Consistency of Radio Occultation Climatologies from Different Satellites

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Acknowledgements

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UCAR (University Corporation for Atmospheric Research) in Boulder, CO, USA

GFZ (German Research Centre for Geosciences) Potsdam, Germany

EUMETSAT (European Organisation for the Exploitation of Meteorological Satellites) in Darmstadt, Germany

ECMWF (European Centre for Medium-Range Weather Forecasts), Reading, UK, is acknowledged for the continuous provision of analysis and forecast data

Motivation

Long-term climate monitoring based on radio occultation data will require the combination of data from different satellites.
In the best case we would hope for:

Consistent results for data from **different satellites**

Consistent results for retrievals from **different centers** (see talk by Andrea Steiner)

WegCenter RO Profiles

Profile retrieval, termed "**Occultation Processing System – OPS**" (current version: 5.4) starts with **excess phase** and **orbit data** from different processing centers (UCAR, GFZ, EUMETSAT, ..).

Consistent retrieval for all satellites.

High altitude initialization by:
Statistical Optimization using **ECMWF forecasts.**

OPSv5.4 uses (still) geometric optics and dry air retrieval, focusing on the UTLS.

"**Occultation event data**" (OED), **Level 2:** Single Profiles, format, including **Retrieval to A Priori Error Ratio** (RAER) and **Tropopause Parameters.**
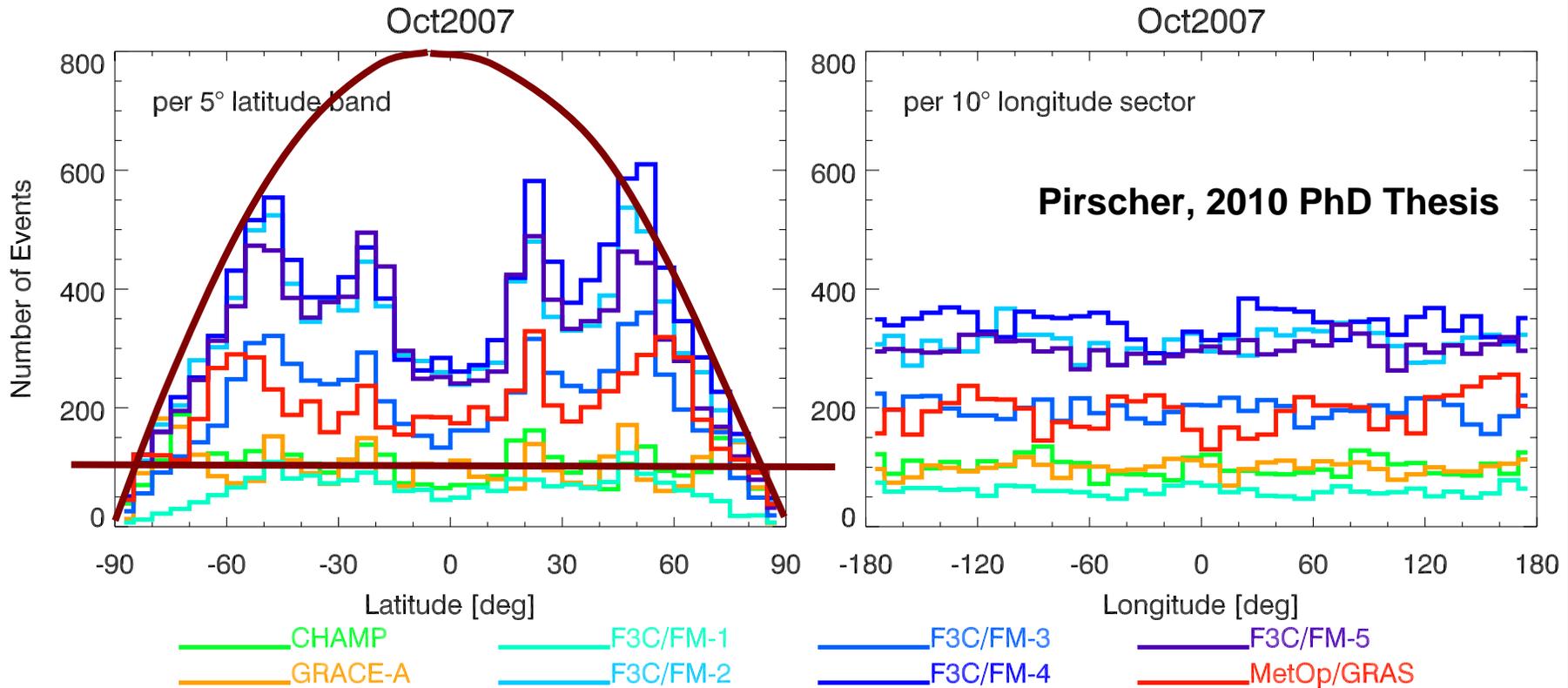
WegCenter Climatologies

Binning and Averaging – "Climate Processing System" (CLIPS)

- **Radio Occultation profiles in a "bin" are collected and averaged**

- **"Fundamental" bins with 5° latitudinal and 60° longitudinal width are combined to build zonal mean monthly climatologies.**

- **Basic latitudinal resolution is 10°, each of the 18 latitude bands (pole to pole) contains two 5° bands, and the mean profiles for these two bands are averaged, weighted with the surface area.**

- **Seasonal climatologies are obtained by averaging over three months.**

- **Annual climatologies by averaging over a calendar year.**

- **200 m vertical spacing was chosen for the altitude gridding.**

Climatology Data (CLD), Level 3: Bending Angle, Refractivity, Pressure, Geopotential Height, Dry Temperature.

Data from different missions

Oct2007 — per 5° latitude band

Oct2007 — per 10° longitude sector

Pirscher, 2010 PhD Thesis

Legend: CHAMP, GRACE-A, F3C/FM-1, F3C/FM-2, F3C/FM-3, F3C/FM-4, F3C/FM-5, MetOp/GRAS

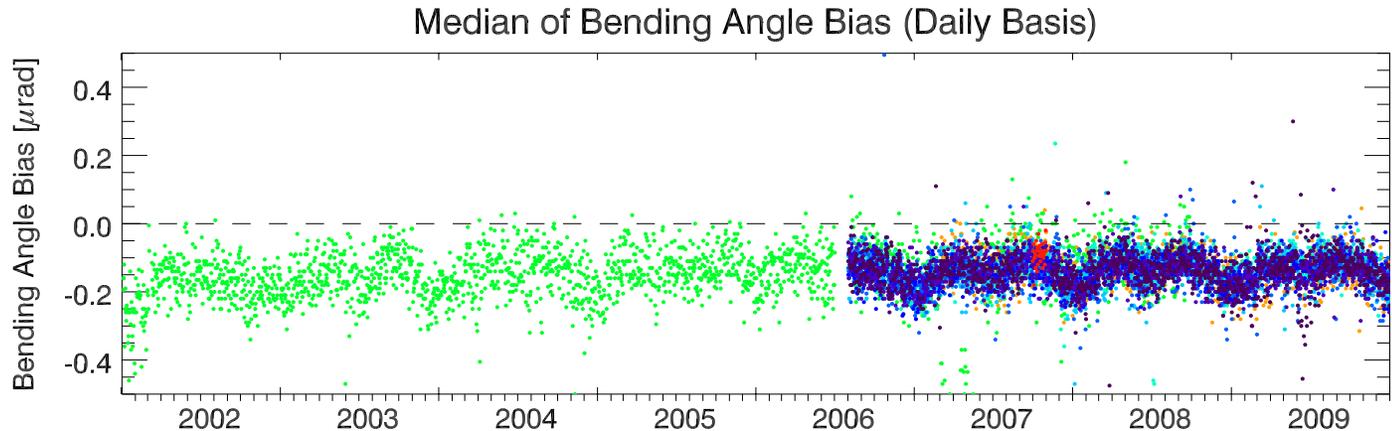**Different sampling strategies, depending on the latitudinal distribution**
Straight line (equal numbers per latitude): cosine-weighting (CHAMP)
**Curved line (equal numbers per area): No weighting (COSMIC-II ?)**
Currently: cosine-weighting for all satellites

Data Quality

Median of Bending Angle Bias (Daily Basis)

CHANP: Mean: -0.16 μrad
GRACE-A: Mean: -0.12 μrad
F3C-FM1:   Mean: -0.14 μrad
F3C-FM2:   Mean: -0.14 μrad
F3C-FM3:   Mean: -0.14 μrad
F3C-FM4:   Mean: -0.14 μrad
F3C-FM5:   Mean: -0.14 μrad
F3C-FM6:   Mean: -0.14 μrad
MetOp: Mean: -0.09 μrad

Median of Bending Angle Noise (Daily Basis)

CHAMP: Mean: 4.74 μrad
GRACE-A: Mean: 2.70 μrad
F3C-FM1:   Mean: 2.65 μrad
F3C-FM2:   Mean: 2.46 μrad
F3C-FM3:   Mean: 2.62 μrad
F3C-FM4:   Mean: 2.54 μrad
F3C-FM5:   Mean: 2.71 μrad
F3C-FM6:   Mean: 2.49 μrad
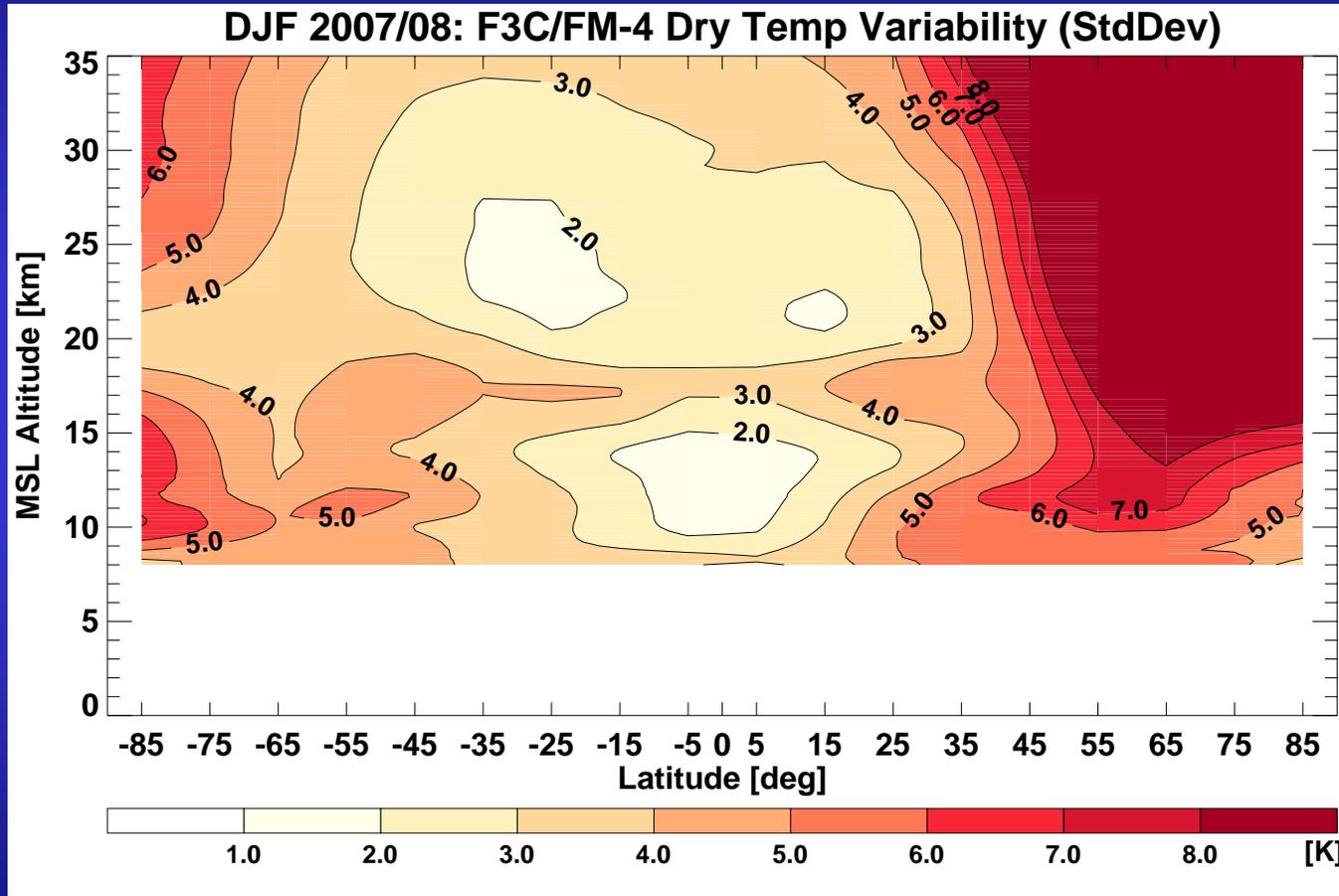MetOp: Mean: 0.98 μrad
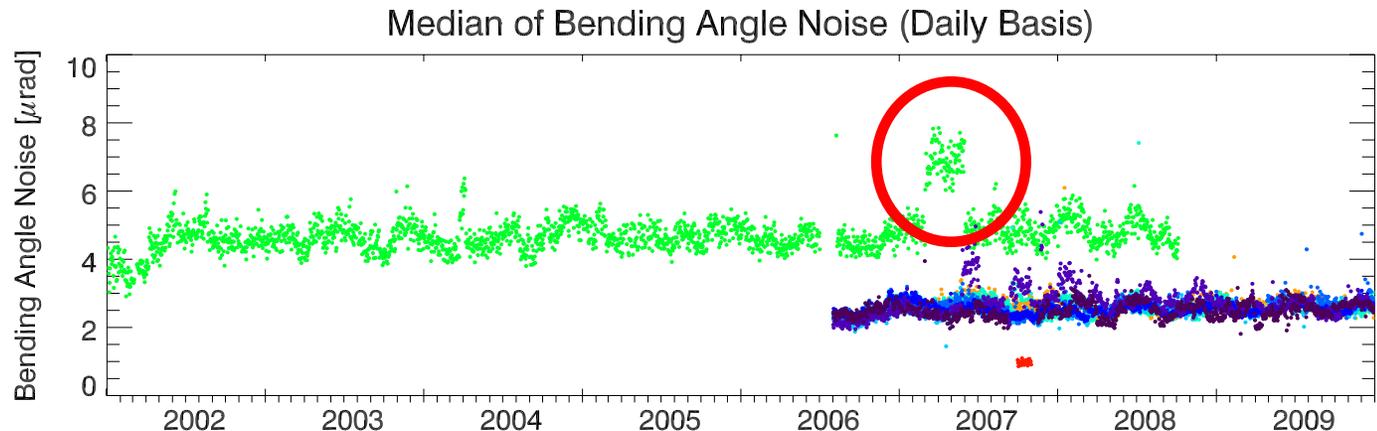
Bending Angle Statistics between 65 km and 80 km
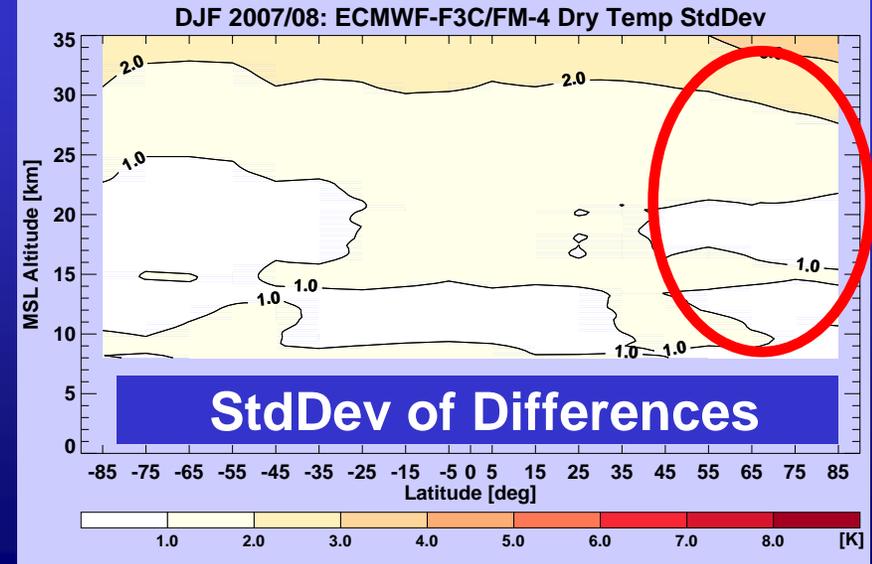**"Bias" means – difference to MSIS climatology.**
Annual and semi-annual cycle.

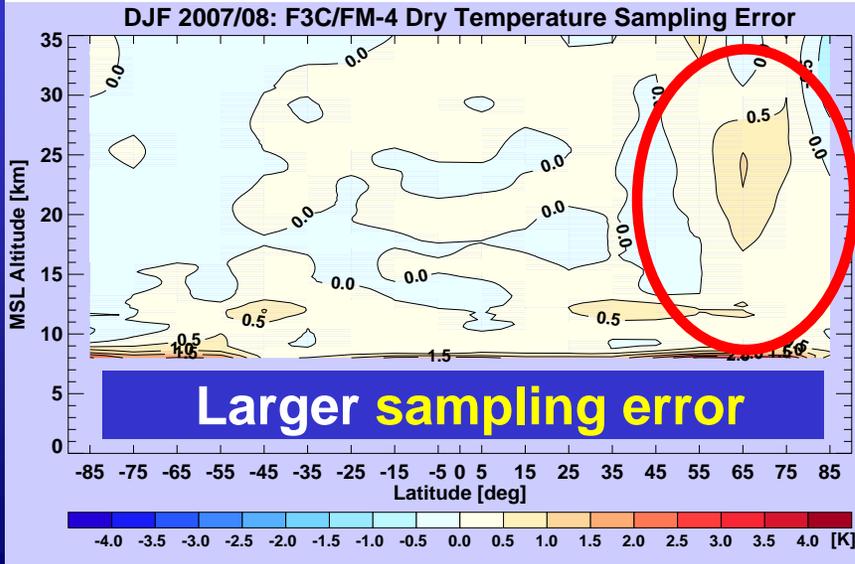# Data Quality
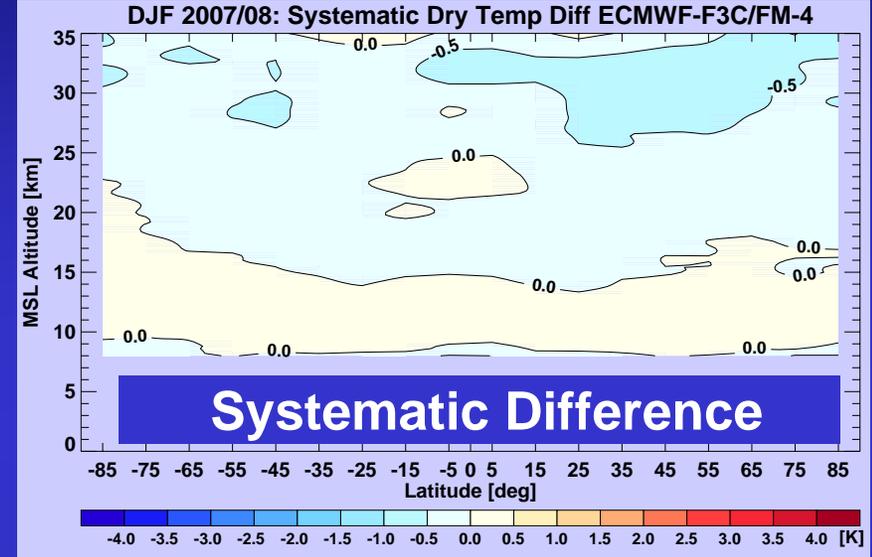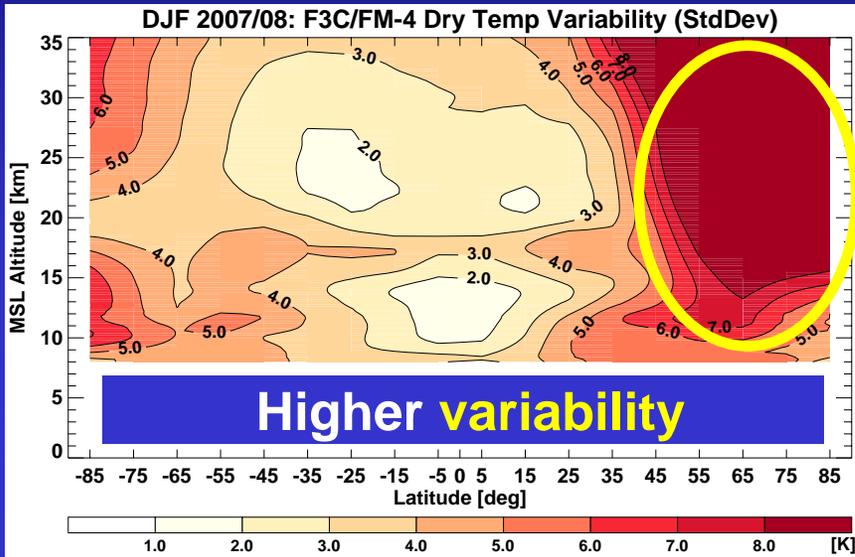
Data Quality
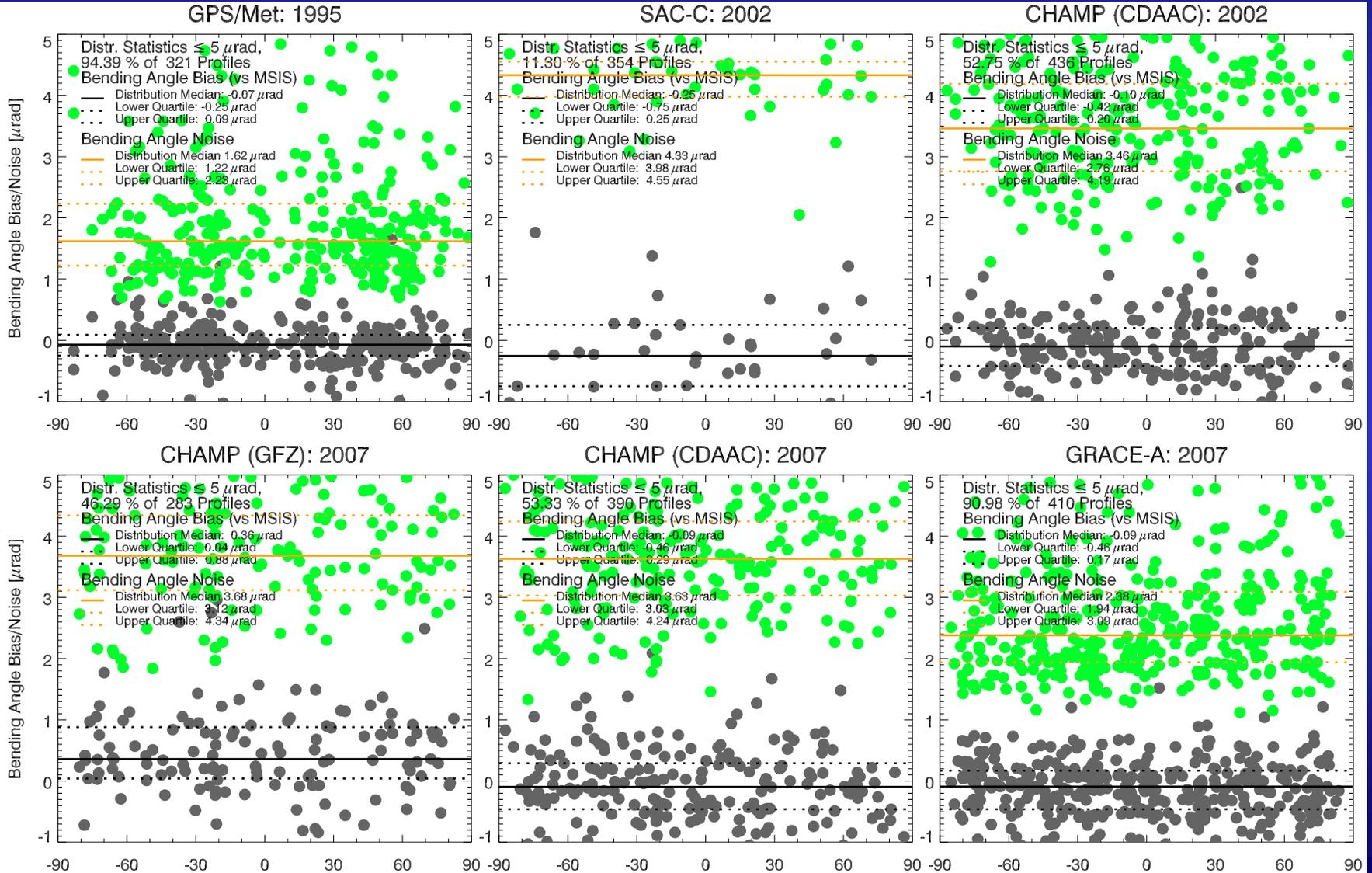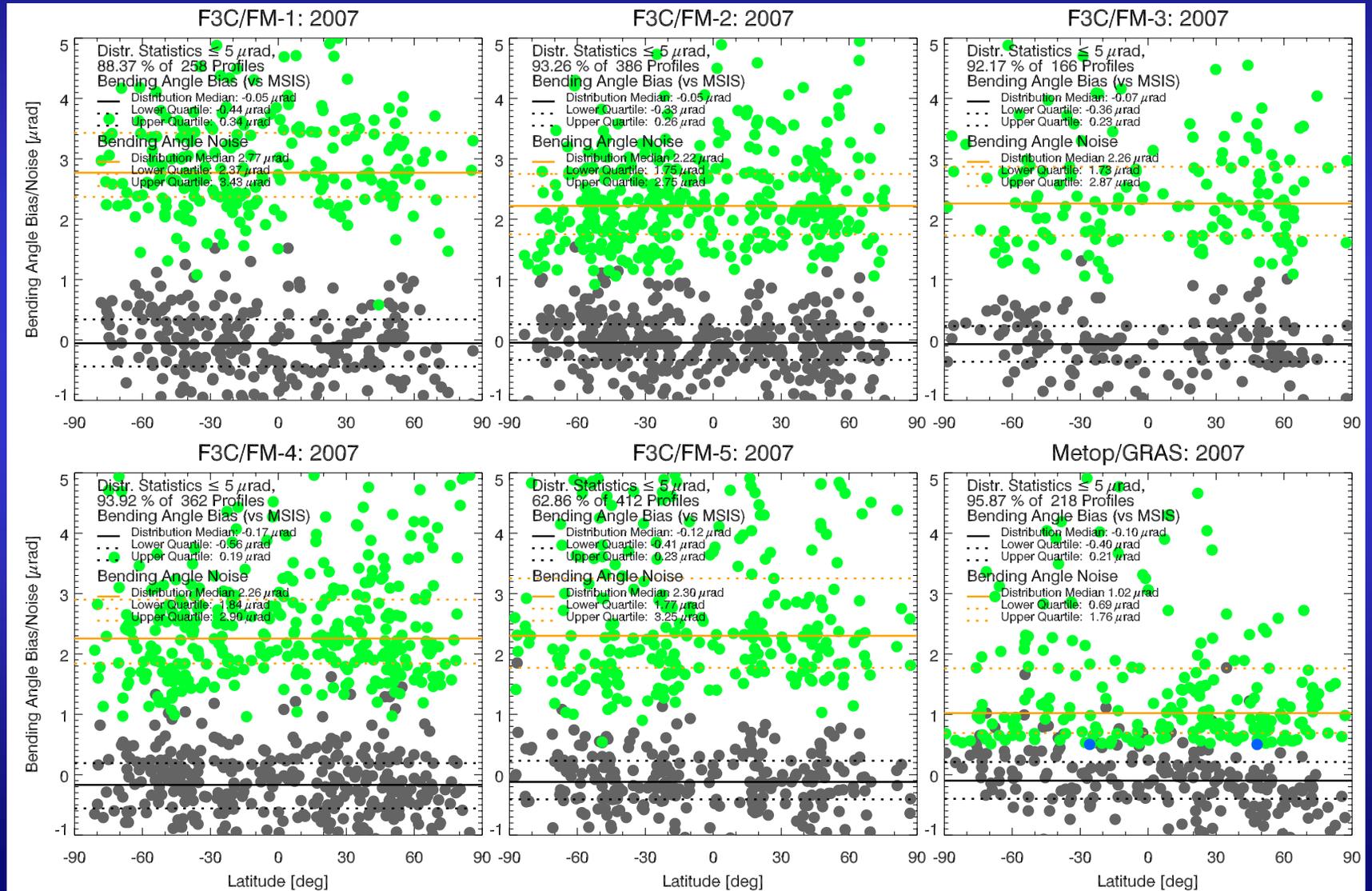
Single-COSMIC Climatology

DJF 2007/08: F3C/FM-4 Dry Temp Variability (StdDev)

DJF 2007/08 dry temperature variability. Mean state is much harder to capture, if the variability is high, e.g., tropopause region, winter Extratropics vs. Low Lat
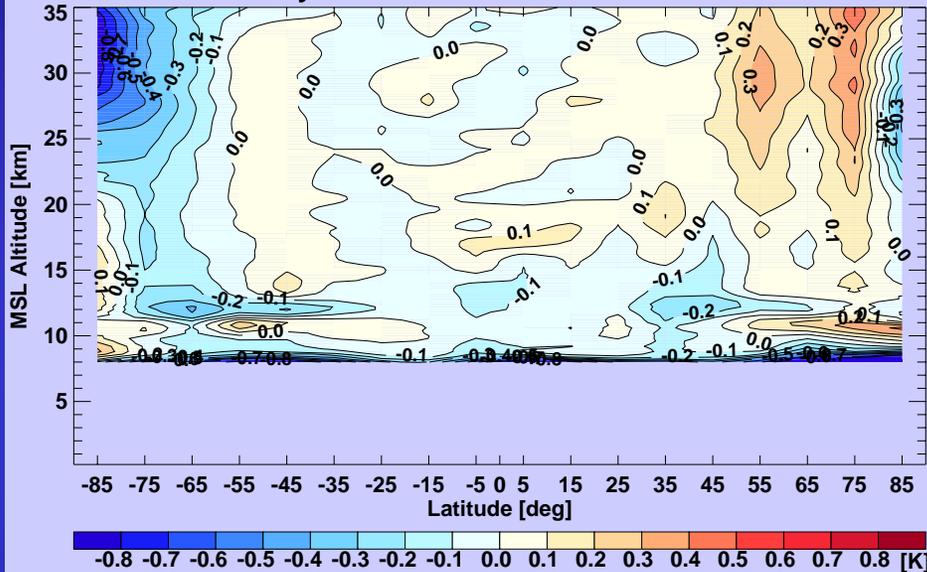
Seasonal F3C-FM4 Climatology

DJF 2007/08: F3C/FM-4 Dry Temp Variability (StdDev)

Higher variability

DJF 2007/08: Systematic Dry Temp Diff ECMWF-F3C/FM-4

Systematic Difference

DJF 2007/08: F3C/FM-4 Dry Temperature Sampling Error

Larger sampling error

DJF 2007/08: ECMWF-F3C/FM-4 Dry Temp StdDev

StdDev of Differences

Sampling Error

Even with perfect observations, climatologies from two satellites would be slightly different, because measurements are taken at different times an locations

Estimation of the sampling error based on **ECMWF** 3D fields on four time layers per day (as proxy for the "true" temporal and spatial evolution):
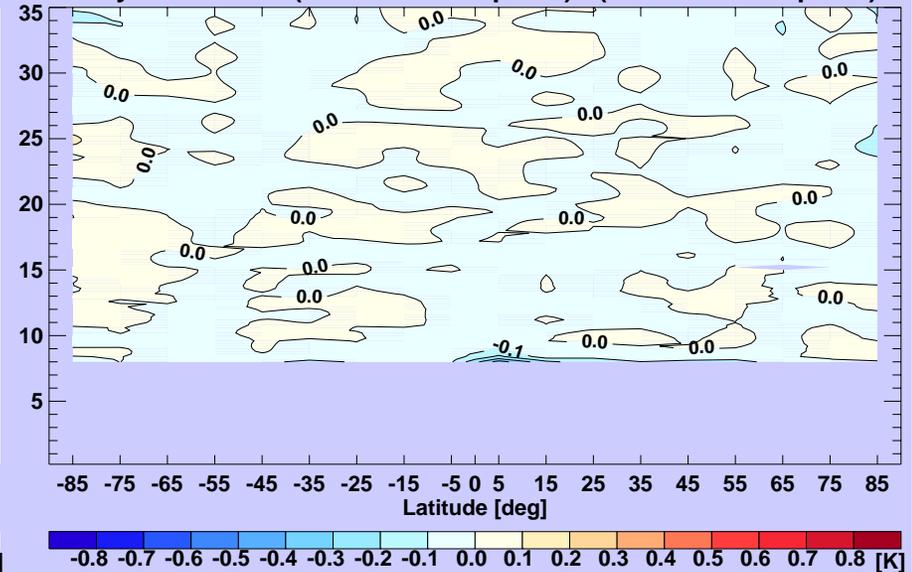
"True" **profiles** at the RO locations
minus
"True" **mean field**

Consistency of RO Data

Systematic Differences between 2007 annual mean, zonal mean Tdry climatologies from different Formosat-3/ COSMIC satellites (FM-1 and FM-4).

After subtraction of the estimated sampling errors from both climatologies, differences are < 0.1 K almost everywhere (despite errors in sampling error estimation for both satellites)
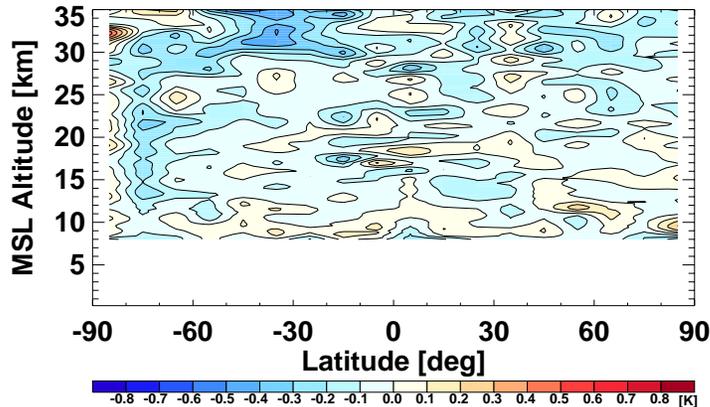
Consistency – JJA 2007

COSMIC-FM2 minus COSMIC-FM4

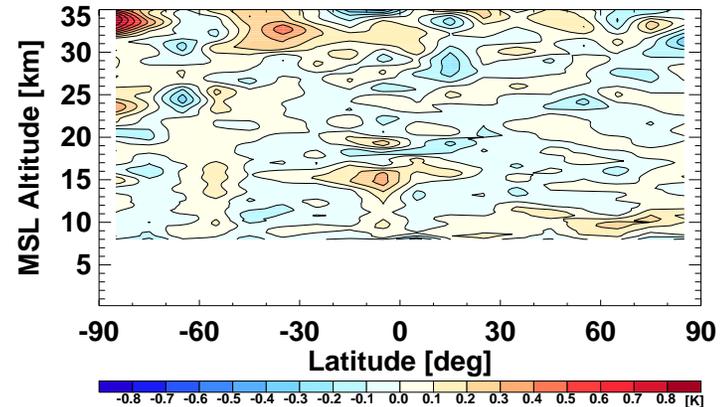Tdry: JJA 2007: (F3C/FM-2-Sampl Err) - (F3C/FM-4-Sampl Err)

Sampling errors subtracted, Mean(ΔT) = 0.008 K
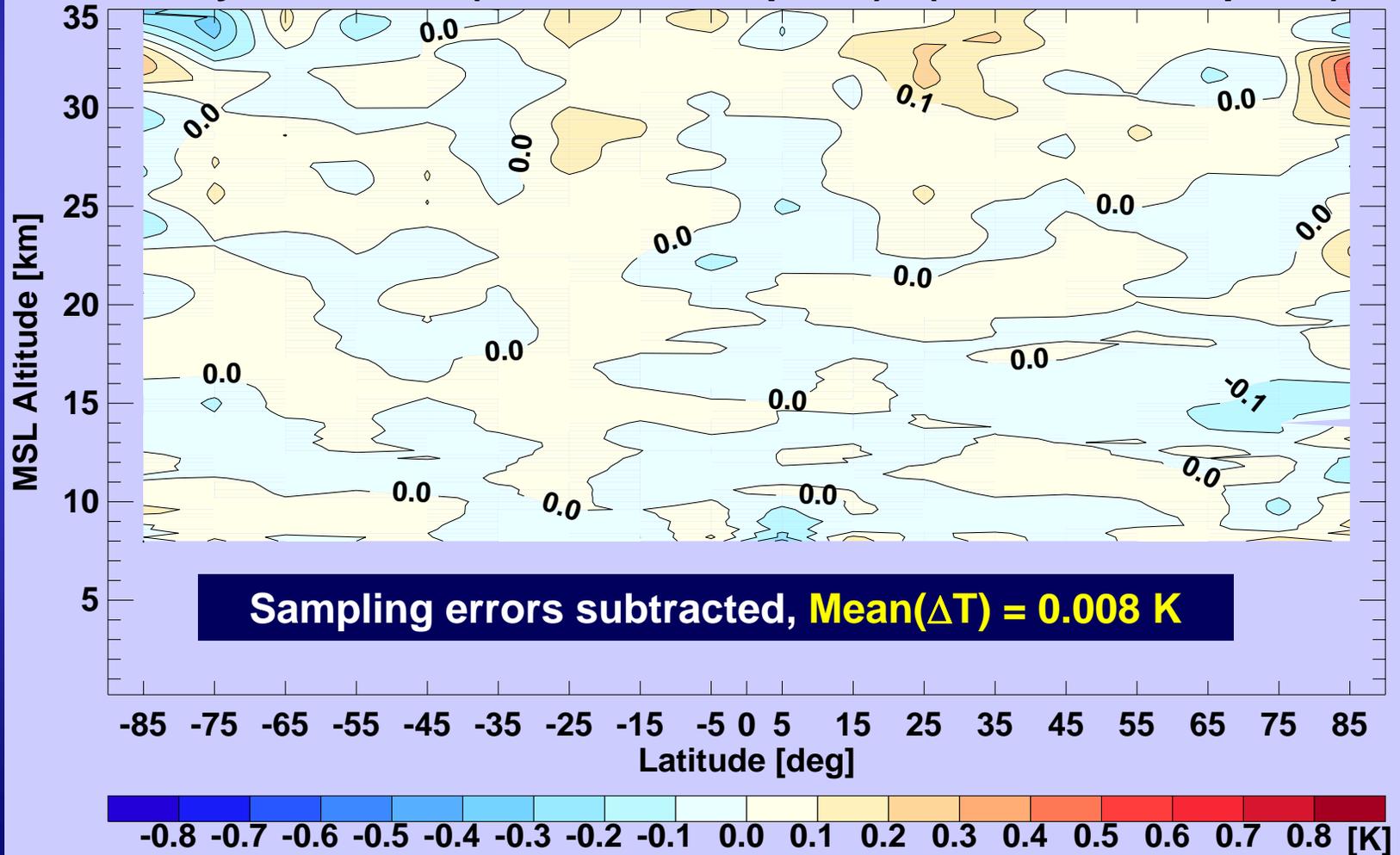
Consistency of RO Data

Oct 2007: Deviations of Dry Temperature (Sampling Error Subtracted)
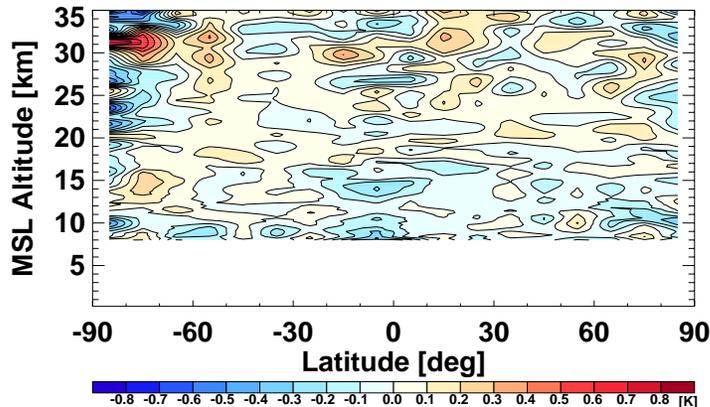
Monthly mean dry temperature (Oct 2007) wrt satellite mean
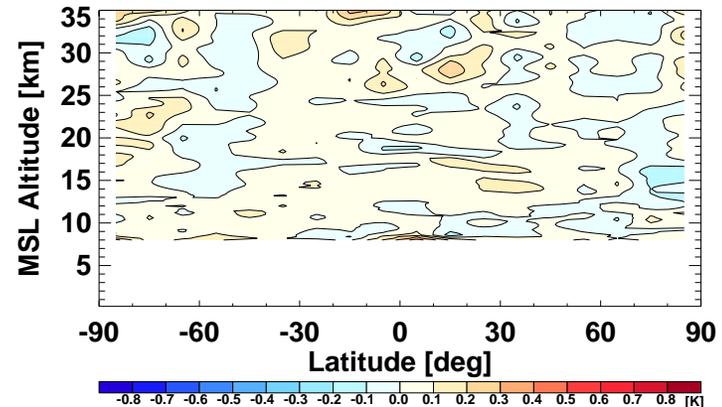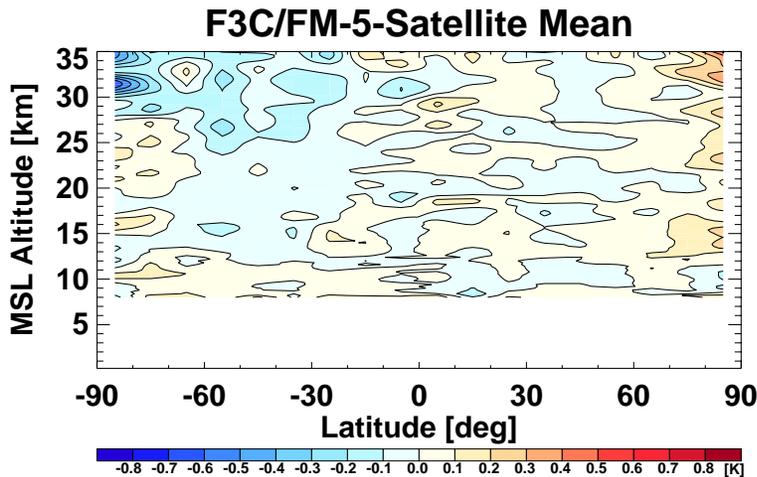
Consistency of RO Data

F3C/FM-3-Satellite Mean

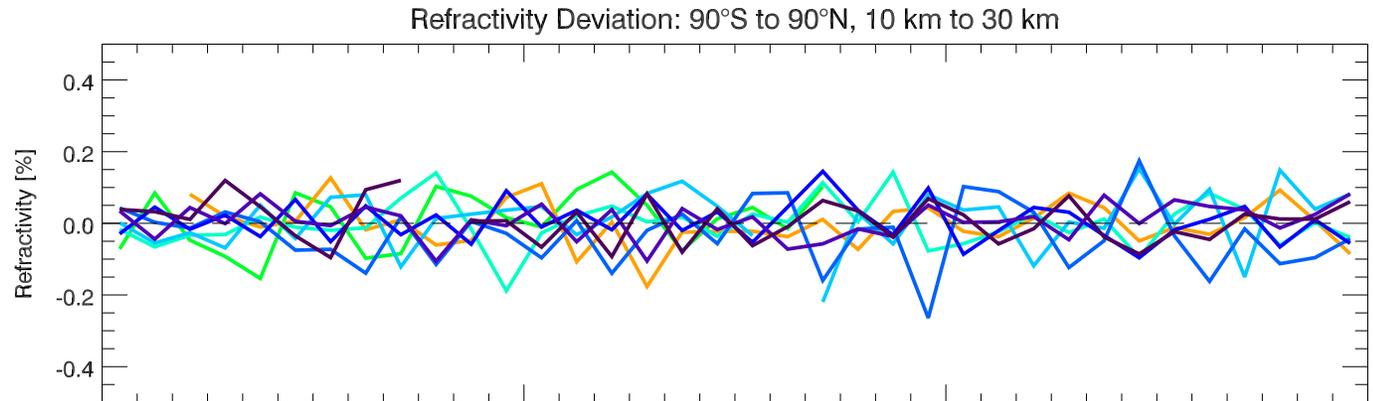**F3C/FM-4-Satellite Mean**

F3C/FM-5-Satellite Mean
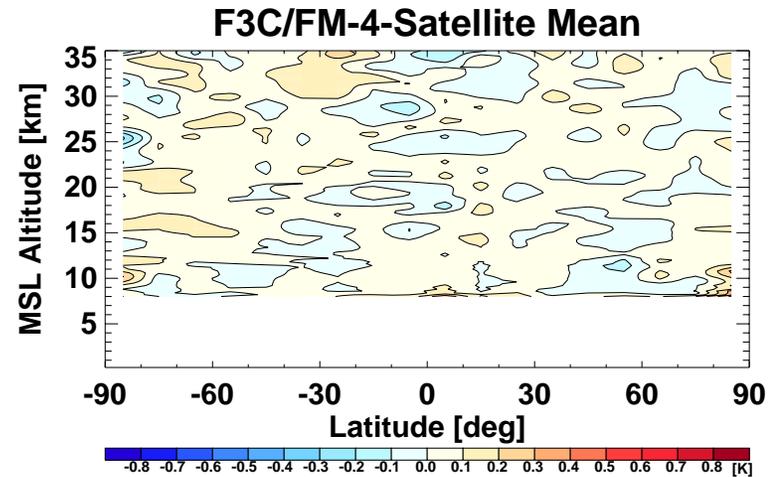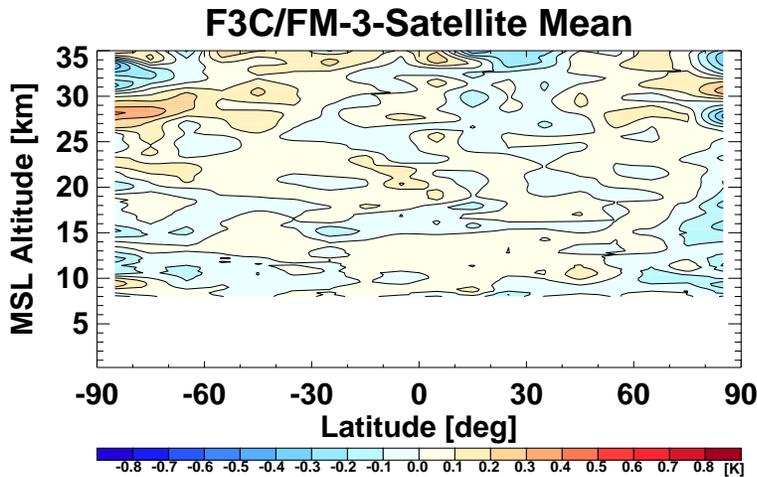
GRAS excess phase data have only been available in offline mode. There seems to be something wrong in our Tdry retrievals

**Monthly mean dry temperature (Oct 2007) wrt satellite mean**

Refractivity Consistency

Refractivity Deviation: 90°S to 90°N, 10 km to 30 km

CHAMP: Mean: 0.01 %
GRACE-A: Mean: -0.00 %
F3C/FM-1: Mean: -0.00 %
F3C/FM-2: Mean: 0.01 %
F3C/FM-3: Mean: -0.03 %
F3C/FM-4: Mean: 0.01 %
F3C/FM-5: Mean: 0.01 %
F3C/FM-6: Mean: 0.01 %

Sampling Error Subtracted Refractivity Deviation: 90°S to 90°N, 10 km to 30 km

CHAMP: Mean: -0.01 %
GRACE-A: Mean: -0.00 %
F3C/FM-1: Mean: 0.00 %
F3C/FM-2: Mean: 0.00 %
F3C/FM-3: Mean: 0.00 %
F3C/FM-4: Mean: -0.00 %
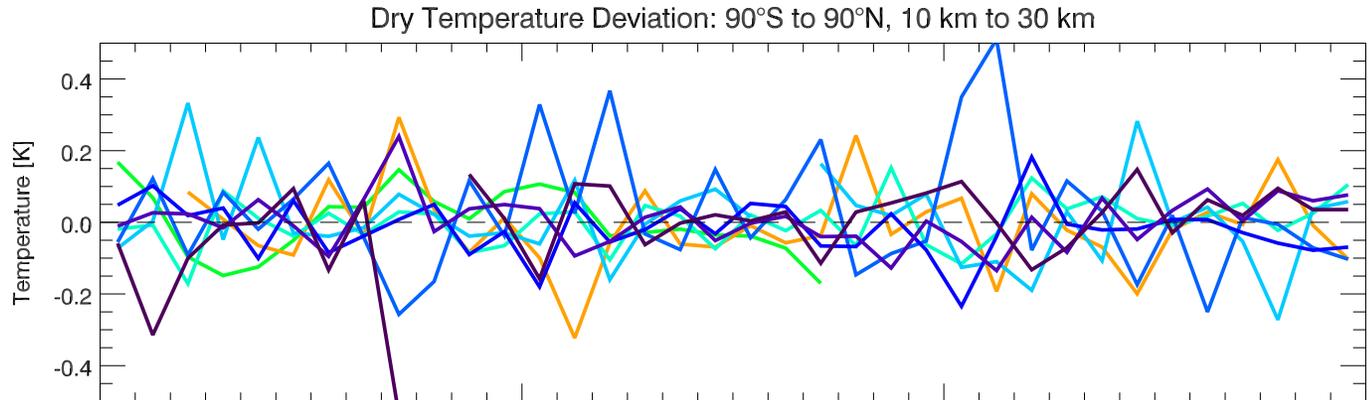F3C/FM-5: Mean: 0.00 %
F3C/FM-6: Mean: 0.00 %
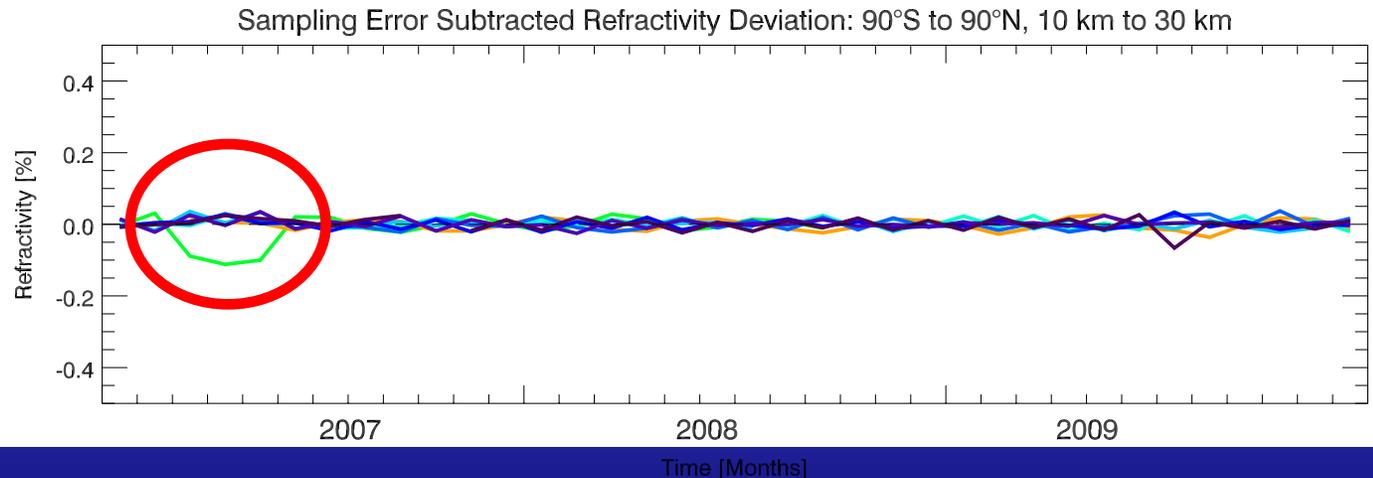
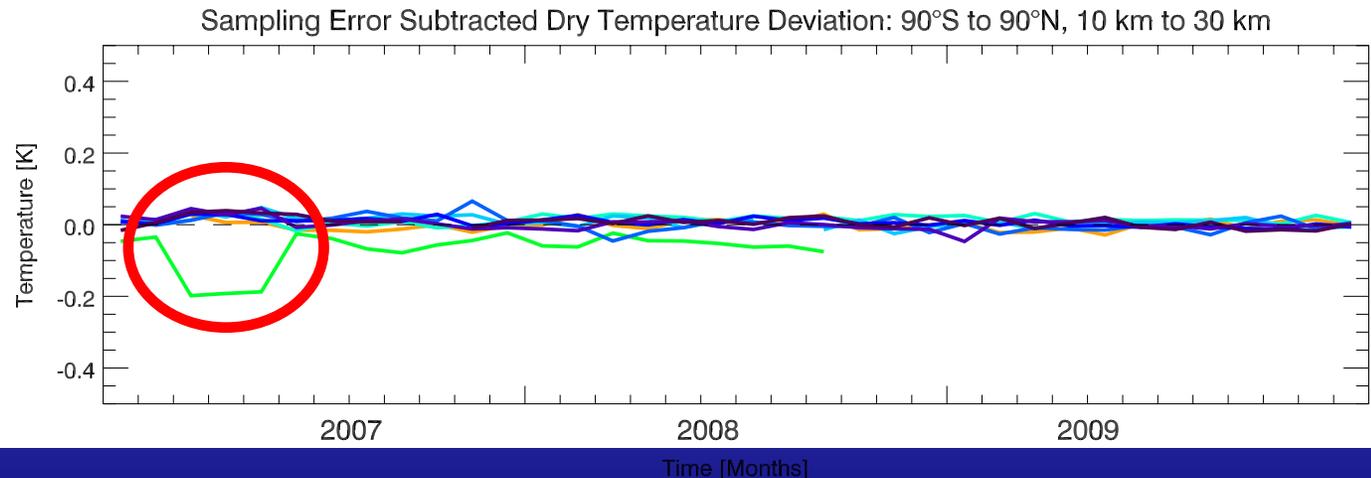**Monthly refractivity differences relative to the satellite mean**

Further reduced when the estimated sampling errors are subtracted

CHAMP "excursion" (MAM 2007) corresponds to high BA noise

Dry Temperature Consistency

Dry Temperature Deviation: 90°S to 90°N, 10 km to 30 km

CHAMP:	Mean: -0.00 K
GRACE-A:	Mean: -0.01 K
F3C/FM-1:	Mean: 0.00 K
F3C/FM-2:	Mean: 0.01 K
F3C/FM-3:	Mean: 0.03 K
F3C/FM-4:	Mean: -0.02 K
F3C/FM-5:	Mean: 0.00 K
F3C/FM-6:	Mean: -0.01 K

Sampling Error Subtracted Dry Temperature Deviation: 90°S to 90°N, 10 km to 30 km

CHAMP:	Mean: -0.07 K
GRACE-A:	Mean: -0.00 K
F3C/FM-1:	Mean: 0.01 K
F3C/FM-2:	Mean: 0.01 K
F3C/FM-3:	Mean: 0.00 K
F3C/FM-4:	Mean: 0.01 K
F3C/FM-5:	Mean: 0.00 K
F3C/FM-6:	Mean: 0.01 K

Time [Months]

Monthly dry temperature differences relative to the satellite mean

Further reduced when the estimated sampling errors are subtracted

CHAMP offset mainly between 25 km and 30 km

Summary

- **RO data from different satellites are encouragingly consistent**

- **Even more, when the sampling errors of both climatologies are subtracted**

- **Different measurement noise leads to different downward propagation of potential biases in the background, used for statistical optimization**

- **For Tdry more pronounced than for refractivity**

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Thank you!