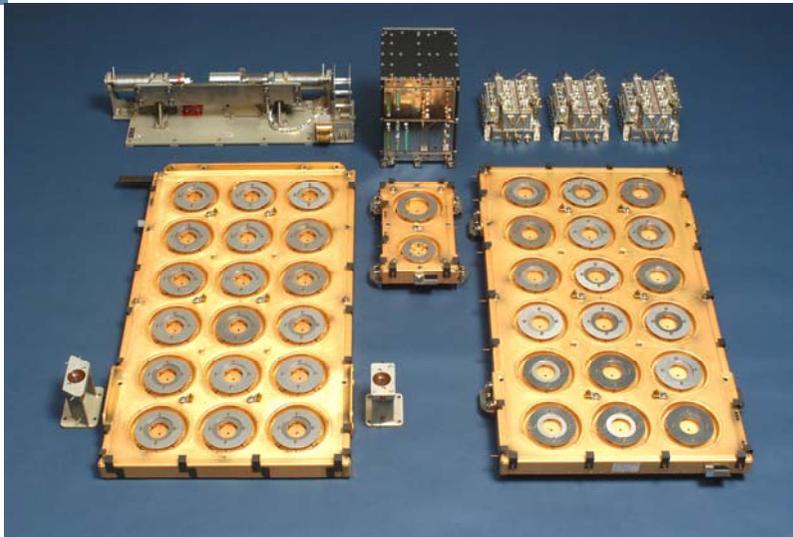


MetOp GRAS Measurements

The Instrument Perspective



Magnus Bonnedal Saab Space
Jacob Christensen Saab Space
Manfred Sust Austrian Aerospace
Marc Loiselet ESA/ESTEC

MetOp GRAS Operation

Log:

- GRAS was commanded into occultation mode 2006-10-27 and started to deliver occultation measurements.
- One Instrument reset in 10 months; Jan 2007 (buffer overflow, S/W now patched)

In 71 days, 1000 orbits:

- 27497 GPS Zenith tracked periods
- 23140 rising occultations tracked
- 24058 setting occultations tracked

- Average = 660 occultations/day

Tracking Performance Evaluation

Objective:

To evaluate occultation data tracking in terms of DF, SF and RS altitudes.
We need an approximate ray altitude without inversion but using model atmospheres.
[CIRA-86+Q developed at IGAM/UG, based on COSPAR CIRA-86]

Method:

1. From GRAS RTN and Ephemeris data, calculate the angular separation, θ_G , between MetOp and GPS occulting SV (mapped onto measurements).
2. Calculate θ_M and RTH from model atmosphere for actual latitude and month using:

$$\alpha(h) = 10^{-6} \cdot N(h) \cdot \sqrt{2\pi \frac{R_E(lat) + h}{H_s(h)}} \cdot \left[1 + 10^{-6} \cdot (\sqrt{2} - 1) \cdot \frac{(R_E(lat) + h)}{H_s(h)} \cdot N(h) \right]$$

$$a(h) = (R_e(lat) + h) \cdot (1 + N(h)10^{-6})$$

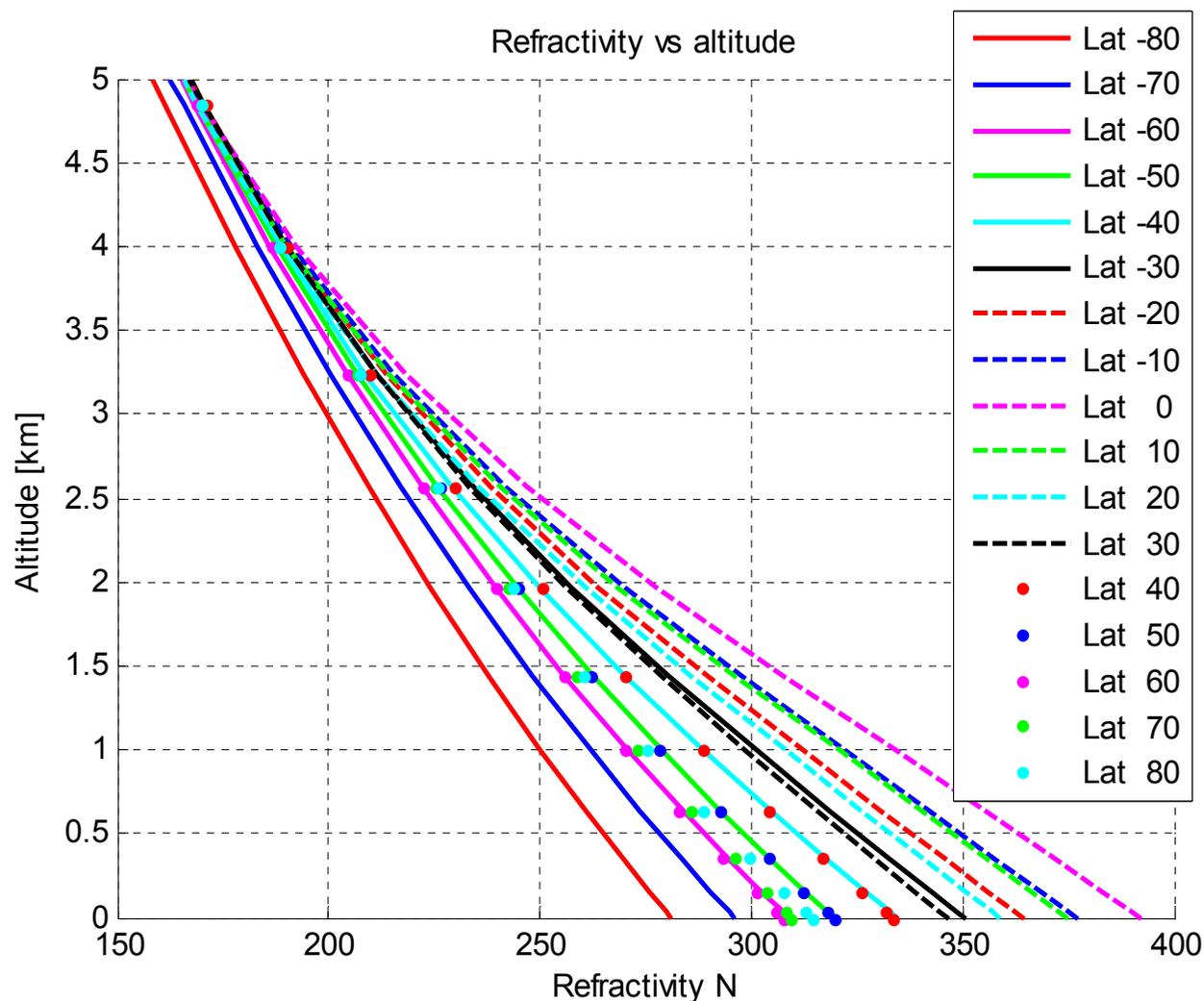
$$\theta_M(h) = \alpha(h) + \arccos\left(\frac{a(h)}{R_L}\right) + \arccos\left(\frac{a(h)}{R_G}\right)$$

3. Map RTH onto measurements by interpolating between θ_G and θ_M

Reference Atmospheres

Selected reference atmospheres from the CIRA-86+Q :

- Month = November
- The closest 10° latitude [-80:80]

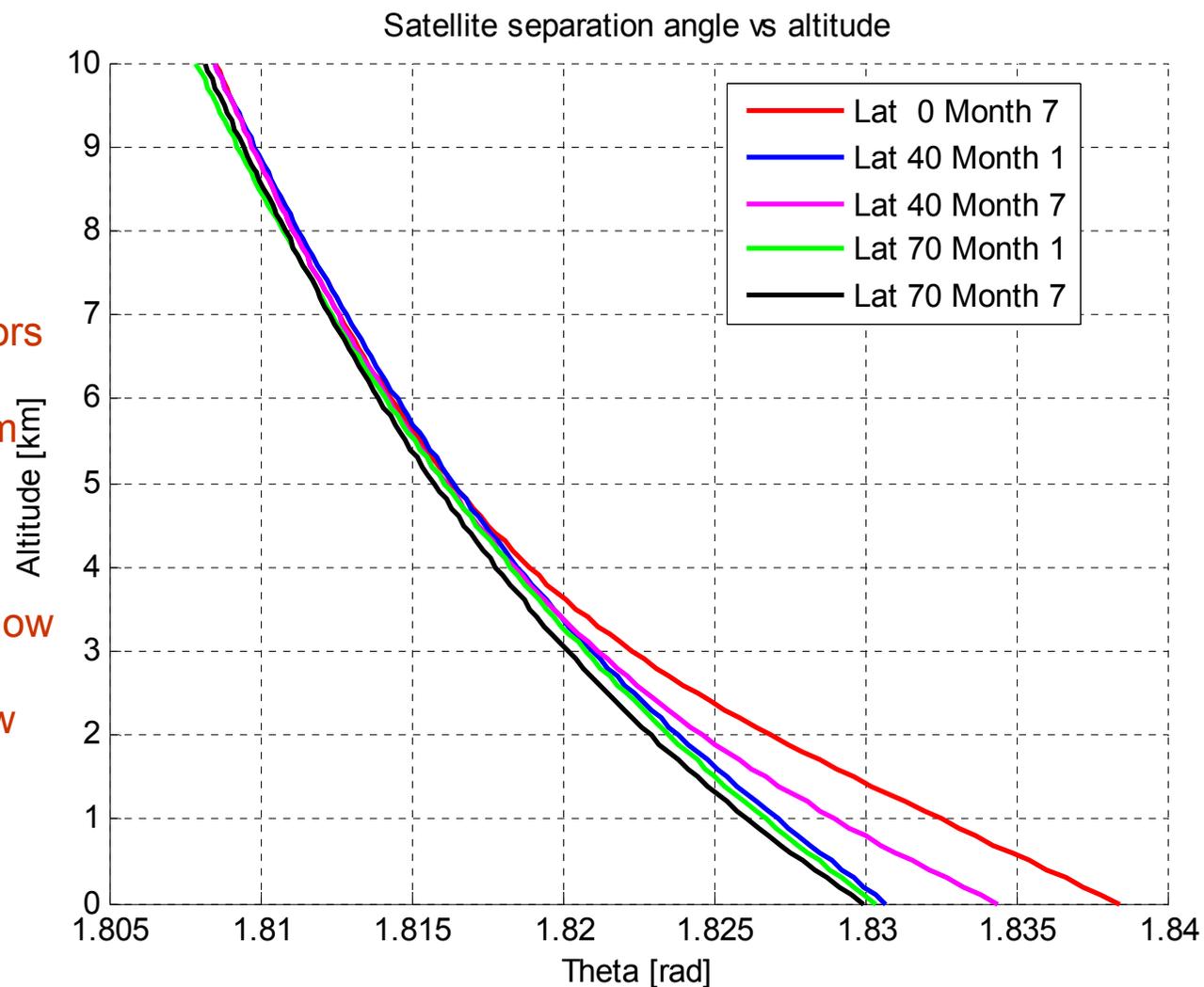


Retrieval of RTH

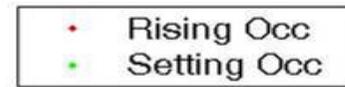
Expected accuracies:

- GPS and LEO position errors will not contribute.
- $\Delta RTH < 200\text{m}$ down to 5 km
- $\Delta RTH \sim 1\text{ km}$ at 2 km

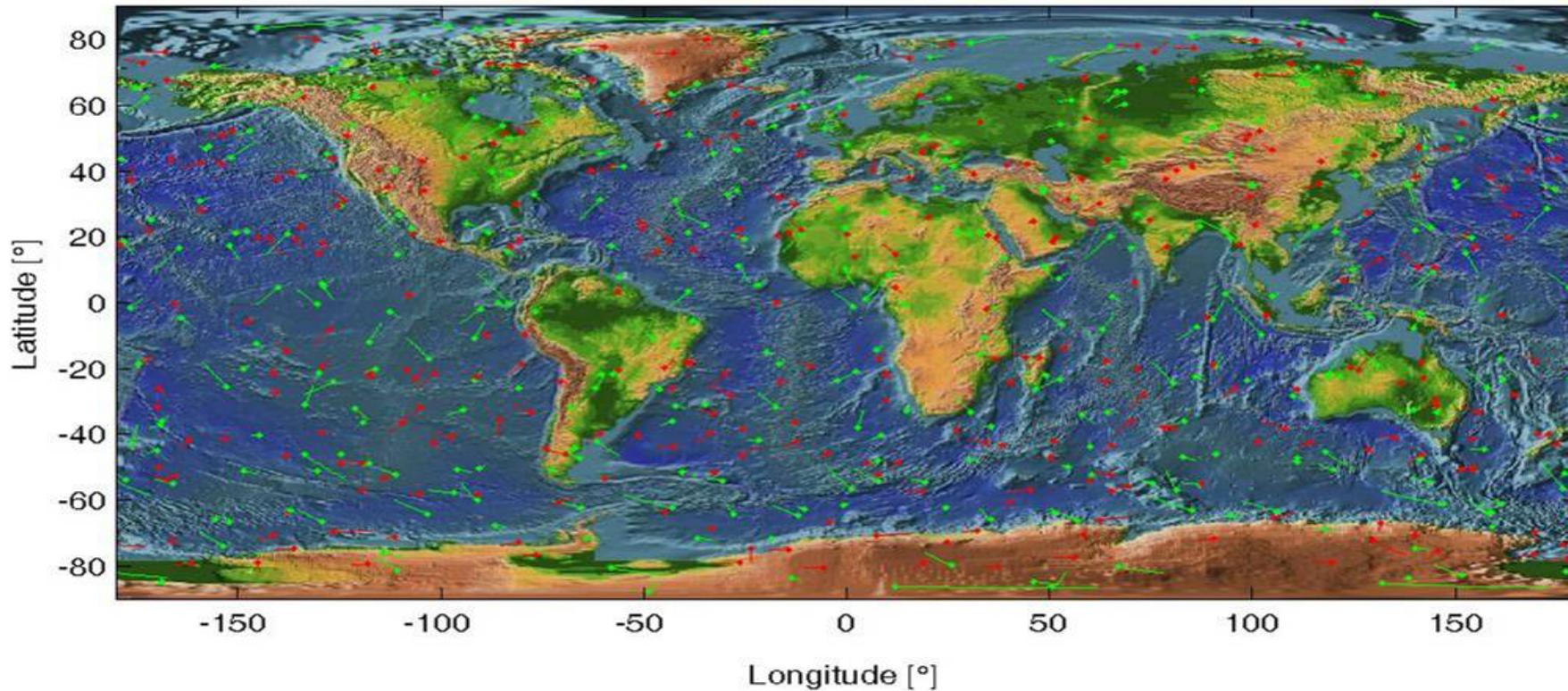
- Dense atmospheres will show too low RTH
- Thin atmospheres will show too high RTH



Number of Occultations

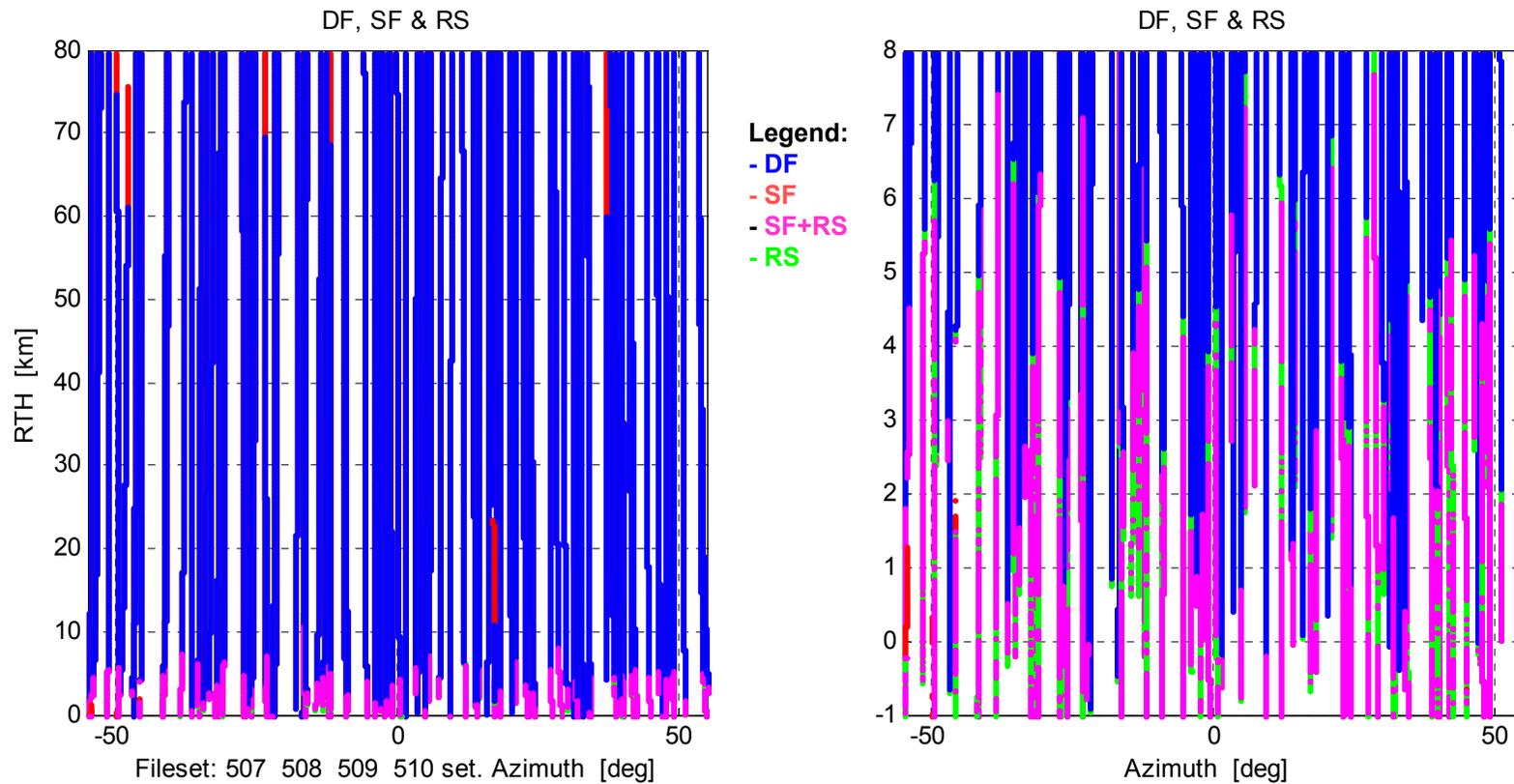


Occultations sensed by GRAS on 1st-Nov-2006



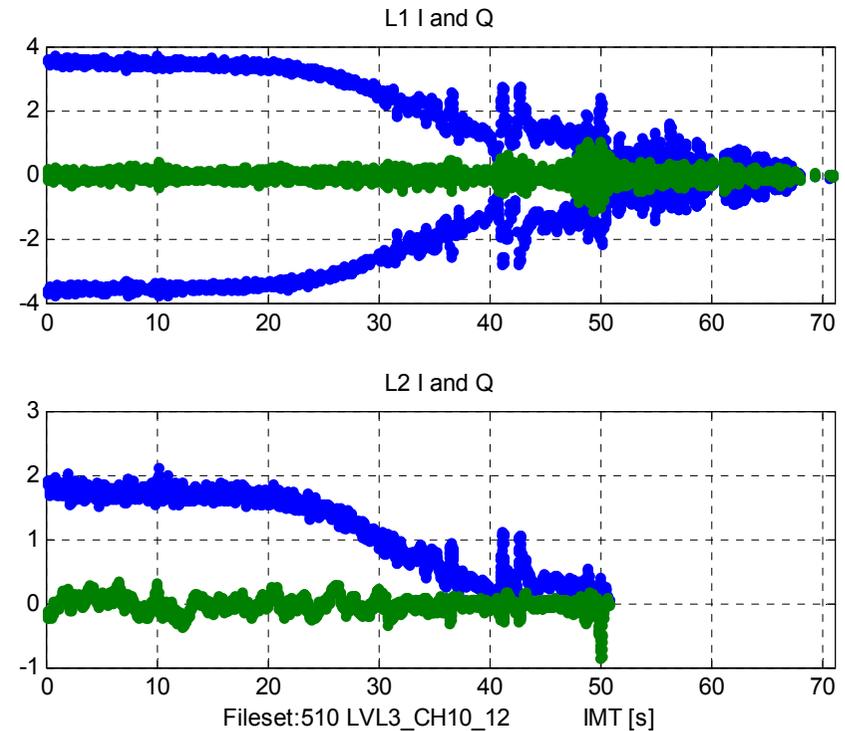
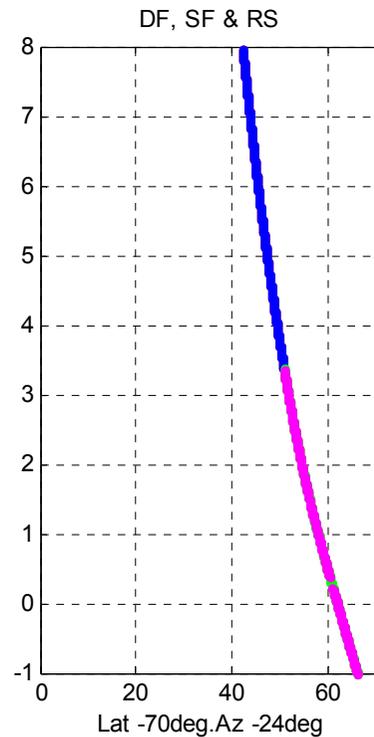
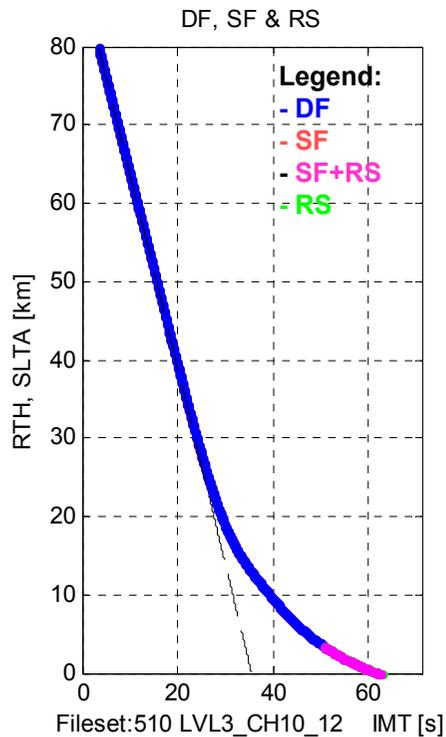
660 (338 setting / 322 rising) occultations on 1st November 2006

Azimuth Coverage



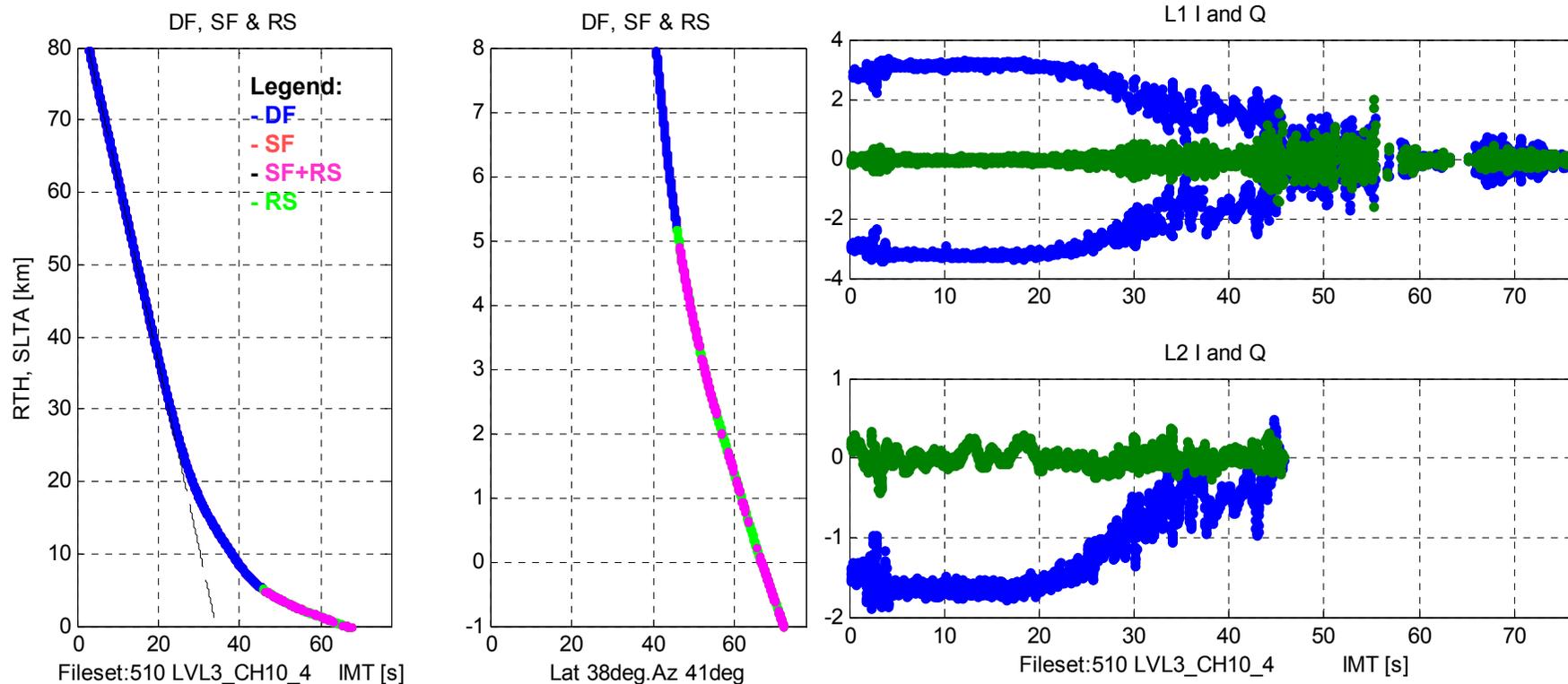
Good coverage over the full range $Az = \pm 55^\circ$ (default setting).
 Handy formula: $N_{OCC}/orb = 2 N_{SV} \sin(Az) \Rightarrow N_{SV} = 29 \quad N_{OCC} = 677 \text{ 1/day}$
 Data: 102 Setting occultations 4 orbits 2006-12-18

Setting Occultation



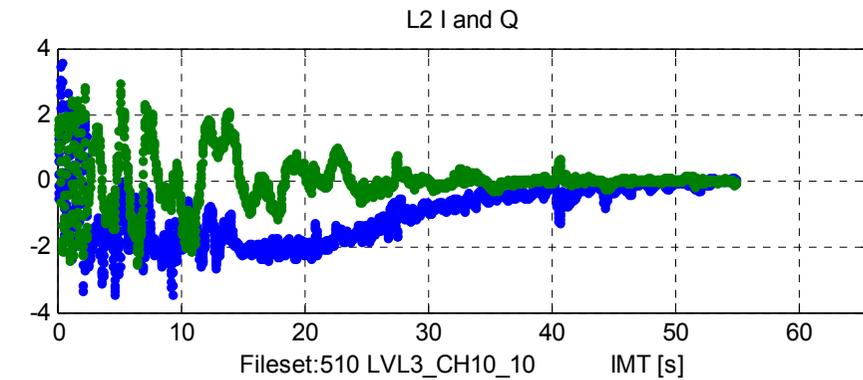
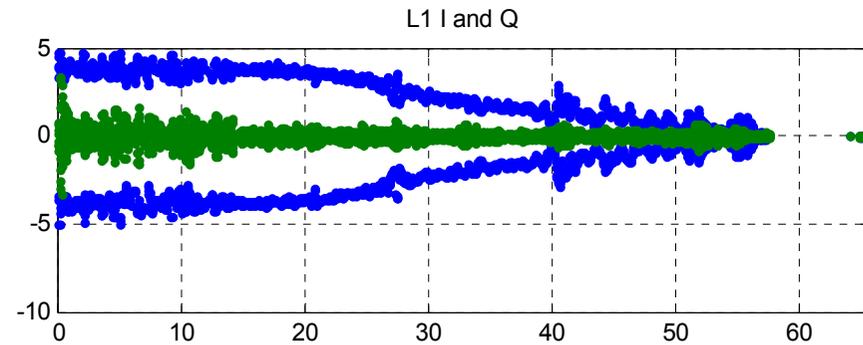
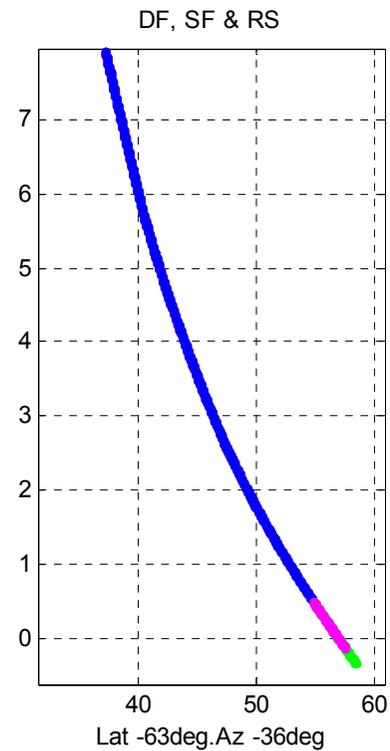
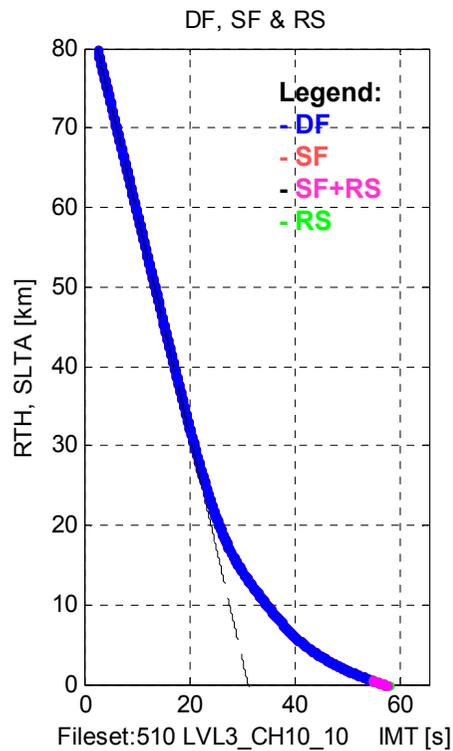
Setting, Lat =-70, 2006-12-18

Setting Occultation



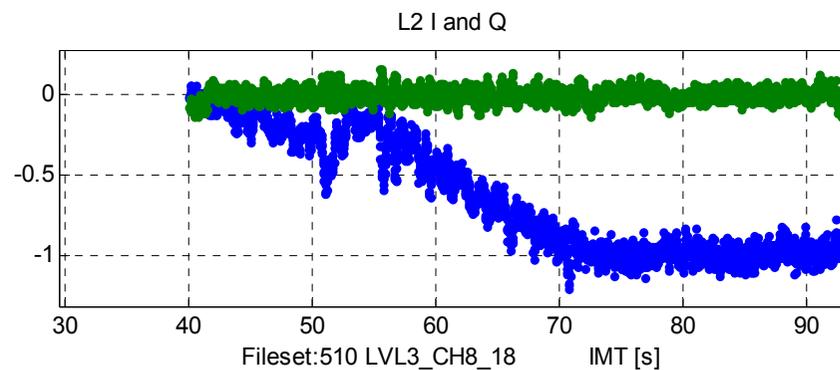
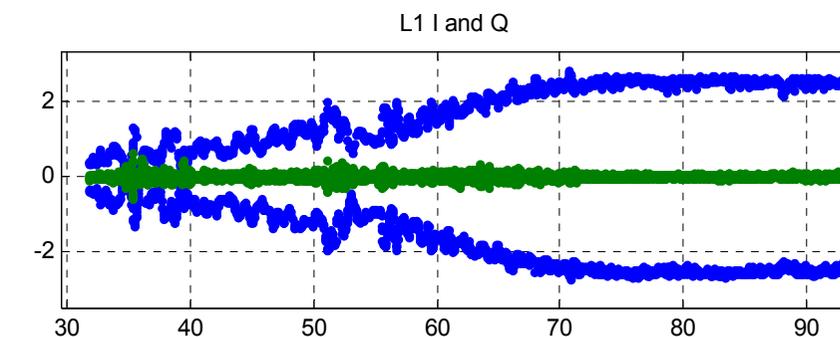
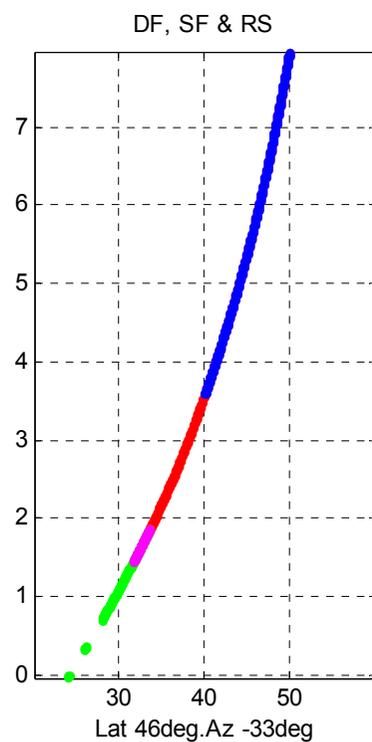
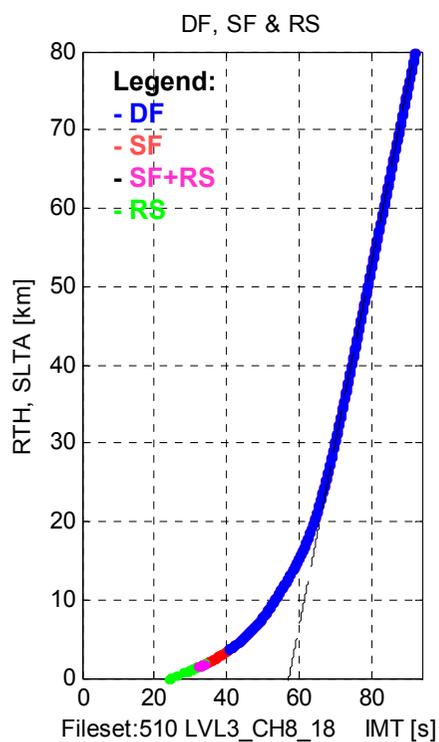
When L2 is lost (due to signal dynamics) Rx switches from 10 ms to 1 ms coherent integration time (to support RS) This sometimes cause temporary L1 loss of lock. L1 can be recovered from RS. Data: Lat =38, 2006-12-18

Setting Occultation



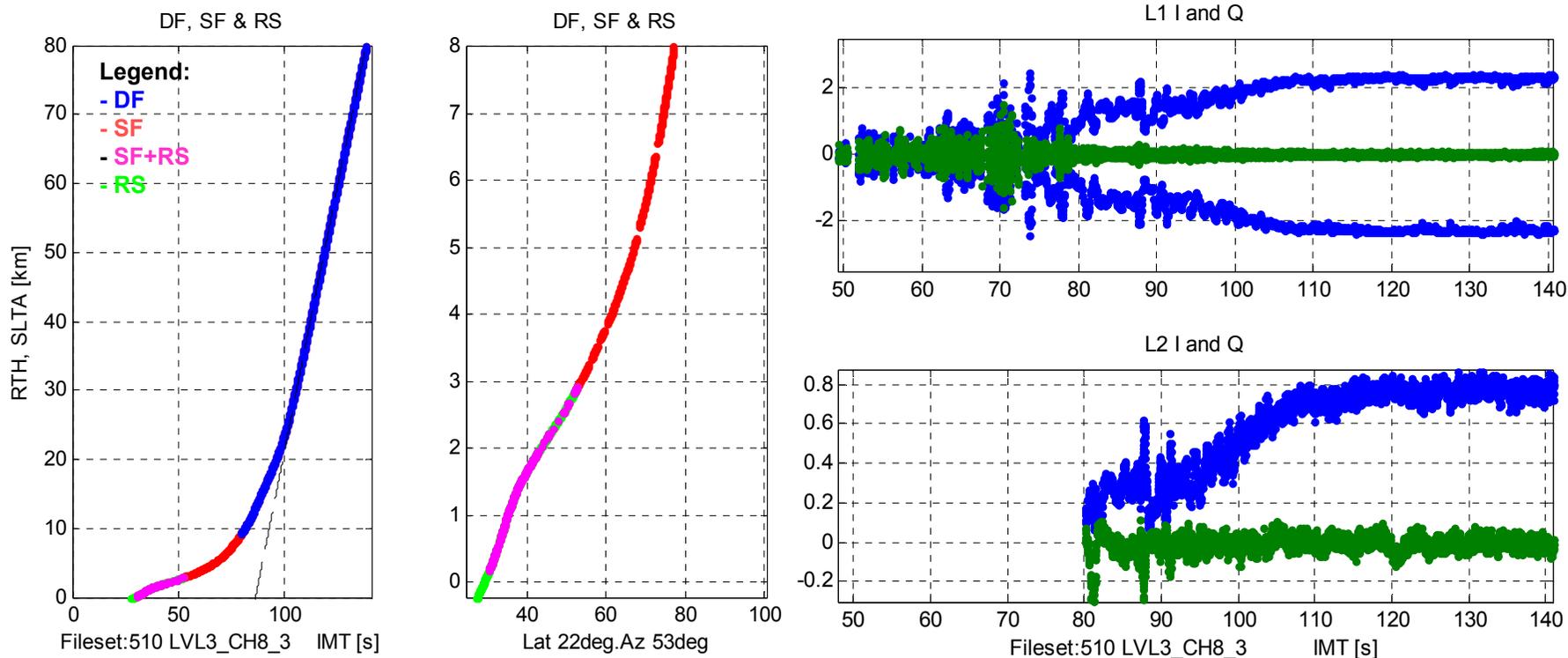
Setting, Lat =-63, 2006-12-18

Rising Occultation



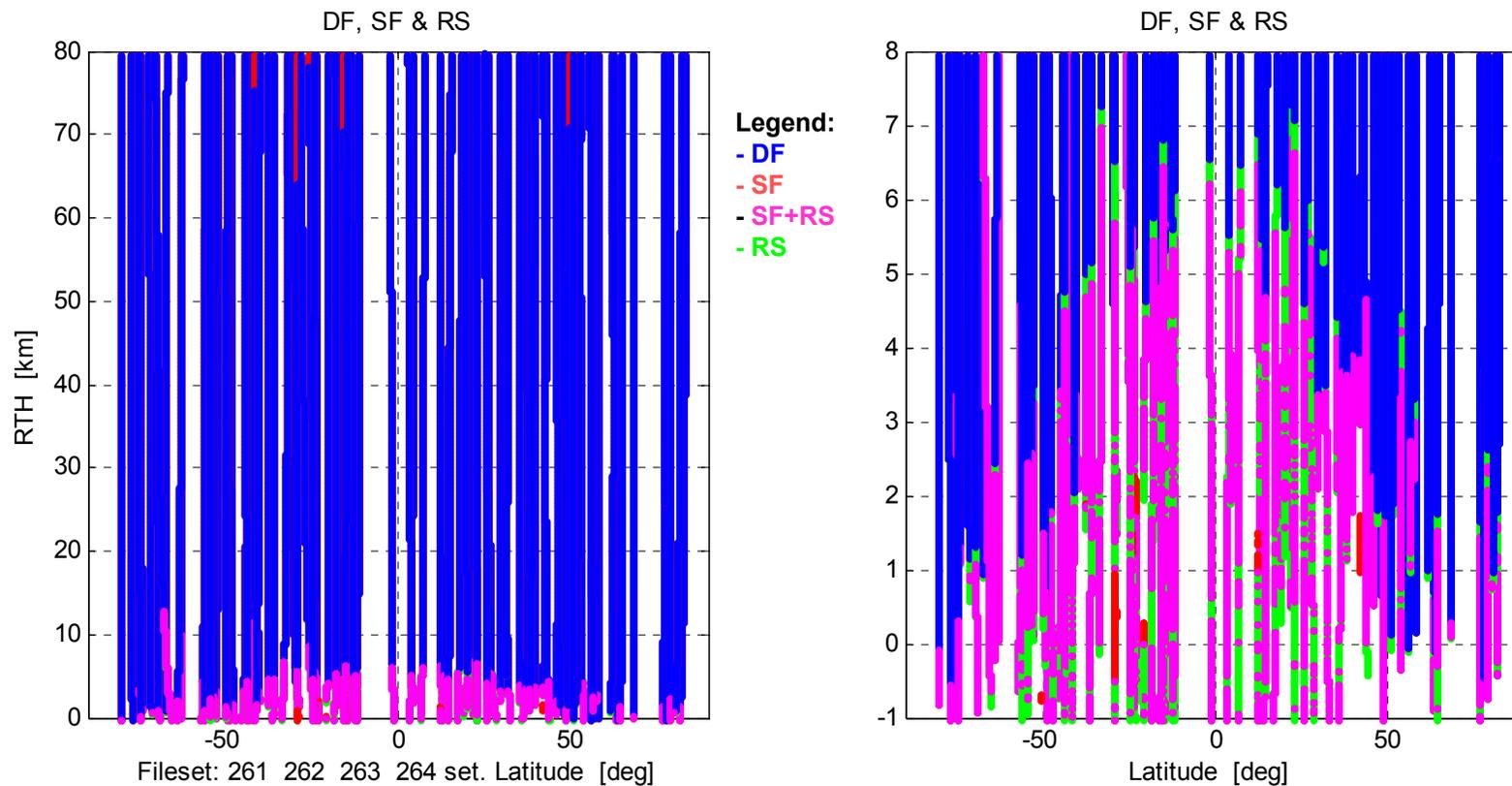
Rising, Lat =46, 2006-12-18

Rising Occultation



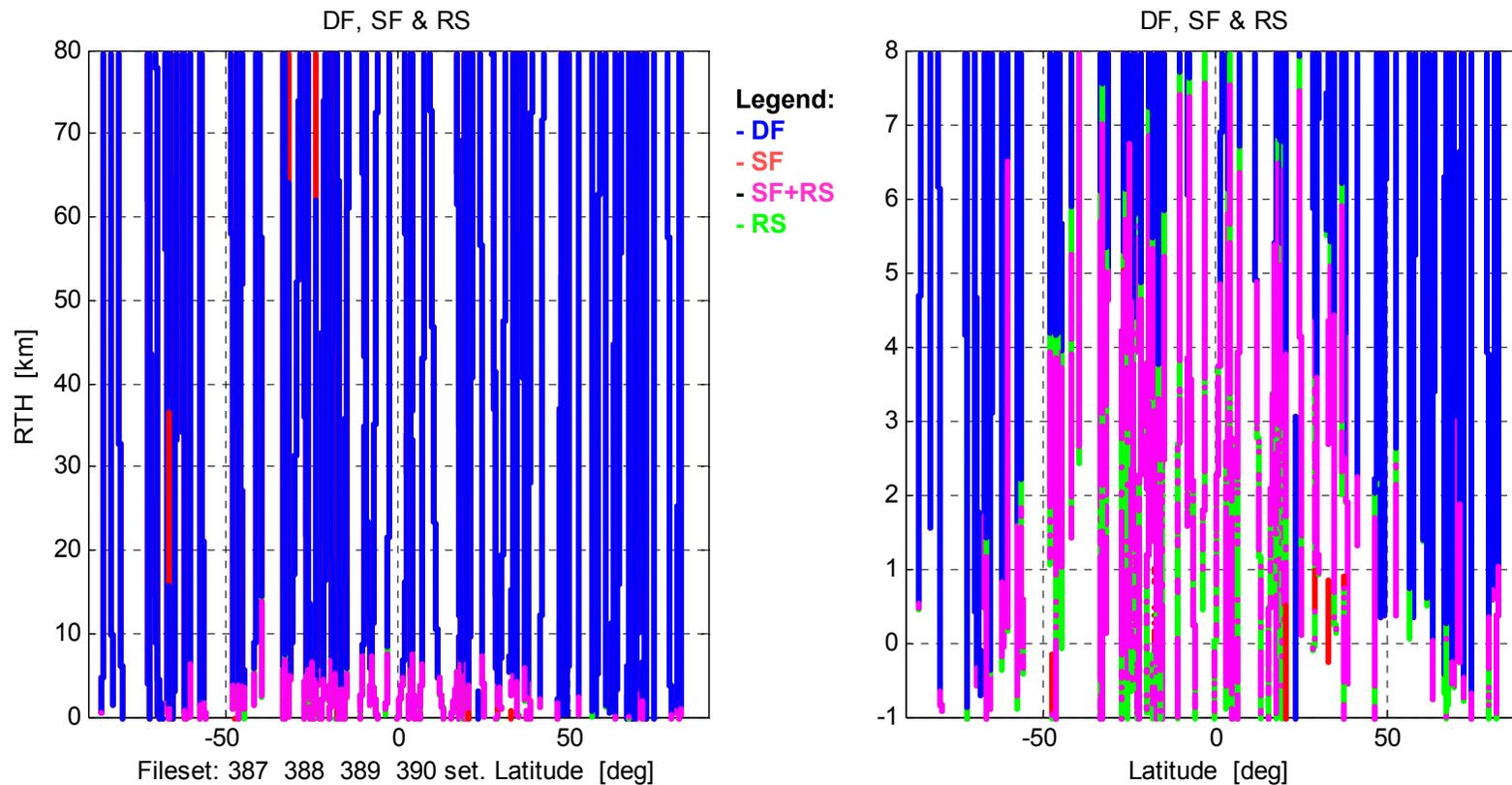
RS is stopped at SLTA = -30 km to free channels for L2 acquisition
Parameter could be increase to ensure continuous L1 data in highly dynamic atmospheres. Data: Lat =22, 2006-12-18

Setting Occ: Altitude vs Latitude



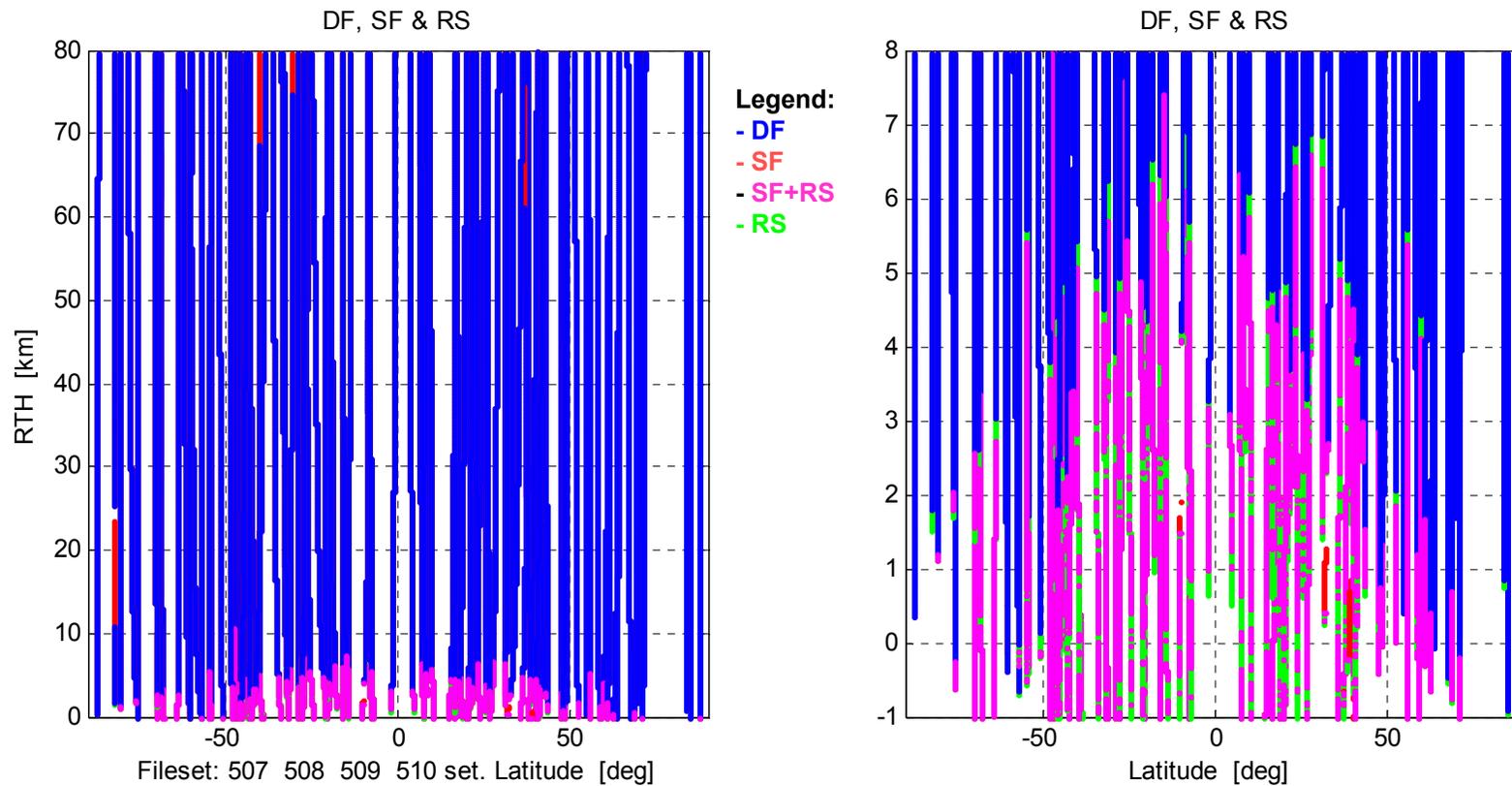
97 Setting occultations 4 orbits 2006-12-01

Setting Occ: Altitude vs Latitude



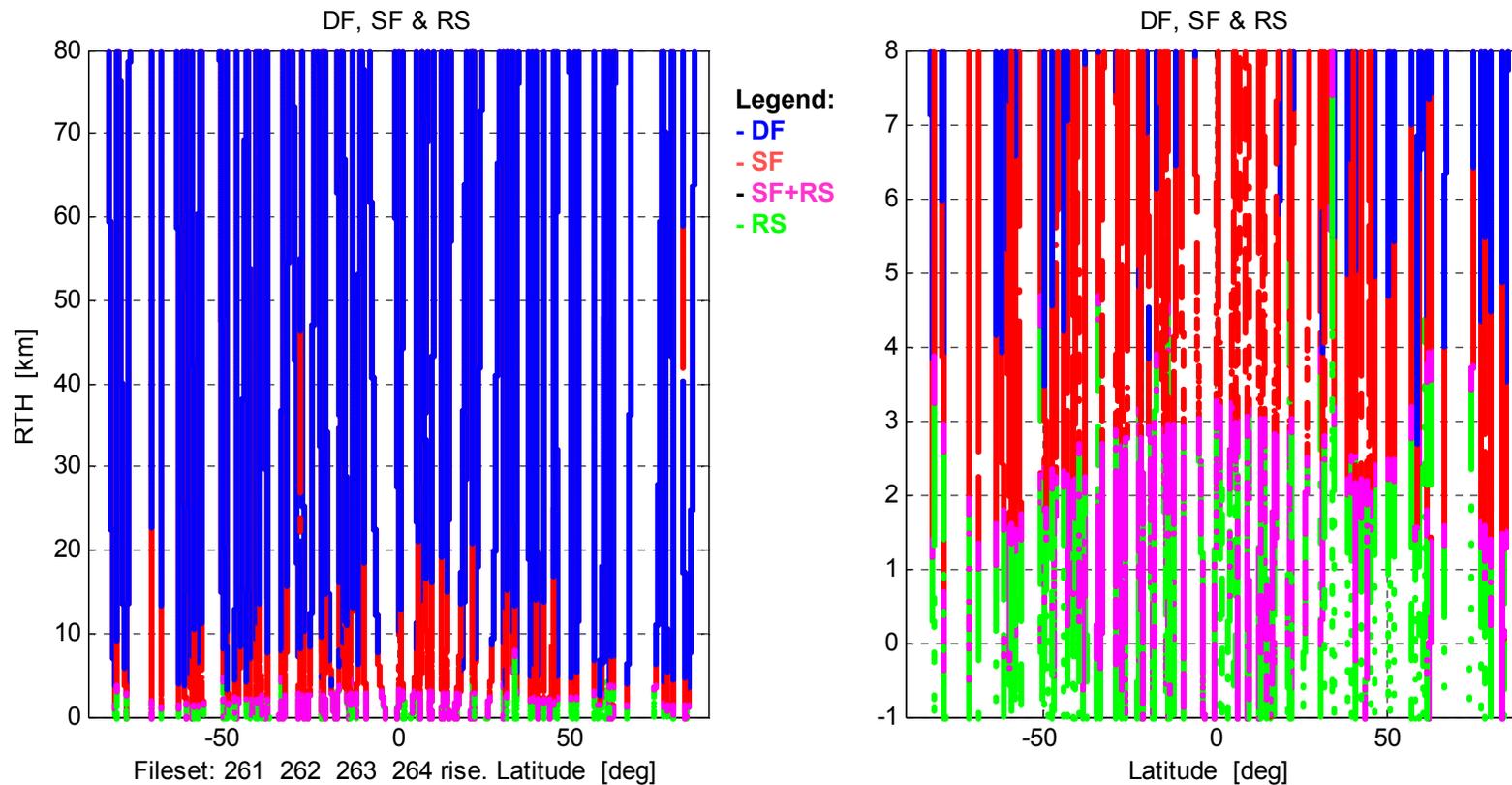
102 Setting occultations 4 orbits 2006-12-10

Setting Occ: Altitude vs Latitude



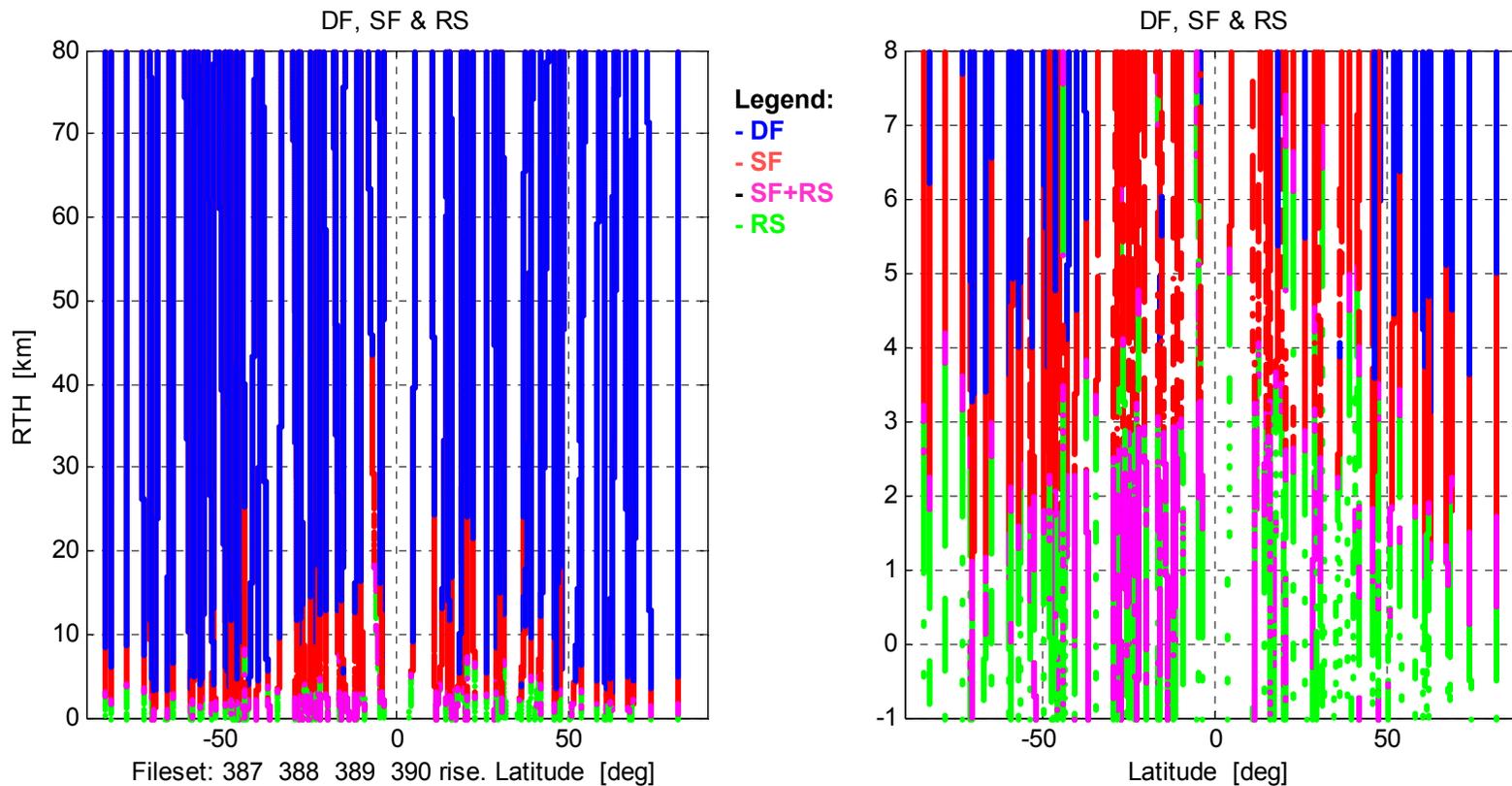
102 Setting occultations 4 orbits 2006-12-18

Rising Occ: Altitude vs Latitude



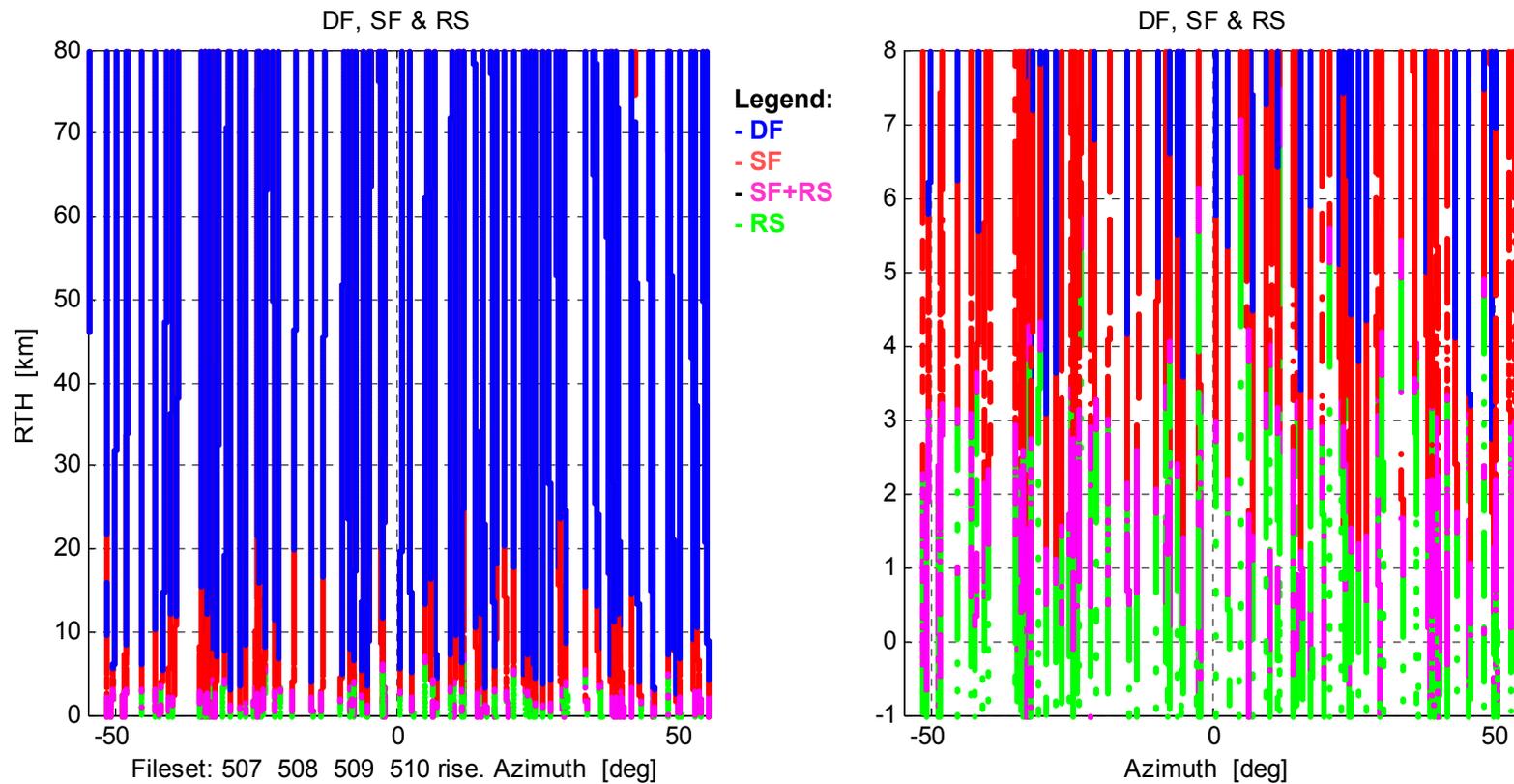
95 Rising occultations 4 orbits 2006-12-01

Rising Occ: Altitude vs Latitude



94 Rising occultations in 4 orbits 2006-12-10

Rising Occ: Altitude vs Azimuth



95 Rising occultations 4 orbits 2006-12-18

210 x 300 x 100 mm³

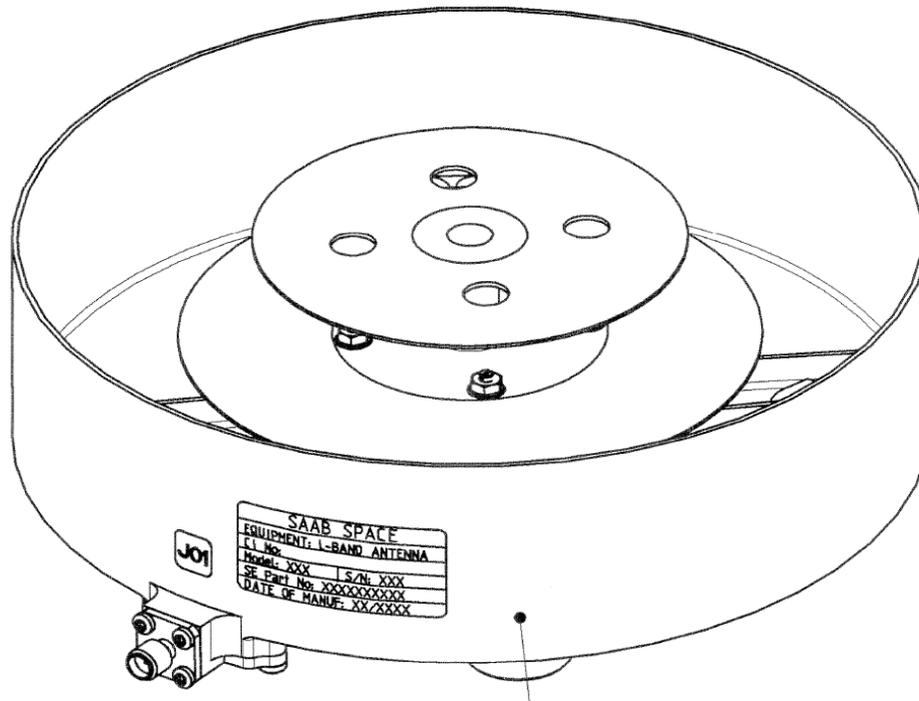
m = ~ 3 kg

P < 11 W



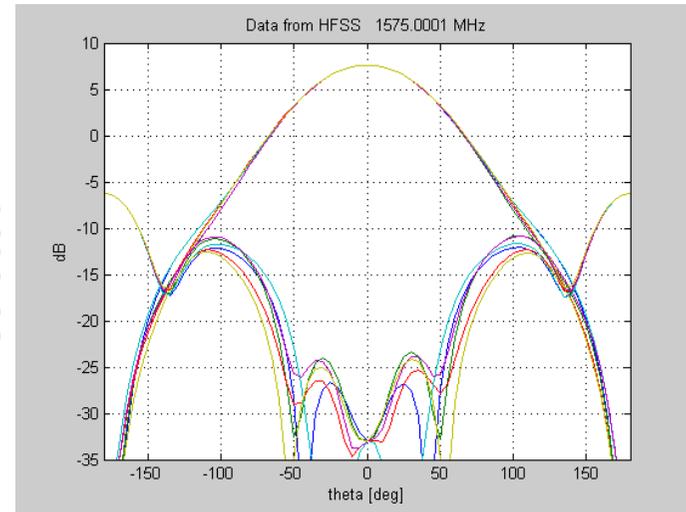
POD-Receiver

POD-Antenna

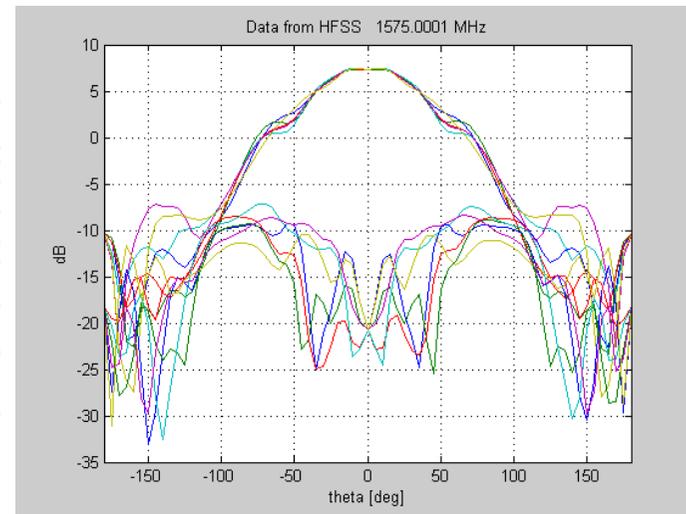


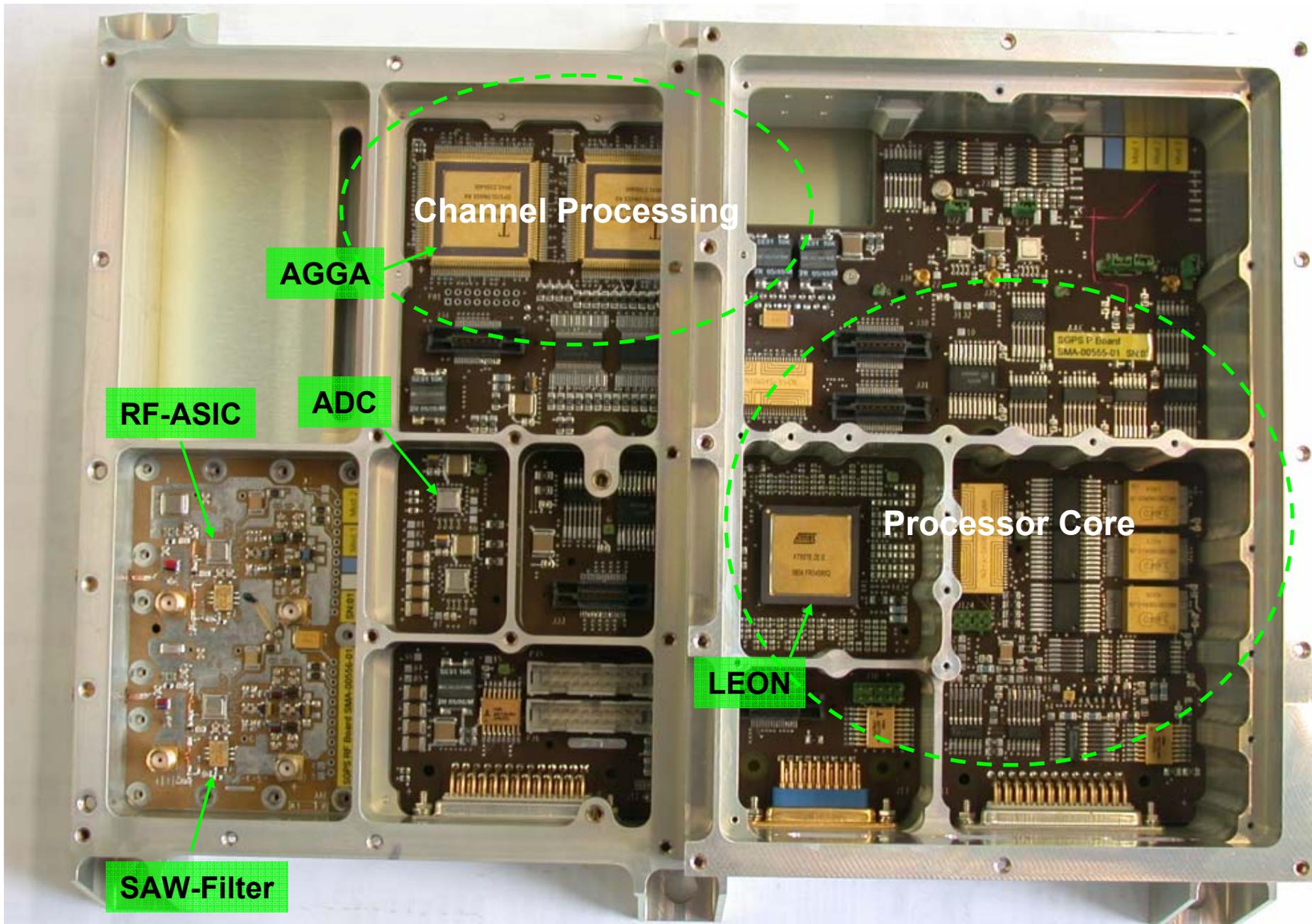
$d = 132 \text{ mm}$
 $h = 55 \text{ mm}, h_{\text{cup}} = 45 \text{ mm}$
 $m = 350 \text{ g}$

isolated



with S/C structure





POD-Receiver

- **Dual-frequency receiver (C/A on L1, P-code on L1 and L2)**
- **1 antenna (cup)**
- **8 dual-frequency channels**
- **Very stable OCXO: Allan deviation (1 s): $< 2 \cdot 10^{-11}$**
- **Navigation performance:**
 - **3D - 3σ position: < 20 m**
 - **3D - 3σ velocity: < 5 cm/s**
- **Acquisition threshold: ~ 30 dBHz**
- **Elevation masking angle: < 10 deg for L1, < 20 deg for L2**
- **Cold start in LEO orbit: < 25 min**
- **TM/TC via UART-interface**

RO-Receiver

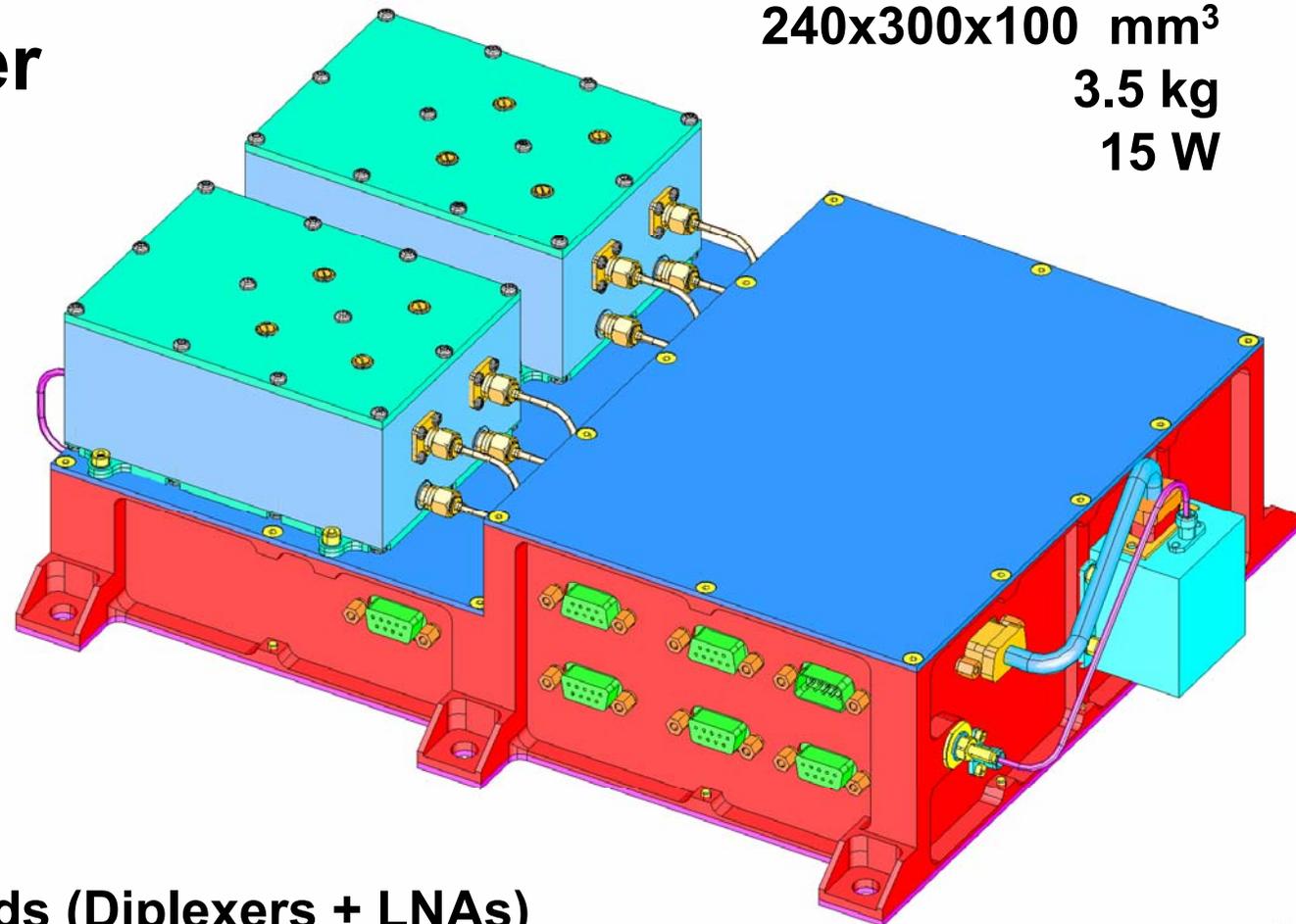
240x300x100 mm³
3.5 kg
15 W

POD

- 1 Antenna
- 8 Dual-Frequency Channels

Occultation

- 1 Antenna
- 4 Dual-Frequency Channels
- External Front-Ends (Diplexers + LNAs)
- Raw-Sampling Hardware Support
- USO: Allan Deviation: 3s - 100s: $< 10^{-12}$, 60 min: $< 10^{-11}$



Conclusions

- **GRAS shows robust autonomous operation**
- **Provides large number of occultations due to wide antenna coverage**
- **Approximate lower limits of tracking altitudes, Setting :**
 - L2: 4 - 7 km (low – high latitude)
 - L1: 1 - 2 km
 - RS: < 1 km
- **Approximate lower limits of tracking altitudes, Rising :**
 - L2: 7 - 15 km
 - L1: 2 km (occasional glitches at low altitudes)
 - RS: 1 km (occasional glitches at low altitudes)
- **Many L1 glitches can be reconstructed with RS data**

- **A new generation POD receiver is being developed (will fly on SWARM)**
- **Modularity allows the concept to be used for RO receiver**