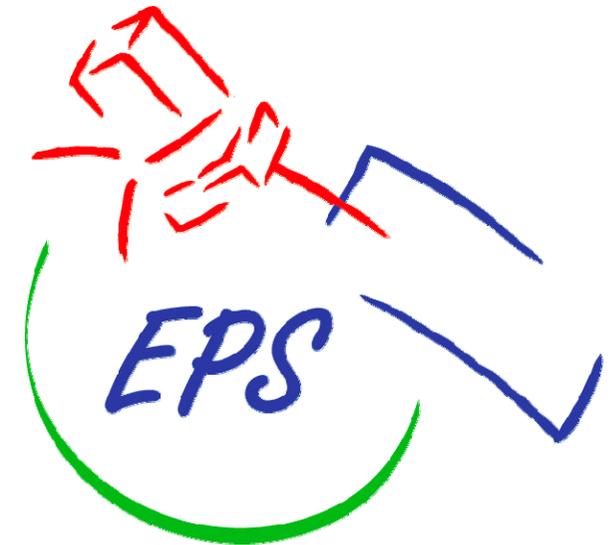




# GRAS on MetOp: The First Operational Radio Occultation Instrument

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J. J. W. Wilson*



OPAC3, Sep. 2007,  
Graz



# Launch from the Baikonour Cosmodrome with Sojuz/Fregat the 19<sup>th</sup> October 2006



# OVERVIEW



- **MetOp Instruments**
- **GRAS**
  - Processing
  - Validation
  - Noise Estimates
  - Analysis of GRAS Processing Delay
- **Conclusion**



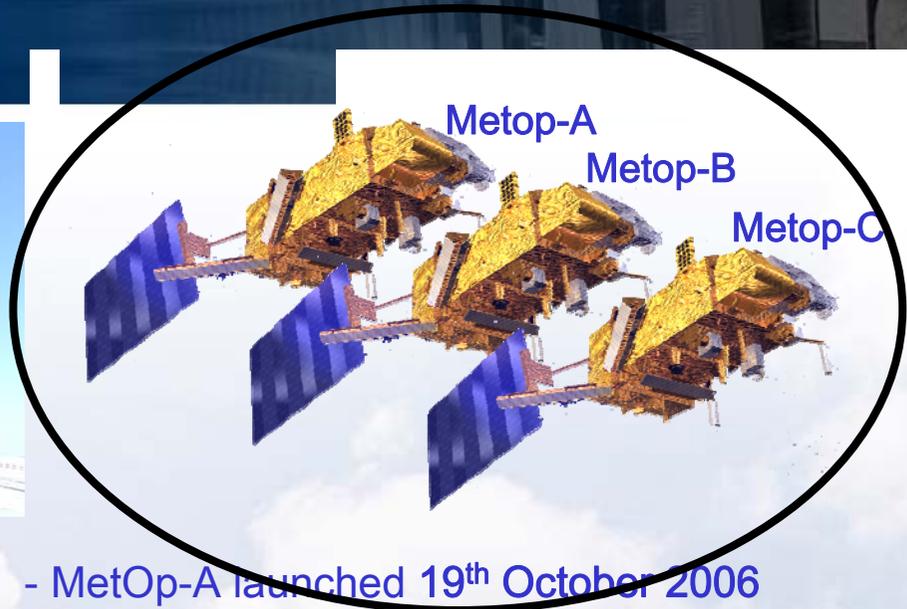
# MetOp: EPS Programme Elements



Polar Stations  
Svalbard, 78 deg Nord



Launcher Service  
(Soyuz/Fregat)



LEOP Service  
(ESOC)



EUMETSAT  
Mission Control Centre

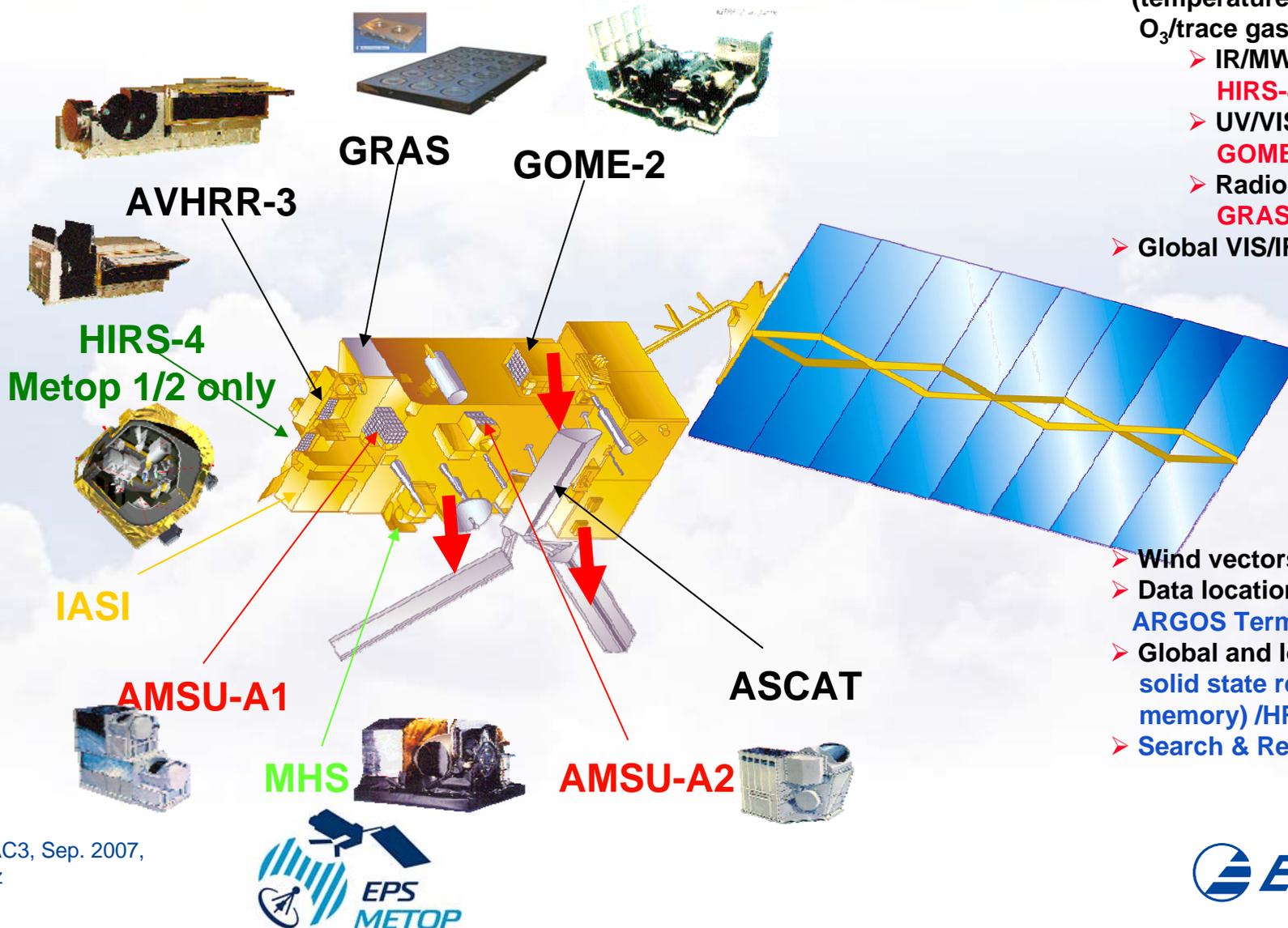


Satellite Application  
Facilities  
(SAF)  
8 Meteorological  
themes

- MetOp-A launched 19<sup>th</sup> October 2006
- Sun-synchronous Orbit
- 820 km, 9h30 LST, 102 min
- Only polar data source from mid-morning orbits
- 11 Instruments
- Metop-B and Metop-C recurrent models
- Soyuz launcher service (Baikonour)
- LEOP Service from ESOC (Darmstadt)
- Central and distributed Ground Segment components
- 14 years of operations

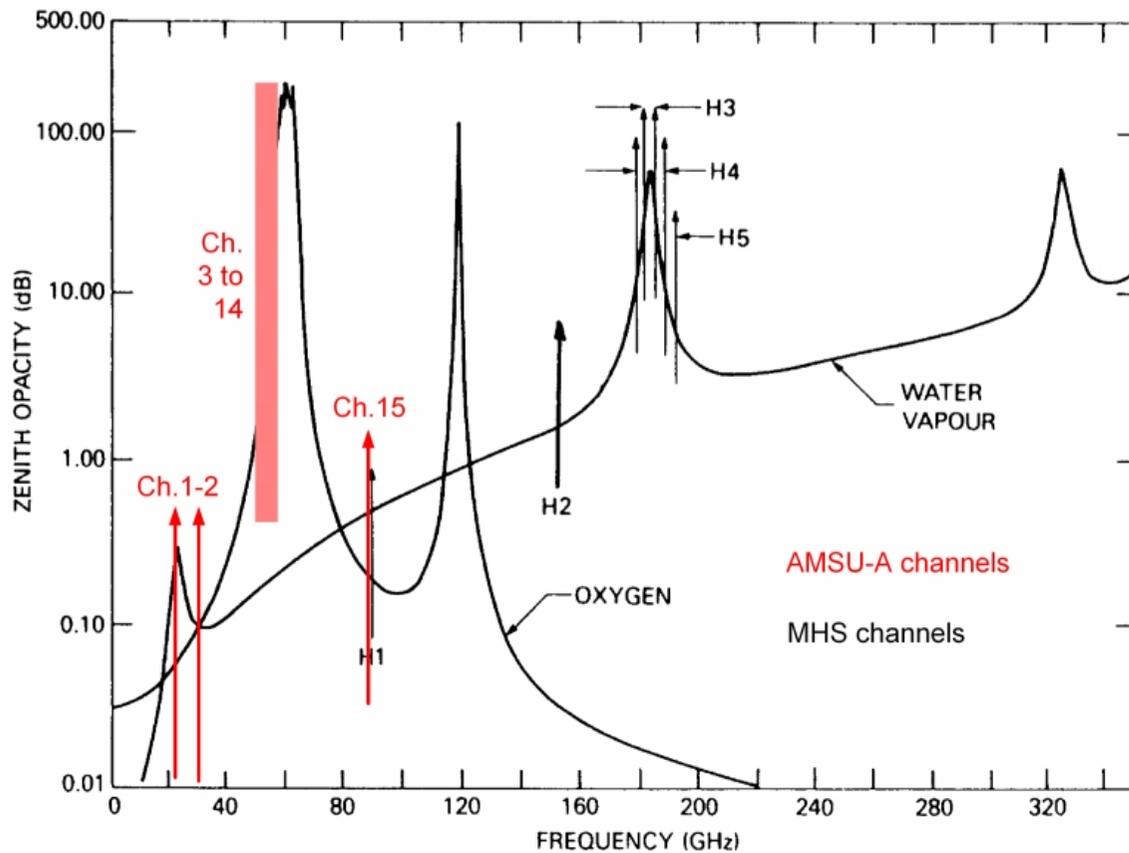


# MetOp: Satellite, Instruments and Missions



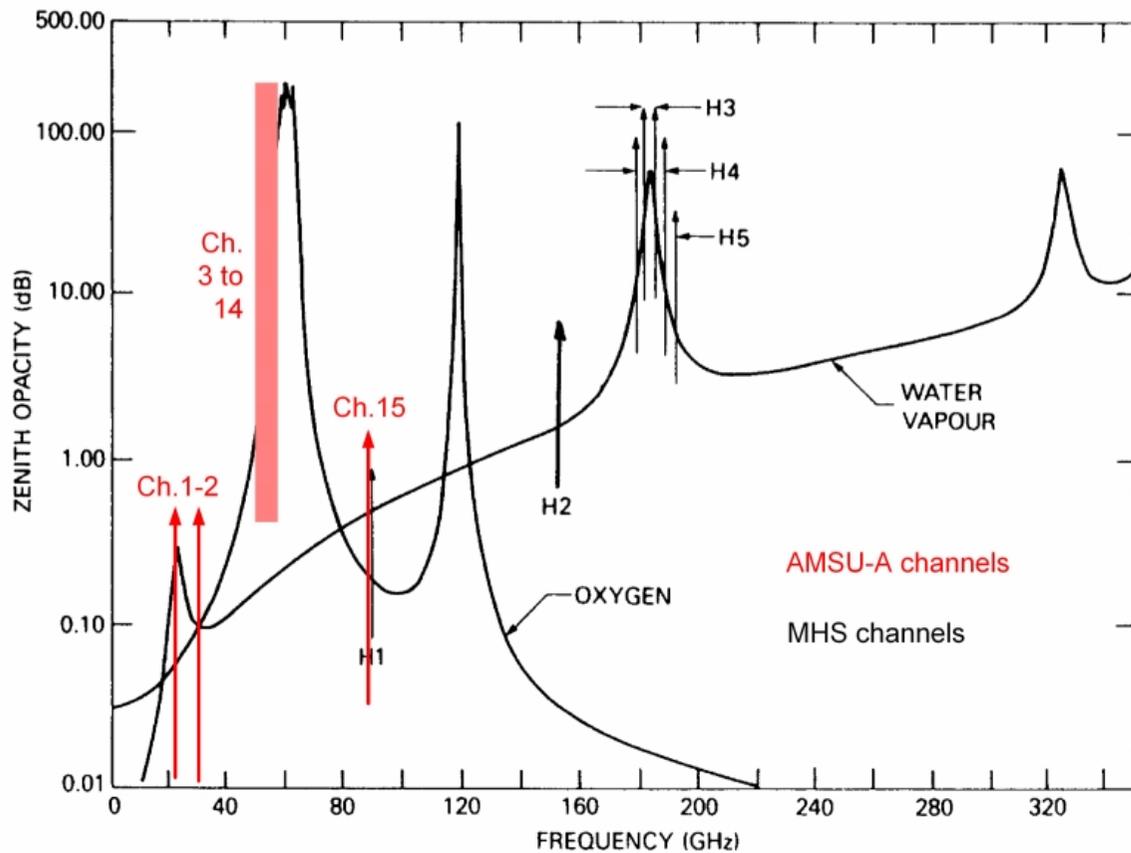
- Atmospheric Sounding (temperature, humidity, O<sub>3</sub>/trace gases):
  - IR/MW sounders: **HIRS-4/IASI, AMSU-A/MHS**
  - UV/VIS sounder: **GOME-2**
  - Radio occultation limb sounder **GRAS**
- Global VIS/IR Imagery: **AVHRR/3**
- Wind vectors over the ocean: **ASCAT**
- Data location and collection: **ARGOS Terminal**
- Global and local data access: solid state recorder (on board memory) /HRPT/LRPT
- Search & Rescue Terminal

# METOP: AMSU-A



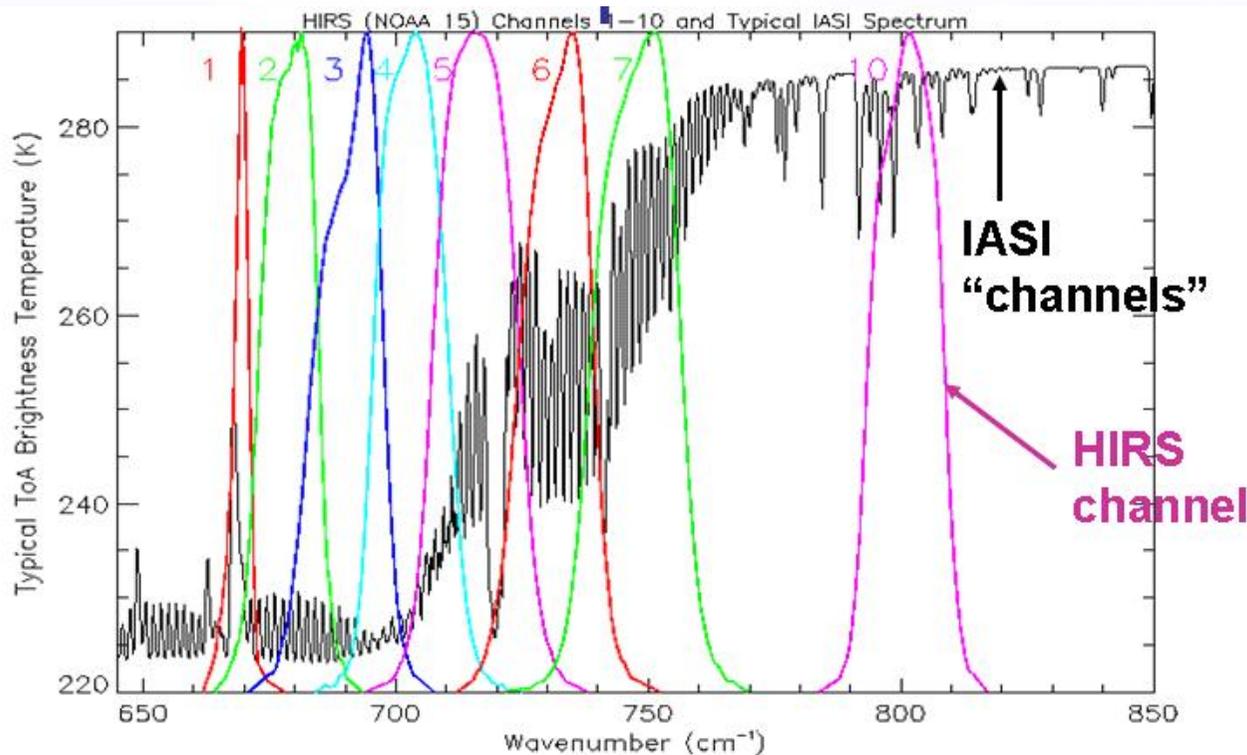
- Microwave radiometer
- 15 channels (23–89GHz)
- 50km nadir resolution
- 2000km swath (50 Deg.)
- Temperature
- Water vapour
- Surface properties
- Emissivity

# METOP: MHS



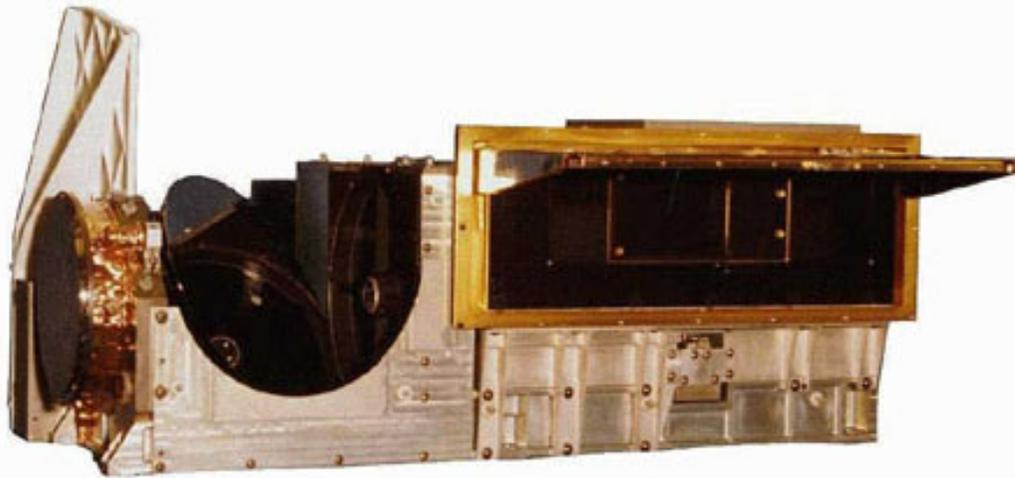
- Microwave radiometer
- 5 channels (89–190GHz)
- 15km nadir resolution
- 2000km swath (50 Deg.)
- Water vapour
- Cloud, precip
- Surface properties
- Emissivity

# METOP: HIRS/4



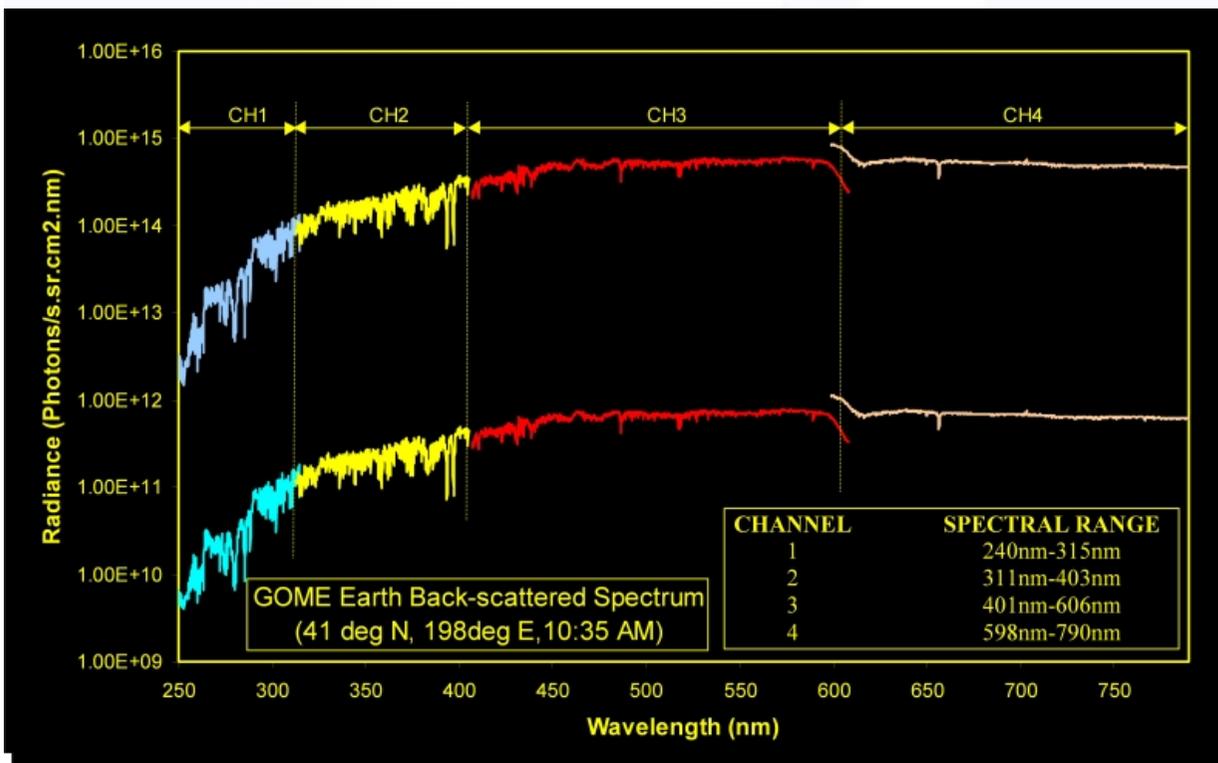
- VIS to IR Radiometer
- 20 channels
- 10km nadir resolution
- 2000km swath (50Deg.)
- Temperature
- Water vapour
- Clouds
- Ozone
- Surface properties

# METOP: AVHRR



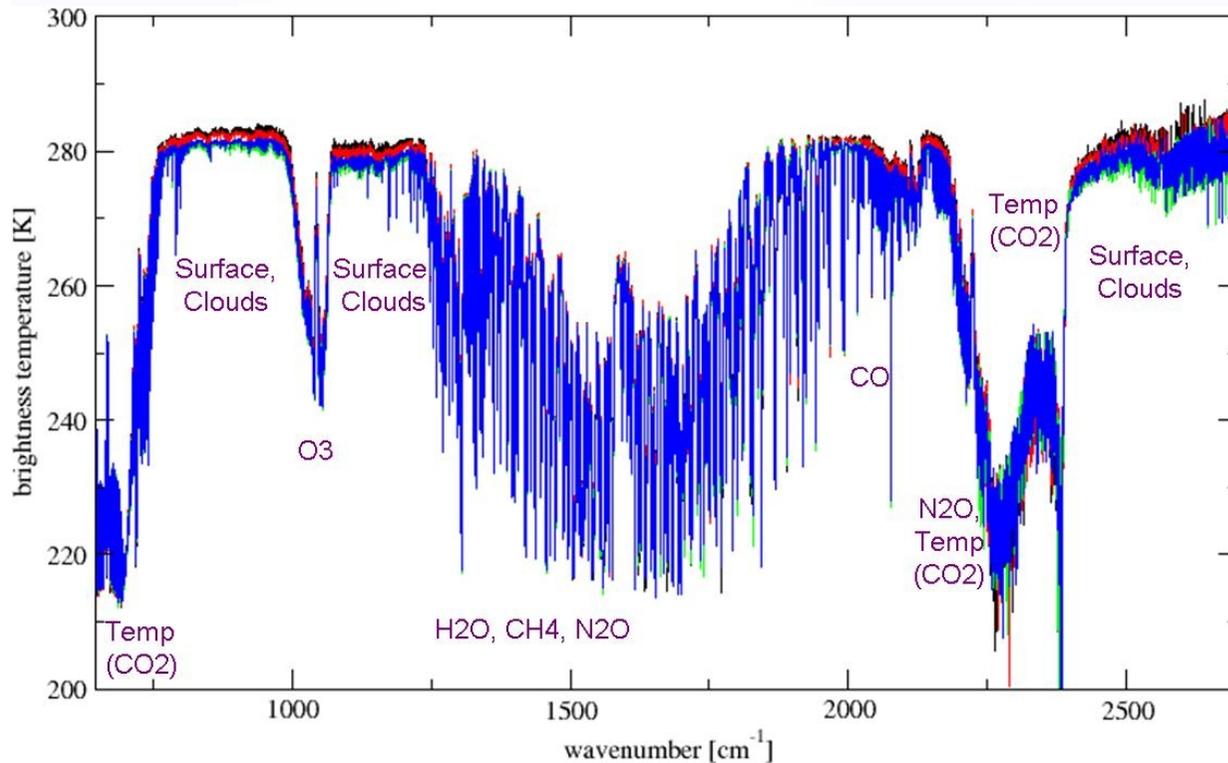
- **VIS to IR radiometer**
- **6 channels**
- **1 km nadir resolution**
- **2800km swath (55 Degrees)**
- **Sea surface temperatures**
- **Cloud properties**
- **Soil properties**
- **Snow cover**
- **Geolocation, Cloud clearing**
- **Internal Geolocation corrected**

# METOP: GOME-2



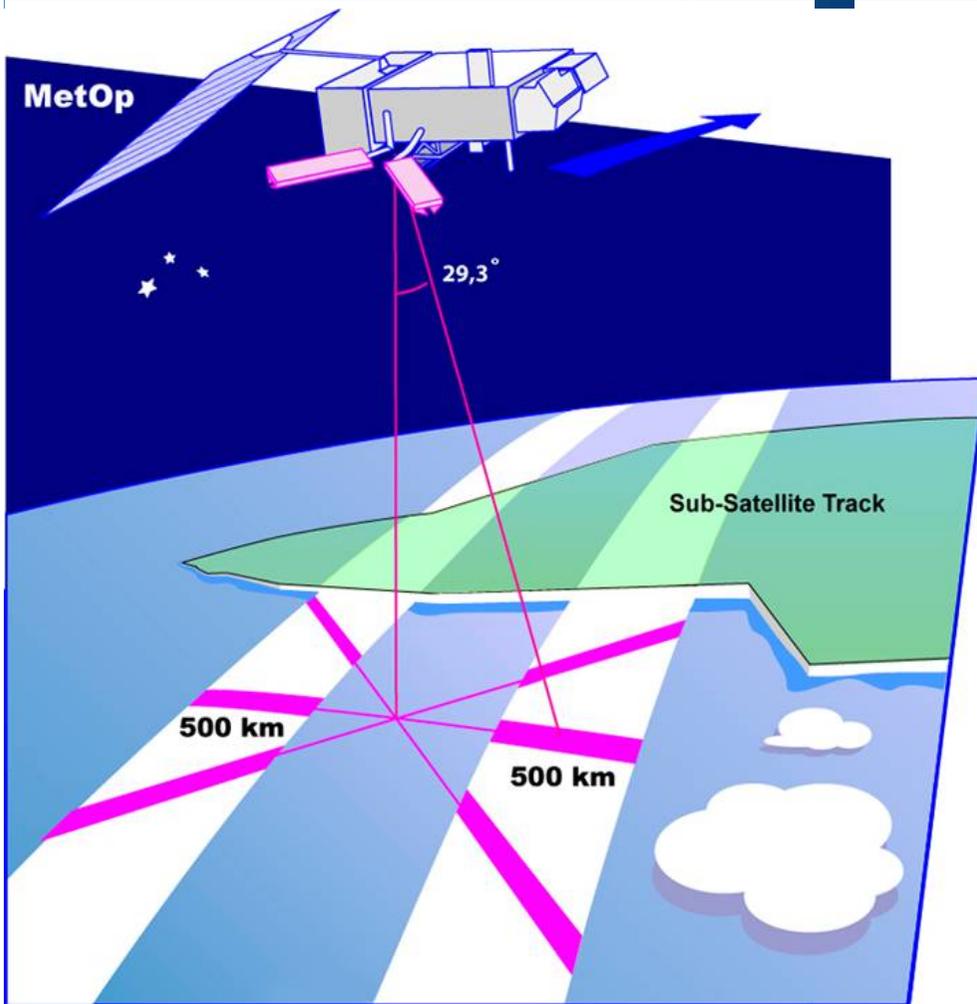
- UV – VIS spectrometer
- 3500 channels (4 main)
- Resolution 80 x 40 km<sup>2</sup>
- 1900km swath (47 Deg)
- Ozone
- Nitrogen dioxide
- Water vapour
- Aerosols

# METOP: IASI



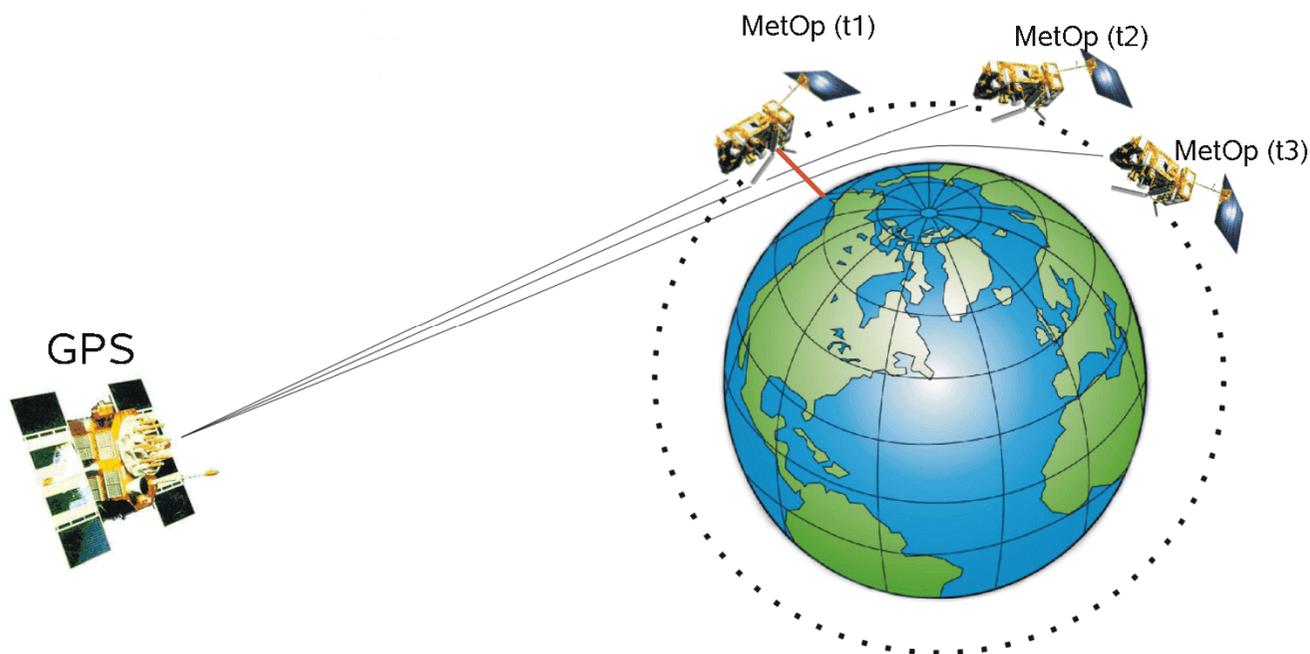
- **Michelson interferom.**
- **8461 channels**
- **Resolution 18km**
- **2000km swath (49 Deg)**
- **Temperature**
- **Water vapour**
- **Ozone**
- **Methane ...**

# METOP: ASCAT



- Real aperture radar
- 25km resolution
- 1700km swath (700 km gap)
- Wind speed
- Wind direction
- Polar ice

# METOP: GRAS



- Radio Occultation
- 2 Rising, 2 setting channels
- 8 zenith channels
- 200m – 1km vertical resolution
- Temperature
- Water vapour
- Climate

# METOP: DISSEMINATION STATUS

Product	Status
AMSU-A Level 1	Started 31 Oct 2006 / resumed 29 Nov 2006
MHS Level 1	Started 27 Nov 2006
HIRS/4 Level 1	Started 28 Nov 2006
AVHRR/3 Level 1	Started 28 Nov 2006
ASCAT Level 1	Started 31 January 2007 (pre-operational)
GOME-2 Level 1	Started 1 March 2007 (pre-operational)
IASI Level 1	Started 24 May 2007 (pre-operational)
GRAS Level 1	Started August 2007 (demonstration)
ATOVS Level 2	PPF being tested, End June 2007
IASI Level 2	PPF being tested, End July 2007

# GRAS: PROCESSING

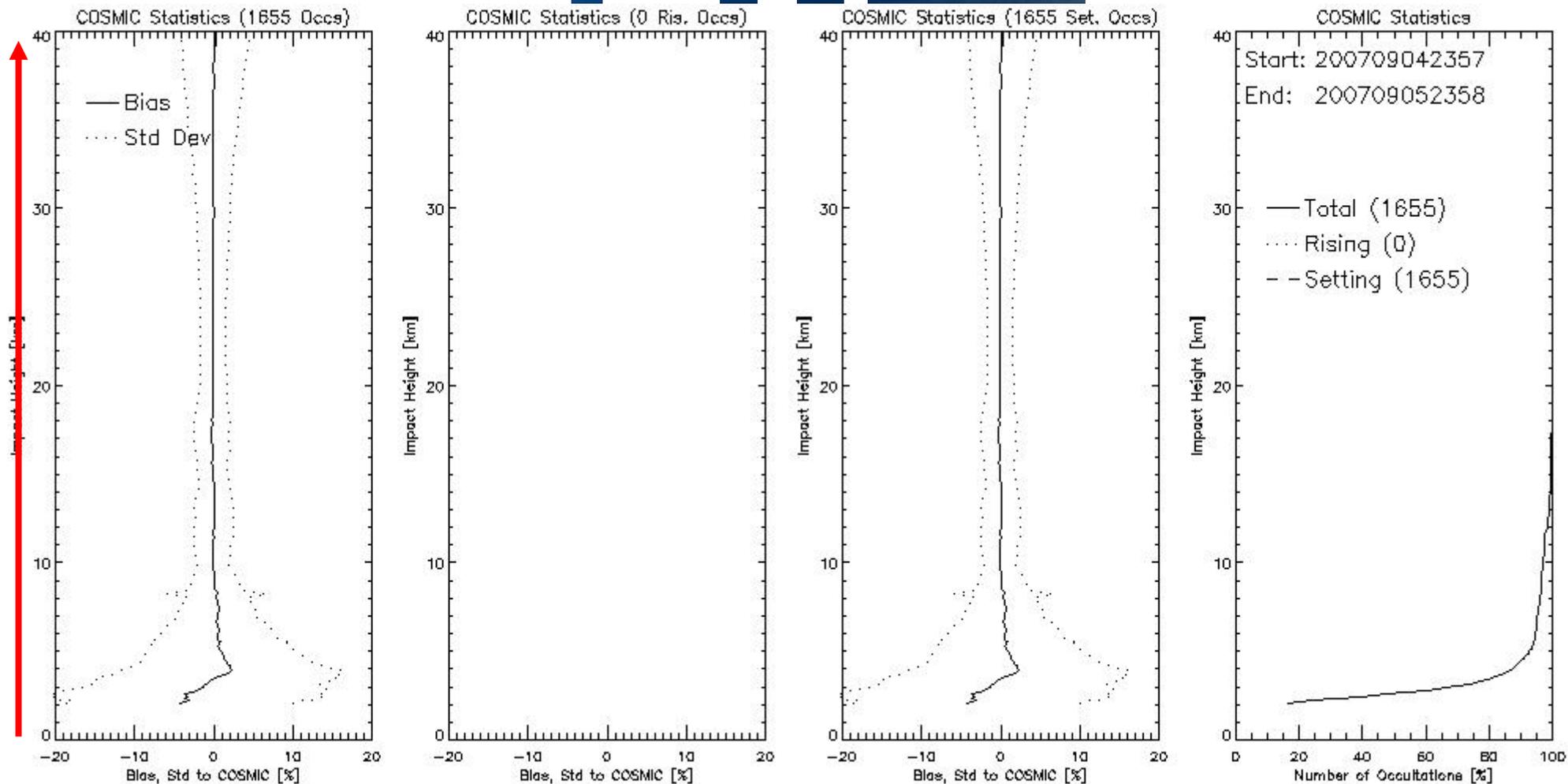
- **Input:**
  - **Measurement Data from Svalbard Ground Station**
  - **GPS Clocks and Orbit Data from Support Network**
- **Orbit Processing:**
  - **1min sequential processing of Clocks and Orbits**
- **Bending Angle Processing:**
  - **Zero Differencing**
  - **Geometrical Optics**
  - **Dual Frequency Tracking**
  - **Open Loop Data not yet included**
  - **Available in NRT within 2h 15min**

# GRAS: VALIDATION

- **ECMWF (O-B)/B Statistics:**
  - 12h or 24h Forecast ECMWF Fields
  - selecting vertical co-located Profile at nearest Time
  - Forward Modelling ECMWF Profiles using ROPP
  - Calculate (O-B)/B Statistics in Bending Angles
- **COSMIC / AMSU Co-Location:**
  - Use GRAS mean Latitude / Longitude Point
  - Search within +/- 3 Hours
  - Search within 300 km Radius

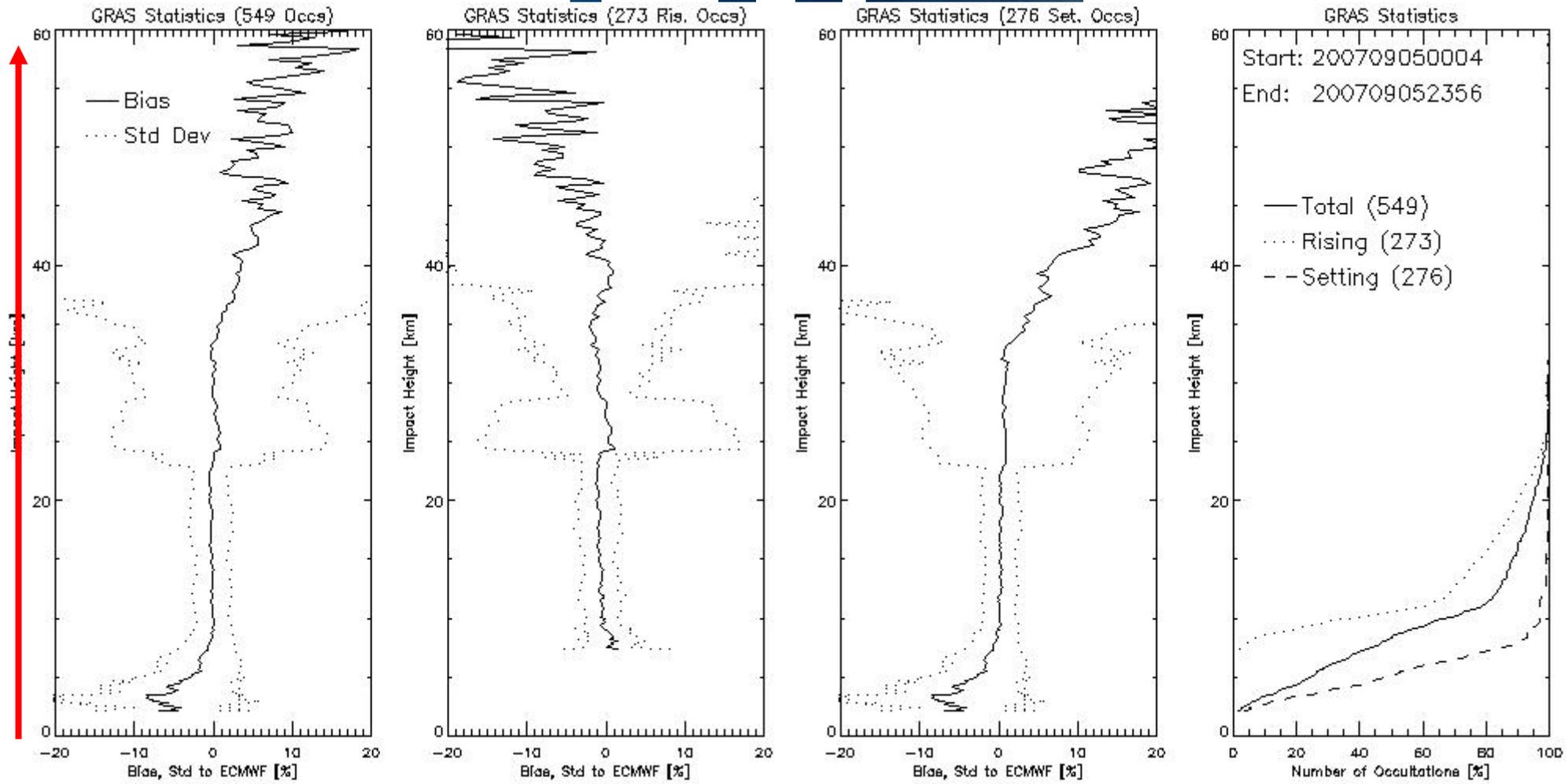
# GRAS: COSMIC VALIDATION (2007/09/05)

0 - 40 km IH

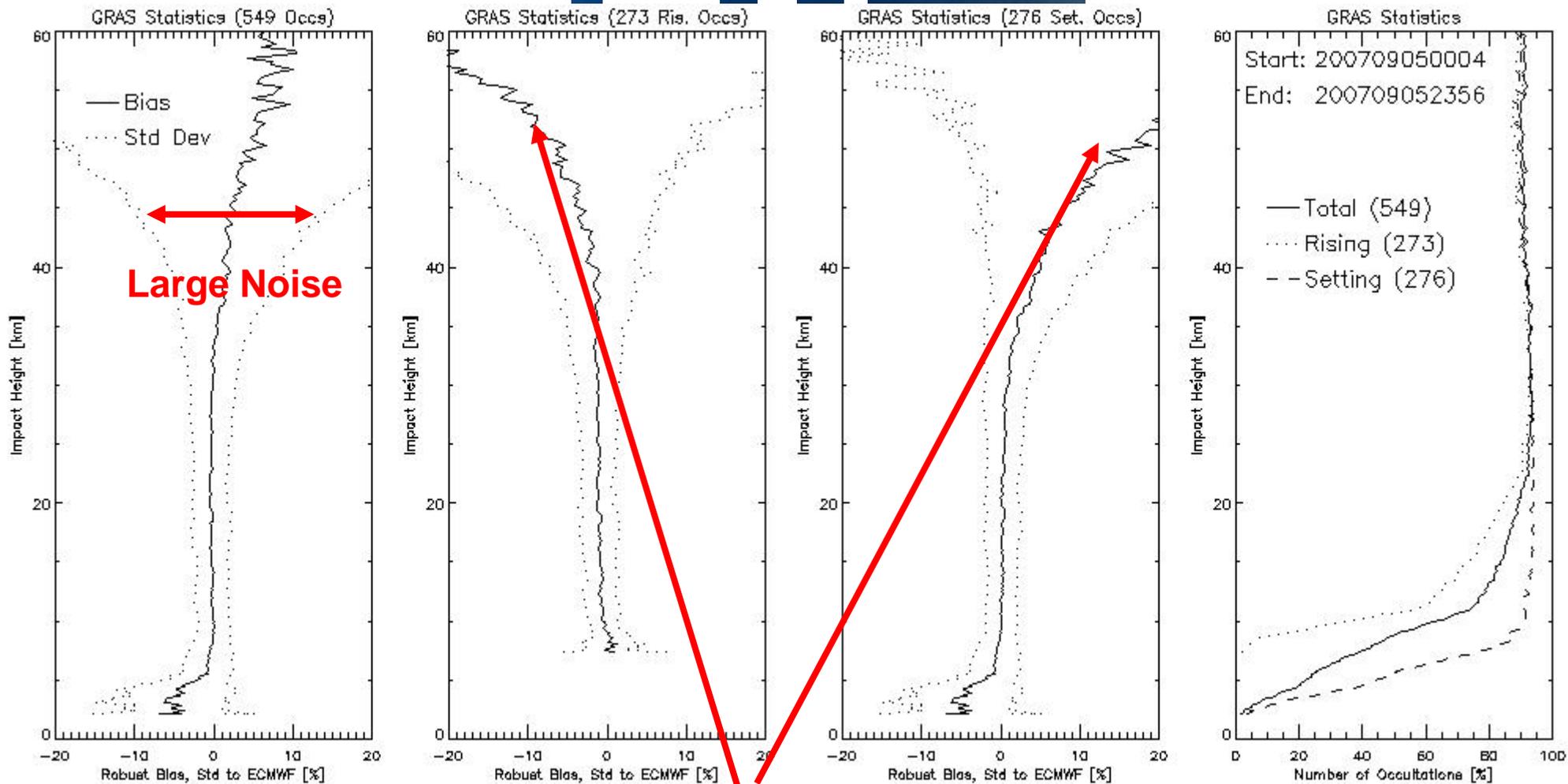


# GRAS: VALIDATION (2007/09/05)

0 - 60 km IH

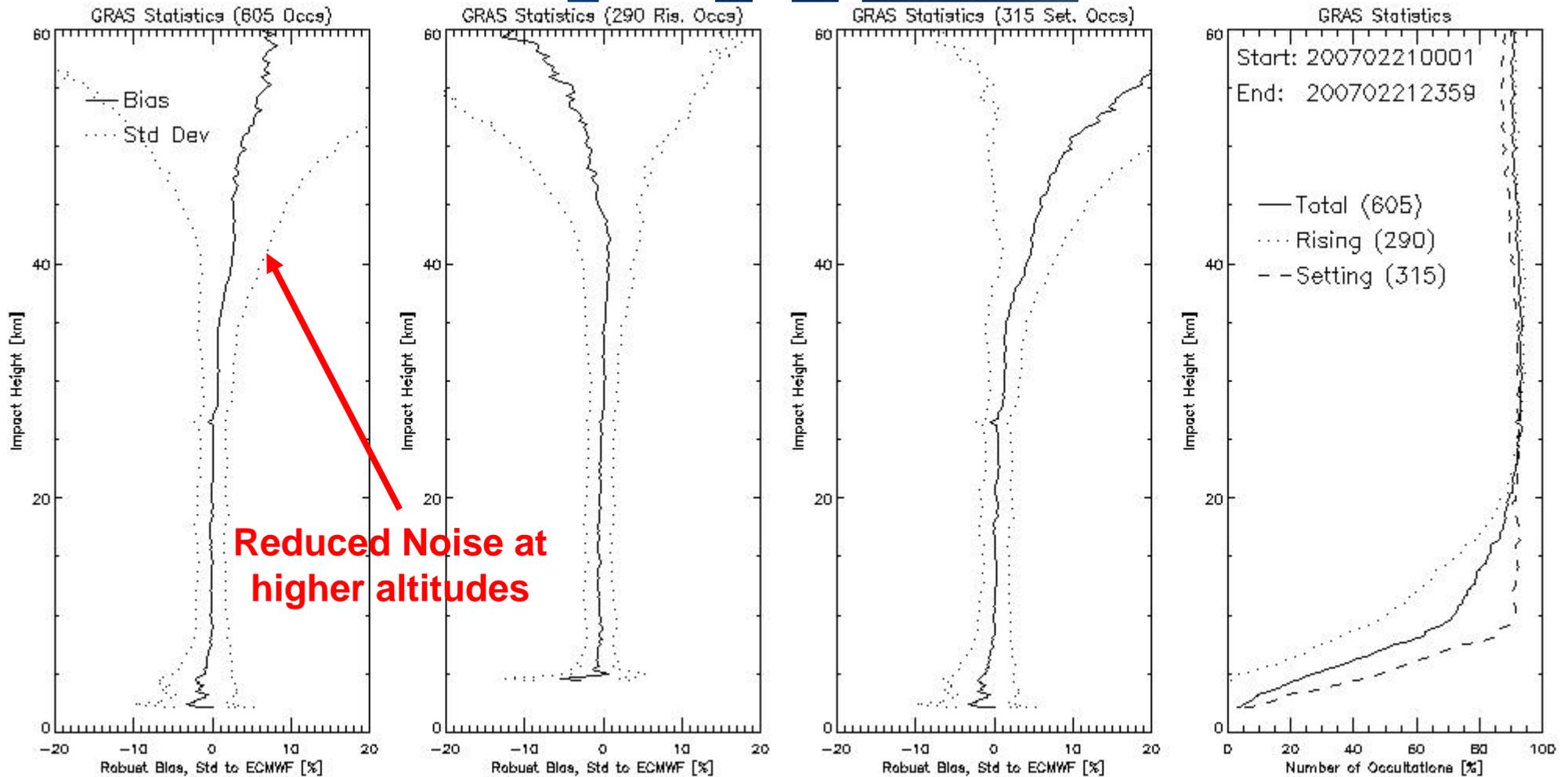


# GRAS: ROBUST VALIDATION (2007/09/05)

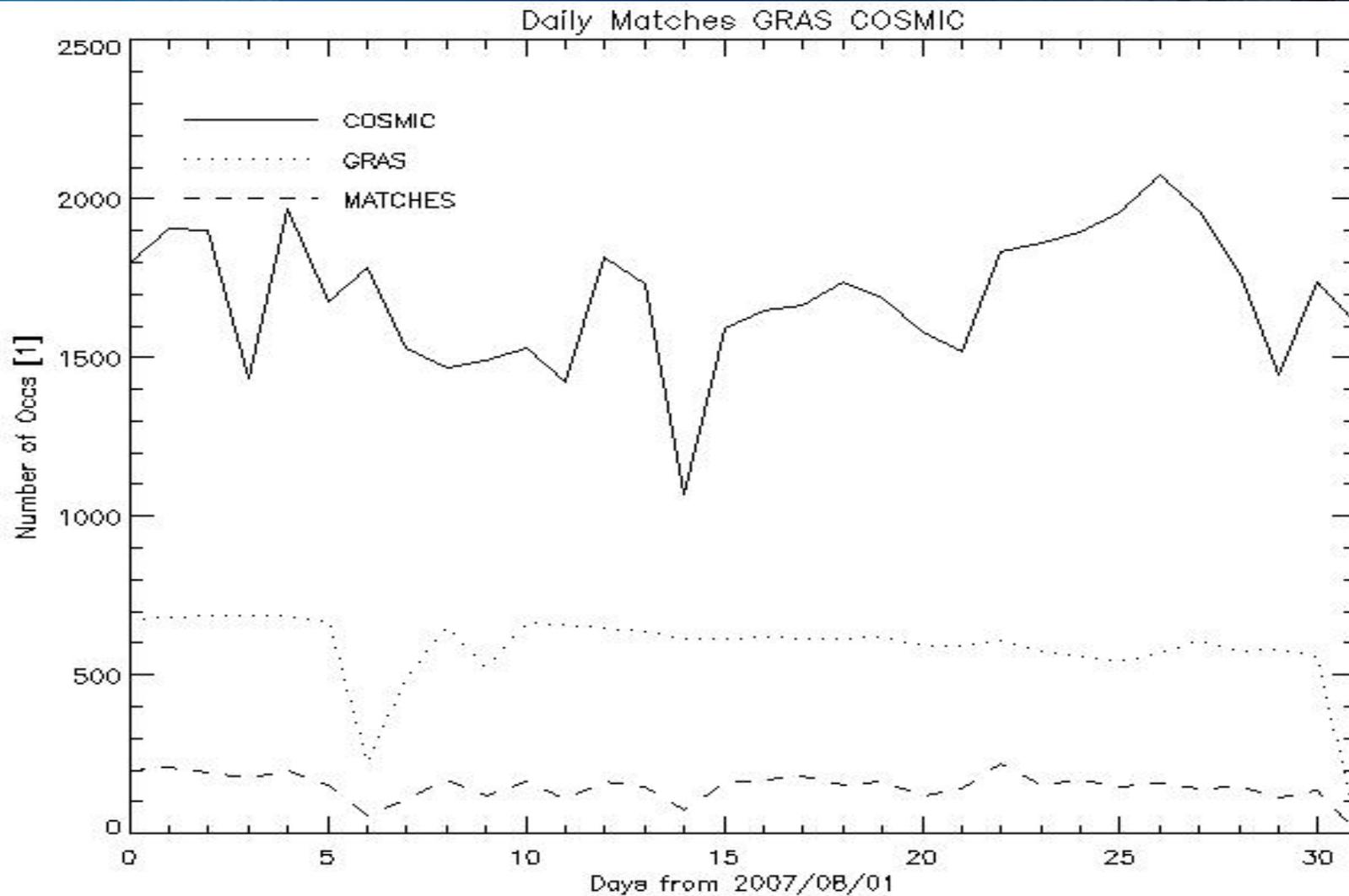


**Different Biases dep. on Set/Ris**

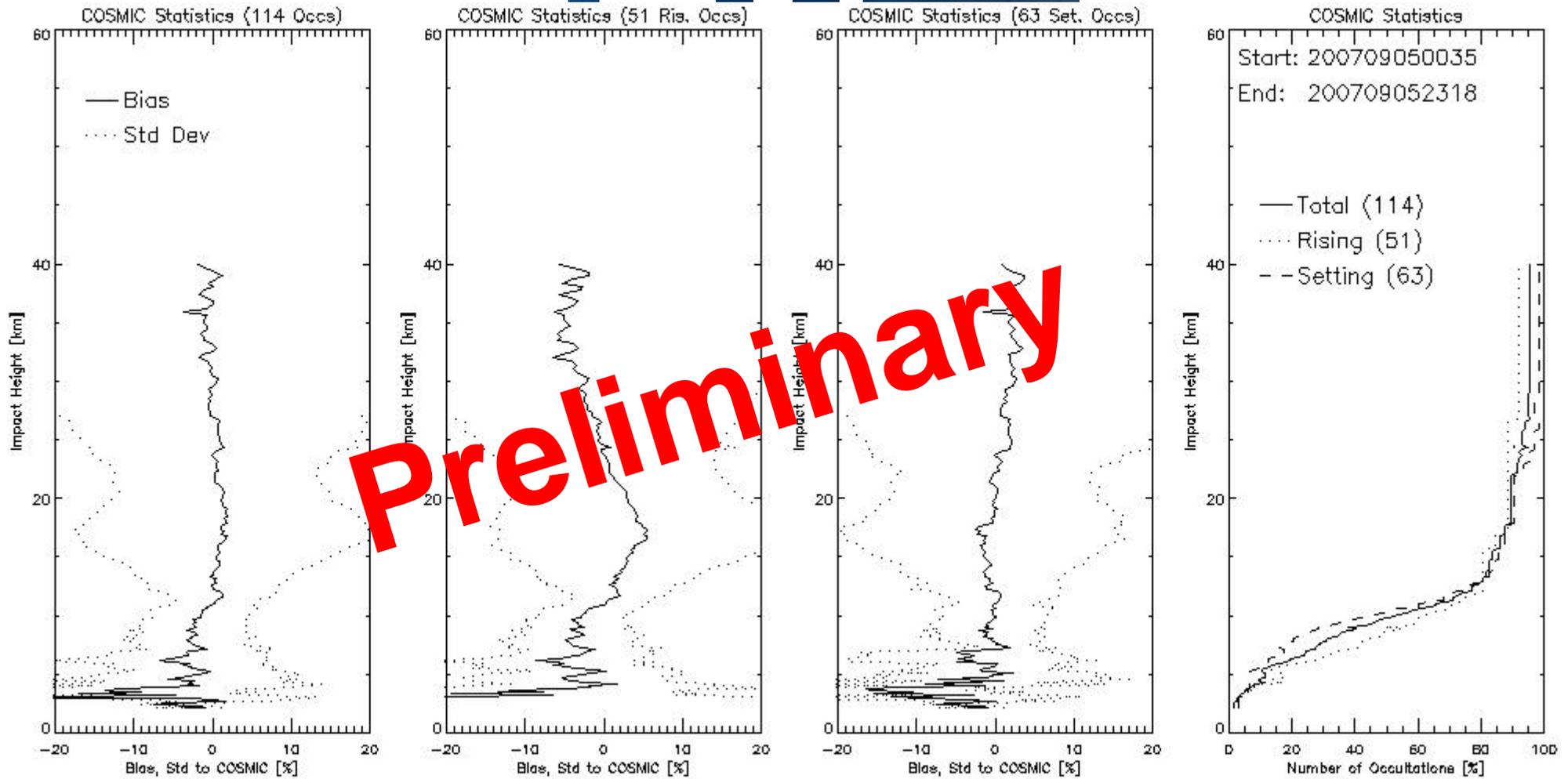
# GRAS: ROBUST IMT2 VALIDATION (2007/02/21)



# GRAS: COSMIC CO-LOCATIONS (2007/08)

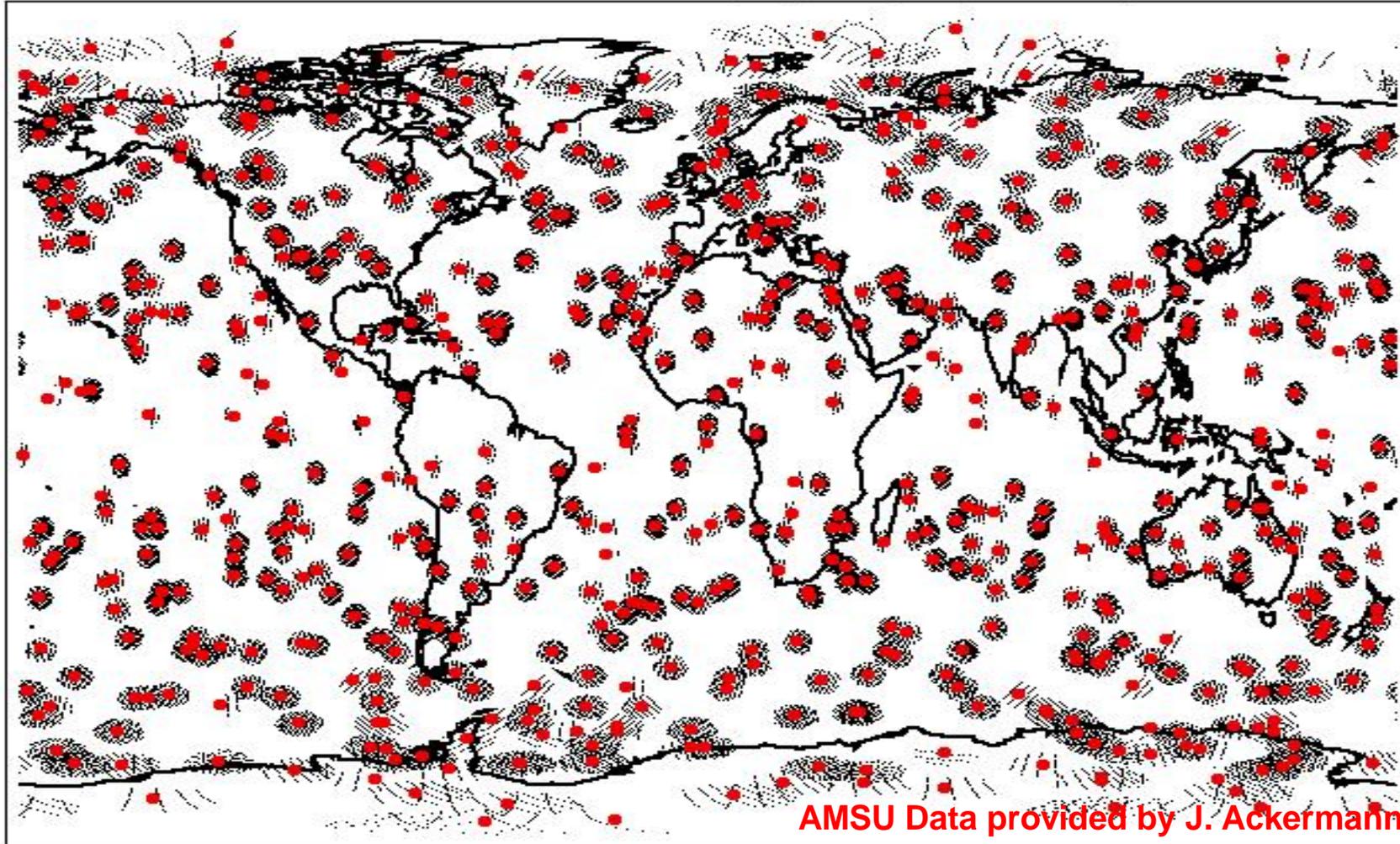


# GRAS: CO-LOCATED COSMIC (2007/09/05)



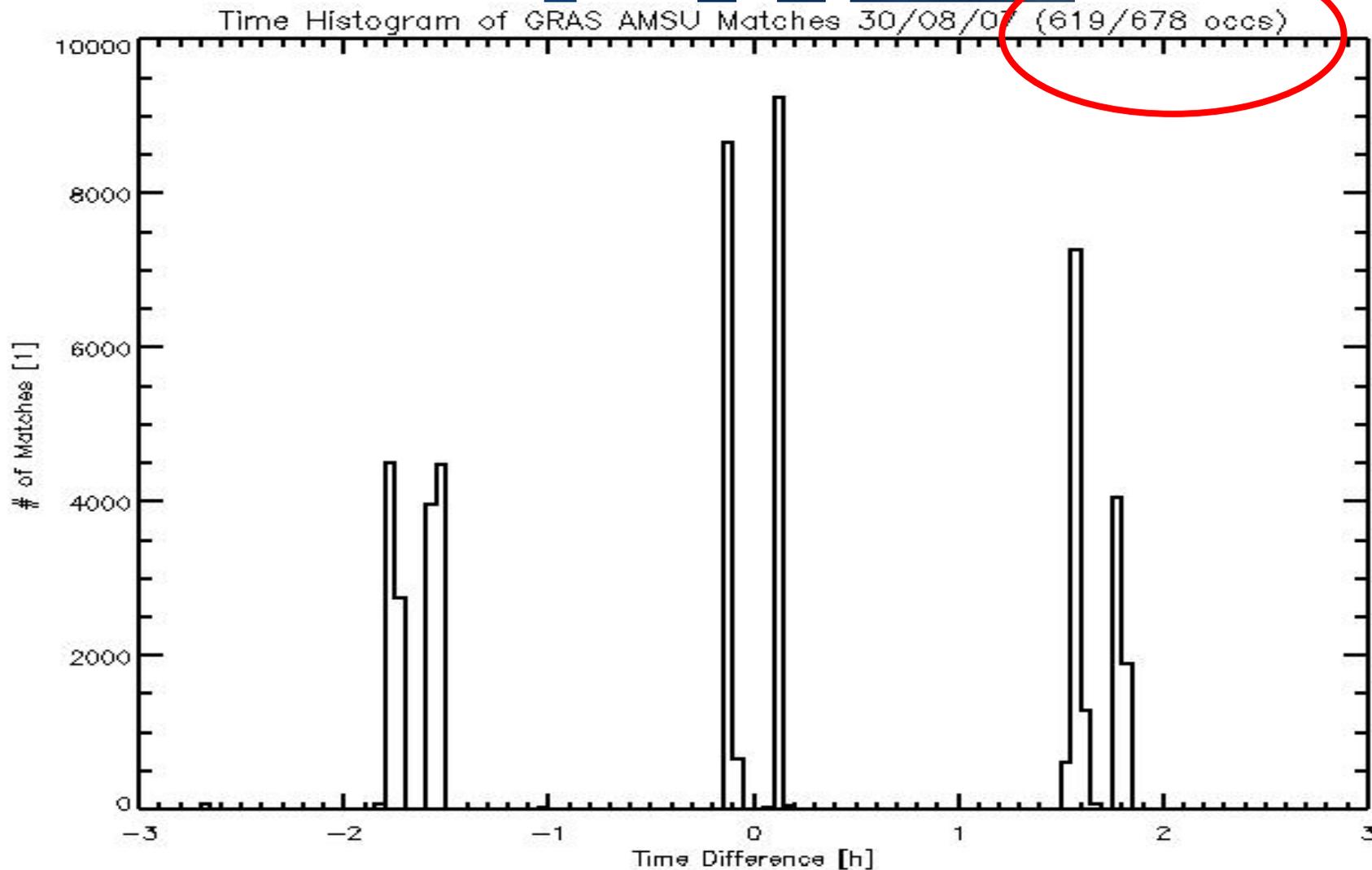
# GRAS: AMSU CO-LOCATIONS (2007/08/30)

AMSU GRAS Co-Locations 30/08/07 (619/678 occs)



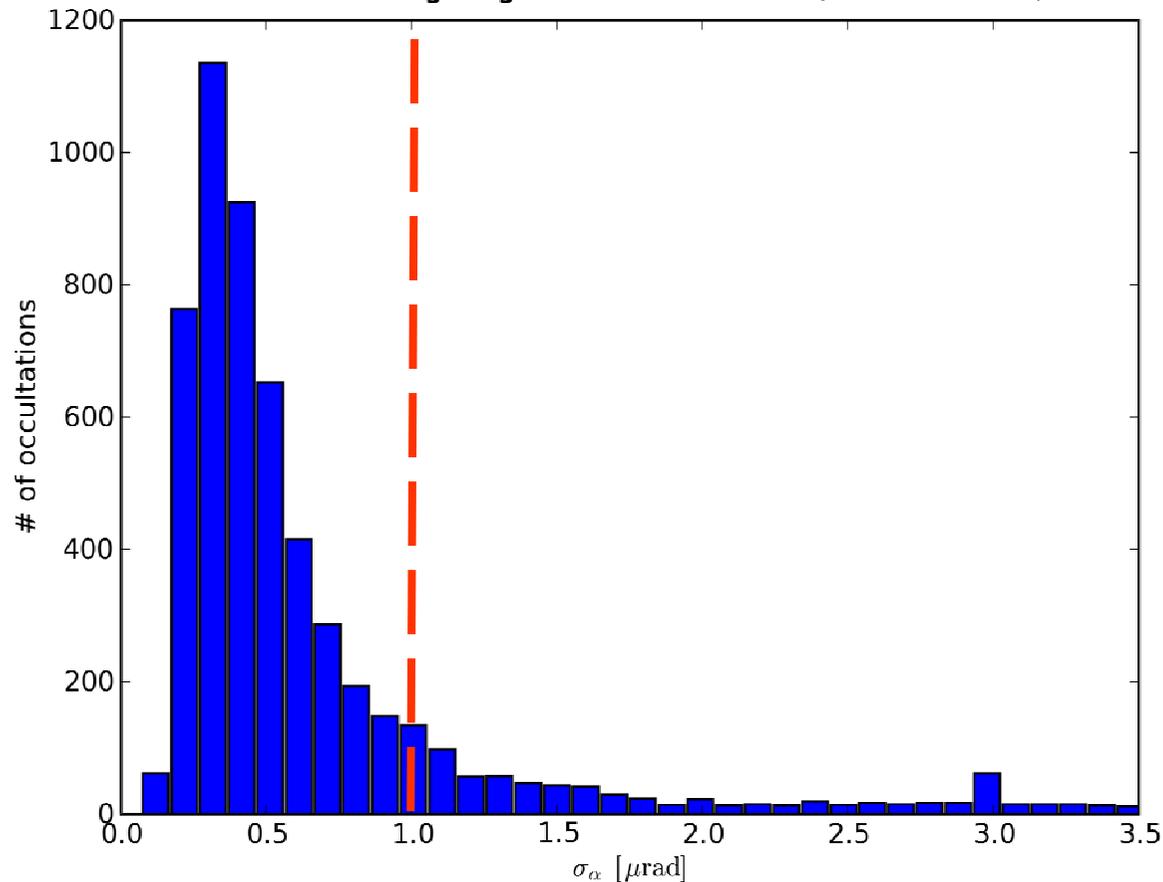
AMSU Data provided by J. Ackermann

# GRAS: AMSU CO-LOCATIONS (2007/08/30)



# GRAS: NOISE ESTIMATES

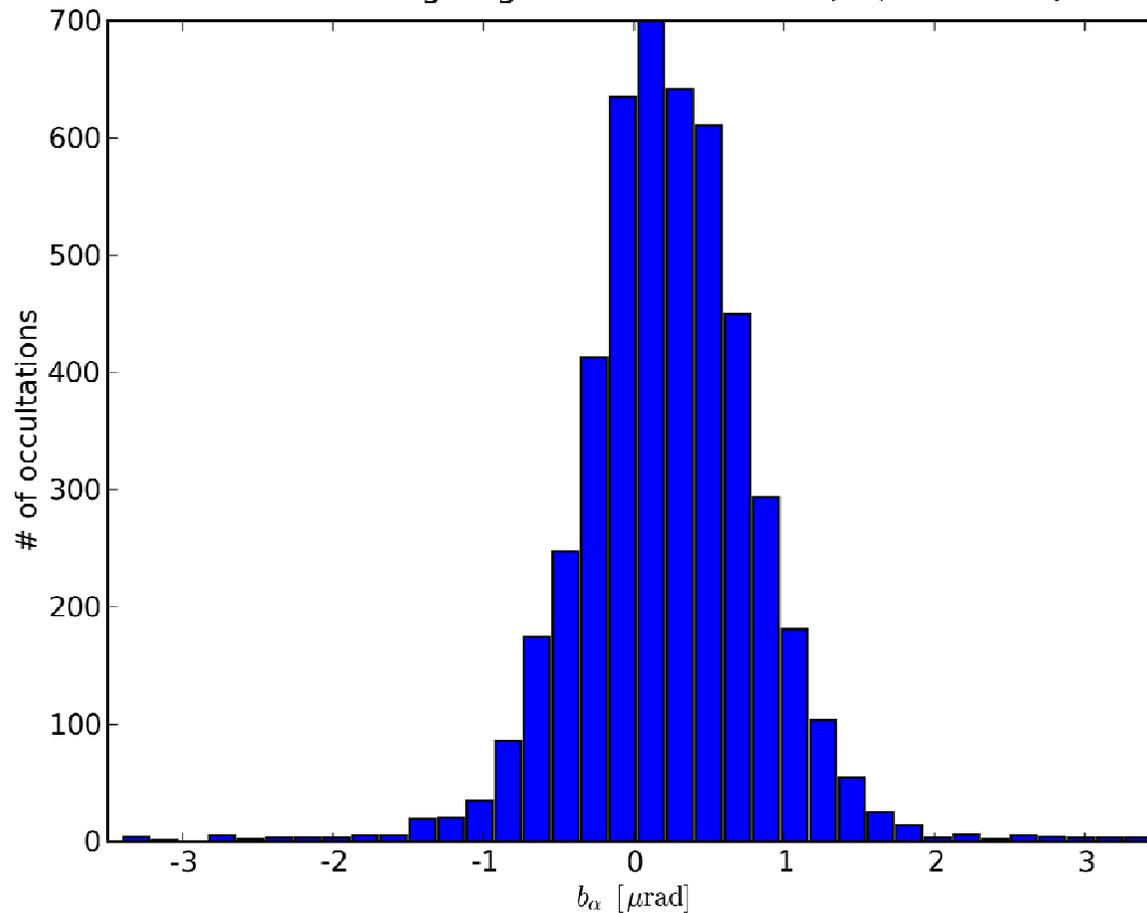
GRAS Bending Angle Noise Statistics (all, n = 5641)



- **Offline Processing**
- **Noise @ 70km**
- **well within Specs!**
- **Same method applied to CHAMP in 2001: ~ 3  $\mu\text{rad}$**

# GRAS: BIAS ESTIMATE

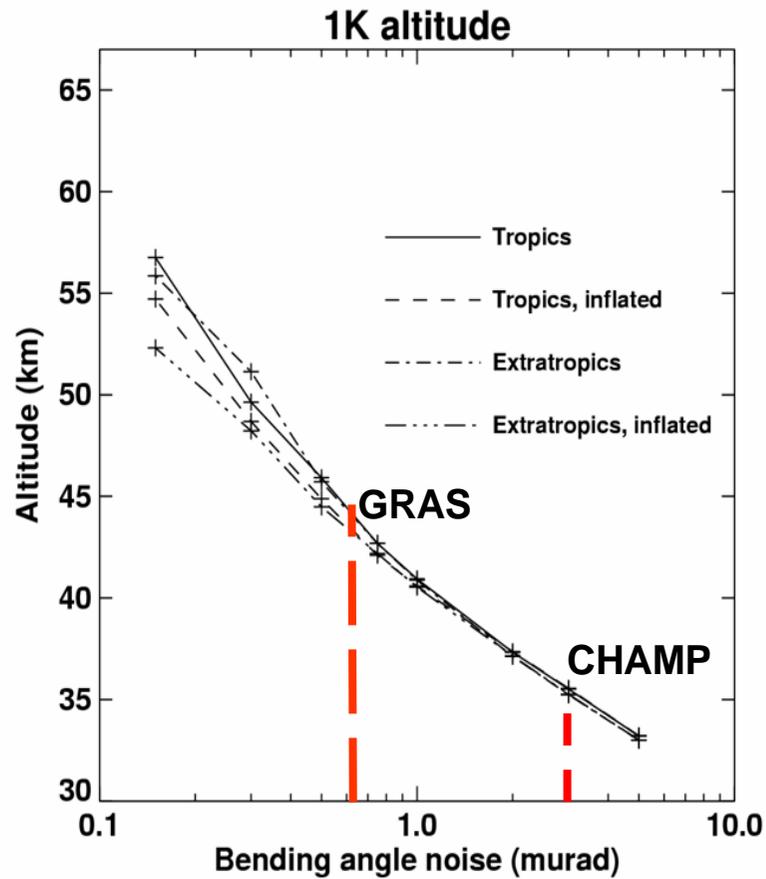
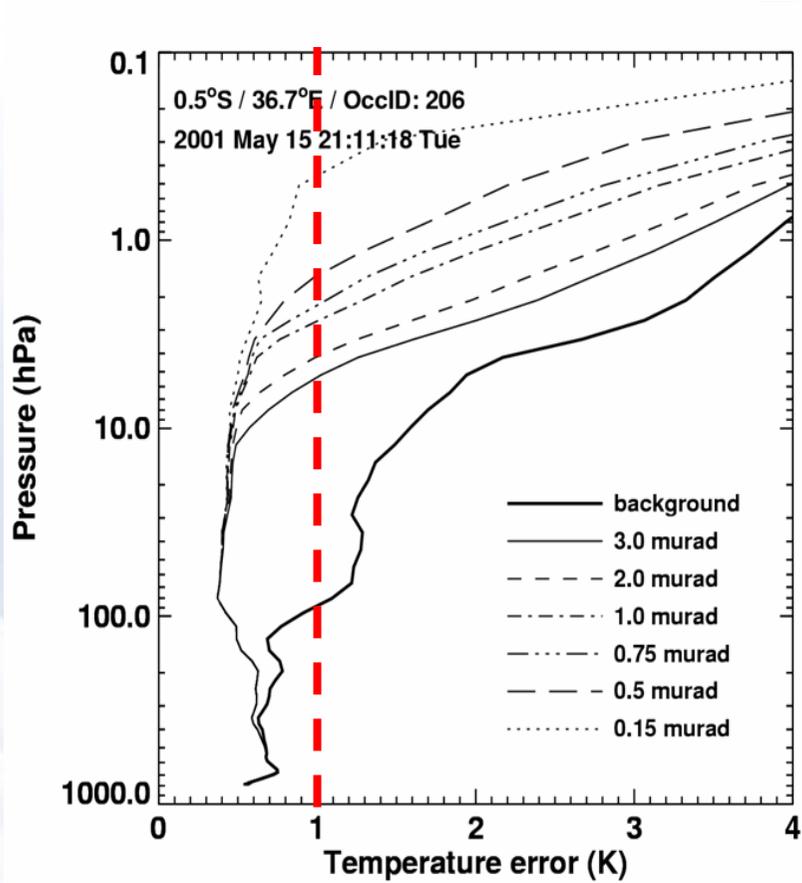
GRAS Bending Angle Noise Statistics (all, n = 4890)



- Orbit errors introduce diff. bias depending on setting or rising
- Not found with POD batch processing



# GRAS: IMPACT ESTIMATES



(Marquardt and Healy, 2005, unpublished)

# GRAS: ANALYSIS OF PROCESSING DELAY

- **GRAS was added later to MetOp Satellite**
- **No prior Experience with Radio Occultation**
- **Very different concept to scanning Instruments**
- **Sequential POD Processing**
- **Insufficient Test Data**
- **Operational Environment / External Sub-Contractor**
- **Rapid Development of processing Algorithm in last Decade**

# CONCLUSIONS

- **MetOp:**
  - **First European operational Polar Satellite**
  - **All instruments are working fine**
- **GRAS:**
  - **Rising worked out of the box**
  - **Very stable Clock**
  - **MORE THAN 600 OCCULTATIONS TRACKED PER DAY**
  - **PSEUDORANGE SUFFICIENT FOR ORBIT DETERMINATION**
  - **NRT AND CLIMATE PROCESSING**