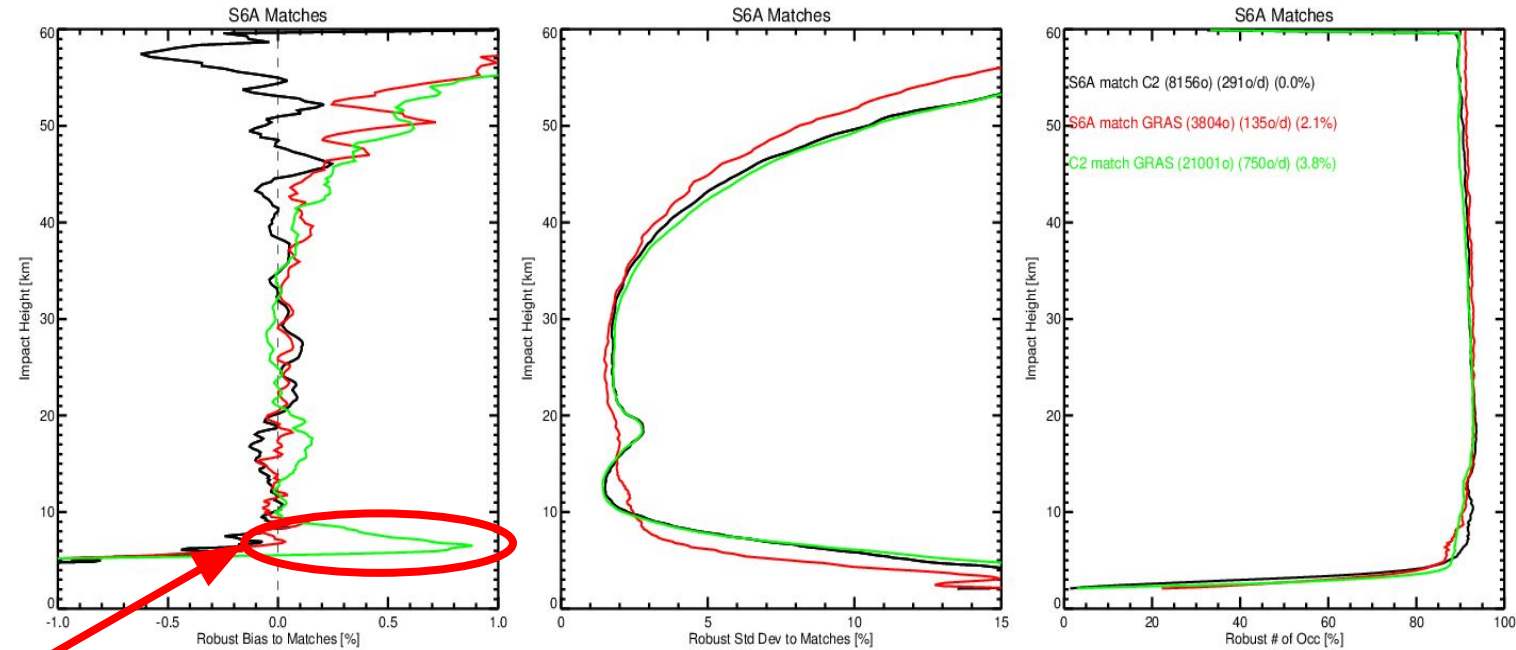

Bending angle bias (left) and standard deviation (right) of S6A occultations against ECMWF forecast data, for different latitude bands. Note: (a) occultations / day lower as this was on offline reprocessing run for 01 Jan to 20 Mar 2021; (b) standard deviations contain 2 contributions, of instrument and of ECMWF forecast.

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Bending angle bias (left), standard deviation (middle), penetration (right) of S6A occultation matches against COSMIC-2 (black), GRAS (red), and COSMIC-2 matches against GRAS (green), all using 300km/3h. Brackets give total number of occultations, per day, and failure rate, data from 20th Feb '21 to 20th Mar '21.

Limitation of current GRAS processing, to be resolved with PPF 5.0 (Note: also present in S6A GRAS matches, but less visible as these are covering all latitudes).

Reprocessing: Overview

Mission	Start Record	End Record	Nom. Occs / Degr. Occs	Avg. Occs/Day
EUMETSAT - RO Level 1b Bending Angle Profiles FCDR				
Metop-A	2006/10/27 09:57	2020/06/30 23:54	2,761,522 / 531,378	659
Metop-B	2012/09/29 20:56	2020/06/30 23:56	1,712,580 / 177,793	668
Metop-C	2018/11/17 20:57	2020/06/30 23:52	355,788 / 32,862	657
CHAMP	2001/05/19 00:10	2008/10/05 02:42	539,093 / 124,334	246
GRACE	2007/02/28 00:14	2017/11/20 23:55	448,864 / 71,650	133
COSMIC	2006/04/22 00:27	2020/04/25 19:32	5,961,727 / 1,693,560	1496

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# Reprocessing: Old (v1.4) vs. New Wave Optics (v2)
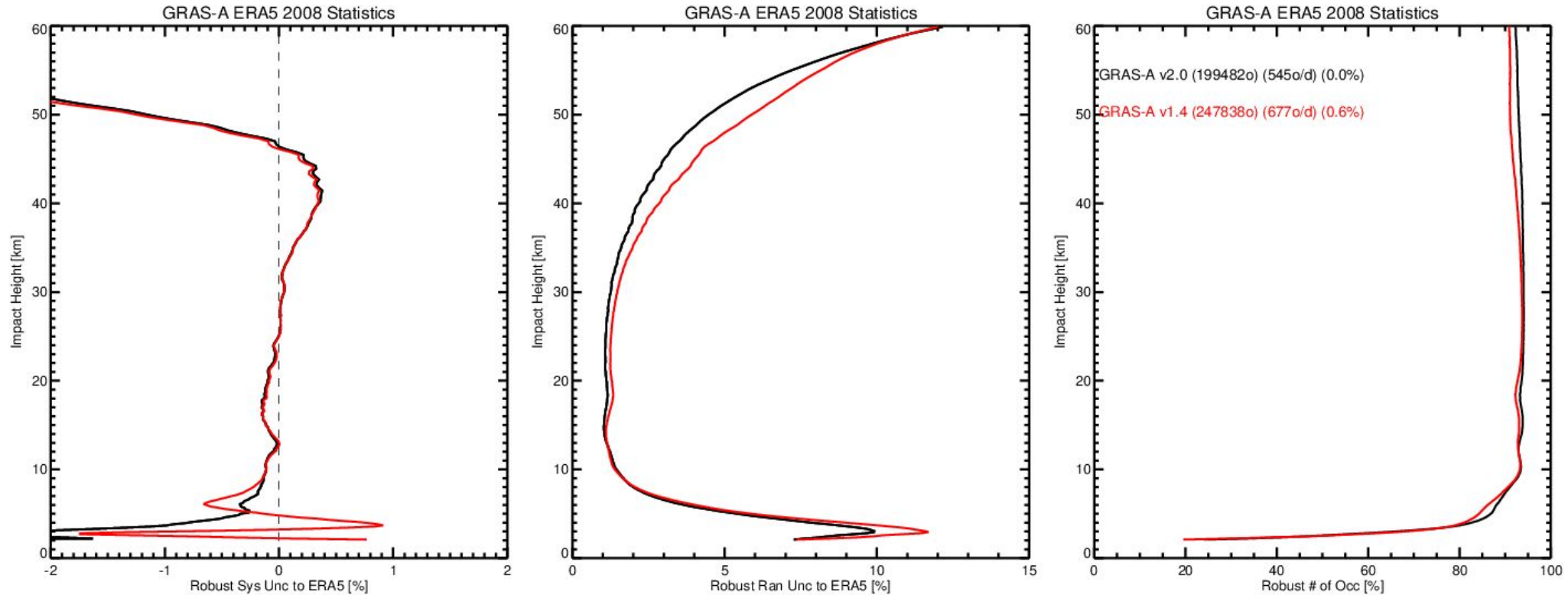
- Difference between old (red) and new (black) bending angle statistics against ERA 5 (Metop-A, 2008);
- Tropospheric biases are actually more in line with other centres than before;
- Metop-A new reprocessing currently has fewer occultations / day, looking into dedicated reprocessing of missing data;
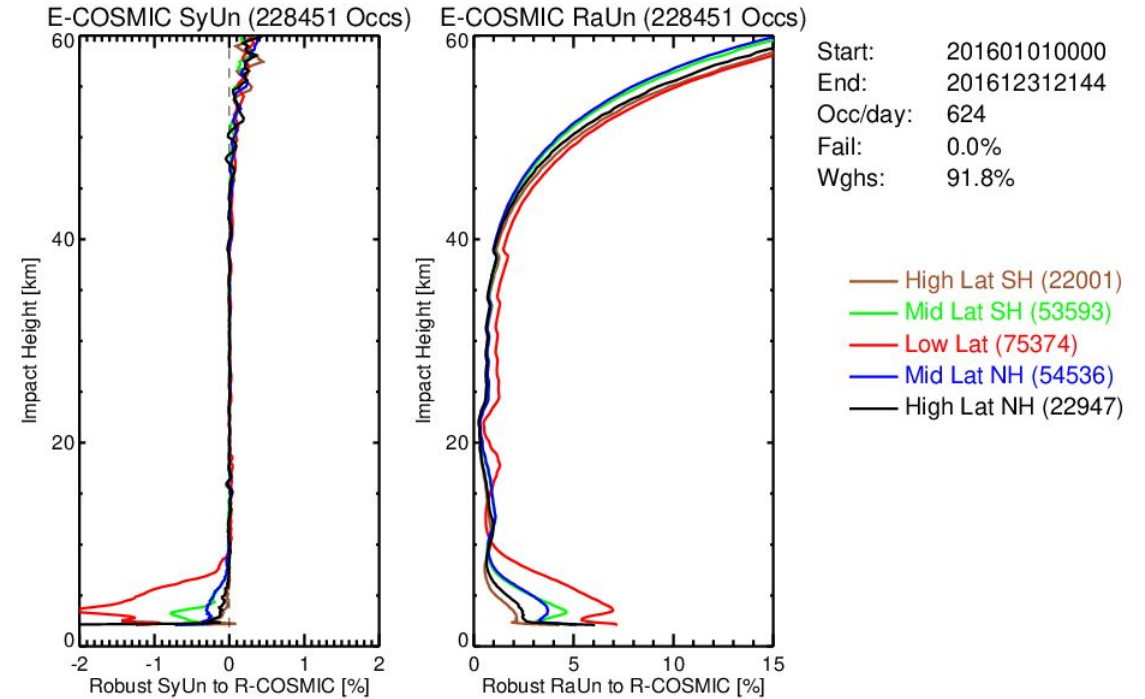- Rising/setting asymmetry reduced (though it still exists for GRAS).

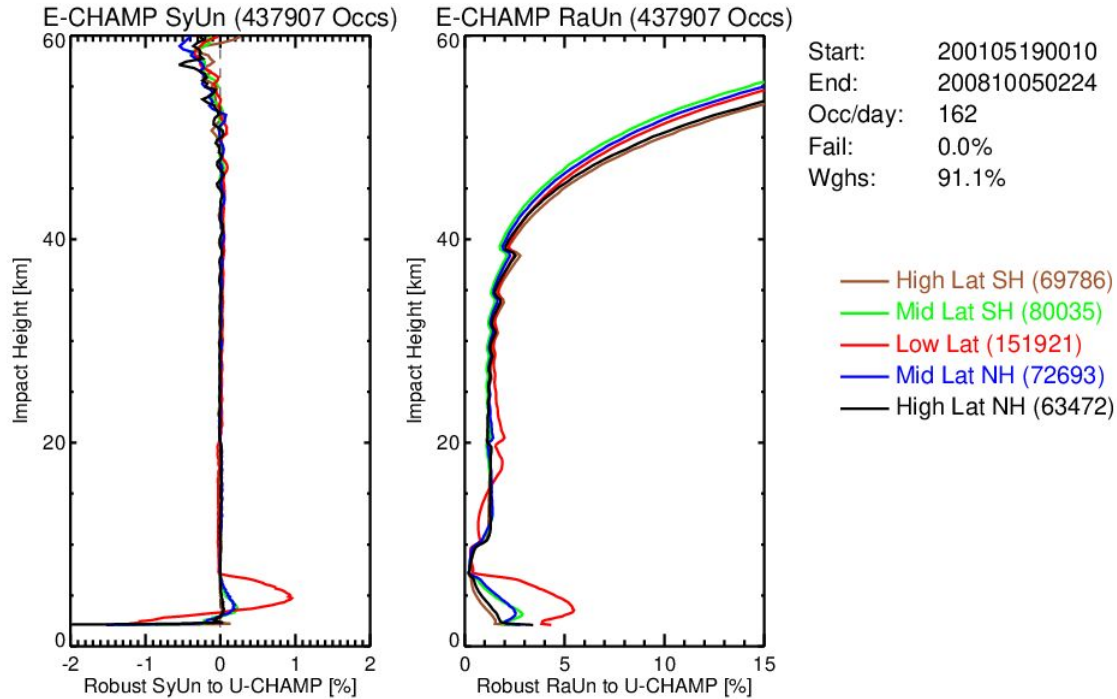EUMETSAT

Reprocessing: COSMIC
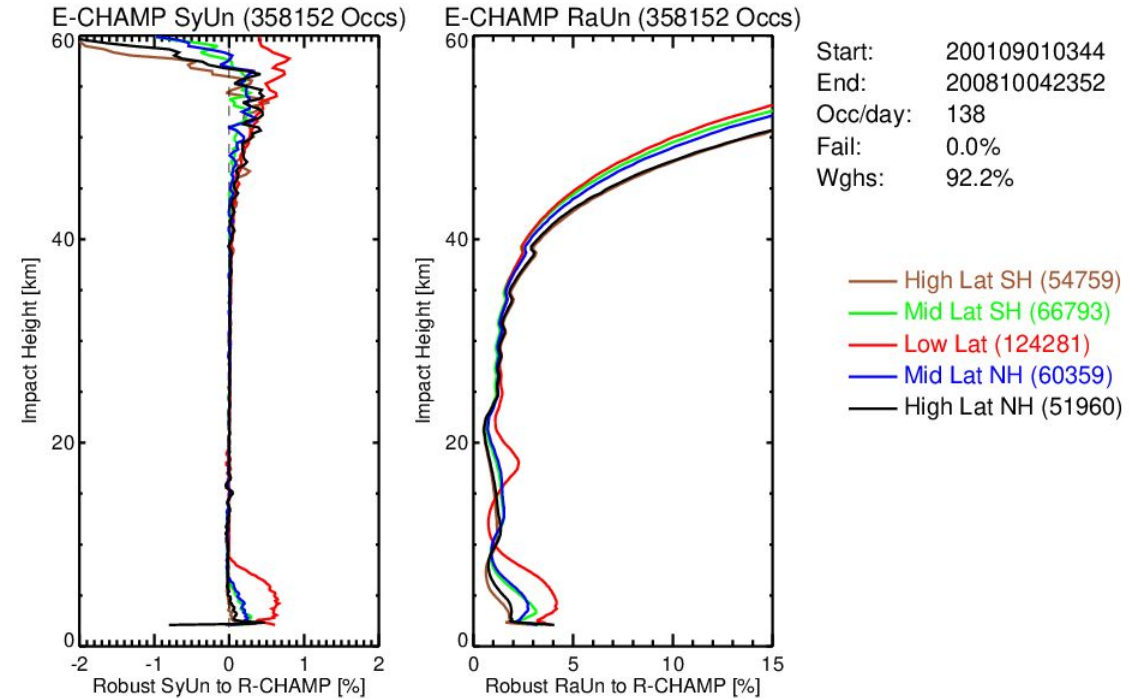
EUM vs. UCAR
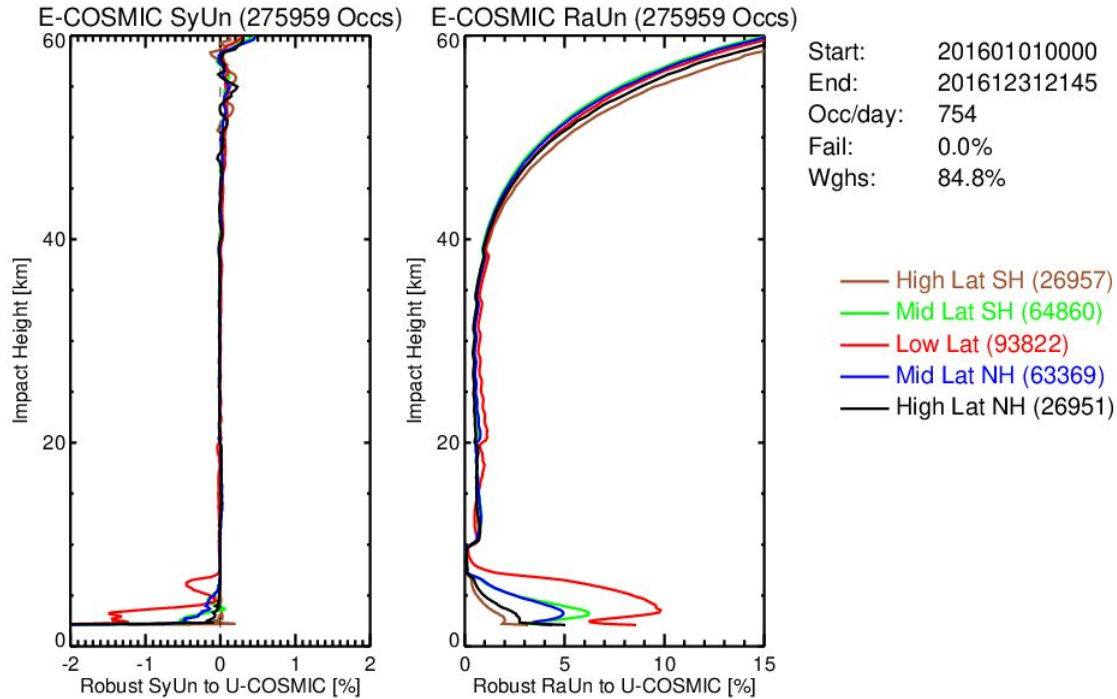
EUM vs. ROM SAF

- EUM HQ COSMIC vs. UCAR (left) and EUM ROM SAF (left), EUM and ROM SAF start at atmPhs;
- One year (2016), direct matches; fewer occultations in the ROM SAF data set;
- Steps in standard deviations visible, likely due to EUM thinning, looking into cause and might re-reprocess;

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Reprocessing: CHAMP
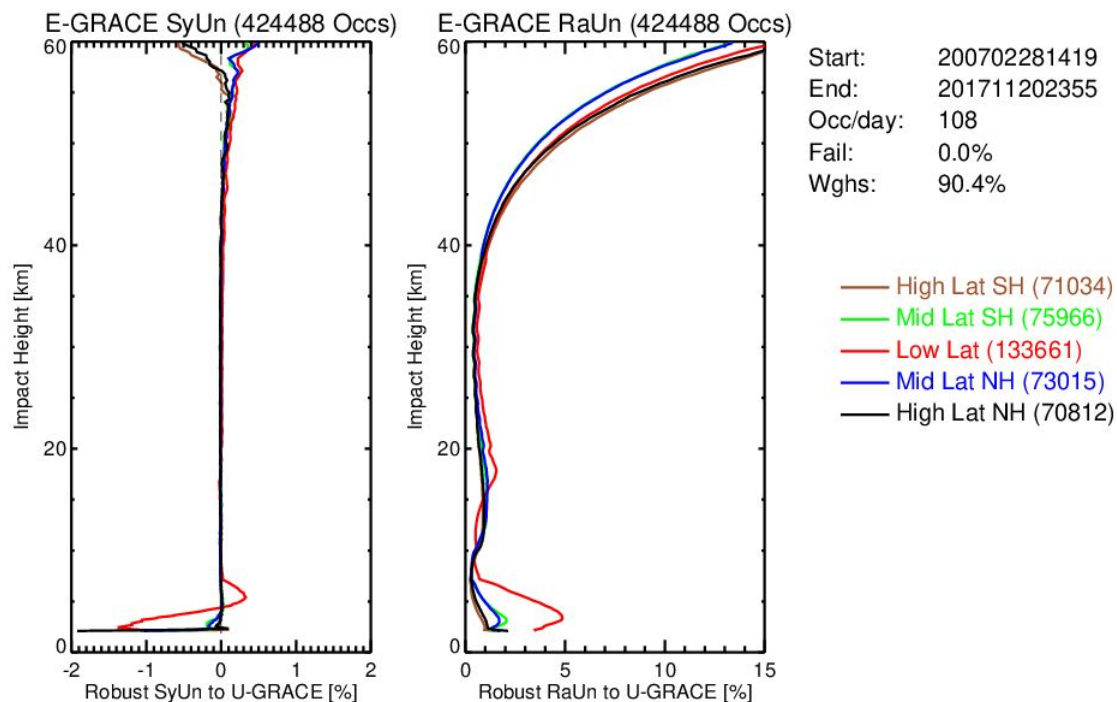
EUM vs. UCAR

EUM vs. ROM SAF

- EUM HQ CHAMP vs. UCAR (left) and EUM ROM SAF (right), EUM and ROM SAF start at atmPhs;
- Seven years, direct matches; fewer occultations in the ROM SAF data set;
- Steps in standard deviations visible, likely due to EUM thinning, looking into cause and might re-reprocess;

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Reprocessing: GRACE

EUM vs. UCAR

- For all three missions excellent agreement in terms of bias;
- UCAR provides highest number of occultations/day for COSMIC/CHAMP/GRACE, EUM fewer, ROM SAF still fewer;
- Slightly better agreement with UCAR than with ROM SAF above 7 – 8 km;
- Tropospheric deviations between data sets comparable;
- EUM HQ with small negative biases in the Tropics (we are also working on that …).

- EUM HQ GRACE vs. UCAR, EUM starts at atmPhs;
- Ten years, direct matches.

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Overview of main other EUMETSAT Activities

- **GRAS instrument updates:**

  - Metop-A occultations were extended into the ionosphere during 2020 (Riccardo's talk), EUMETSAT plans to extend all Metops occultations into the ionosphere (later 2021, up to about 300km);

- **Improved wave optics processing** (Fast Phase Transform – FPT, PPF 5.0):

  - already used for reprocessed data and Sentinel-6 NTC;

  - GRAS NRT processing: being validated jointly with the ROM SAF;

  - to be rolled out for GRAS operations in April/May;

  - test data available on request;

- **Reprocessing:**

  - within 2021, plan to re-do and correct mentioned minor issues found in reprocessing validation;

- **EPS-SG:**

  - on-going activities (documentation, data processing, test data, etc).

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Summary

Sentinel-6:

- Status:
  - most performance related requirements are fulfilled, some will need to be re-evaluated once JPL has updated instrument;
  - Cal/Val tasks finalized; commissioning on-going;
- Ongoing/Upcoming Activities:
  - NWP Partners are evaluating JPL provided Near-Real-Time data;
  - NASA/JPL updating instrument s/w to track occultations more robustly;
  - ~ May 2021: instrument s/w upload and evaluation;
  - ~ May/June 2021: Near-Real-Time data assessment completed, data disseminated globally;
  - ~ July/August 2021: Non-Time-Critical data assessment completed, data disseminated to users;

Reprocessing:

- improved wave optics processing based CHAMP, GRACE, COSMIC, GRAS up to mid-2020 available (on request);
- very good agreement with UCAR and ROM SAF CHAMP, COSMIC, GRACE data sets;

EUMETSAT Activities:

- Metop-A GRAS ionospheric extension evaluated, continuous measurements on all Metops planned for later 2021;
- Updated reprocessing being prepared.

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