Influence of Ionospheric Scintillations on the Processing of Radio Occultation Data from the Metop Satellites

Stig Syndergaard

Danish Meteorological Institute

Background on Metop RO

- Metop A launched October 2006; Metop B September 2012
- Both satellites in the same Sun-synchronous orbit crossing the equator at around 9:30 am and 9:30 pm local time
- Provides RO measurements up to 80 km
- Near real-time bending angle provided by EUMETSAT
- Refractivity and 1Dvar products provided by the ROM SAF (DMI)

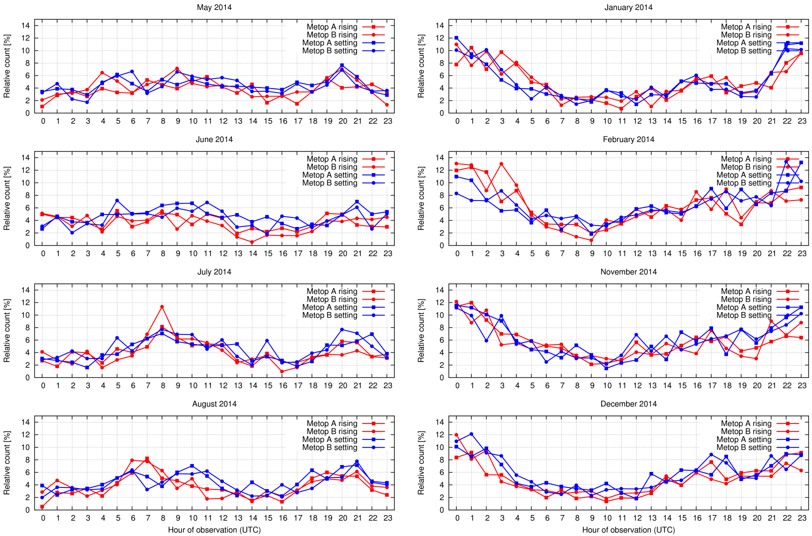
Problem

- Not all occultations make it to refractivity (processing fails at DMI)
- Poor fit to climatology used in statistical optimization between 40 and 60 km
- Number of occultations that fail correlates with seasonal and diurnal cycle (UTC), and depends on geographical location
- Problem first noticed in late 2011 and still persists (for both Metop A and B)

This presentation:

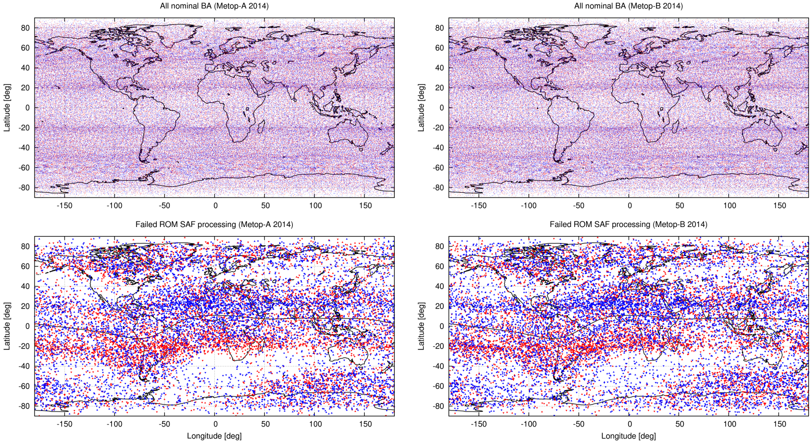
Closer look at one year of data (2014) to understand the correlations

Correlation with UTC and season



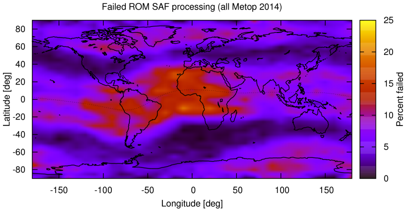
Number of failed occultations in percent binned by hour of observation

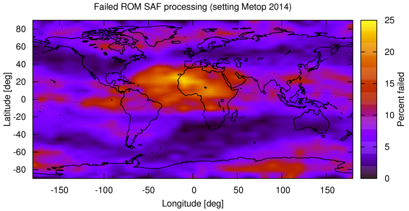
Geographical distribution



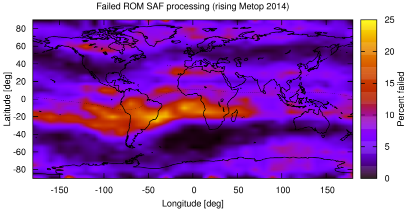
- Rising occultations (red) fail mostly south of the geomagnetic equator
- Setting occultations (blue) fail mostly north of the geomagnetic equator
- Most failures are occultations where the signal propagated through the ionosphere across the equator
- Also concentrations of failures at high northern and southern latitudes

Geographical distribution

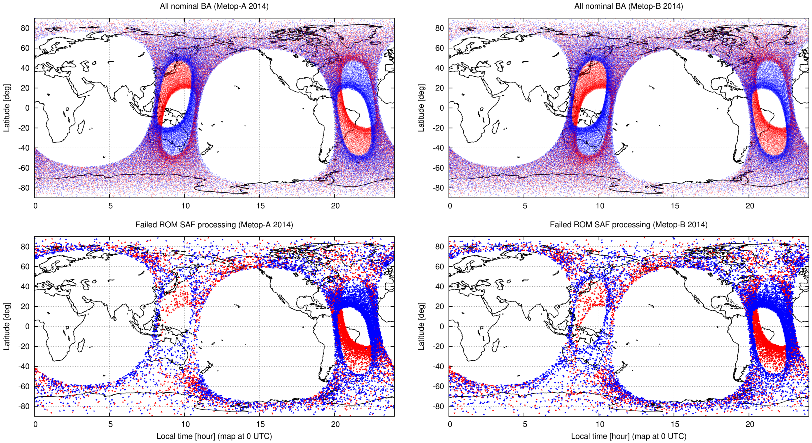




- Frequency of failed setting occultations peaks at about 25% near the west coast of North Africa
- Frequency of failed rising occultations peaks at about 25% near the east coast of South America

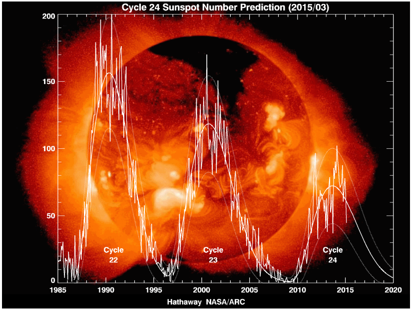


Local time distribution



- Most occultations fail in the evening sector, which coincides with the ascending node of the Metop orbits
- When occultations fail around 00:00 UTC they fail around the west coast of North Africa (mostly setting) and the east coast of South America (mostly rising), but it does not explain why more fail at 00:00 UTC (for some months) than at other times

Solar activity and ionospheric scintillations



(http://solarscience.msfc.nasa.gov/predict.shtml)

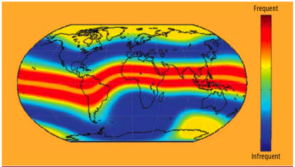
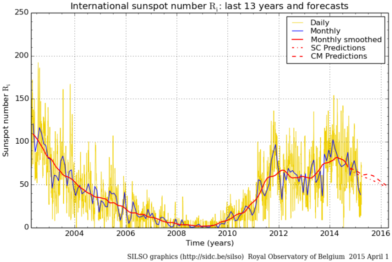


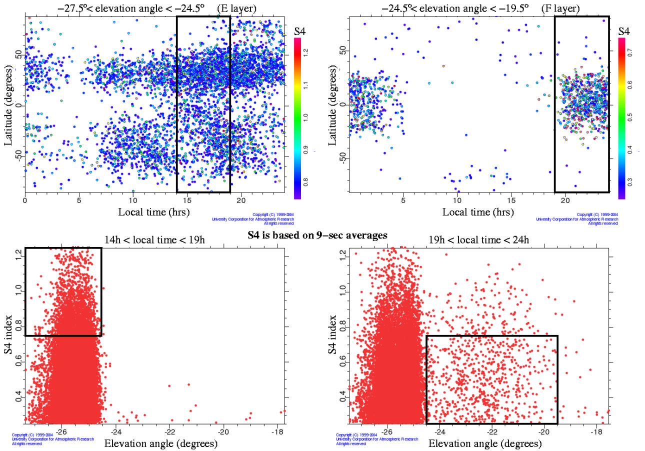
FIGURE 1 Scintillation map showing the frequency of disturbances at solar maximum. Scintillation is most intense and most frequent in two bands surrounding the magnetic equator, up to 100 days per year. At poleward latitudes, it is less frequent and it is least frequent at mid-latitude, a few to ten days per year.

Kintner et al., Inside GNSS, (2009)
(http://www.insidegnss.com/node/1579)



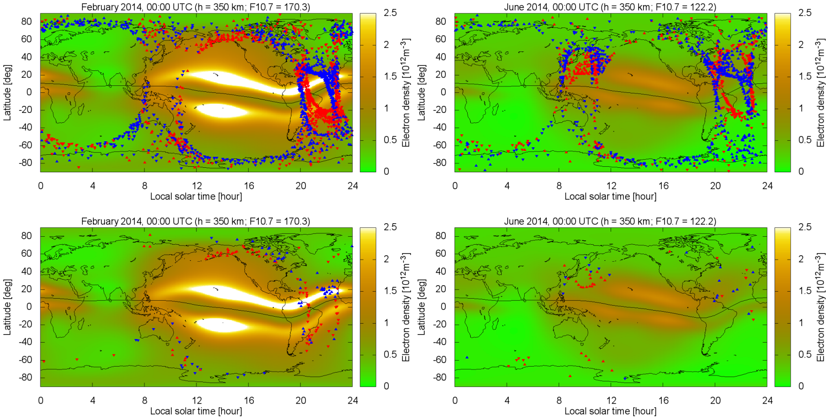
- ∼11-year cycle (more like 13 years since last)
- Cycle 24 peaked in 2014
- Also a secondary peak near the end of 2011
- Explains why we did not see the problem before late 2011

Ionospheric scintillations measured by COSMIC (2007)



- Explains local time dependency (overlap with Metop being in morning/evening orbits)
- Indicates that our troubles are mostly due to F-layer scintillations
- Still does not explain UTC and seasonal dependencies (but cf. study by Carter et al., 2013 – yesterday presentation)

Correlation with ionospheric dynamics (Metop 2014)



- NeQuick climatological model (Nava et al., JASTP, 2008)
- Electron density model (not a scintillation model)
- True monthly average of F10.7 (http://swc.nict.go.jp/sunspot/latest30sunspot_e.php)
- UTC dependency may be explained indirectly by SAA (South Atlantic Anomaly)

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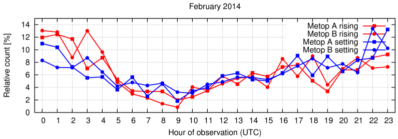
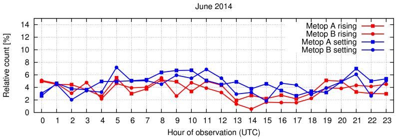
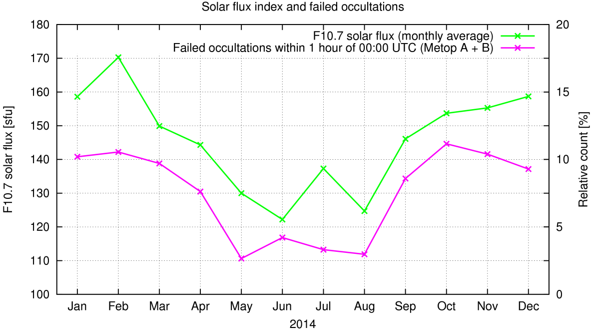
Correlation with F10.7 index

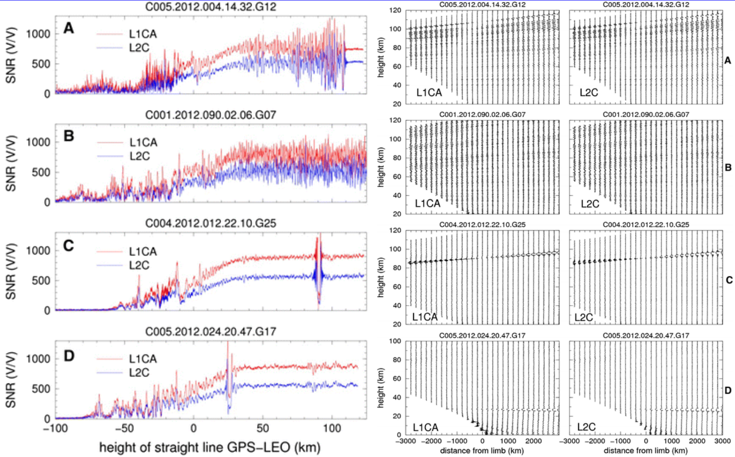






- Indicates that the apparent seasonal dependency is rather a dependency on solar activity that varies throughout the year
- Correlation could be coincidental; needs to be verified with data from other years

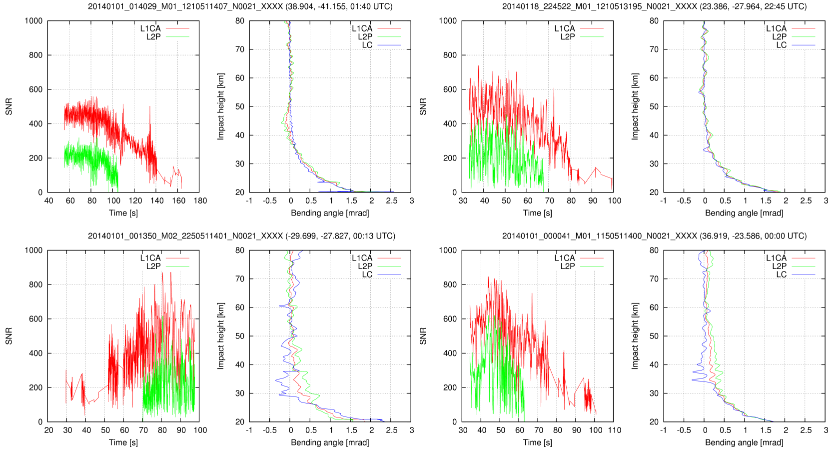
Signatures of scintillations in COSMIC data



Sokolovskiy et al., GPS Solutions, (2014) (http://link.springer.com/article/10.1007/s10291-013-0340-x/fulltext.html)

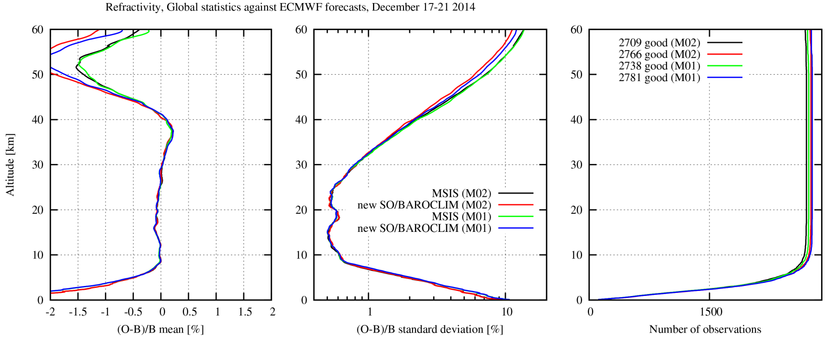
- Ionospheric scintillations from E-layer irregularities are seen as localized amplitude/SNR responses
- Ionospheric scintillations from F-layer irregularities are seen as significant amplitude/SNR noise over a longer time/vertical range

Examples of failures in Metop data



- Amplitudes indicate F-layer scintillations
- ROM SAF processing terminates because of a poor fit to climatology between 40 and 60 km
- Could processing be improved to 'save' some of these?

Refractivity statistics (current & future processing)



- ROM SAF plan to implement improved statistical optimization that will solve an issue generally unrelated to ionospheric scintillations
- Need QC in future processing to mark occultations that are severely affected by scintillations
- ∼20% of currently failed occultations passed such QC
- Resulting in slightly smaller standard deviation to ECMWF forecasts above 45 km
- Resulting in larger mean difference to ECMWF forecasts above 45 km
- Are moderate ionospheric scintillations that pass new QC creating a bias?

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Summary and conclusions

- One year (2014) of Metop data analyzed for failed occultations
- Number of failures largest around the geomagnetic equator: setting above; rising below
- Peaks at $\sim$25% near the west coast of N. Africa (setting) and east coast of S. America (rising)
- Strong correlation with UTC for some months
- Most failures in the evening coinciding with ascending node of Metop
- Presumably caused by F-layer scintillations
- Correlation with diurnal cycle and geographical location related to SAA
- Variation in solar activity throughout 2014 may explain apparent seasonal dependency
- Occultations fail due to excessive noise in bending angles between 40 and 60 km
- With improved processing more profiles make it to refractivity; results in smaller standard deviation, but larger mean difference to ECMWF