Comparison of GRAS processing results obtained at EUMETSAT and UCAR

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EUMETSAT

Outline

- Purpose of the study

- Main differences between GRAS and IGOR processing

- Orbit determination

- Bending angle comparison
  - UCAR vs. EUMETSAT
    - » bias comparison
    - » UCAR GRAS analysis vs. ECMWF model
    - » structural uncertainty
    - » effect of data gaps
  - Zero difference vs. Single difference

- Summary and discussion

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Reasons for processing METOP/GRAS data

- EUMETSAT - funded structural uncertainty study
- CDAAC interested in routinely processing these data
- Technically Interesting because

1. Well supported stable platform
2. High gain antennas
3. Ultra stable oscillator
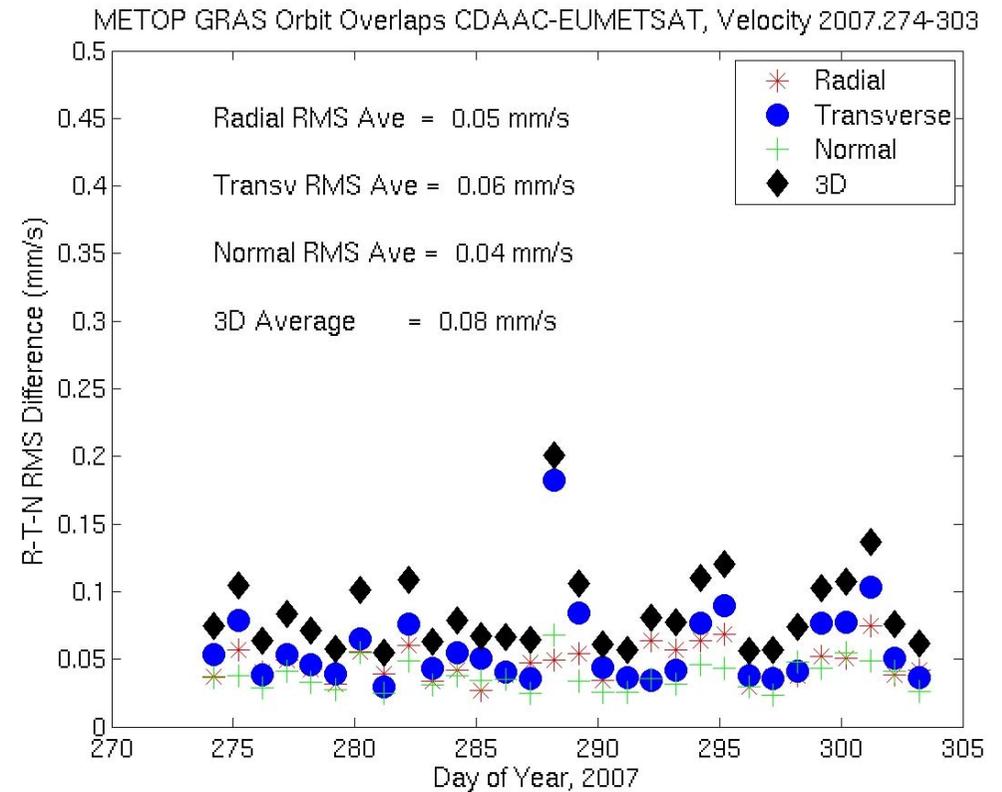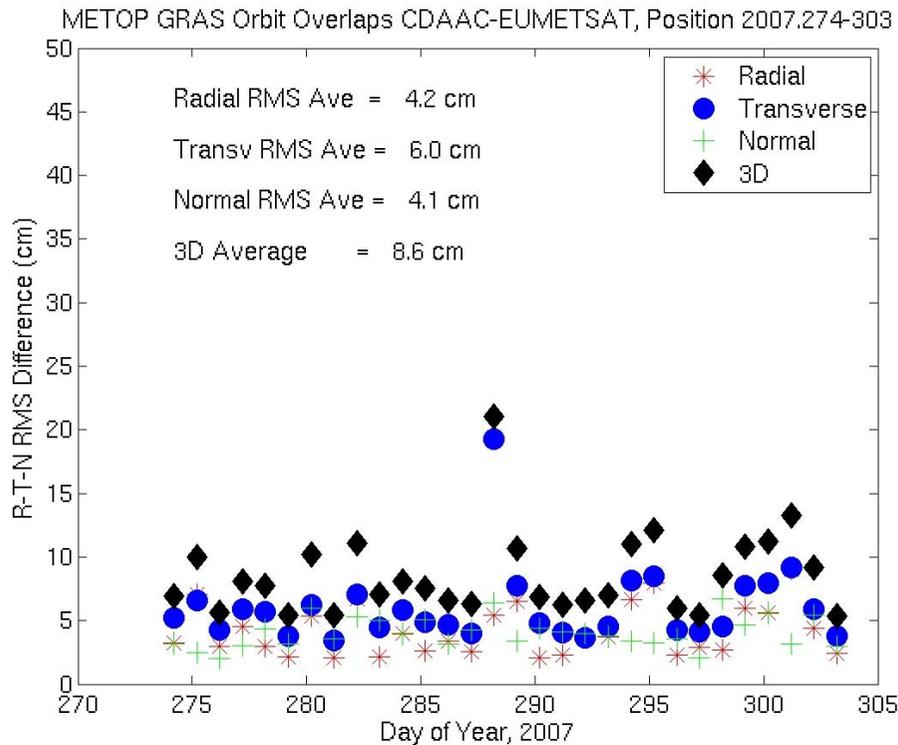4. 1000Hz open loop data
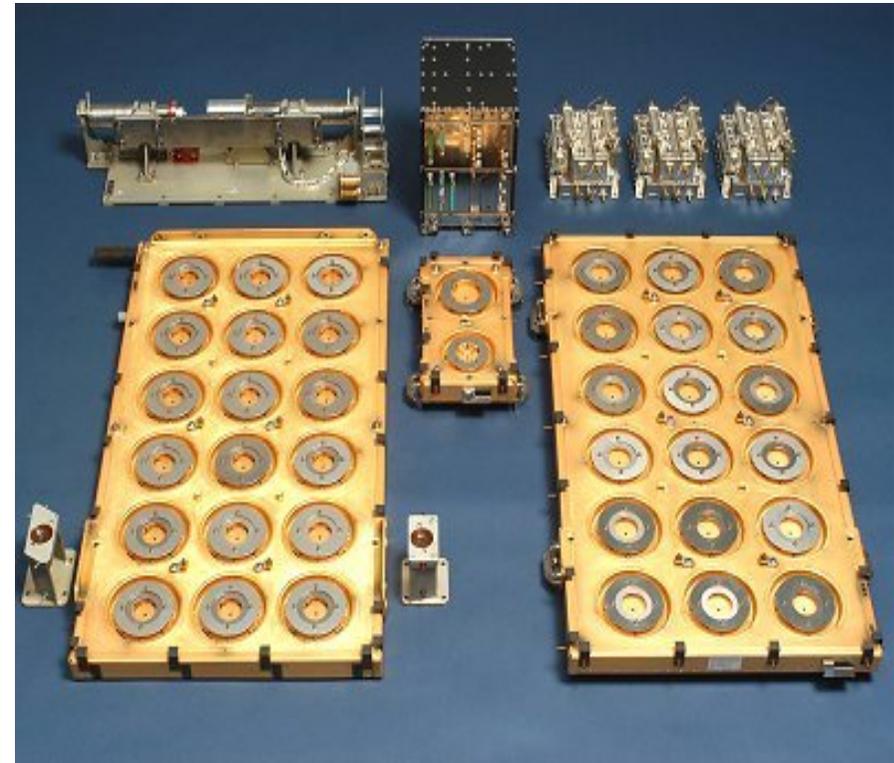
Processing Outline - Differences that may contribute to structural uncertainty

The Level 0 - Level 1 translation is more involved for GRAS than for JPL / BRE type receivers.   Decisions are made at this early step that could lead to structural uncertainty

The GRAS data have frequent gaps - how to deal with them contributes to structural uncertainty

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Precision Orbit Determination

METOP GRAS Orbit Overlaps CDAAC-EUMETSAT, Position 2007.274-303

Radial RMS Ave = 4.2 cm
Transv RMS Ave = 6.0 cm
Normal RMS Ave = 4.1 cm
3D Average = 8.6 cm

* Radial
● Transverse
+ Normal
◆ 3D

METOP GRAS Orbit Overlaps CDAAC-EUMETSAT, Velocity 2007.274-303

Radial RMS Ave = 0.05 mm/s
Transv RMS Ave = 0.06 mm/s
Normal RMS Ave = 0.04 mm/s
3D Average = 0.08 mm/s

* Radial
● Transverse
+ Normal
◆ 3D

	MEAN Position Difference (cm)	STD Position Difference (cm)	MEAN Velocity Difference (mm/s)	STD Velocity Difference (mm/s)
Radial	0.7	4.2	-0.01	0.05
Transverse	0.9	6.0	-0.01	0.06
Normal	2.9	4.1	0.00	0.04
3D		8.6		0.08

No statistically significant velocity <u>biases</u>

GRAS Global Bending Angle Comparison

UCAR minus EUMETSAT 2007.274-304

OPAC workshop, Graz, Austria, Sept. 6-10, 2010
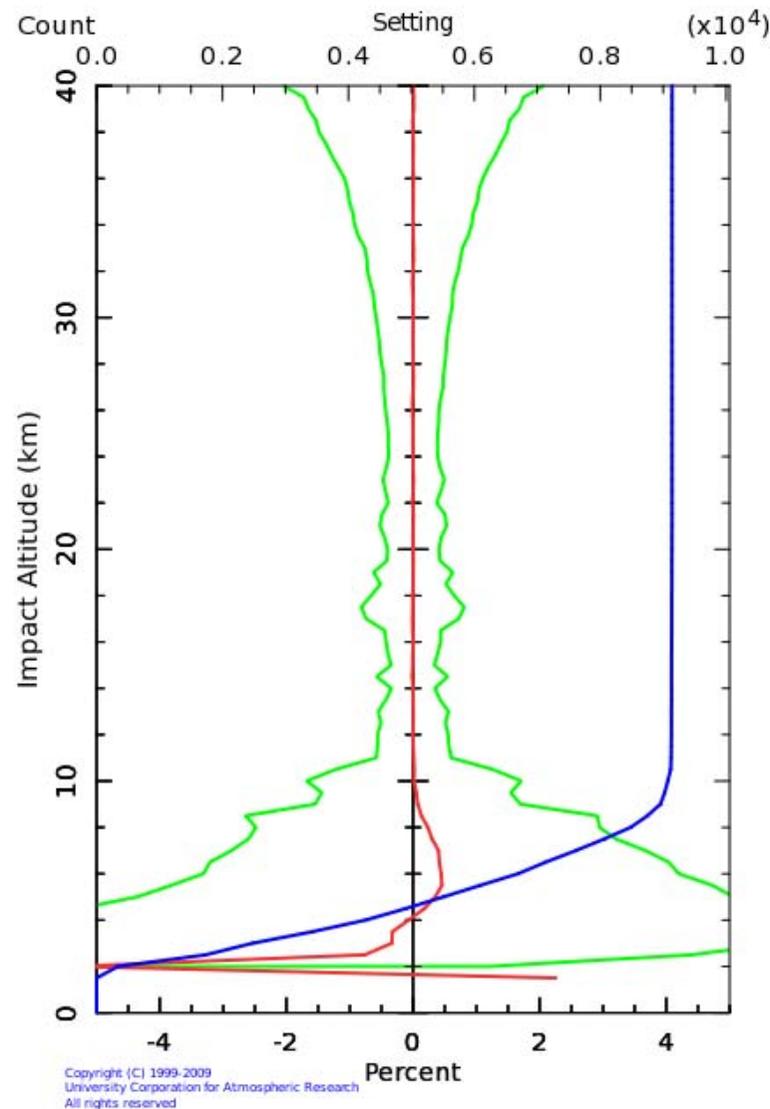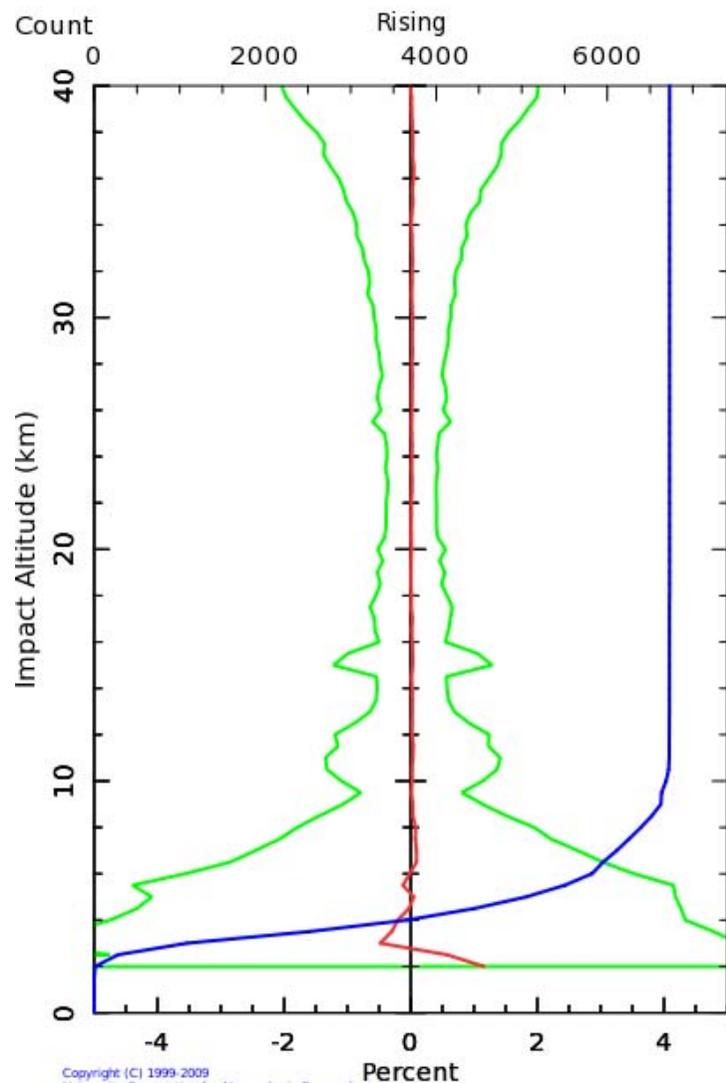
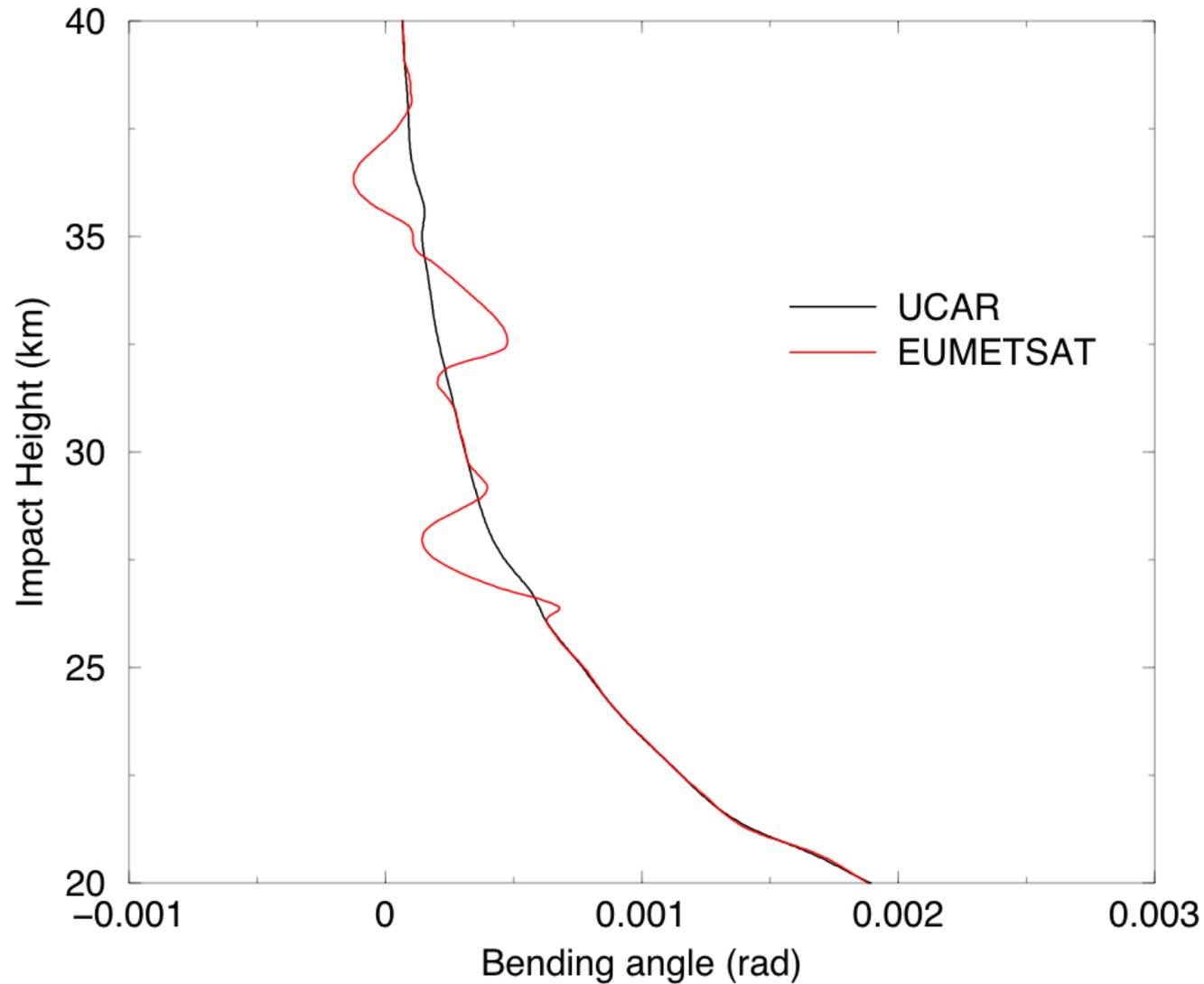# GRAS Global Bending Angle Comparison
UCAR minus EUMETSAT One day 2007.274
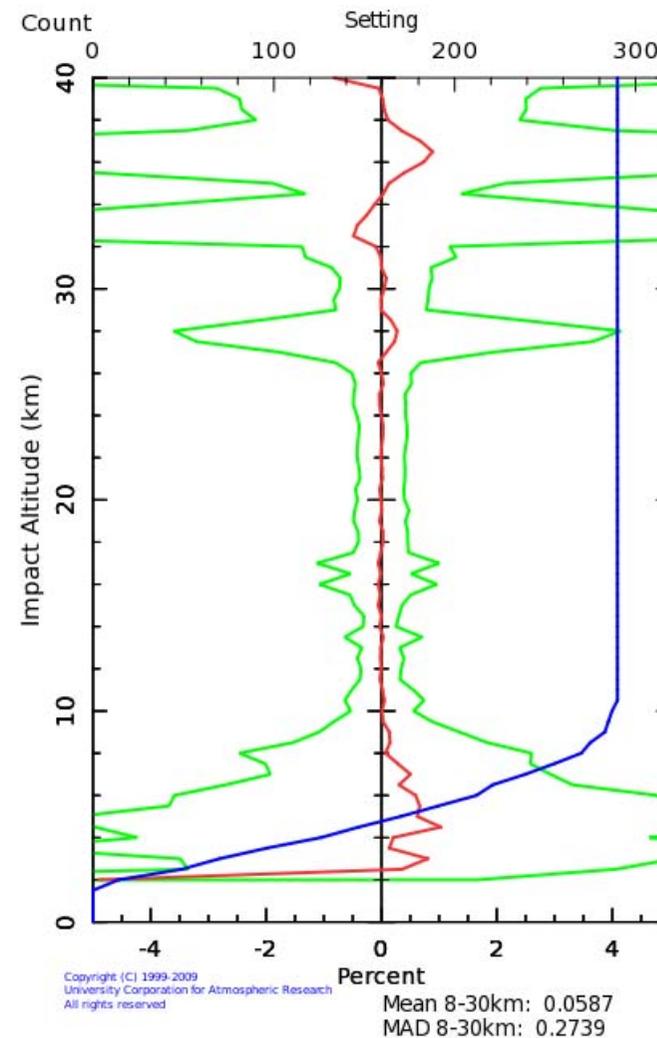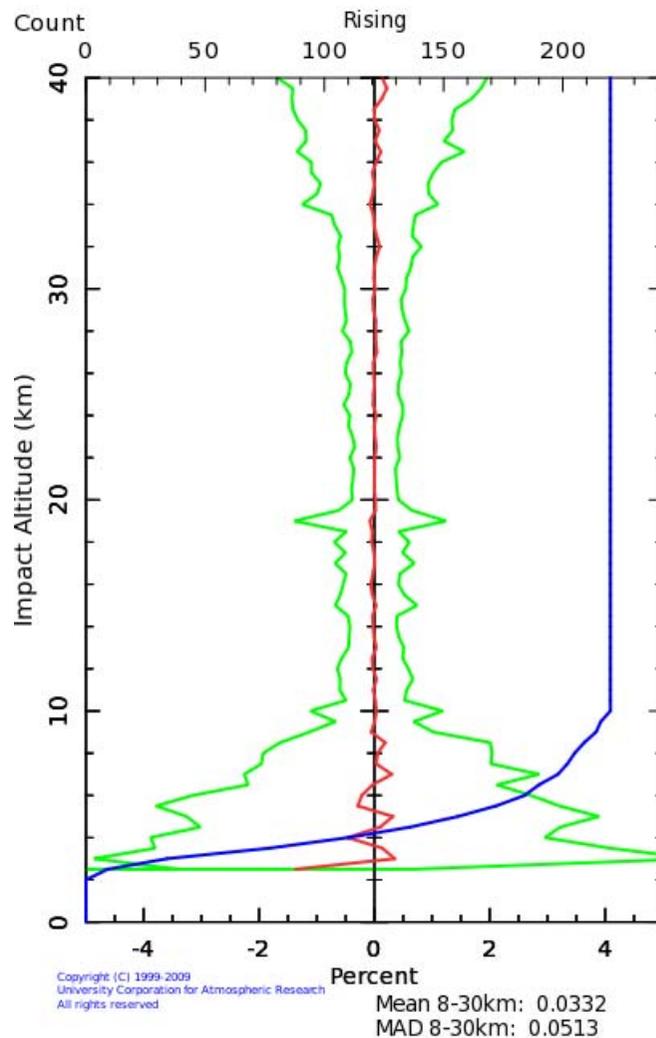
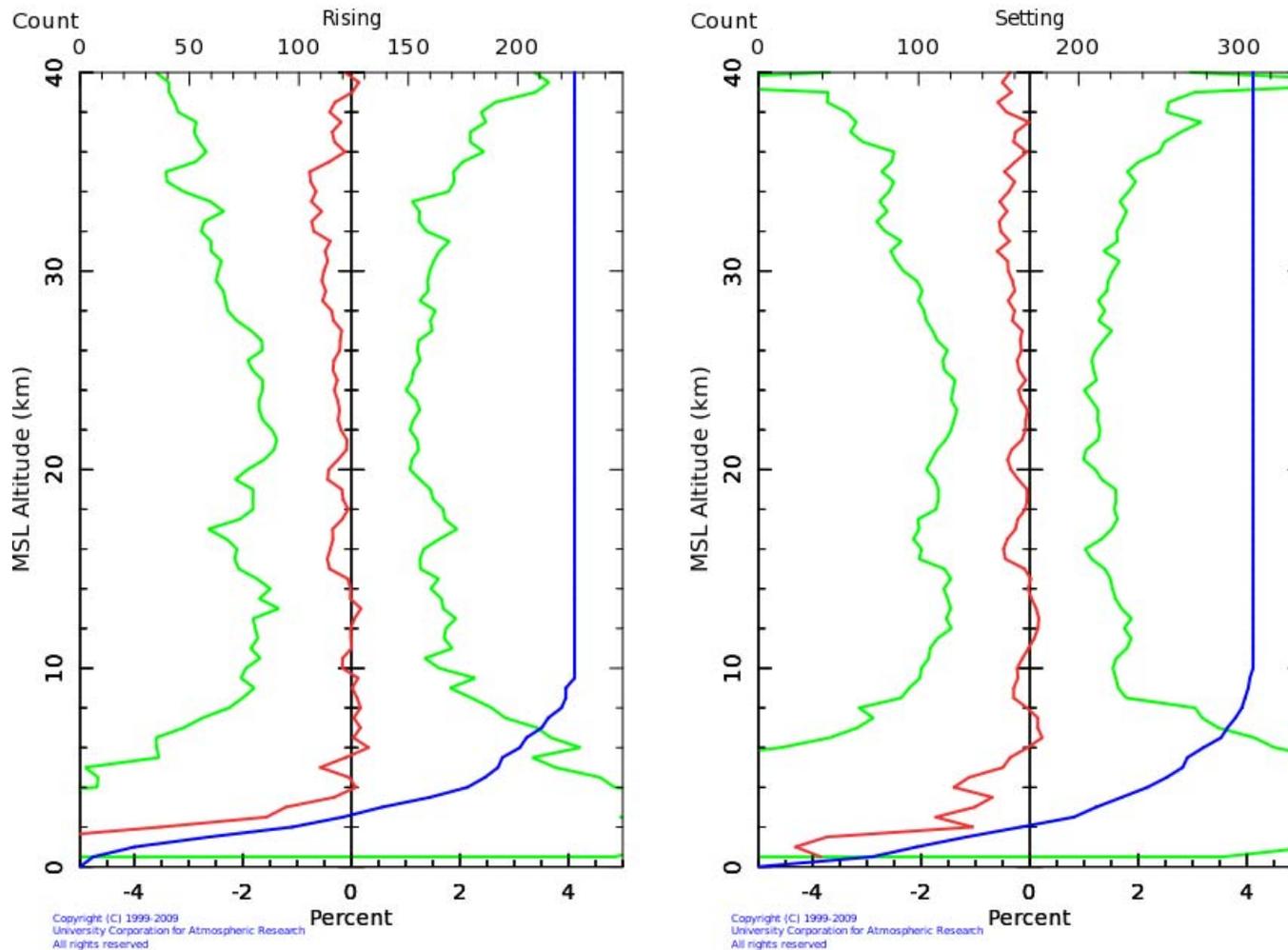
Setting Occultations Show Outliers

Example Outlier Profile comparison
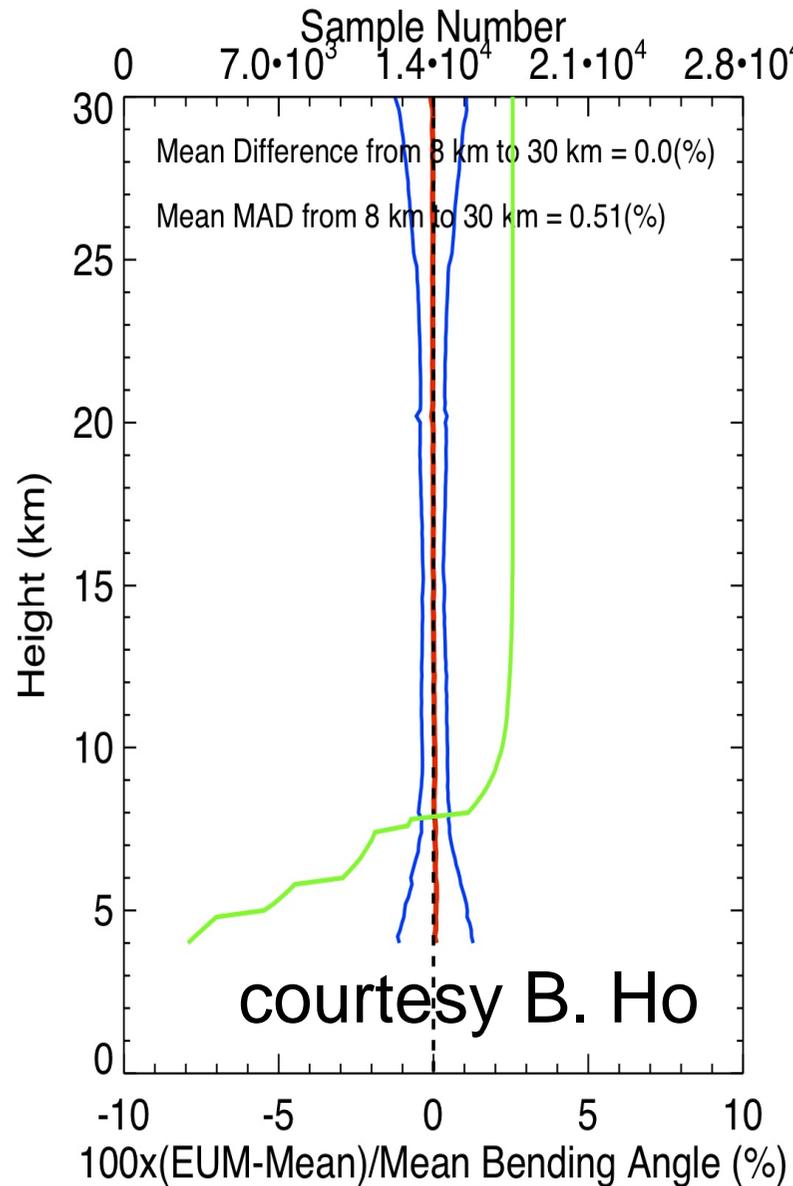

2007.274.20.06.G30

GRAS Global Bending Angle Comparison
UCAR minus ECMWF One day 2007.274

No apparent outliers in UCAR profiles

Comparison of CHAMP EUMETSAT vs. Multi-Center profiles

Mean Difference from 8 km to 30 km = 0.0(%)

Mean MAD from 8 km to 30 km = 0.51(%)

courtesy B. Ho

$$MAD = \frac{\left(\sum_{i=1}^{N} \frac{|a_i - b_i|}{a_i} * 100 \right)}{N}$$

compute MAD for every height layer
a_i: EUMETSAT profile i,
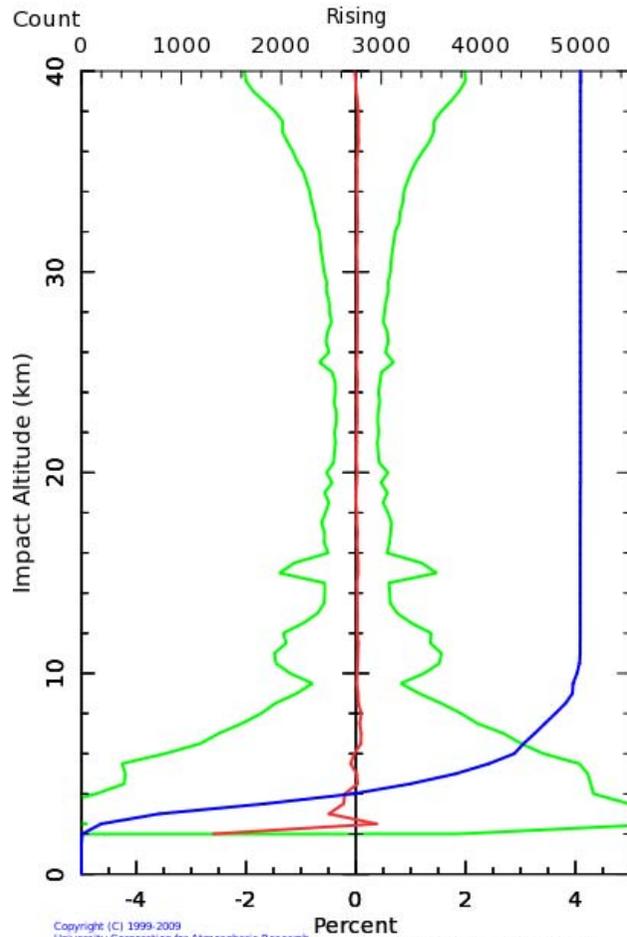b_i: average of several centers profile
N: number of profiles (~16000)
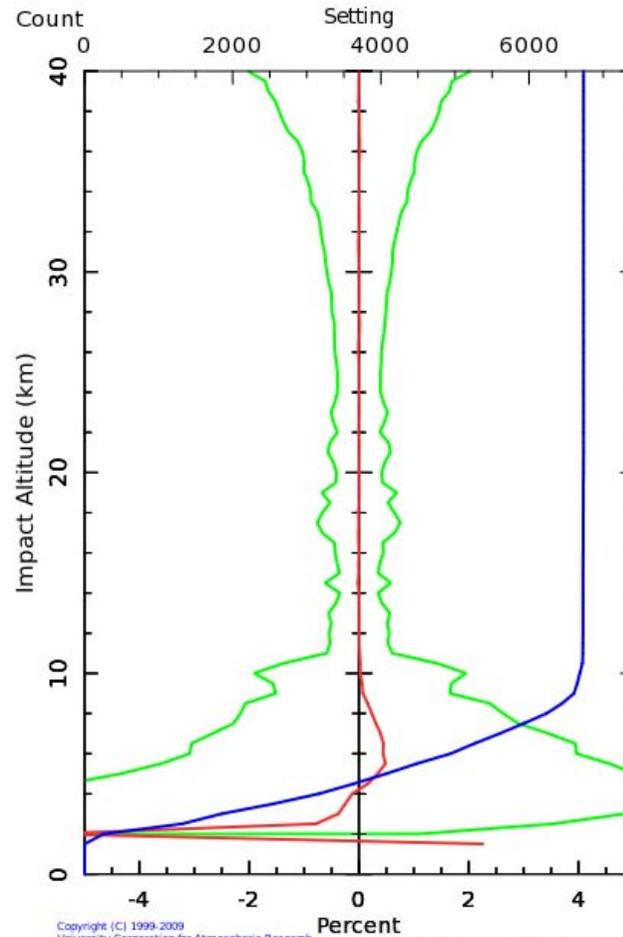Mean MAD is average over all layers

8-30 km
Mean Difference: 0.00 %
Mean MAD   : 0.51 %

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Comparison of GRAS UCAR and EUMETSAT profiles

8-30 km rising
Mean Difference: 0.02 %
Mean MAD   : 0.81 %

8-30 km setting
Mean Difference: 0.00 %
Mean MAD   : 0.76 %

Mean 8-30km: 0.0233%
MAD 8-30km: 0.8059%

Mean 8-30km: 0.0017%
MAD 8-30km: 0.7595%

Structural Uncertainty Results Overview

CHAMP comparison
(EUMETSAT vs. average
of 4 processing centers)

Mean Difference: 0.00 %
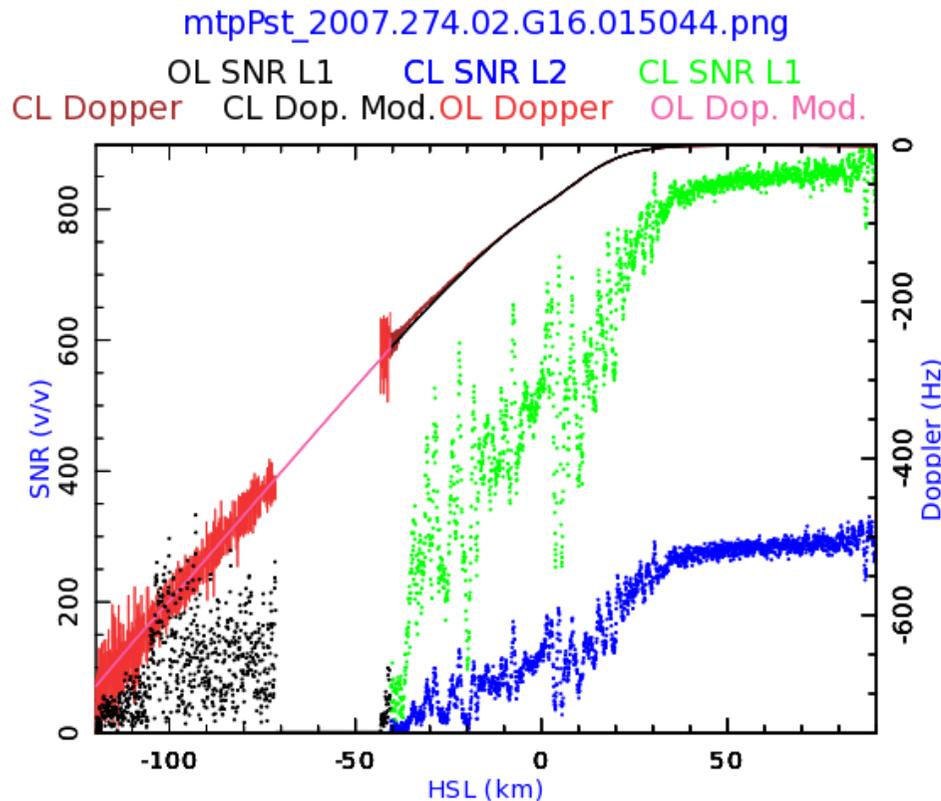Mean MAD   : 0.51 %

GRAS comparison
(EUMETSAT vs. UCAR
setting only)

Mean Difference: 0.00 %
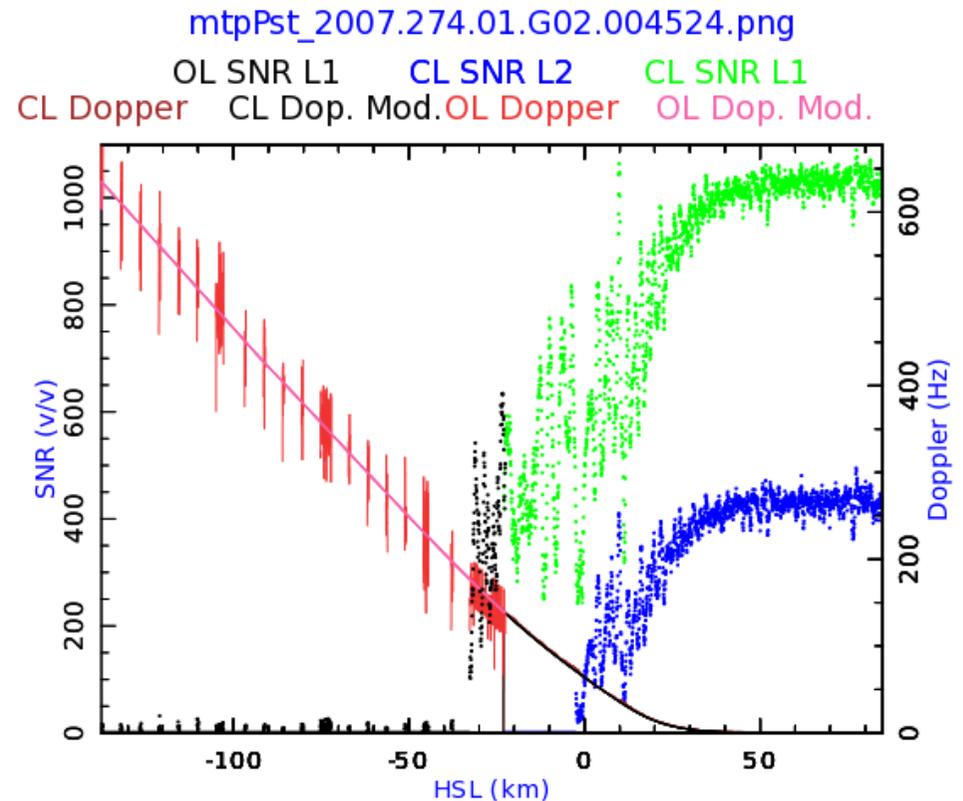Mean MAD   : 0.76 %

These results are consistent because Ho et al. compare
EUMETSAT CHAMP results against an average of 4
centers which is expected to be a factor of two less noisy
than the results from any individual center.

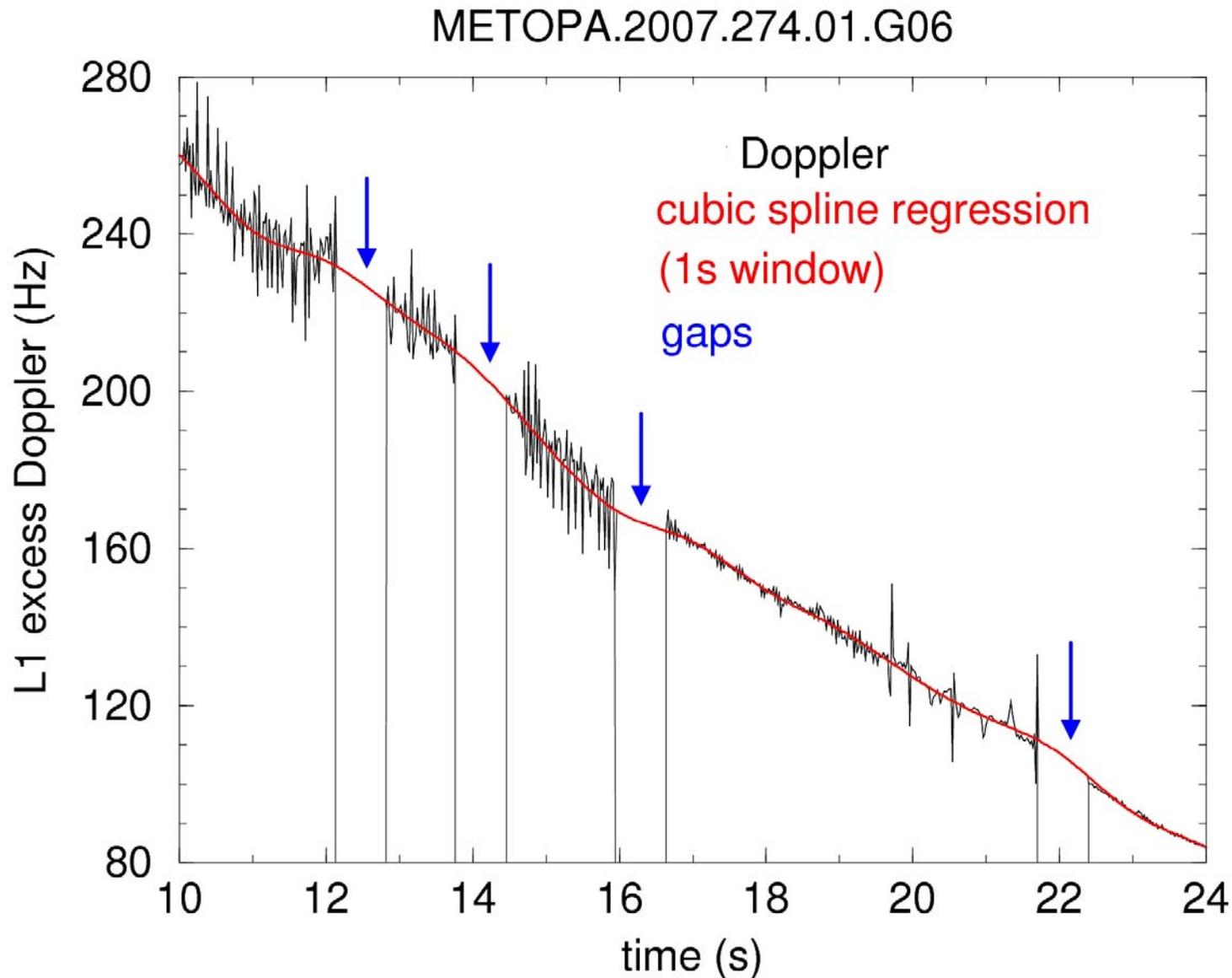# Examples of METOP occultations

Setting occultation with gap

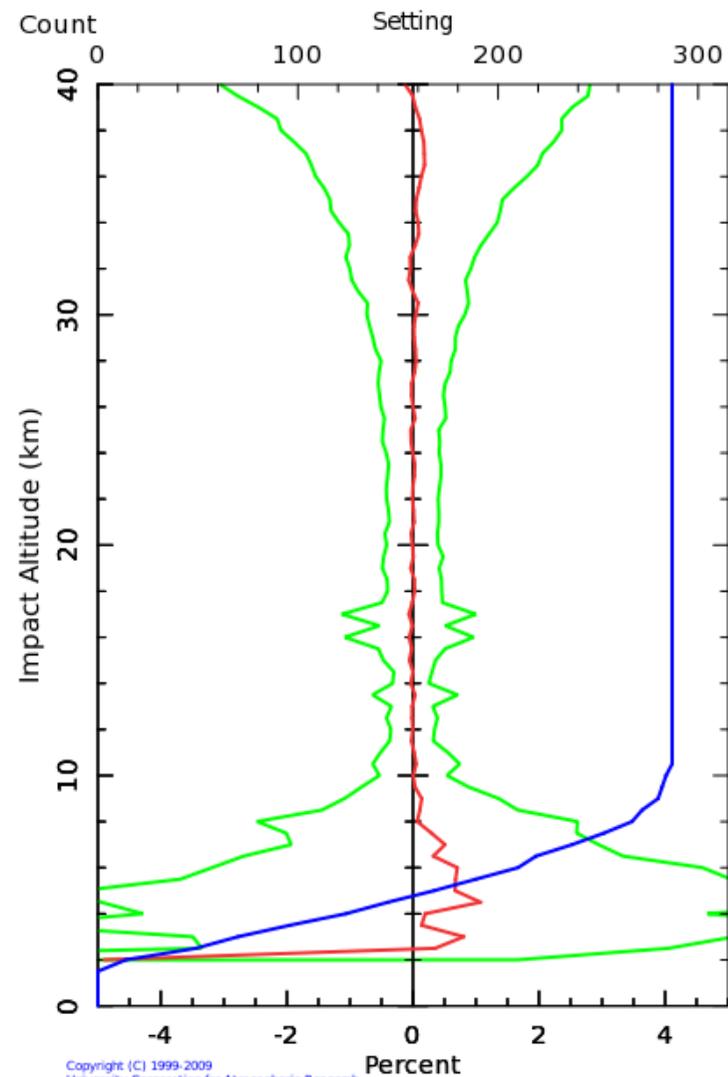Rising occultation, lots of gaps!
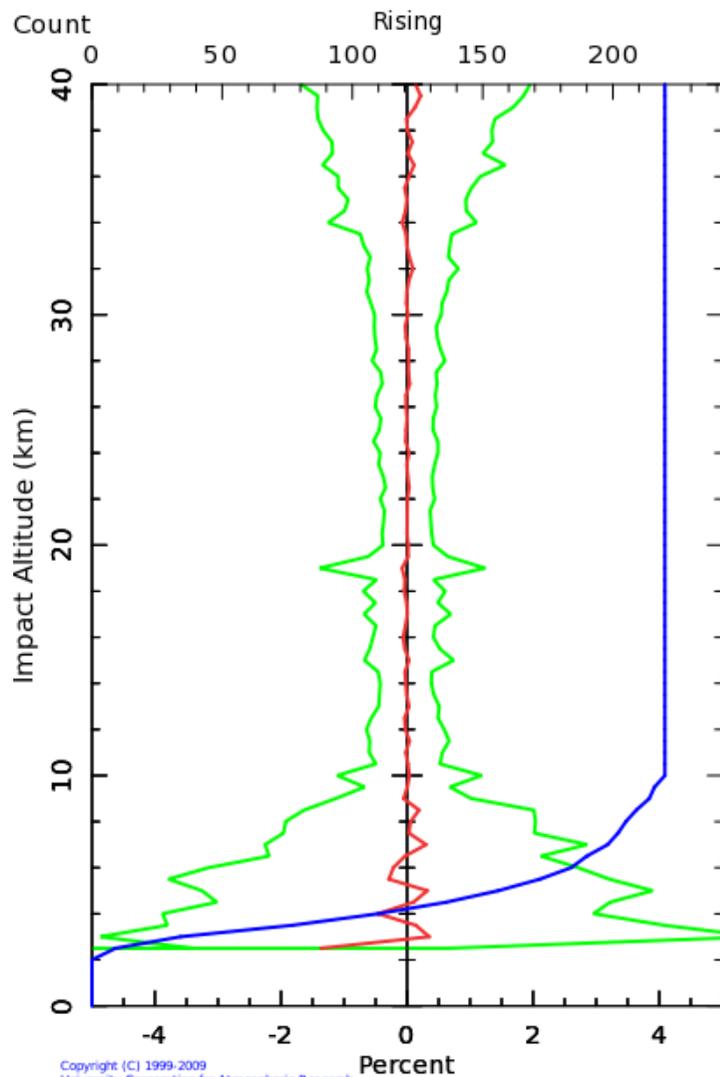
Few (no?) gaps in the closed loop part above open loop tracking

Filling gaps in Doppler by cubic spline regression (least squares fit by spline)

Applied in the closed-loop (CL) mode for the gaps < 1 sec

METOPA.2007.274.01.G06

Mean 8-30km: 0.0332%
MAD 8-30km: 0.8029%

Mean 8-30km: 0.0559%
MAD 8-30km: 0.8161%

T ransparent curves show UCAR vs. EUMETSAT BA comparison excluding profiles affected by gaps. Thicker lines show comparison that include gap fixed data.
No difference above 10 km - Differences belwo 10 km will be discussed in next talk

OPAC workshop, Graz, Austria, Sept. 6-10, 2010

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# The Advantage of the GRAS Ultra Stable Oscillator

GRAS has a USO - allowing for processing of undifferenced RO observations

COSMIC does not have a USO and must process single or double differenced observation

We compared single difference and zero difference processing of GRAS - to help decide whether to consider a USO for "COSMIC II / Formosat7"
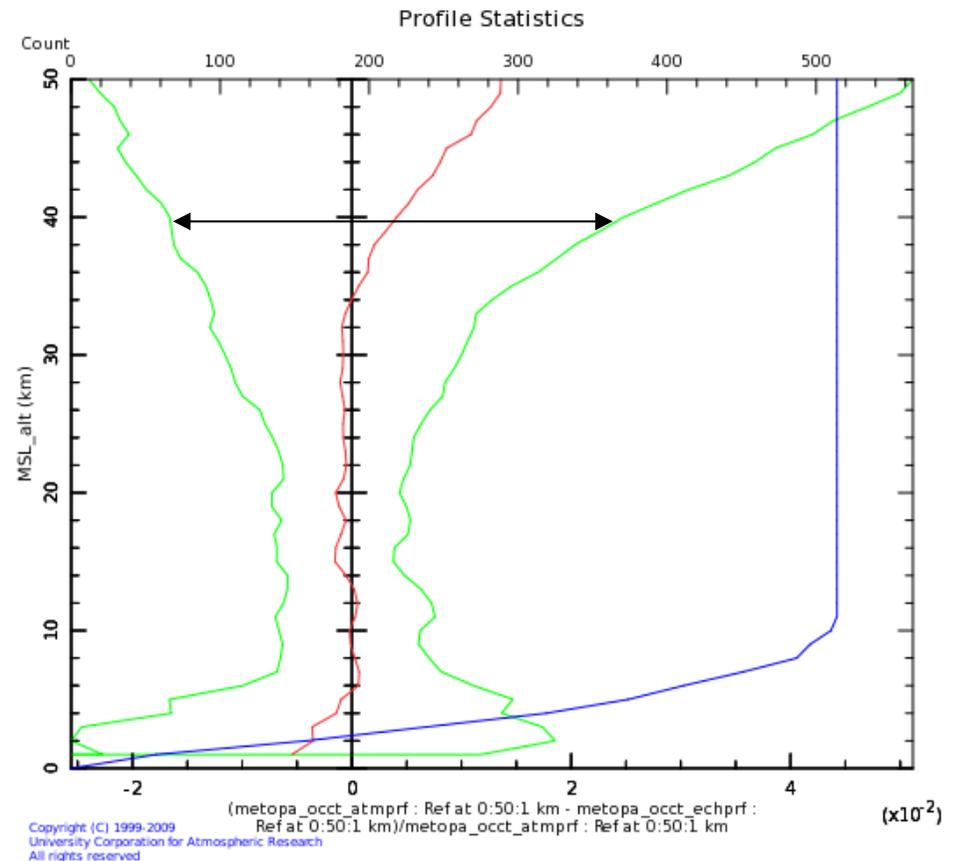
Single Difference vs. Zero Difference

UCAR GRAS refractivity statistics compared to ECMWF
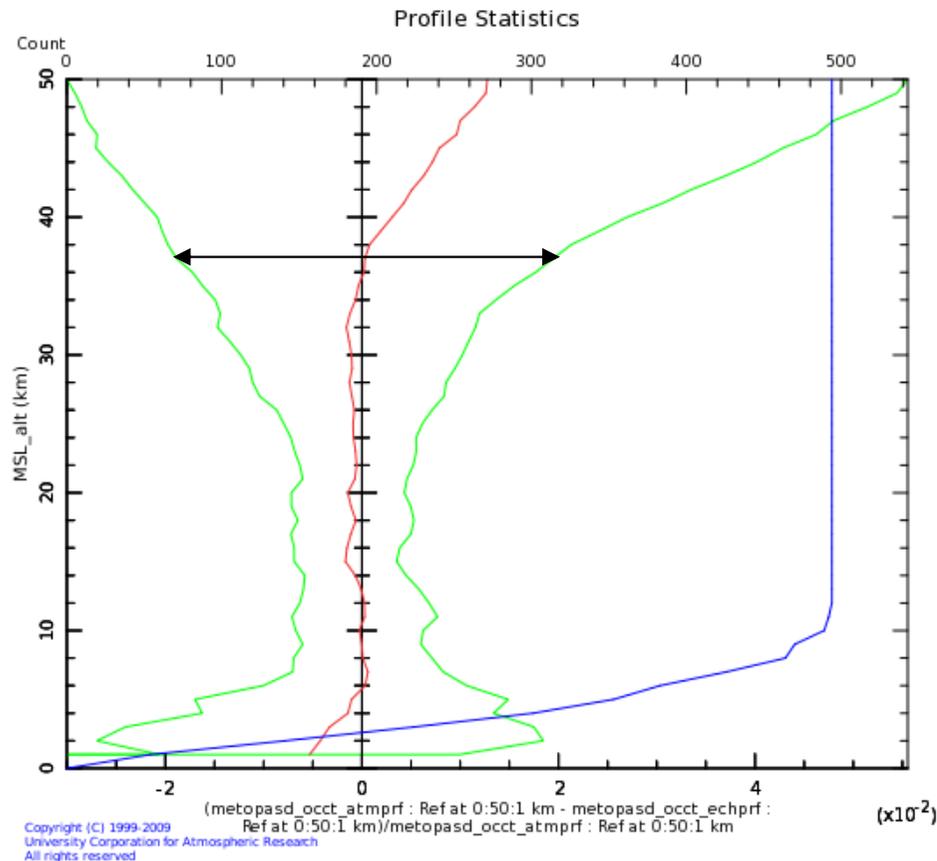
single difference

+/- 2% stdev at ~37 km

zero difference

+/- 2% stdev at ~40 km

OPAC workshop, Graz, Austria, Sept. 6-10, 2010

Summary

- UCAR / CDAAC developed processing string for GRAS data
    - Level 0-1 translator was developed with help from EUMETSAT
    - Used existing CDAAC software to the extent possible
    - Conducted first structural uncertainty RO study based on a non-JPL receiver
- Orbits estimated at EUMETSAT and UCAR show no significant bias
- Bending angle profiles processed at UCAR and EUMETSAT agree in the 8-30 km height range without any bias (1-month comparison)
- Bending angle "Mean MAD" setting profiles agree at a level that is consistent with multi-center comparisons based on CHAMP data
- Rising profile Mean and Mean MAD agree slightly worse
- Gaps in GRAS data contribute to structural uncertainty below 10 km
- GRAS data zero difference processing reduces noise in stratospheric BA profiles

Zero Difference vs. Single Difference BA

Ref: metopa-echprf, 2007.274-304 LEO1
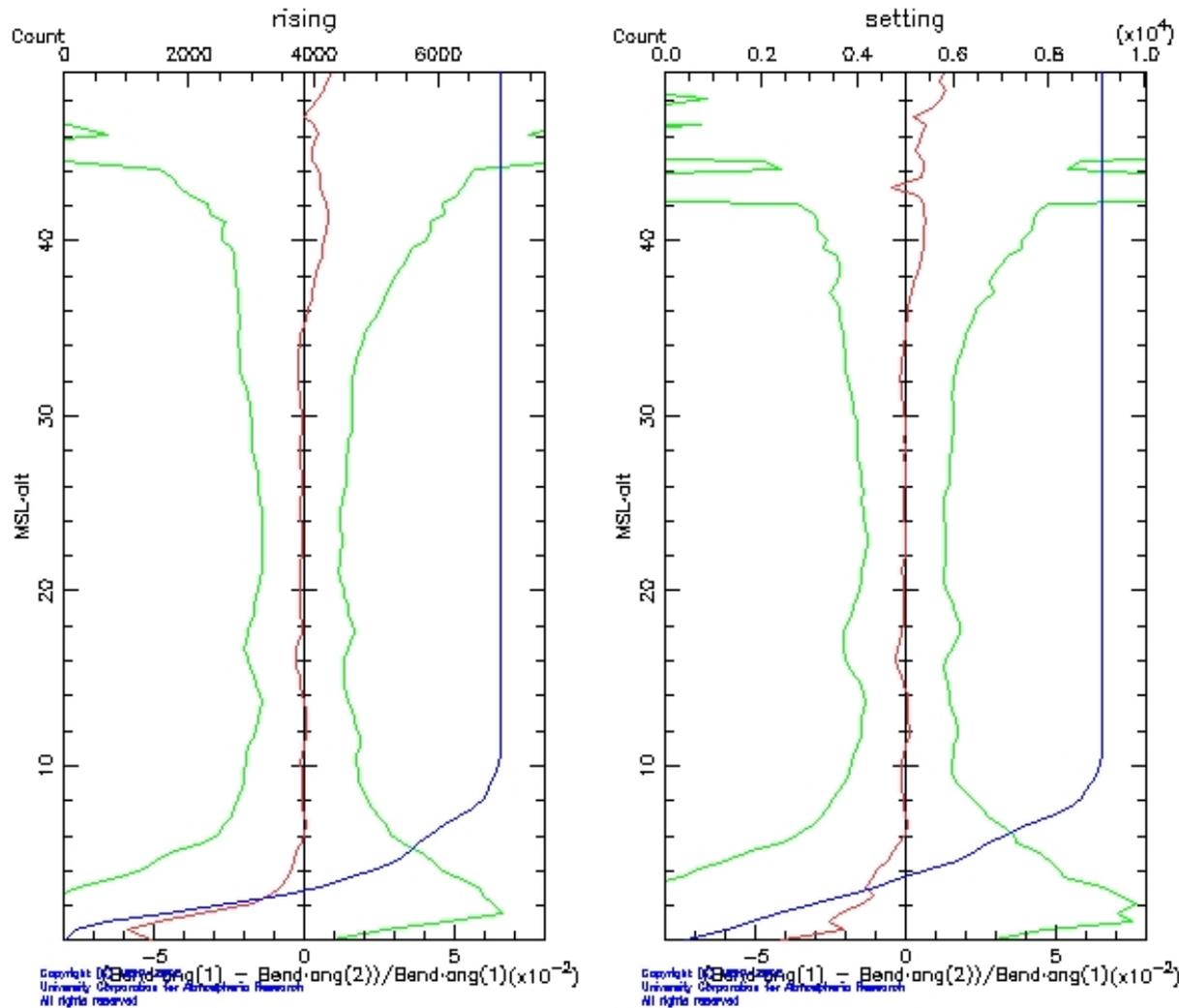
Zero difference processing has slightly lower noise > 30 km