Updates on the EUMETSAT Occultation Prediction Product and Introduction of a new reprocessed GRAS Data Set

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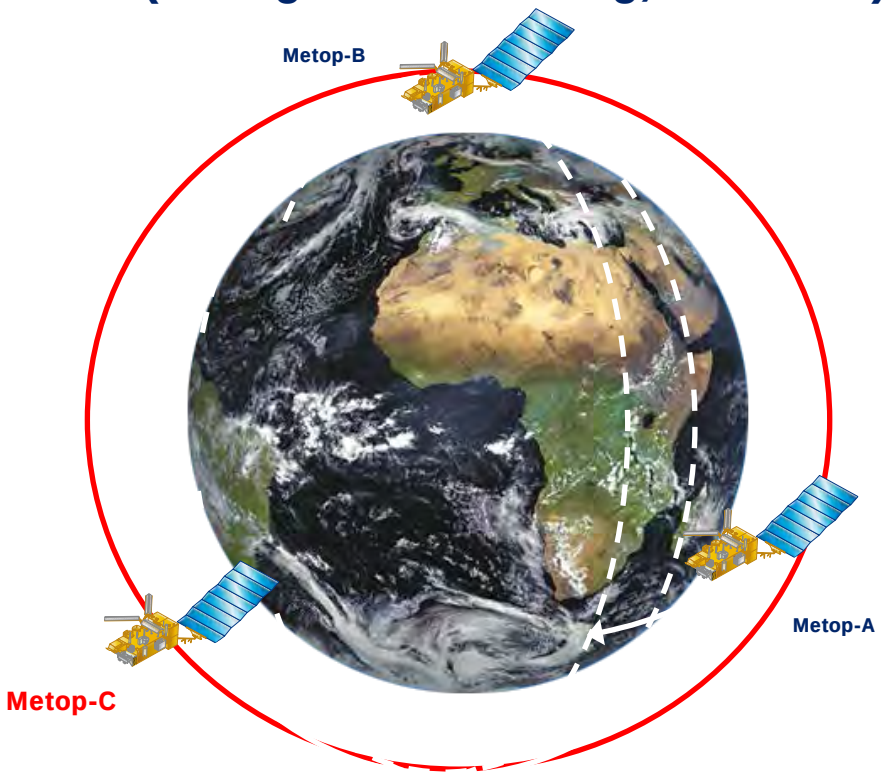
Content

- EPS:
  - 2018 Completion of the “Constellation”: Metop-C
  - Occultation Predictions
  - Reprocessed Data Set of > 10 years of GRAS / Metop-A and -B
- EPS-SG:
  - Overview
- Jason-CS:
  - Overview

EPS: “Constellation” Completion

- **Metop-C**
  - Launch planned, 19 September (00:47 UTC, 02:47 CET)
    18 September (21:47, Kourou local time)
  - **Will become prime satellite after commissioning**
  - **Transition with EPS-SG**
- **Metop-B**
  - **Present prime satellite**
  - **Will become secondary satellite**
- **Metop-A**
  - **Additional operational capacity, but in drifting orbit**
  - Until end of life/de-orbiting ~end 2021/early 22

Tri-star configuration (during commissioning, TBC after)



Sun-Synchronous Orbits, 14 Orbits/day
Nominal Inclination 98.7 degrees (North = 90 degree)
Nominal Local Time of Descending Nodes (LTDN) 9h30

Slide by M. Luger/R. Evans, EUMETSAT

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EPS: Occultation Prediction

Background:

- initially in-house development, provided on demand
- since June 2017, provided as “best effort / semi-operational” service; see also: link.
- provided for all Metop, GRAS instruments (thus including Metop-C from September)

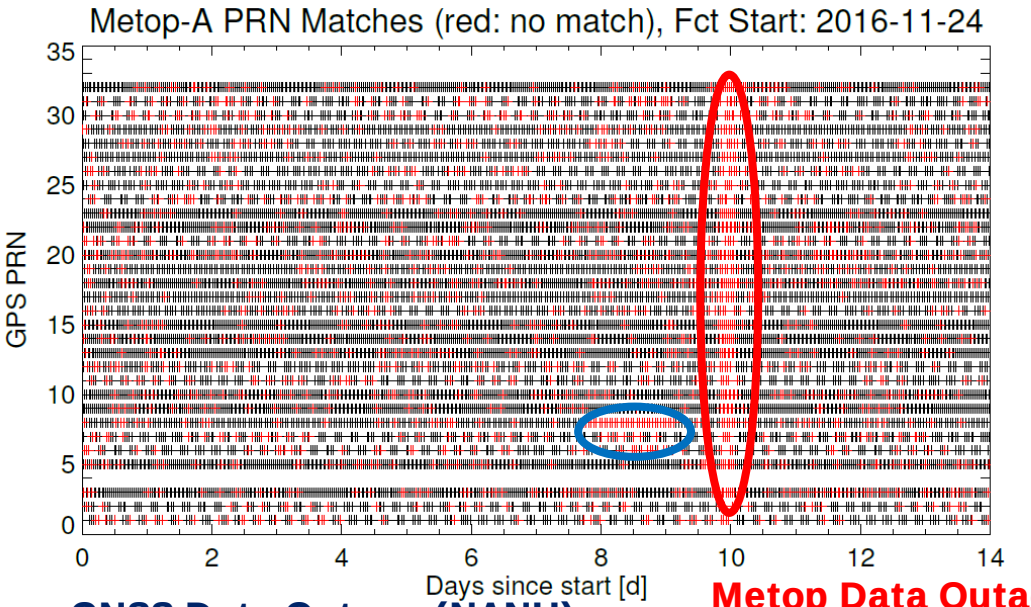
Status:

- providing all possible occultations over the next 14 days, plus the sub satellite points
- daily generation, usually provided within first 6h of the day
- noted 10 day interruption in Jan 2018, otherwise continuous provision
- but generally about 80+% are actually observed by GRAS instrument

Next Steps:

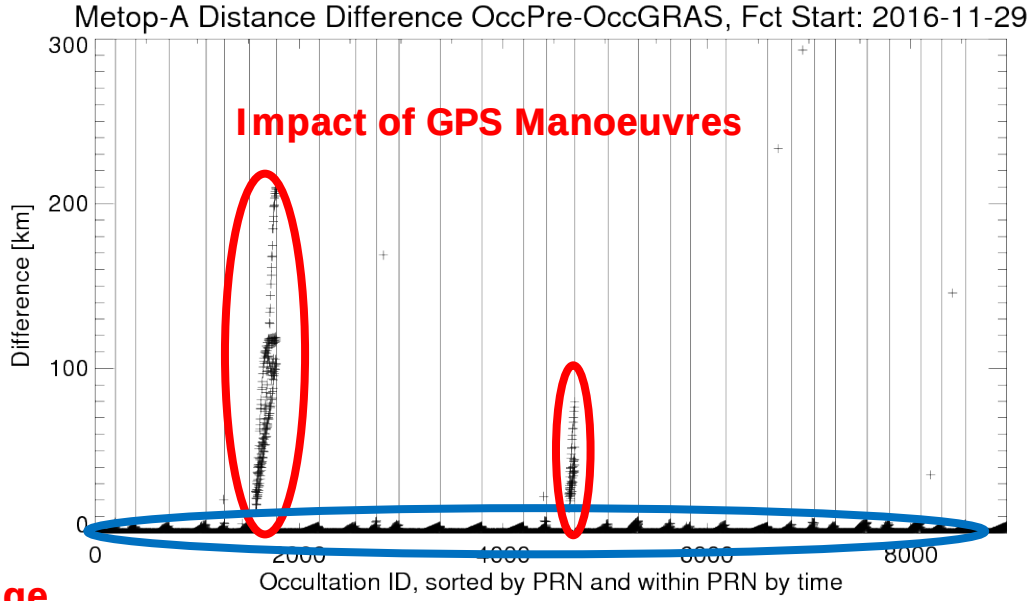
- work on more robust, operational provision, currently exploring options (a complication is the “unusual” daily delivery, all other EPS products are provided as quickly as possible, within e.g. for EPS a 2h 15min timeliness)
- work on improved prediction quality indicator:
  - identifying cause for GRAS failures and flag those, err on the side of caution
  - removing very short occultations (are currently marked with quality = 0 already)
  - include GNSS and LEO maneuver (and campaigns) where possible
  - further analysis instrument vs. predictions to understand limitations
  - further analyze the actual GRAS data quality vs. the prediction

EPS: Occultation Prediction: Reminder



GNSS Data Outage (NANU) due to Manoeuvre

Metop Data Outage due to Manoeuvre



Impact of LEO Manoeuvre

(left) Example of GPS occultation prediction matches against GRAS observations over the 14 day prediction period (on average about 85% or predicted also observed by GRAS);
(right) generally high accuracy in reference position prediction achieved, but LEO and GPS maneuvers impact the predicted occultation location accuracy; small LEO maneuver impact (on day 9) visible for each GPS satellite towards the end of prediction period (small ripples); large impact of GPS PRN 08 and 17 visible for these GPS satellites.

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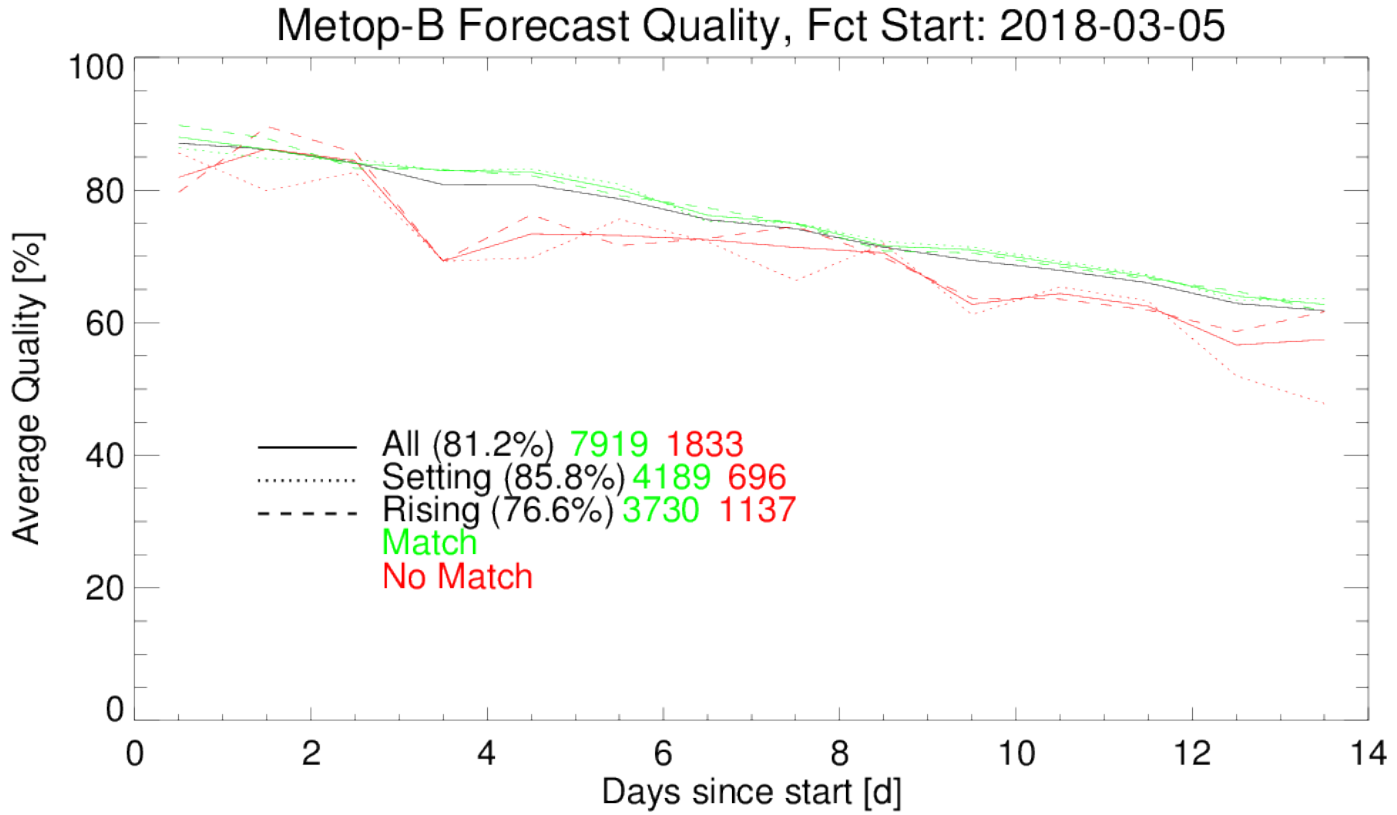
EPS: Occultation Prediction: Quality Indicator

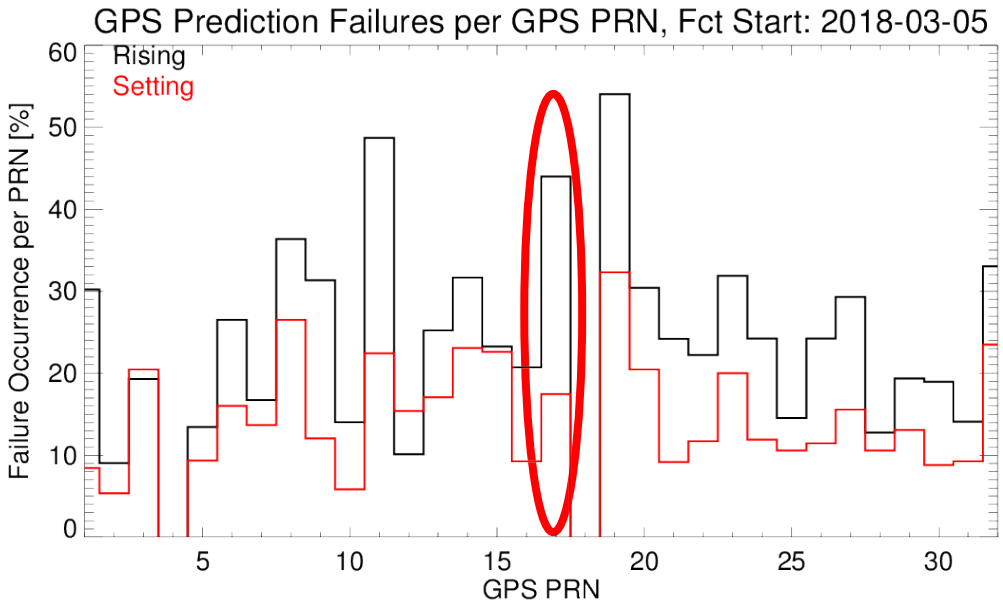


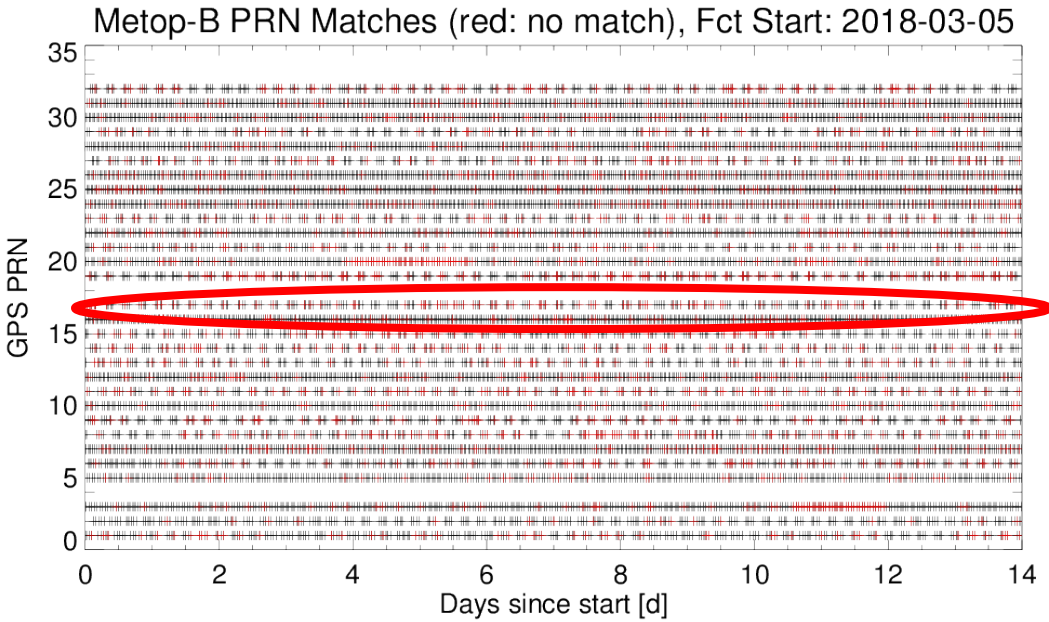
Example of GPS occultation prediction quality, separated for setting/rising and for those actually matched/unmatched, over the 14 day prediction. Current quality setting are based on:

- reduced quality over time (linear, by 30% over 14 days)
- occultation is on the edge of the occultation antenna
- Note: setting/rising not separated, though obvious that this impacts predictions
- Note also: this is an example with 2 GPS satellite outages, thus quality indicator rather poor

EPS: Occultation Prediction: Reassessing Failures

Recent prediction vs. actual observations separated in setting/rising and per GPS PRN (left) and failures per GPS PRN (right)





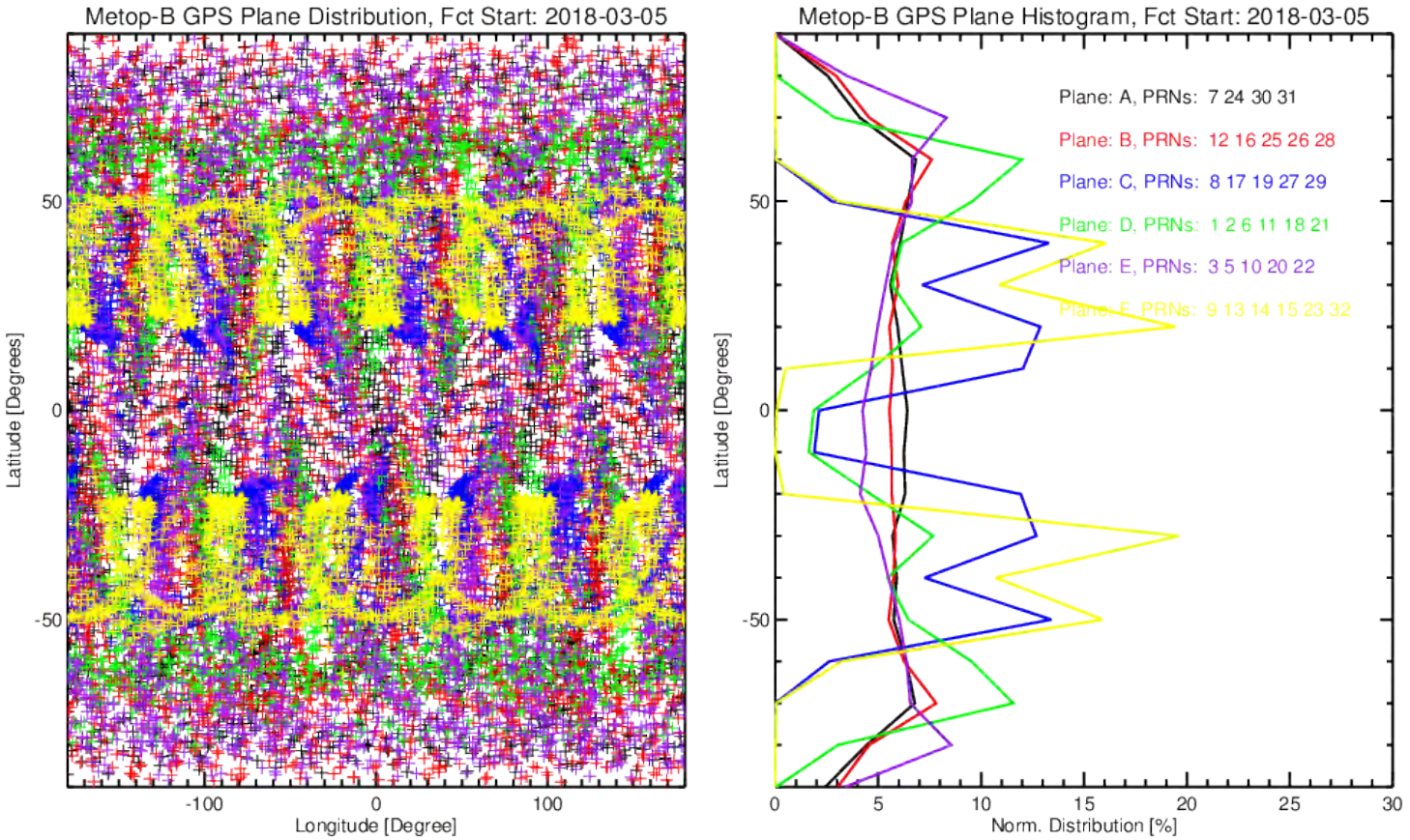
Fairly large difference between rising and setting for some satellites, e.g. PRN 17

PRN 17 also with few occultations predicted

-> indicates rising occultations more difficult to track when generally low number of predictions are made for a certain GPS satellite

EPS: Occultation Prediction: GPS Plane Investigation

Recent prediction vs. actual observations separated per GPS Plane over latitude and longitude (left) and histogram of predictions per GPS plane (right)



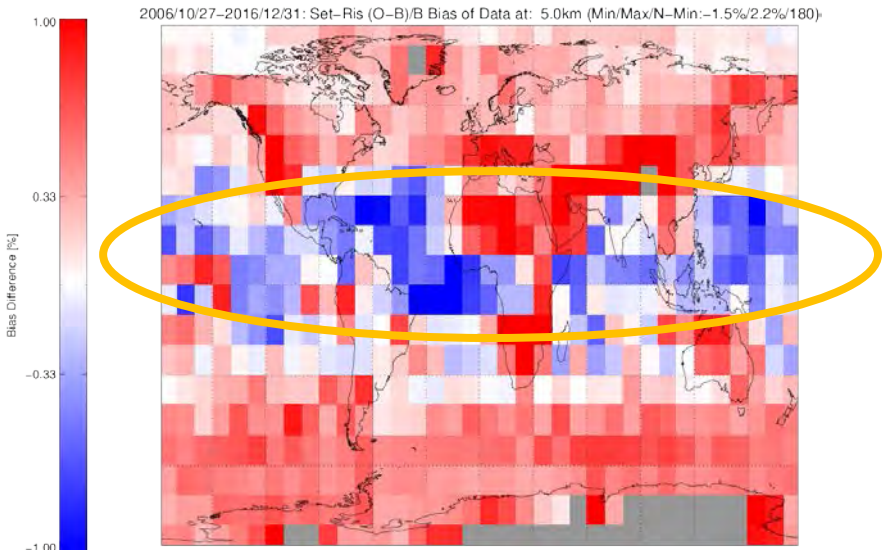
-> indicates certain GPS planes have only observations at certain latitudes, e.g. Plane F, likely due to unfavorable geometry. This can be used as additional quality indicator, flagging in particular rising occultations within this geometry.

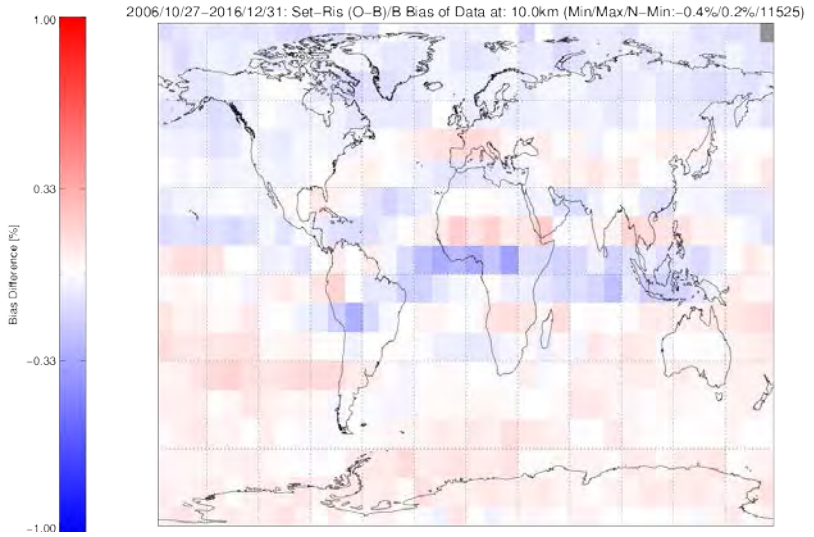
EPS: Reprocessed GRAS Data: Setup

- reprocessing of GRAS, COSMIC, CHAMP:
  - GRAS v1.4 reprocessing finalized (Metop-A and -B up to 2016, shown here); COSMIC/CHAMP from level 0 ongoing
  - Internal GRAS validation done; validations of / against:
    - Orbit, Setting/Rising, AM/PM Wobble
    - ECMWF ERA-I (GRAS later assimilated, has however no discontinuities)
    - UCAR GRAS data (metopa2016 stream – direct match)
    - COSMIC data (cosmic2013 stream – 3h, 300km match)

      -> Selected Examples shown
  - Long term trends:
    - using neutral bending angles directly

EPS: Repro GRAS Data: Set/Ris Diff

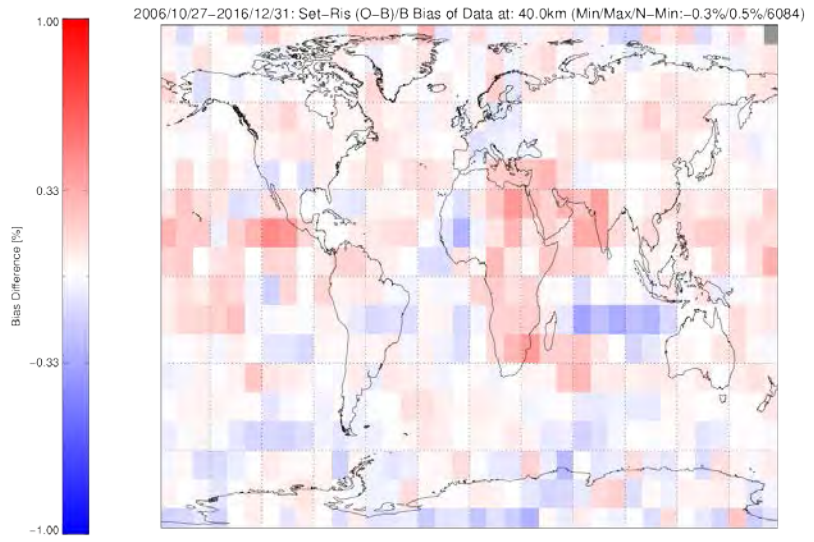




Setting / Rising (O-B)/B bias difference has some geographical patterns at lower altitudes.

Metop-A GRAS reprocessing v1.4 (O-B)/B of setting vs. rising difference [%] . Top left: at 5km impact height ; top right: at 10km; bottom right: at 40km.

Note: total difference out of colour scale for top left.



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EPS: Repro GRAS Data: ERA-I

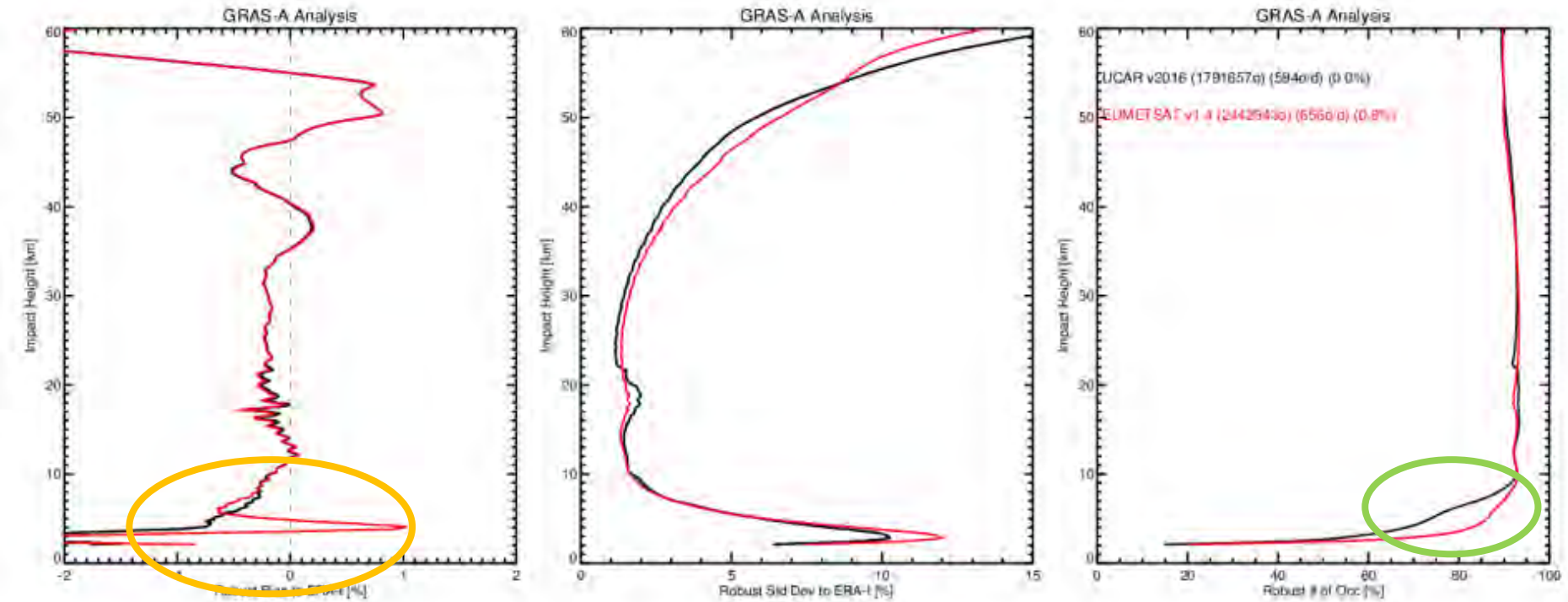

Figure 2 Metop-A GRAS reprocessed bending angle comparison to ERA-Interim forward propagated ones for the complete Metop-A GRAS data record, by UCAR at version 2016 and EUMESAT at v1.4. Robust bias (right), standard deviation (middle), outlier distribution (right), otherwise as Figure 1.

Different bias structures due to processing setup

Improved EUMETSAT penetration to lower altitudes

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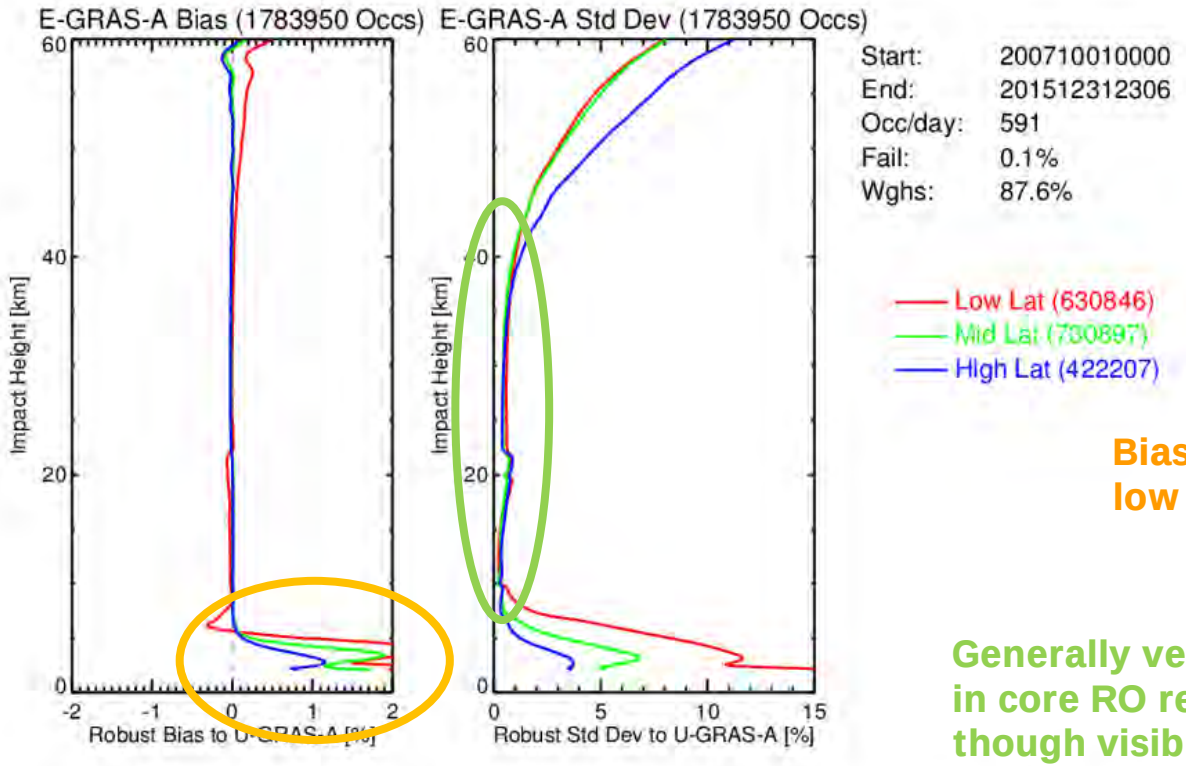
EPS: Repro GRAS Data: Matches GRAS



Bias at all latitude bands, strongest at low latitudes

Generally very good agreement / low noise in core RO region (UCAR switch GO / WO though visible).

Figure 7 $(O_1\text{-}O_2)/O_2$ matches of Metop-A v1.4 reprocessing with UCAR Metop-A 2016 data for different latitude bands using robust statistics; (left) bias, (right) standard deviation, legend gives further information on the data coverage, the averaged number of matched occultations per day, the number of failures (e.g. if no overlapping data is found), as well as the robustness/weight of the statistics. The total number of occultations entering, as well as per latitude band is given in brackets in title/legend.

EPS: Repro GRAS Data: Match Long Term

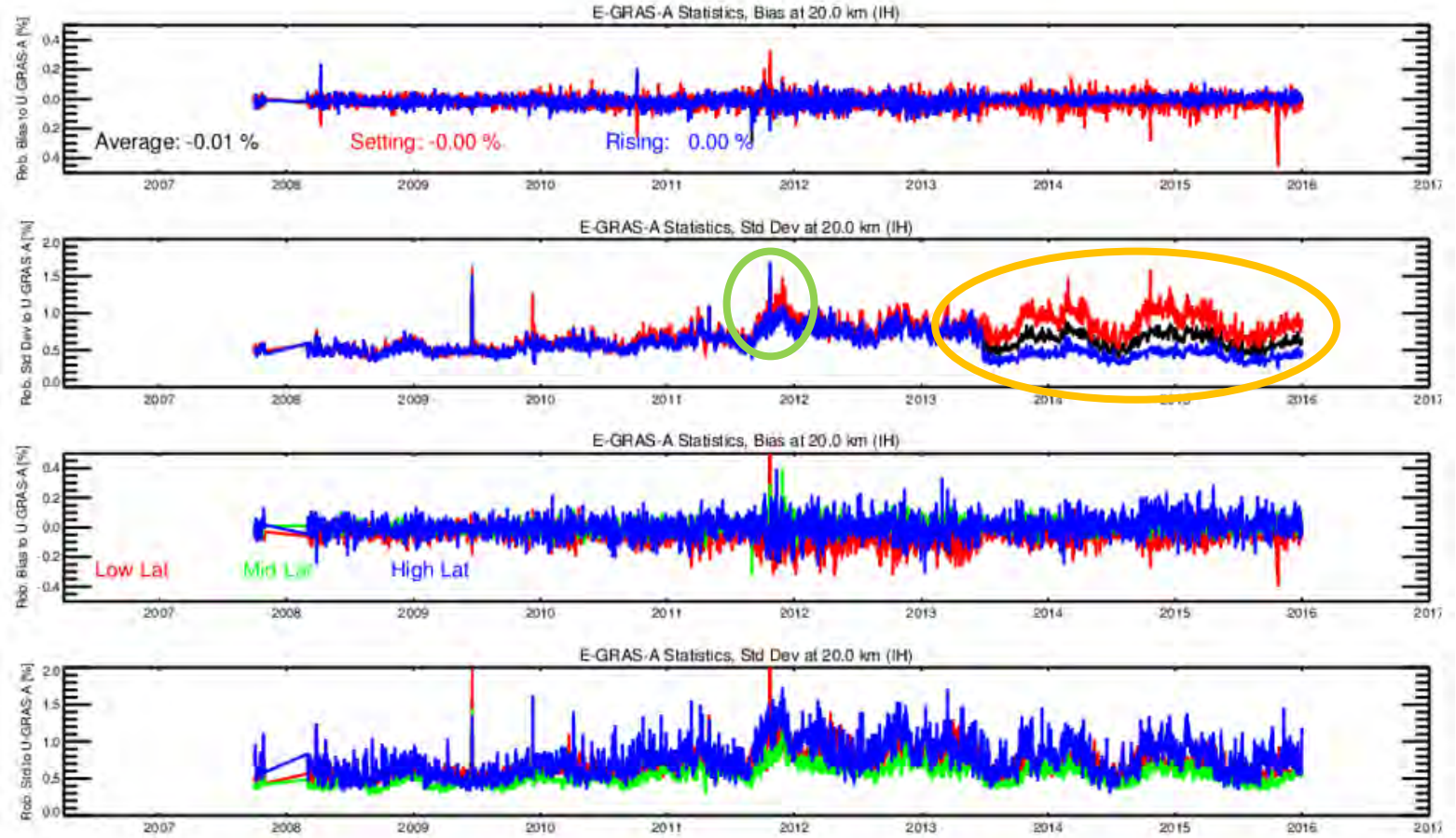
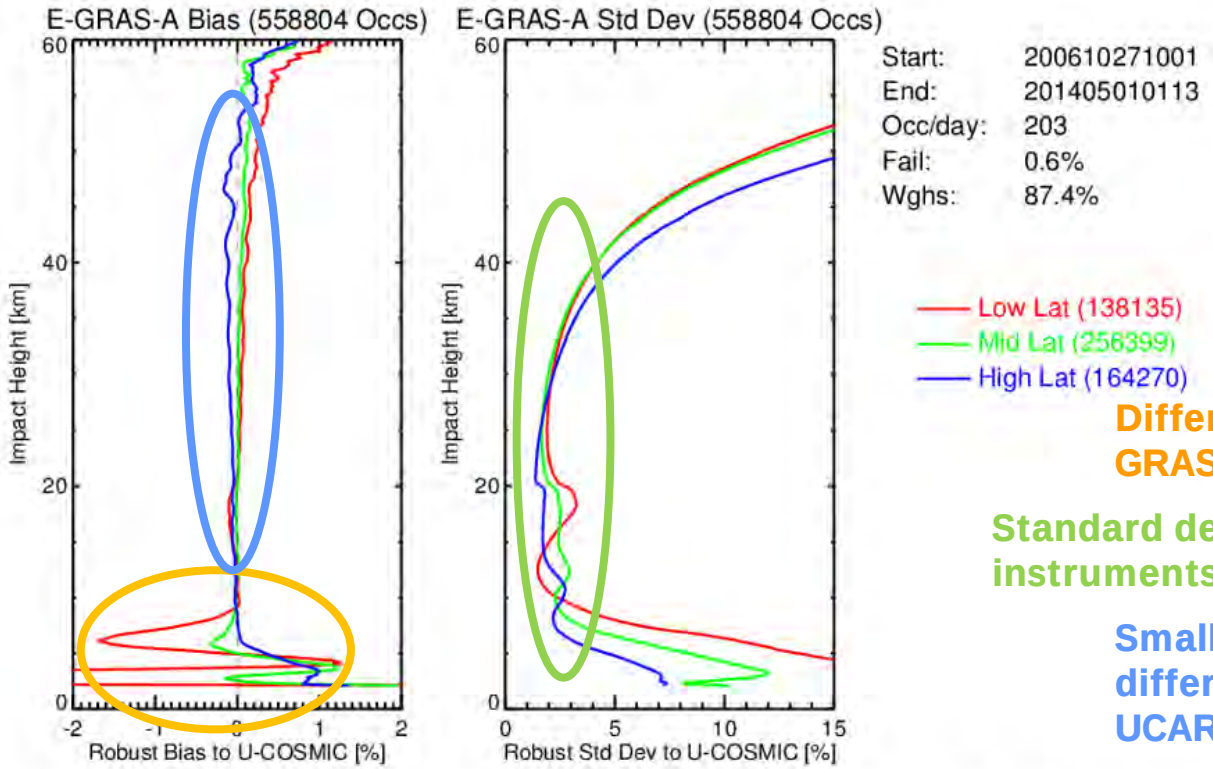


Figure 8 (O_1-O_2)/O_2 matches of Metop-A v1.4 reprocessing with UCAR Metop-A 2016 data at 20km, daily averaged using robust statistics; (top) bias, (middle top) standard deviations for all/setting/rising; (middle bottom) bias, (bottom) standard deviations for different latitude bands. Average bias is also given, seperated for setting/rising/all.

Setting / Rising standard deviations change with instrument update first campaign mid-2013 (more L2 extrapolation afterwards)

Solar cycle 24?

EPS: Repro GRAS Data: Matches GRAS/COSMIC



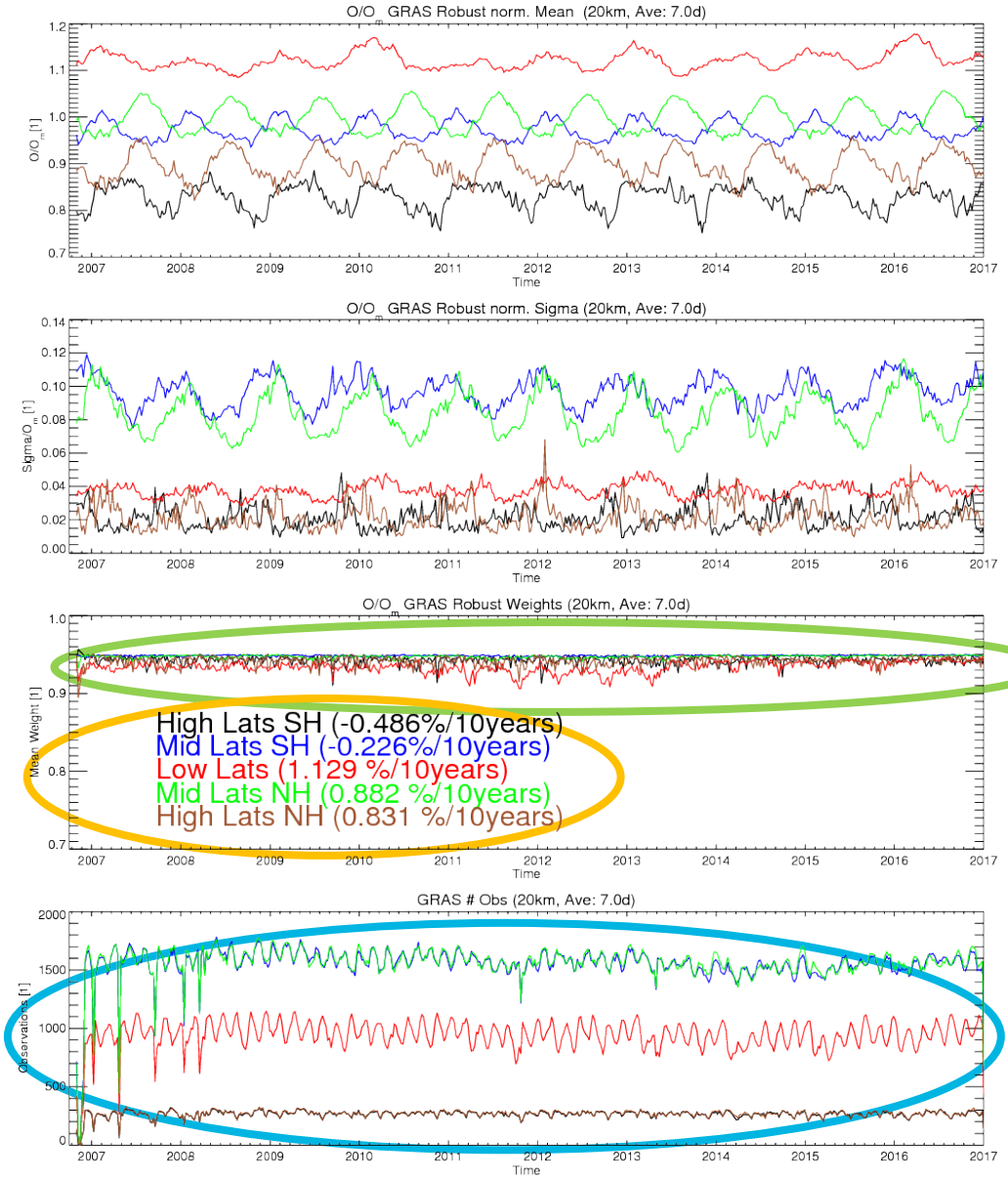
Different bias structure compared to GRAS EUM / UCAR matches

Standard deviation increased since 2 instruments / locations are compared

Small biases visible, potentially due to different processing versions of UCAR / GRAS and UCAR / COSMIC data

Figure 9 $(O_1\text{-}O_2)/O_2$ matches of Metop-A v1.4 reprocessing with UCAR COSMIC 2013 reprocessed data for different latitude bands using robust statistics; (left) bias, (right) standard deviation, otherwise as Figure 7.

EPS: Repro GRAS Data: Trends at 20km



Reprocessing v1.4 trends at 20km, data averaged over 7days; (top) bias, (middle top) standard deviations, (middle bottom) weight, (bottom) number of occultations per interval, separated for different latitude bands. Note: bias, standard deviation normalized to average value at this altitude; compared to UCAR GRAS more data available here, UCAR uses more strict QC.

Trends not too be taken very seriously (simple fit)

High data quality through full period (also for Metop-B, though not shown)

Very stable number of occultations from about 2007 onwards

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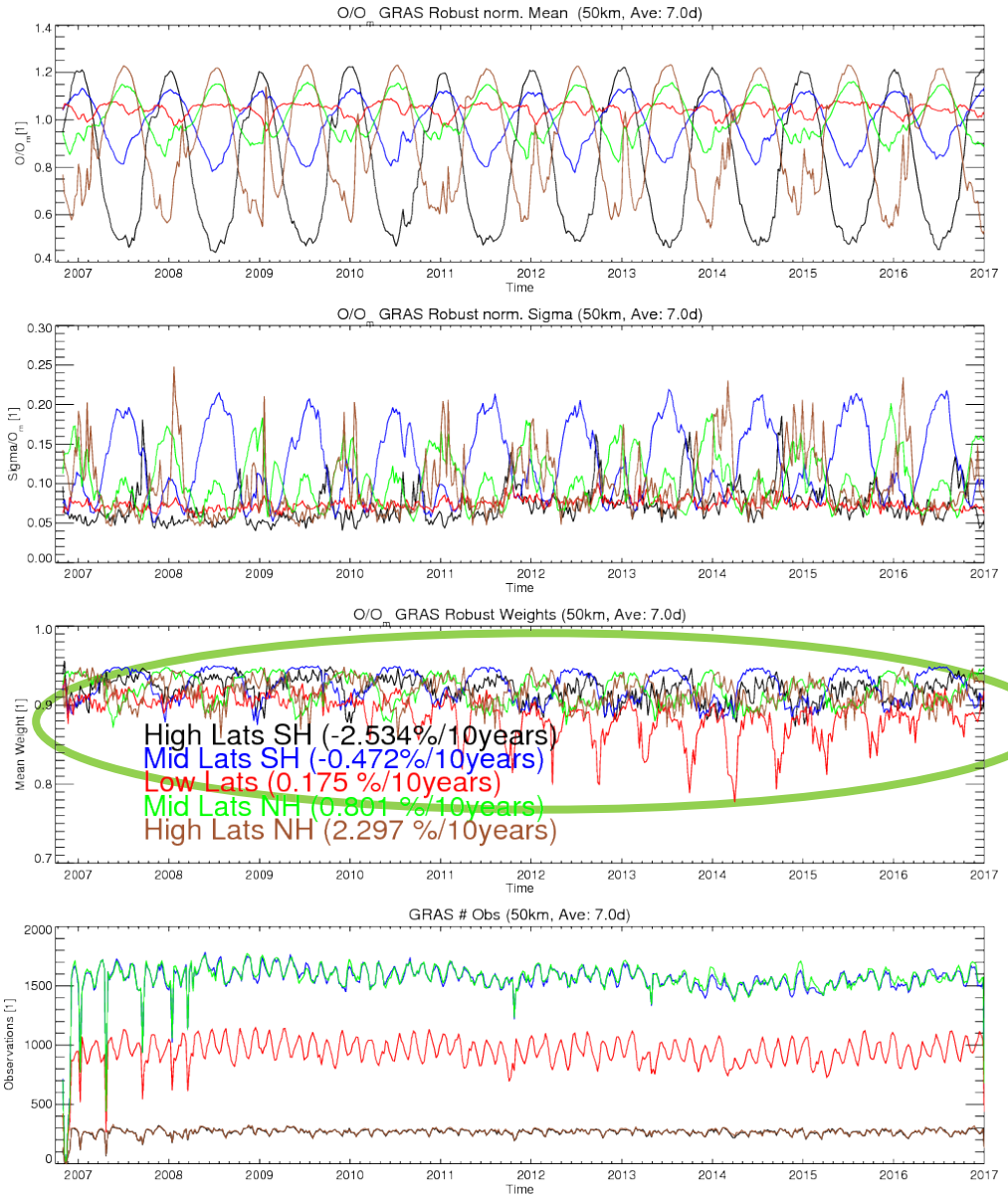
EPS: Repro GRAS Data: Trends at 50km



Reprocessing v1.4 trends at 50km, data averaged over 7days; (top) bias, (middle top) standard deviations, (middle bottom) weight, (bottom) number of occultations per interval, separated for different latitude bands. Note bias, standard deviation normalized to average value at this altitude. Trend simple robust line fit, take with caution.

Low latitude data quality show varying bi-annual pattern over the period

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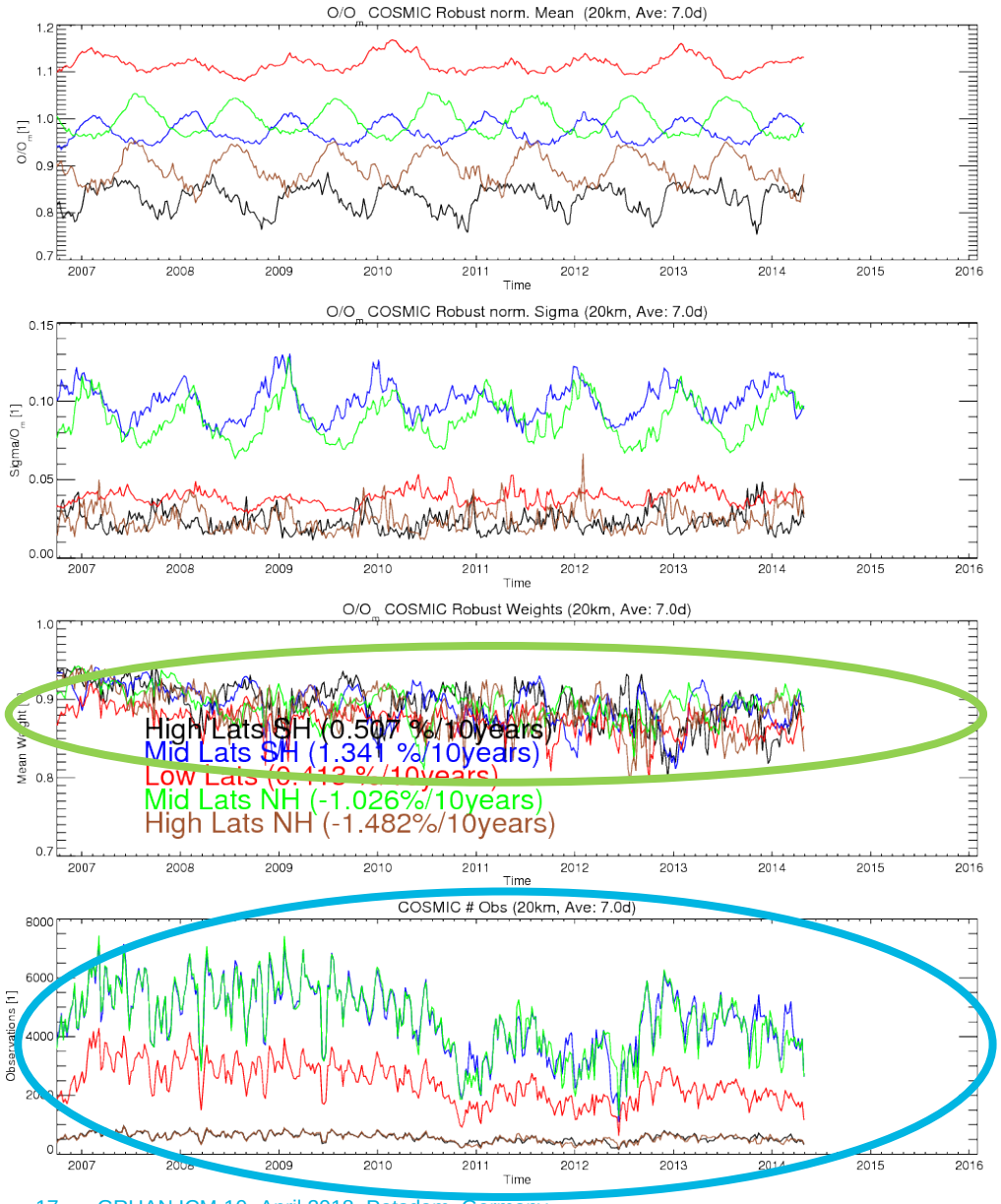
EPS: Repro GRAS Data: COSMIC at 20km



Reprocessing cosmic2013 trends at 20km, data averaged over 7days; (top) bias, (middle top) standard deviations, (middle bottom) weight, (bottom) number of occultations per interval, separated for different latitude bands. Note bias, standard deviation normalized to average value at this altitude. Trend simple robust line fit, take with caution.

Data quality degradation visible over period

Highly varying number of occultations over period

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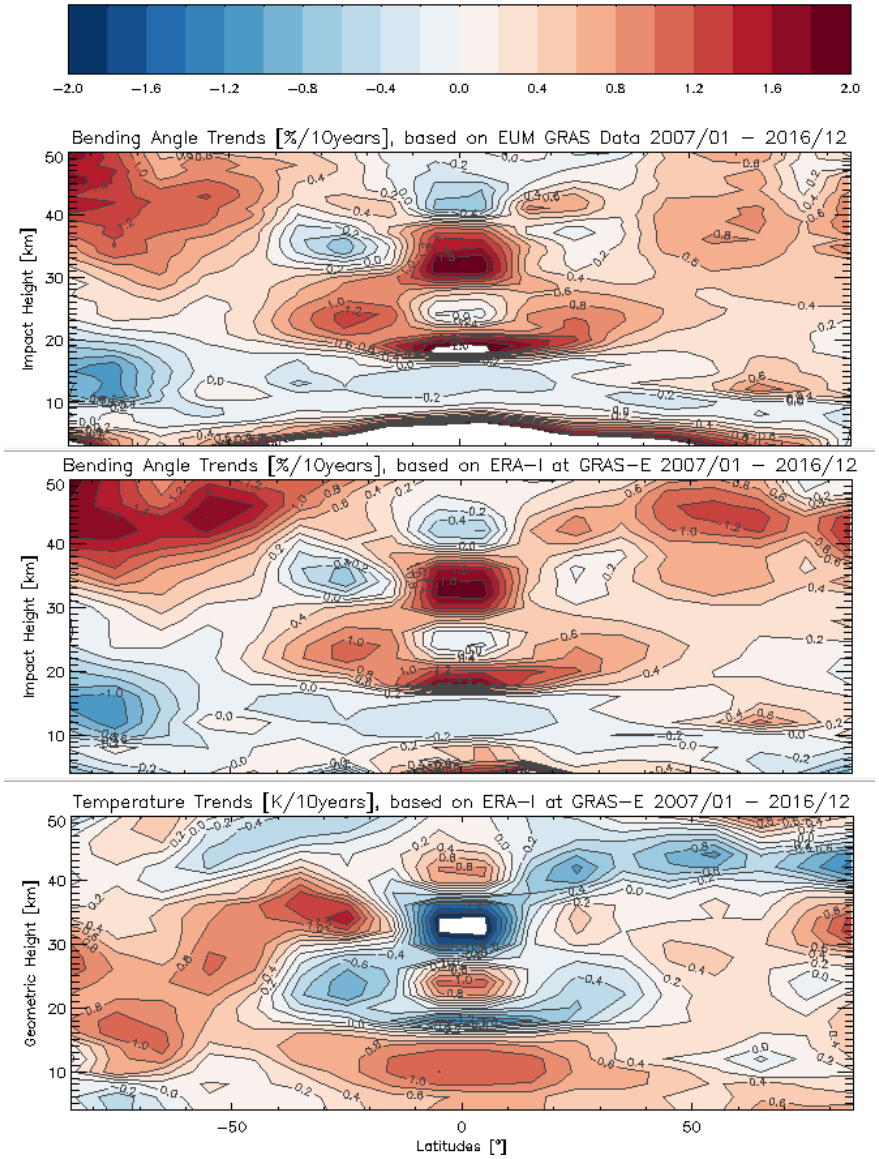
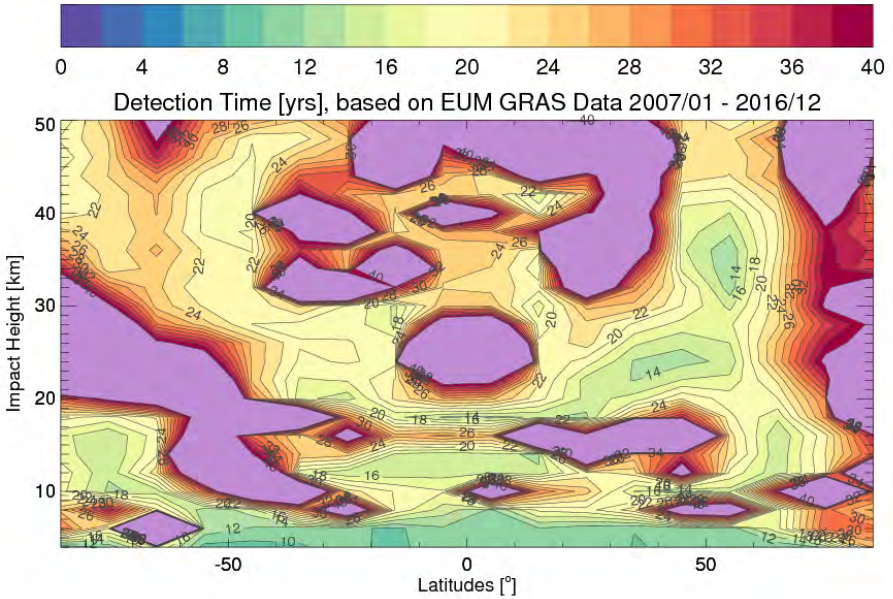
EPS: Repro GRAS Data: Trends?



(left): Reprocessing v1.4 bending angle trends for 10yrs of GRAS / Metop-A data, after seasonal correction (top); ERA-I bending angle trends at GRAS locations, after seasonal correction (middle); ERA-I temperature trends at GRAS locations, after seasonal correction (bottom). Note: no sampling correction applied. (bottom): detection time of trends (purple >40yrs)



With inputs from S. Healy / ECMWF and M. Ringer / UKMO

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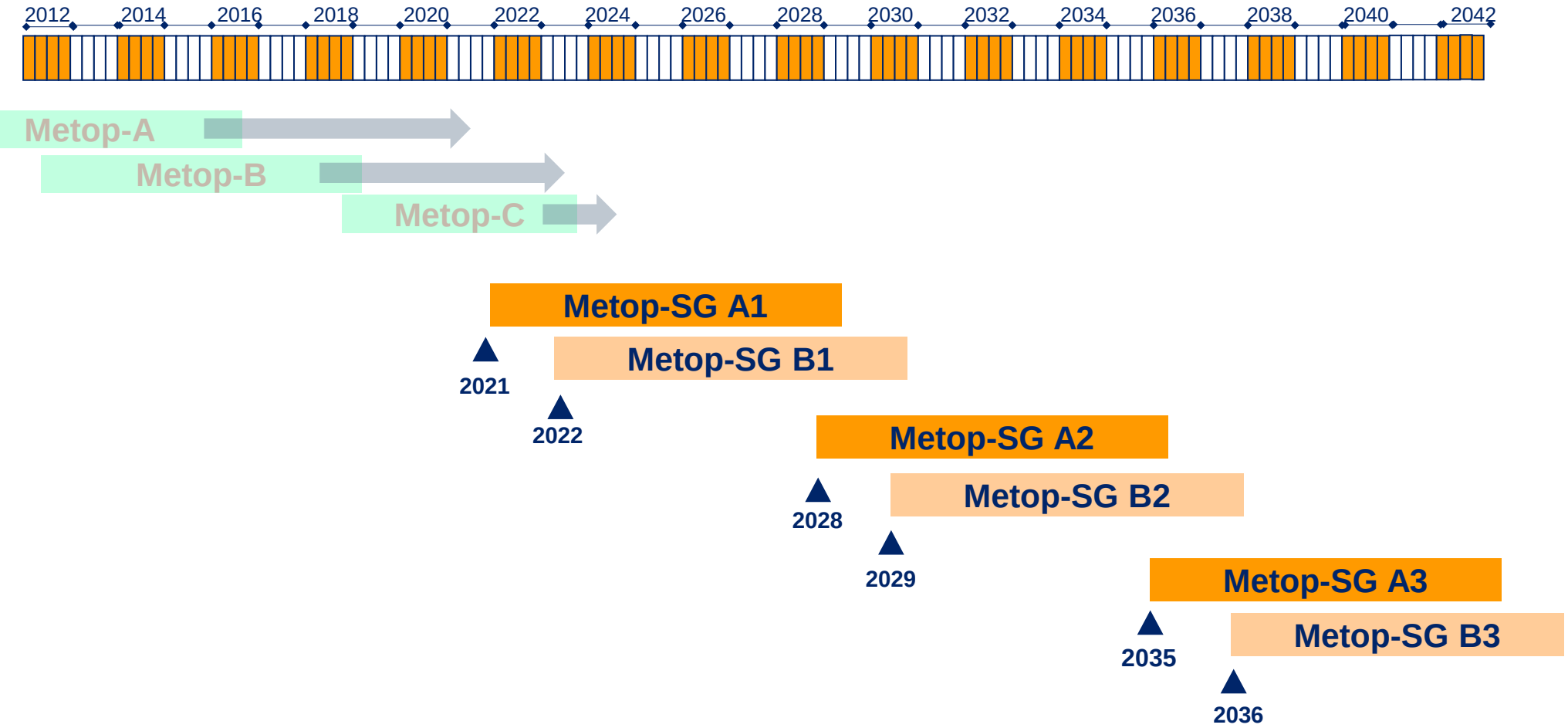
EPS-SG: Overview: Satellites Deployment Schedule



Satellite nominal lifetime: 7.5 years (9.5 years extended)
Satellites will be actively de-orbited
All carry RO instrument, GPS + Galileo (BeiDou, GLONASS).

Slide by G. Kayal, EUMETSAT. modified

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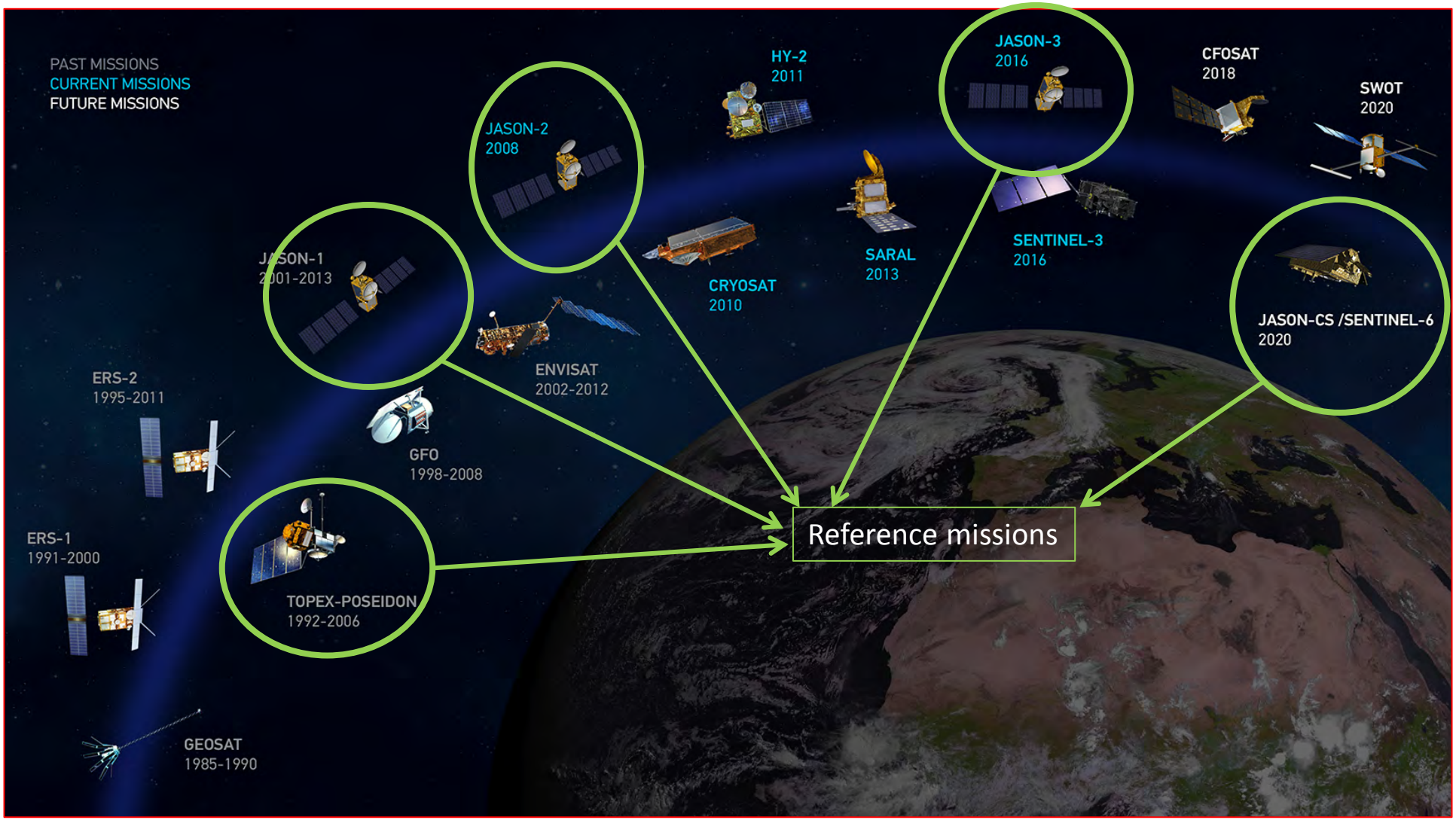
Sentinel-6/Jason-CS: Background Altimetry



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Summary / Future Steps

- EPS:
  - Metop-C launch in Sep 2018, expect several years of 3 Metop coverage
  - occultation predictions: 14 days in advance, targeting e.g. sonde launches, working on forecast quality improvements, will include all Metops (and also plan other EUM missions once available). Quality improvements ongoing.
  - 10 yrs+ GRAS reprocessed data: showing highly consistent, high quality data, currently needs EUM agreement for release; other missions ongoing
    - will be further processed by ROM SAF for refractivity, temperature, water vapor, available ~Q3 2018
- EPS-SG:
  - first launch in 2021 timeframe, 6 satellites all with RO
- Jason-CS:
  - Altimetry main focus of mission, first launch in 2020, 2 satellites with RO
  - RO NRT (3h) service by JPL, RO NTC by EUMETSAT (and JPL?)