GRAS Occultation Predictions

RO Team @ EUMETSAT

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Overview

- Background
- Setup
- Format
- Accuracy and Quality Information
- Summary and Next Steps/Future Work

Background

- Based on accurate GNSS and LEO orbits, one can determine where future occultations are expected (with some uncertainty)
- EUMETSAT has developed a product that provides expected GRAS occultation positions up to 2 weeks into the future, as well as the Metop satellite positions (sub-satellite point)
- Product is currently provided for evaluation, user announcement out, feedback by 31st of Aug 2017
- Occultation prediction product addresses e.g. action 3G-7 of WMO WIGOS GRUAN-GSICS-GNSSRO Workshop on Upper-Air Observing System Integration and Application, Geneva, May 2014
- Allows to schedule observations (e.g. radio sonde, Lidar, etc) to coincide with potential RO observation
- Allows additionally to schedule observations to coincide with the Metop nadir sounder (e.g. IR and MW instruments) overpass

Setup

Daily 2 week forecast generation of orbit & occultation predictions:

- NAPEOS S/W for precise orbit prediction:
  - GPS orbits:
    - latest, precise GPS orbits, as provided by operational EPS/Metop GNSS service (GSN), 1 day fit, propagated into future
  - LEO orbits:
    - latest operational LEO Near Real Time orbit, 7 day fit, propagated into future
- Forecasts:
  - in house occultation prediction tool
  - up to weeks in advance, run daily
  - first quality info based on prediction day (using 30% decrease/14 days) & LEO antenna position
- Period investigated for validation / accuracy estimation:
  - Metop-A: late 2016 and early 2017 data
  - Metop-B: only visual inspection of data, showing no difference to Metop-A data
- Not operational, runs in offline environment with operational data!
- Product stream available here (Note: netCDF4 format)
- Product Format Specification with accuracy info available: here

NetCDF4 File Format / Product Summary

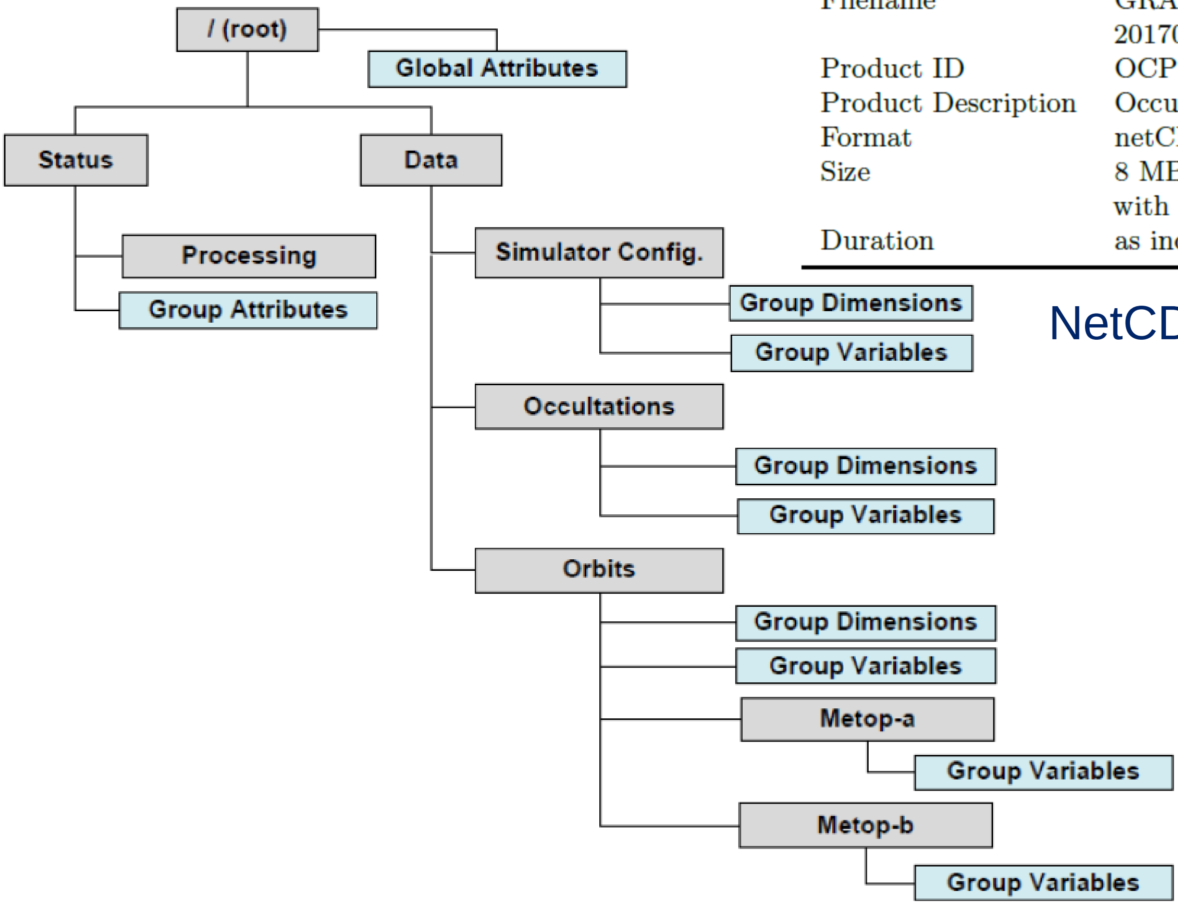

Fig. 2.1: Overall netCDF data group structure of EPS Level 1C file example, assuming Metop-A and -B orbits are covered.

Filename	GRAS_OCP_1C_XXX_20170101000000Z_20170115000000Z_20170101100000Z_YARx_OCCORBPRED.nc
Product ID	OCP
Product Description	Occultation/Orbit predictions for LEO satellites
Format	netCDF-4
Size	8 MB (e.g., for a Metop-A and Metop-B, 14 day predictions, orbits with 1 minute resolution)
Duration	as indicated in file name, here 14 days

NetCDF-4 file product summary sheet.

Note: New NetCDF-4 file format (earlier data provision was in netCDF-3).

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LEO Orbit Position Prediction Accuracy

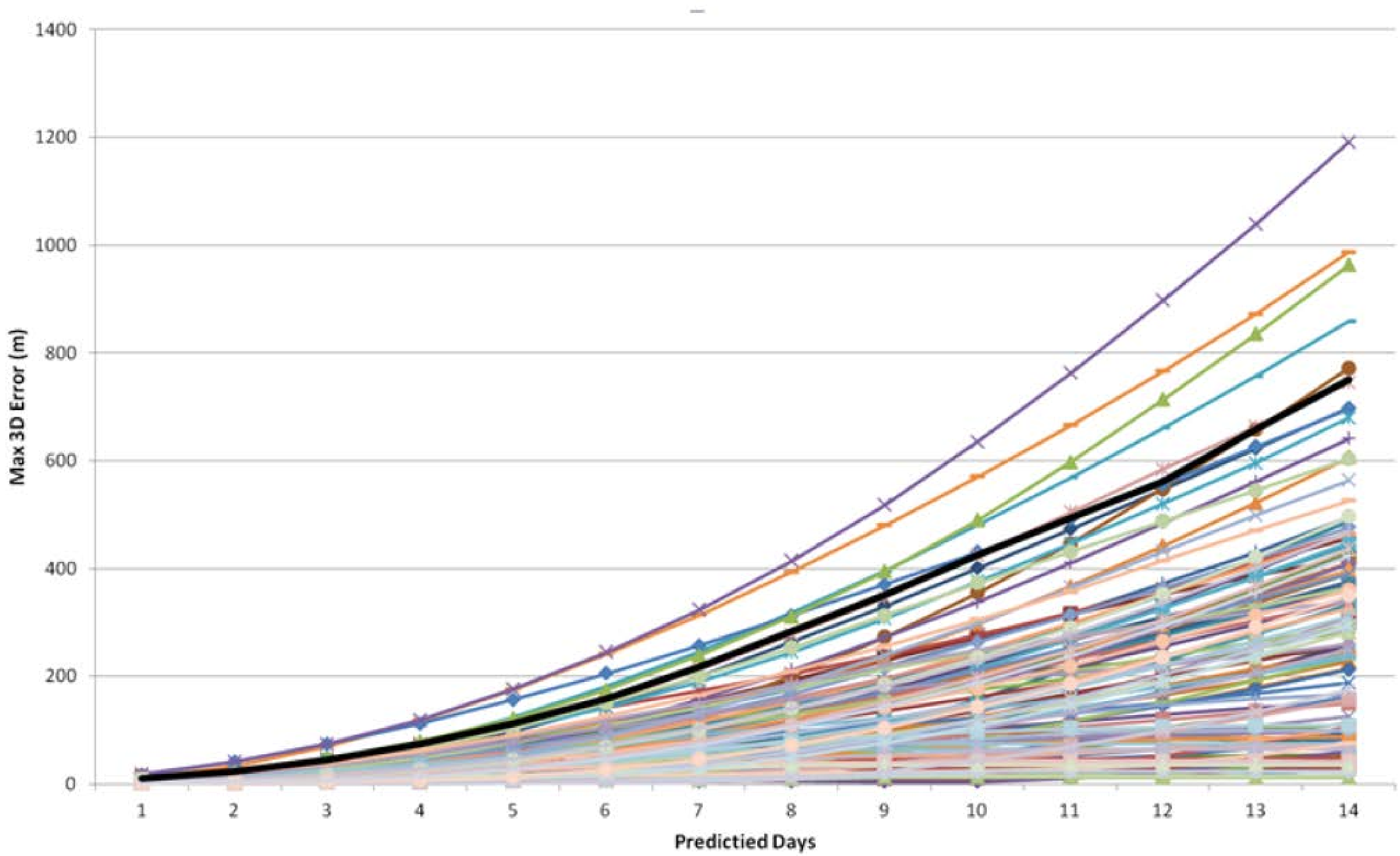


Fig. 4.1: 3D maximum errors over predicted days, for nominal conditions. Each line represents one run.

From PFS

Position Prediction Accuracy Example

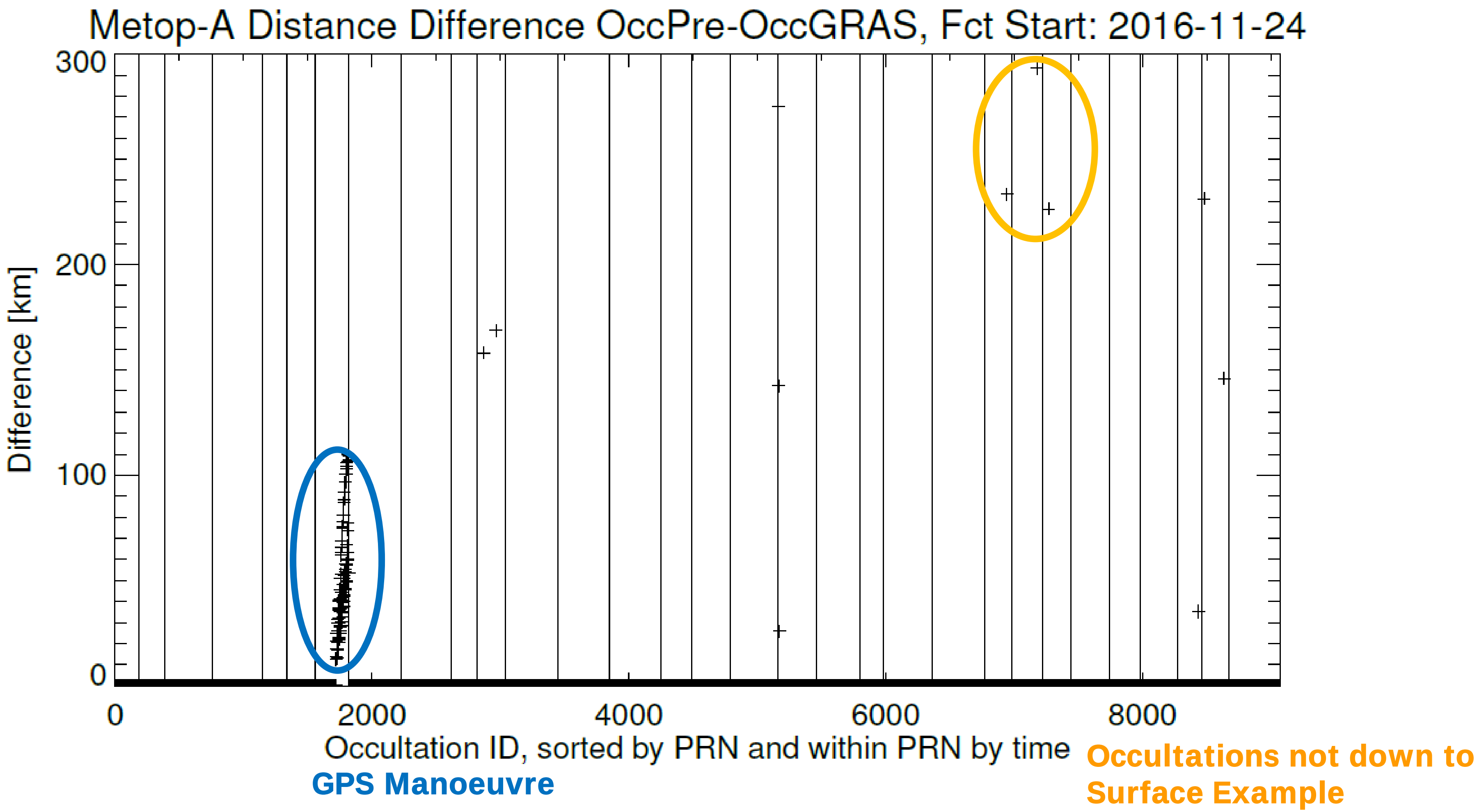
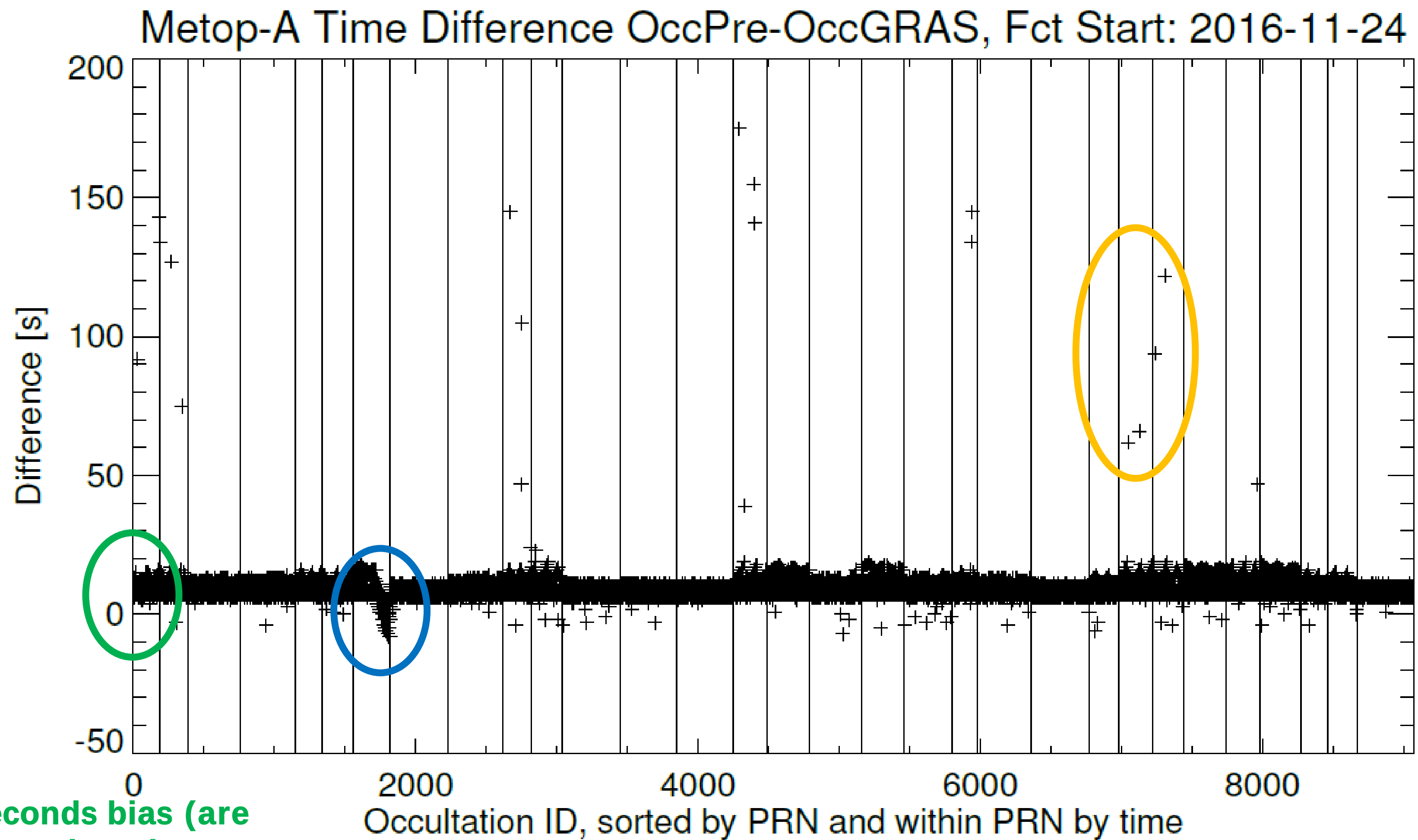


Fig. 4.2: Example of location prediction accuracy for all occultations; x-axis sorted by GPS PRN number and within each PRN by time, PRNs separated by vertical lines.

From PFS

Time Prediction Accuracy Example



Leap seconds bias (are in EUM product, but missing in validation s/w)

GPS Manoeuvre

Occultations not down to Surface/near ground?

Fig. 4.3: Example of time prediction accuracy, otherwise as Figure 4.2.

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GNSS Satellites Match/No Match Example

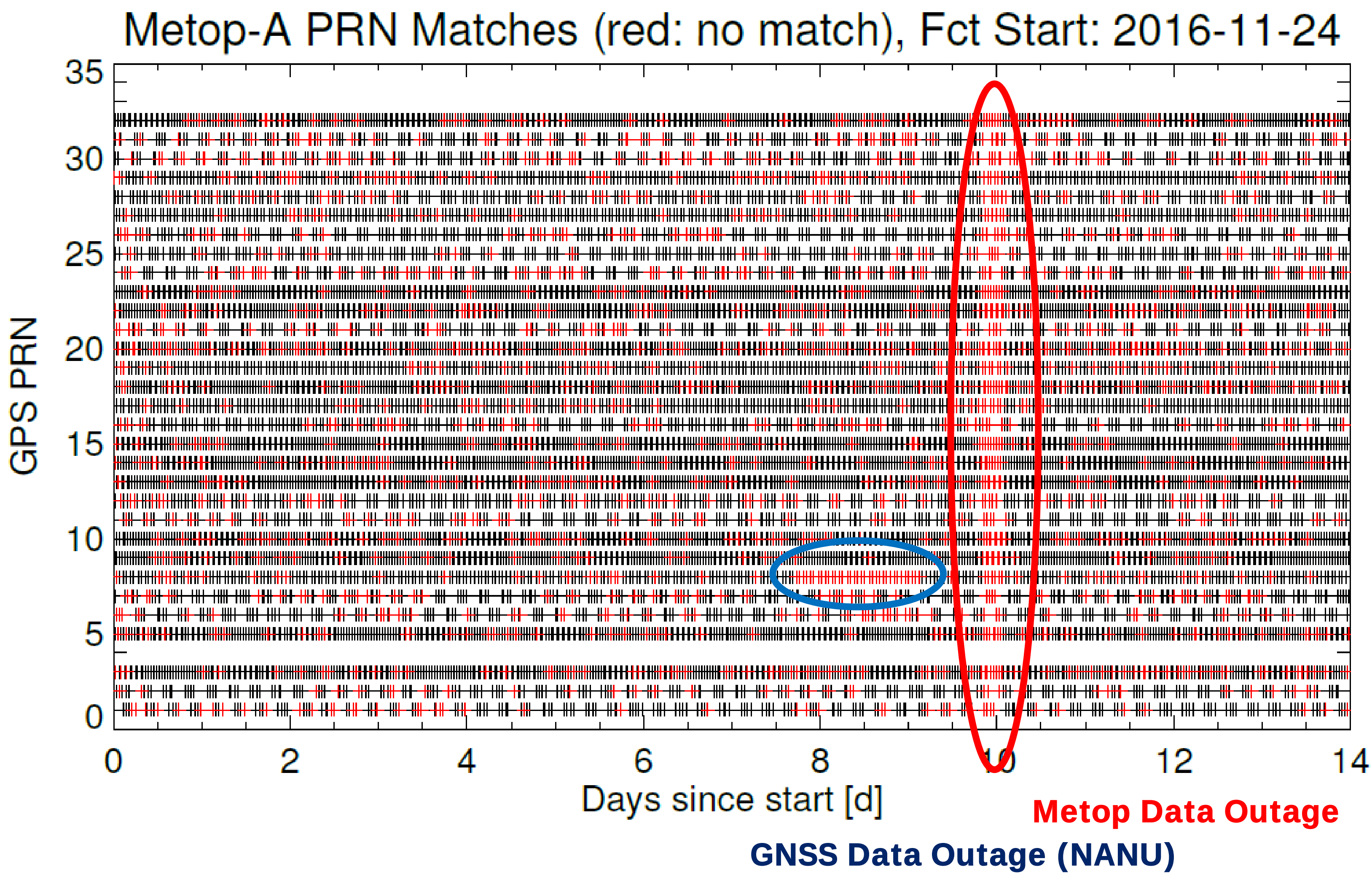


Fig. 4.4: Example of GPS prediction matches over the prediction period, showing an outage of GRAS data around day 10 and an unavailability of GPS PRN 08 starting near day 8.

From PFS

Quality Prediction Accuracy Example

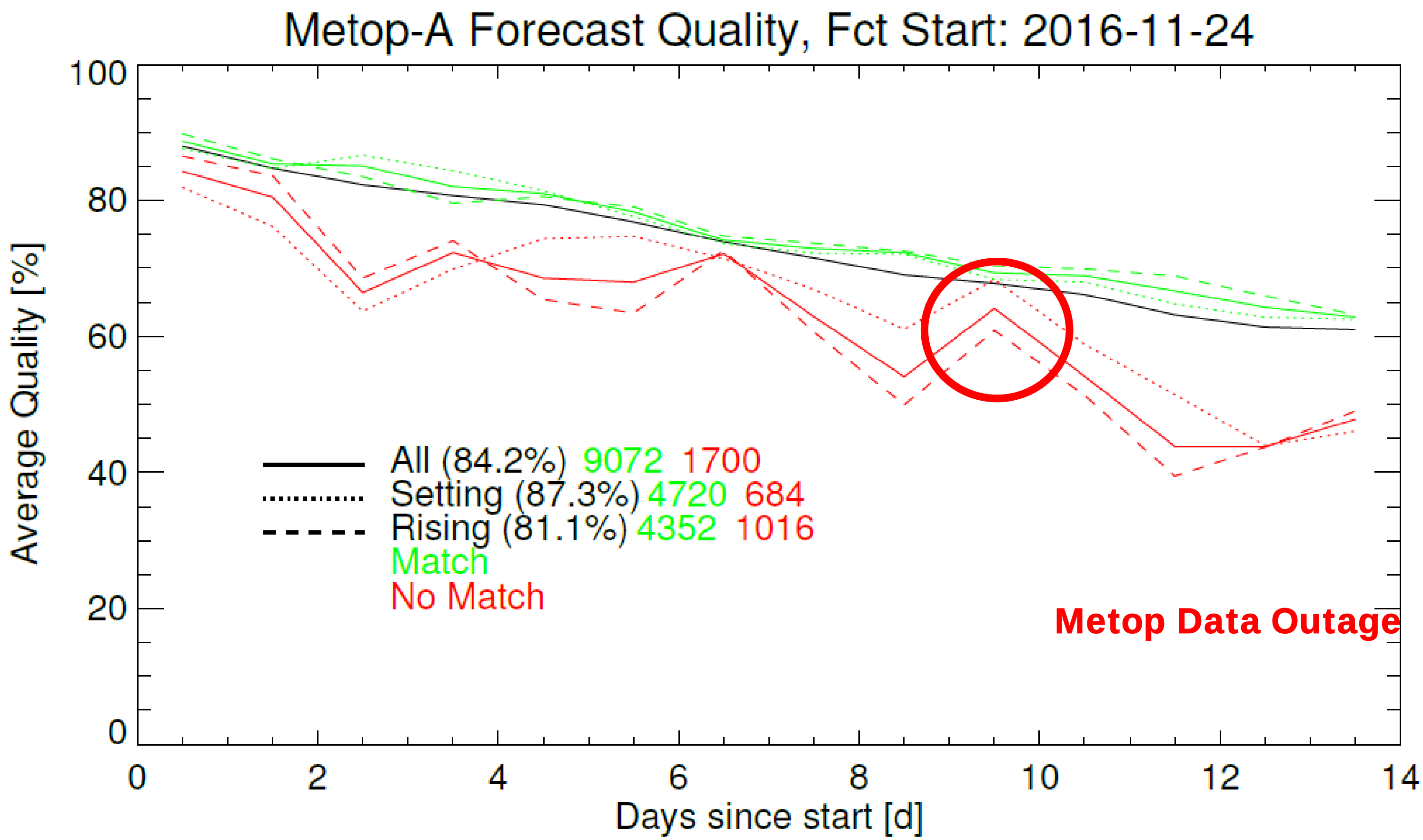
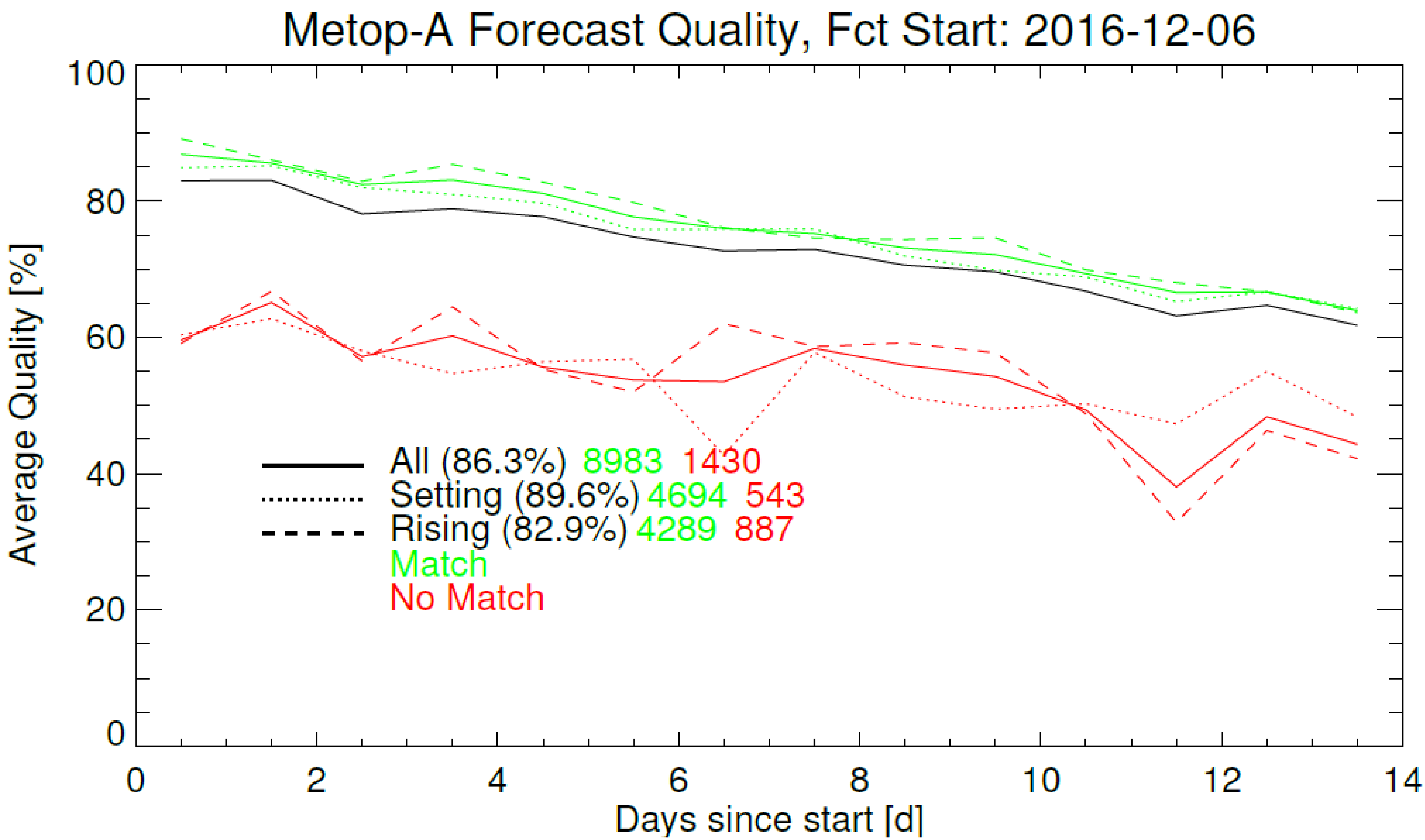


Fig. 4.5: Example of prediction quality information averaged daily over the prediction period, further separated for data that was matched (green), not matched (red), setting (dotted) and rising (dashed). Numbers in () indicate the mean quality over all corresponding occultations. The total number of occultations matched and not matched is also given.

From PFS

Prediction Failure - NANU Impact (1)



No NANU (GPS Outage Info) Use

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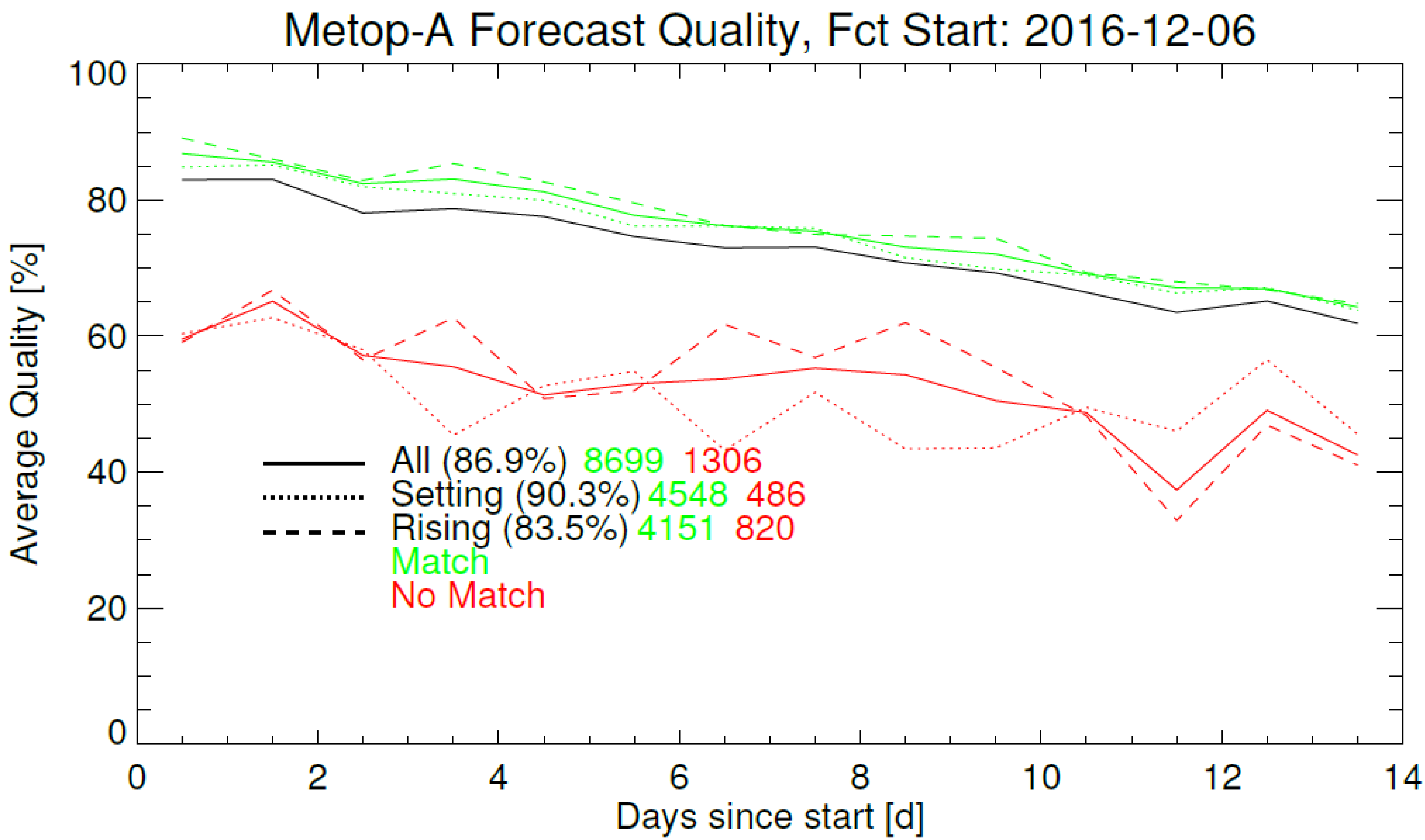
Prediction Failure - NANU Impact (2)



NANU Used for Testing

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Prediction Failure over LEO Antenna

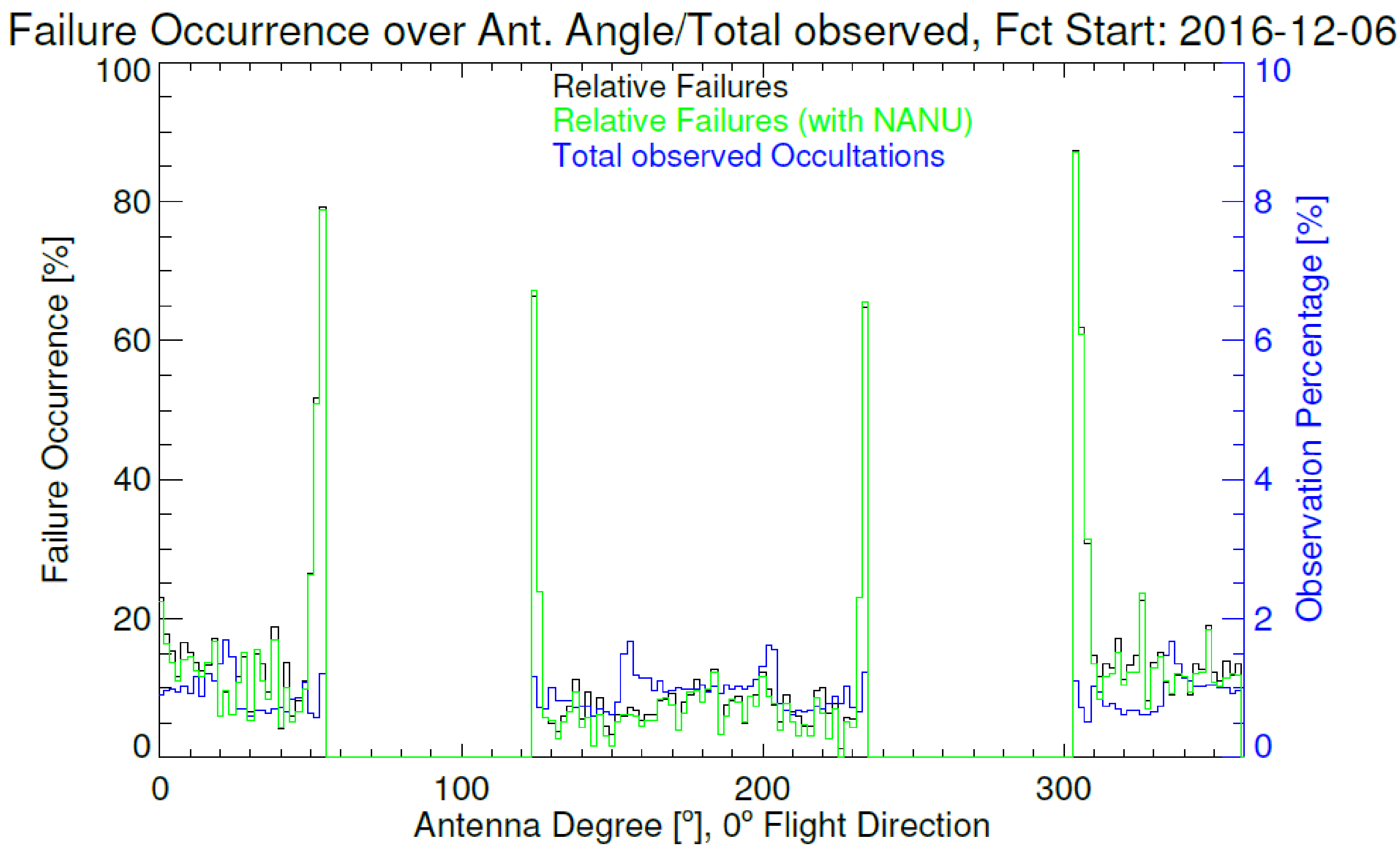

Fig. 4.6: Normalized occultation prediction failures over antenna azimuth, 0 Degrees is flight direction (rising occultations). Bin-size for all histograms is 2 Degrees, failures are shown without NANU (black) and with NANU information (green) taken into account; also shown in blue (right y-axis) is the normalized number of occultations per bin-size.

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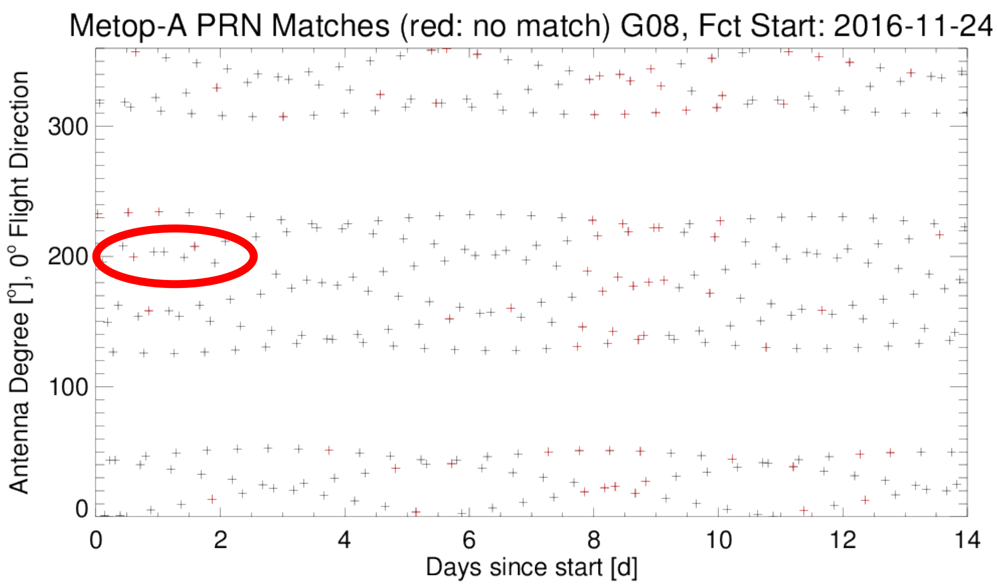
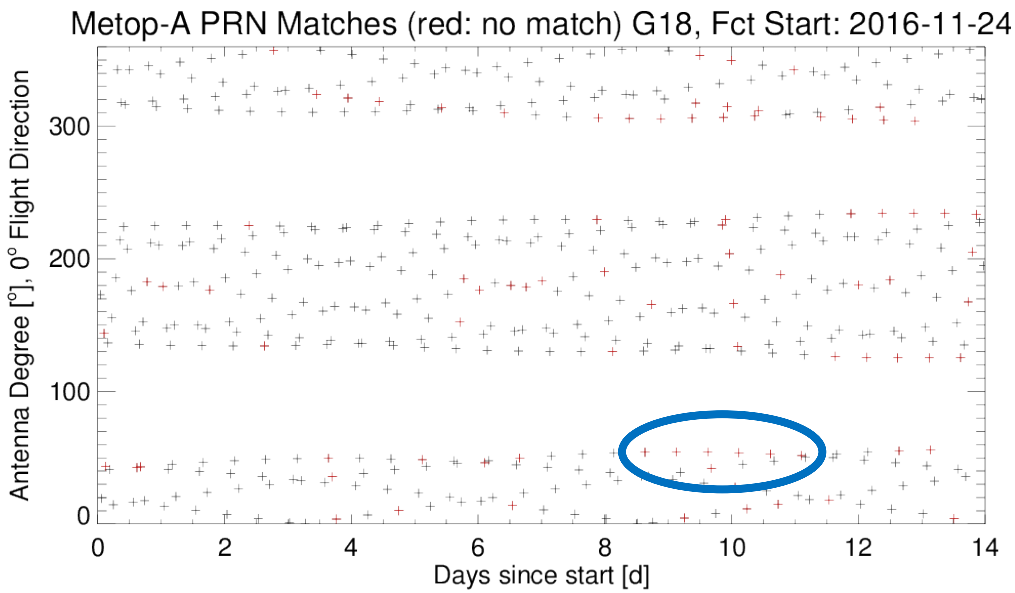
Prediction Failures on Incoming Antenna Angle

The SNR of RO observations decreases towards the receiving antenna edges. Hence more unmatched occultations are expected here. GRAS measures up to about ±55 Degree around the bore-sight of the antenna.

Actual situation for some selected period is less clear though:





Incoming antenna observation angle over the forecast period days for G08 (left) and G18 (right) GPS satellites; forecasting period starting on 2016-11-24. G08 shows the outage of this GPS satellite around day 8.

Example of unexpected no match

Example of expected no match near antenna edge for rising

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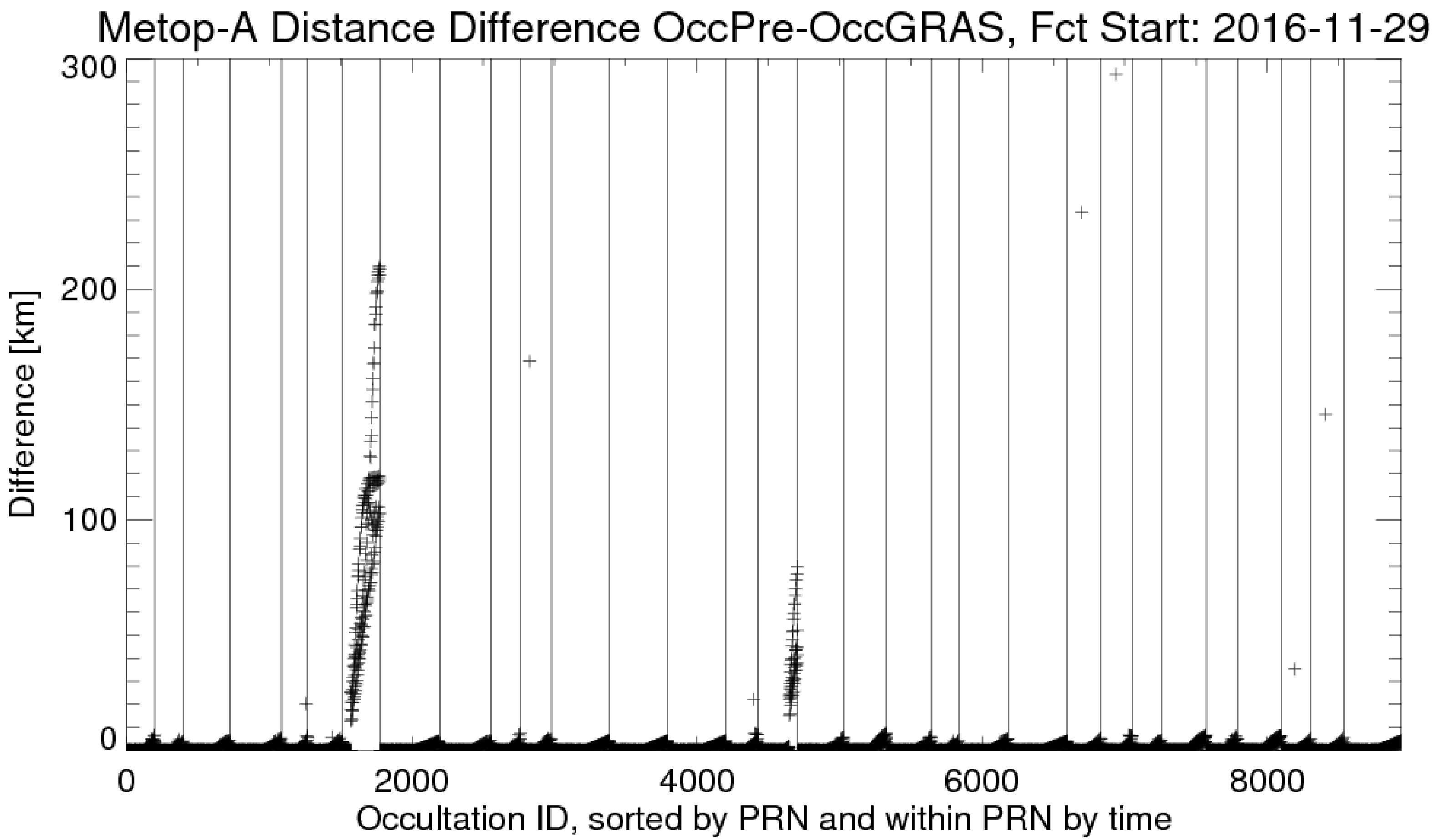
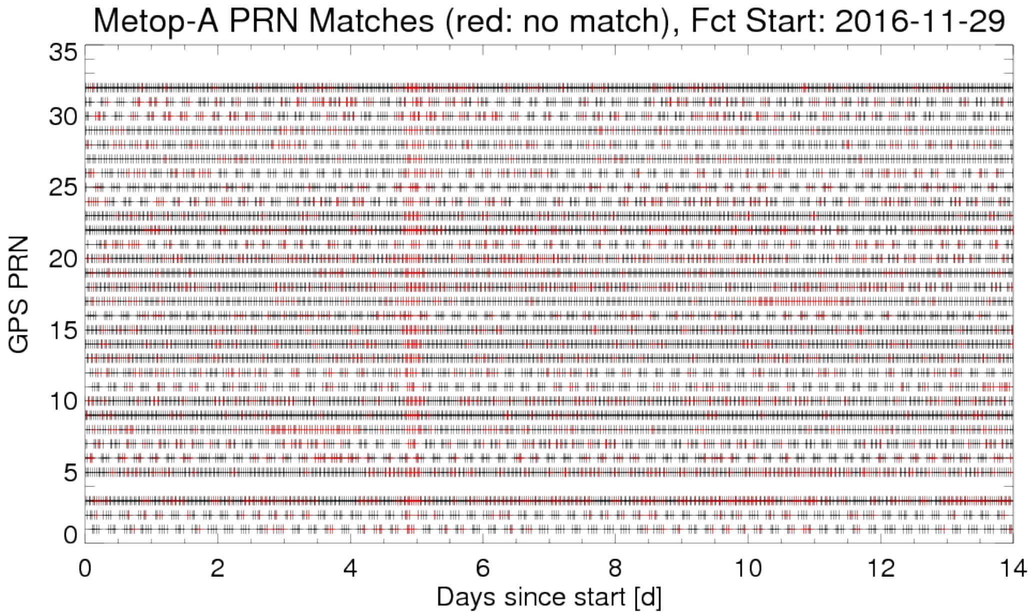
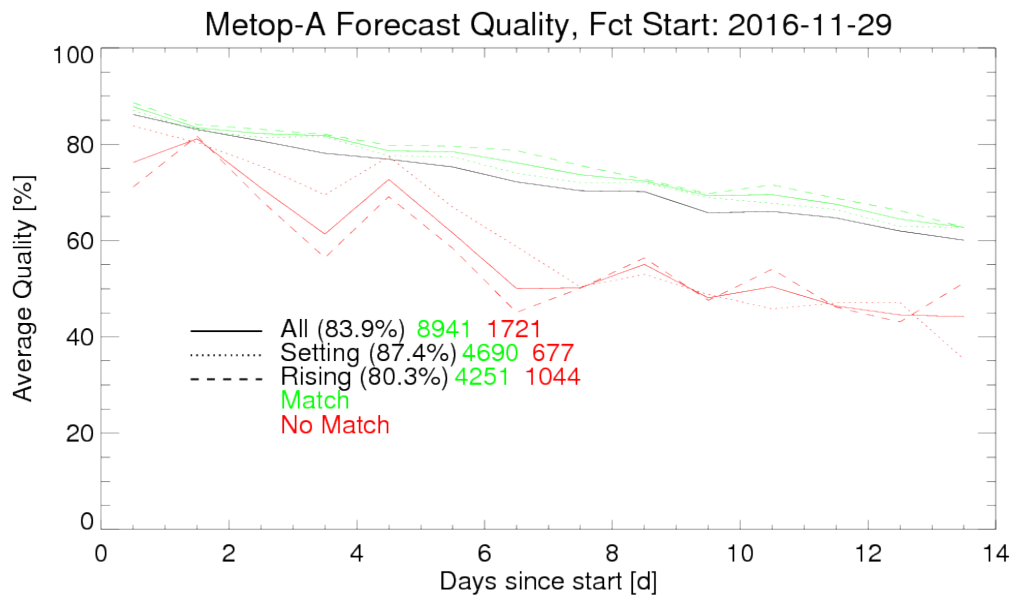
Manoeuvres Impact (1)



Impact of LEO and GPS maneuvers on 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.

Manoeuvres Impact (2)





Impact of LEO and GPS outages on the predicted occultation forecast quality; small LEO outage (late day 4, left plot) degrades quality, visible in No Match increase (right plot). Outages of GPS satellites 08, 17 (08 around day 3 to 4, 17 around day 10 to 11, right plot) does not impact occultation forecast quality visibly (right plot) but will impact position / time prediction.

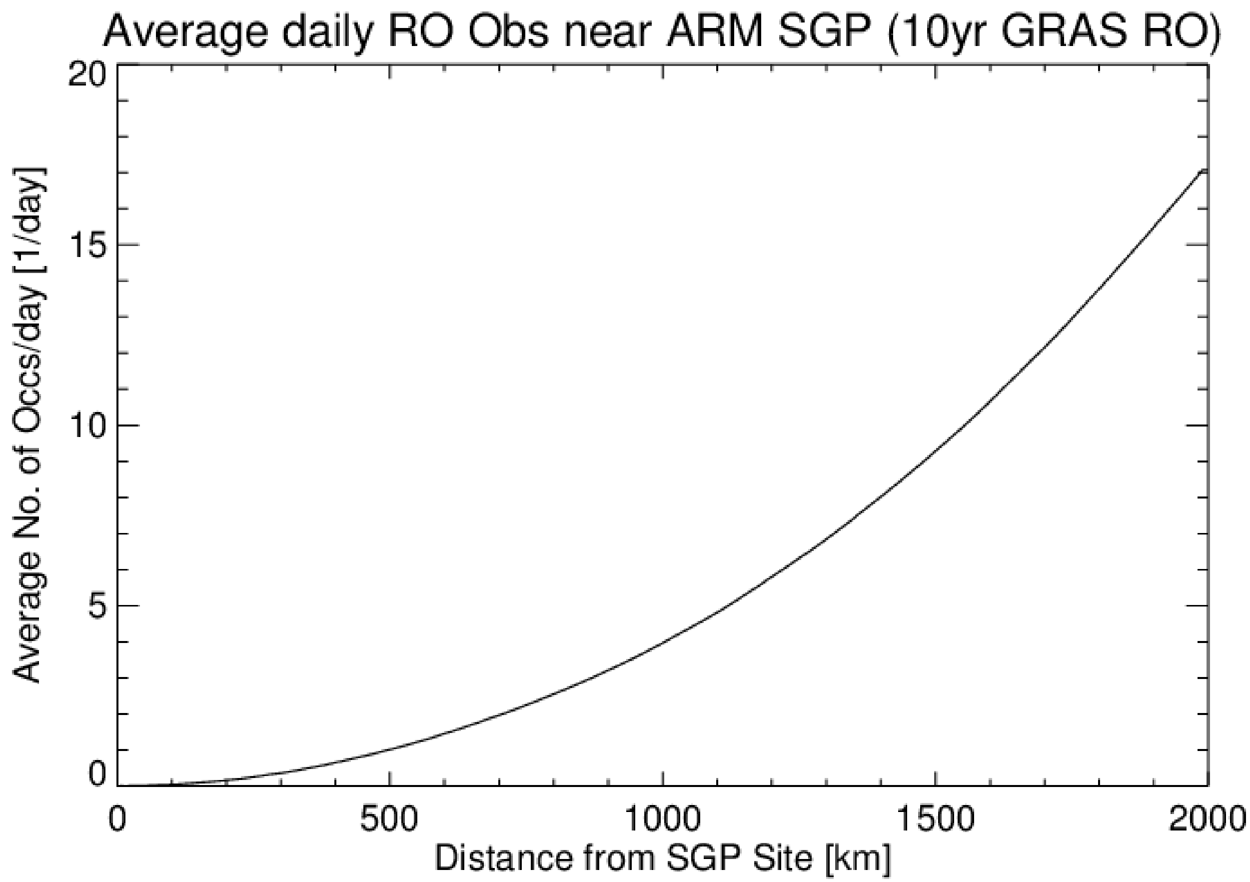
Summary

- GRAS occultation prediction and Metop position product implemented, able to predict about 85% of occultations
- Currently providing 14 day prediction in evaluation period, feedback expected by 31st Aug 2017
- Accuracy of position and time generally high (with no manoeuvre)
- Occultation prediction quality indicator “useful”, but needs improvements
- GNSS/GPS manoeuvres show larger impact on position and time of occultation prediction; LEO impact is minor (albeit data is not available during the manoeuvre)

Next Steps/Future Work

- Evaluate user feedback after Aug 2017
- If decision is to provide daily product “semi-operationally”:
  - Look into improving the occultation prediction:
    - improve robustness of fitting (e.g. when < 7 days for LEO fit available)
    - use NANU for GNSS manoeuvres in quality indicator
    - use LEO manoeuvres info in quality indicator (marking outage of data)
    - further evaluate why GRAS was not measuring some predicted occultations
    - further evaluate why GRAS occultations are incomplete (not to the surface)
    - increase prediction period?
  - Look into improving the orbits prediction:
    - potentially including actual instrument observation geometries (currently only sub-satellite points are provided)
  - Further promote new product/format and work towards all RO missions providing these predicted occultations
  - Evaluate need for “hind-sight” occultation product that would e.g. provide all occultation positions and quality over last month (allows dedicated searching for particular occultations without the need to download full data)

Quick Look at Number of RO / Day at Specific Site



Quick look at 10 years of Metop-A GRAS data (about 650 occs/day on average) and their distribution with respect to the ARMs Southern Great Plains Site.