The ROM SAF RO climate data record: validation and inter-mission consistency

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- ROM SAF gridded monthly-mean climate data record (CDR v1.0)
- Reducing sampling effects (sampling-error correction)
- RO mission differences
- Impacts on atmospheric decadal trends
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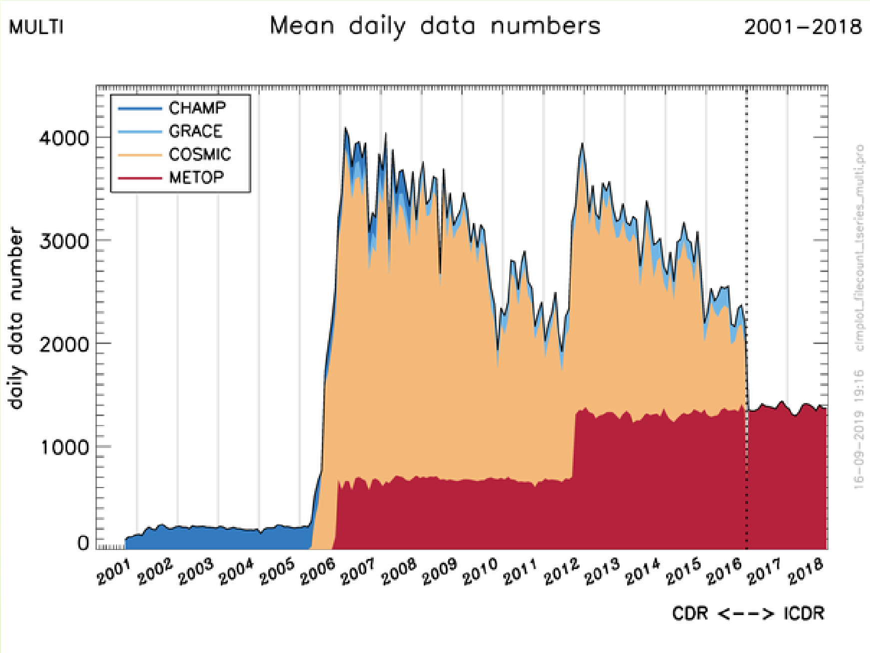
ROM SAF climate data records (CDR v1.0)



Climate data record (CDR)

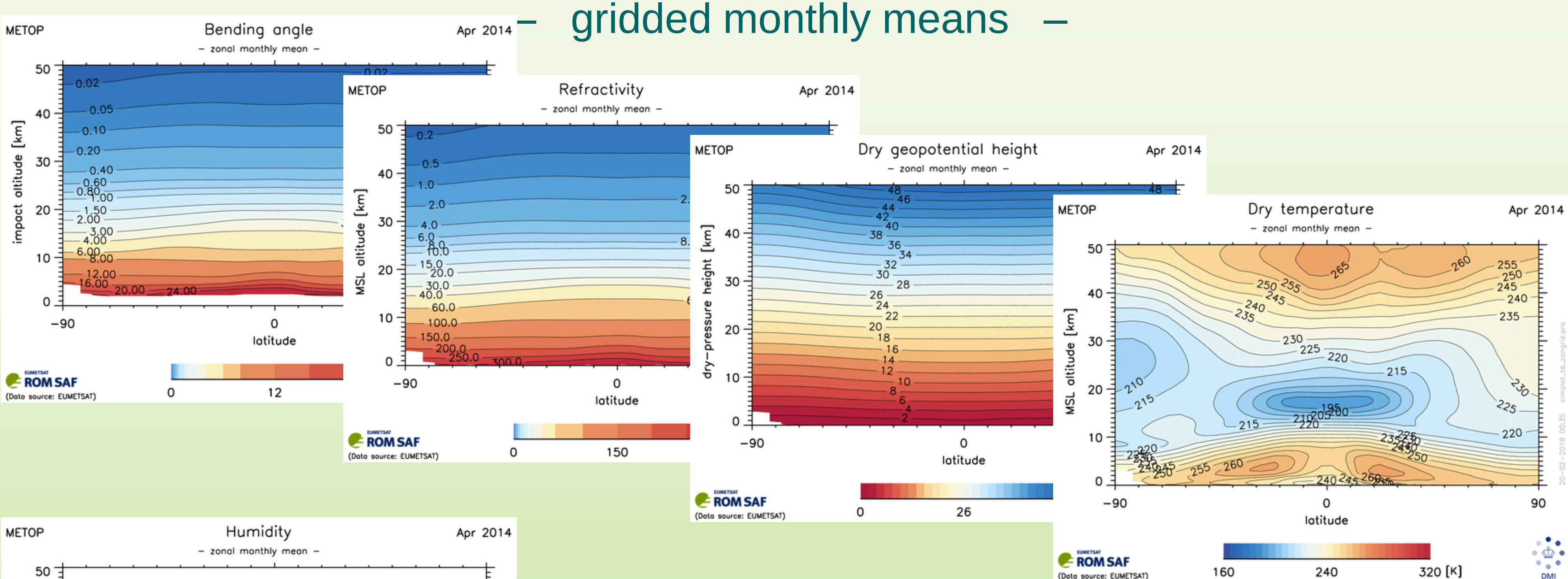
- CHAMP, GRACE, COSMIC, and Metop data
- 15+ years of reprocessed data, Sep 2001 – Dec 2016
- Metop processed with input data (excess phase) from both EUMETSAT and UCAR

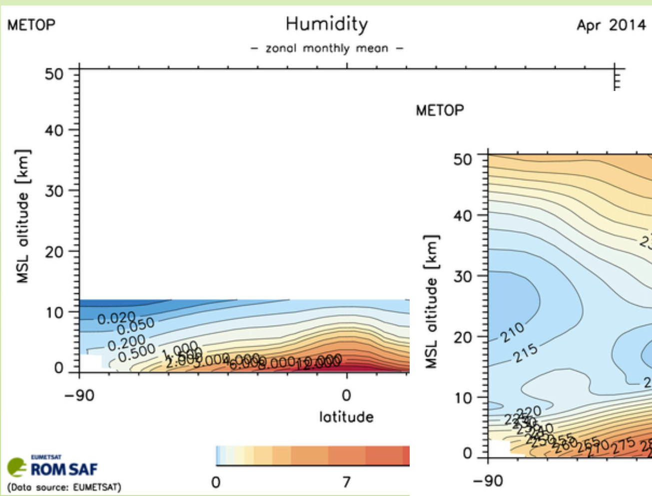
Interim climate data record (ICDR)

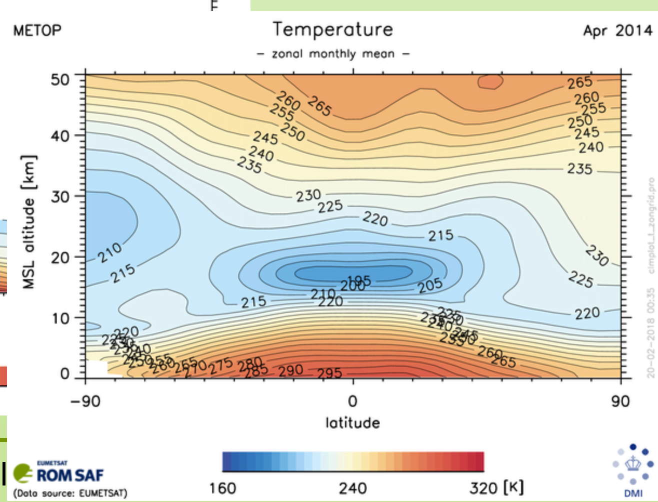
- Metop data
- Currently 2+ years of processed data, starting in Jan 2017 and regularly updated

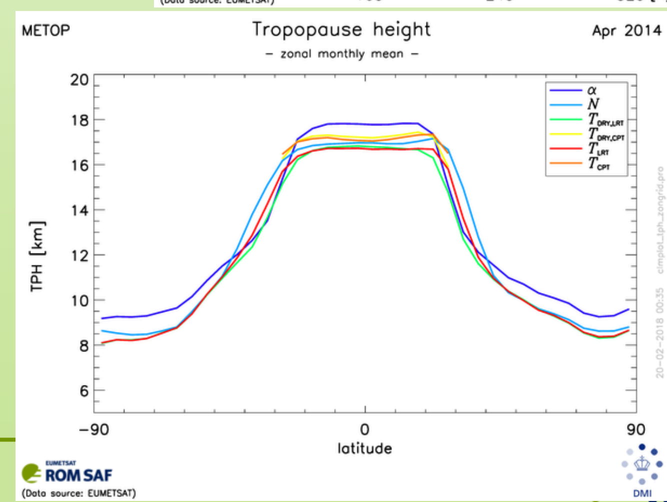
Geophysical variables

– gridded monthly means –







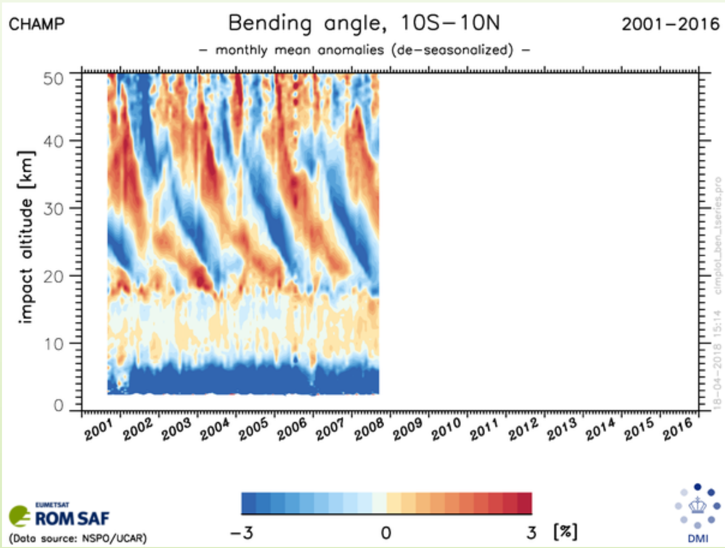


EUMETSAT ROM SAF

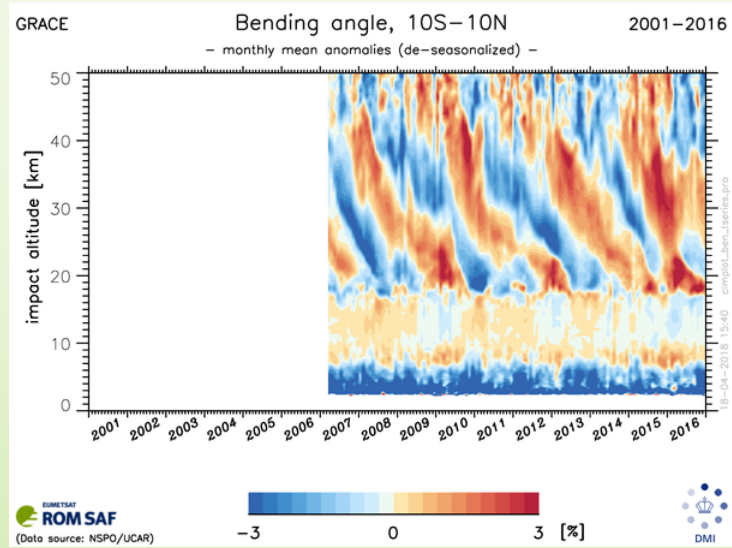
Gridded monthly mean anomalies

– tropical, 10S-10N –

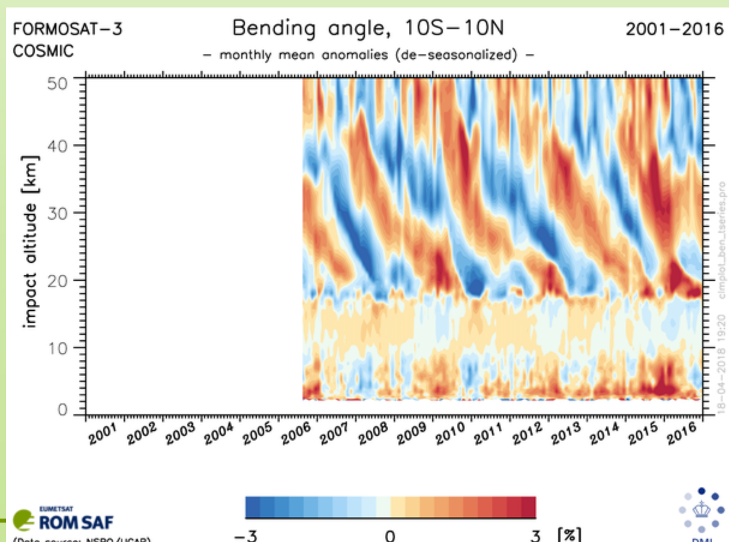
CHAMP



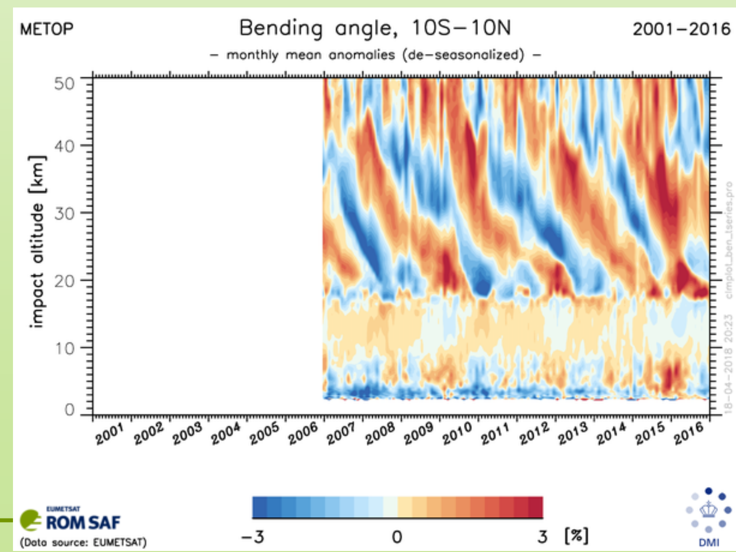
GRACE



COSMIC



Metop



Mission differences in the monthly means

Mission overlaps:

- CHAMP – COSMIC: Aug 2006 to Sep 2008
- GRACE – COSMIC: Mar 2007 to Dec 2016
- Metop – COSMIC: Dec 2006 to Dec 2016

We estimate mission differences as the differences between *sampling-error corrected data* , which is identical to *differences between the departures from a model* (here, ERA-Interim):

$$\text{diff} = O_1 - \left(B_1 - B^{\text{model}}\right) - O_2 + \left(B_2 - B^{\text{model}}\right) = (O_1 - B_1) - (O_2 - B_2)$$

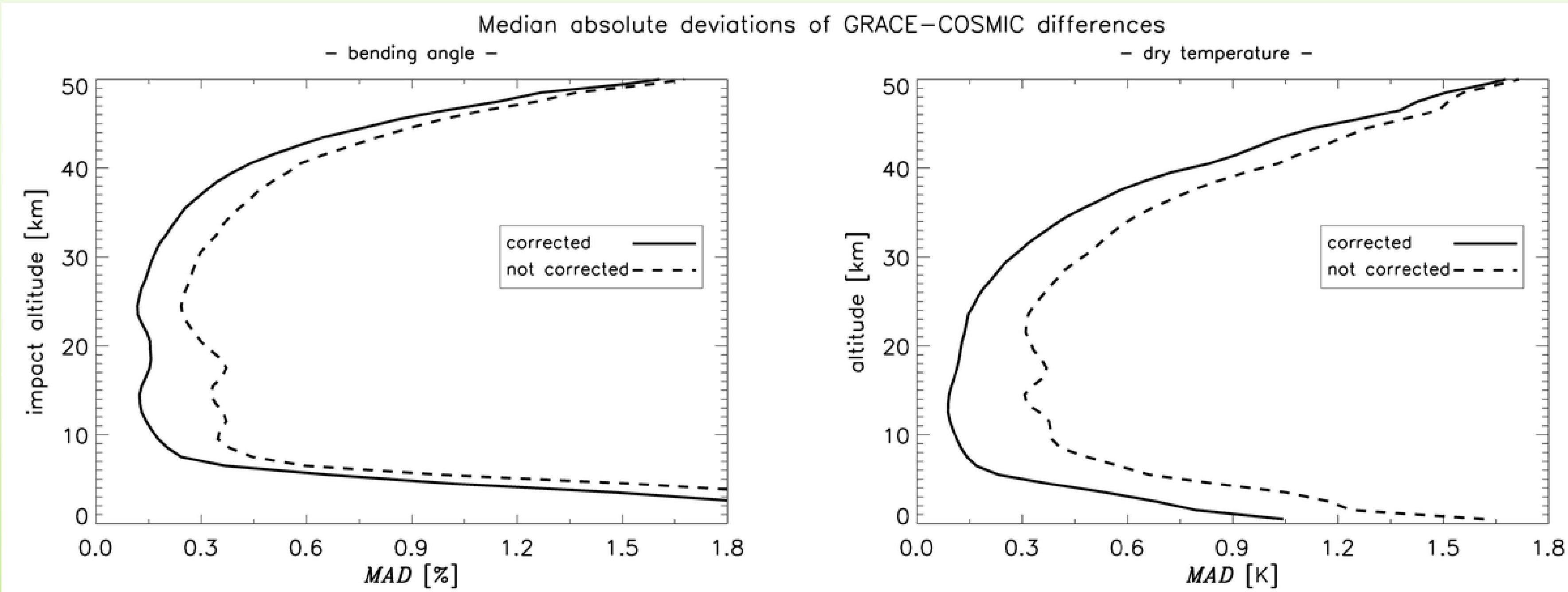
where *O* is RO monthly mean data (“observed”) and *B* is monthly mean co-located ERA-Interim short-term forecast data (“background”).

After the dominating sampling effects are removed, there are still differences due to:

- Random errors: propagated from profile uncertainties, random sampling error residuals
- Systematic biases from input data or from processing system
- Systematic biases from residual sampling errors (e.g., unresolved diurnal effects)

Mission differences: removing sampling effects

example: GRACE-COSMIC



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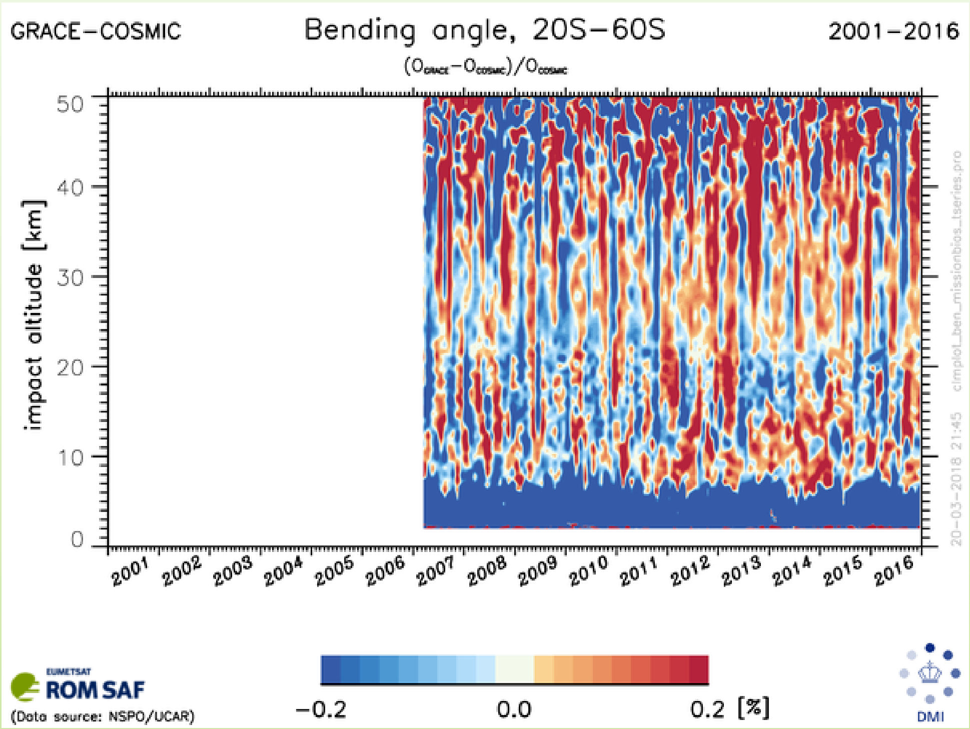
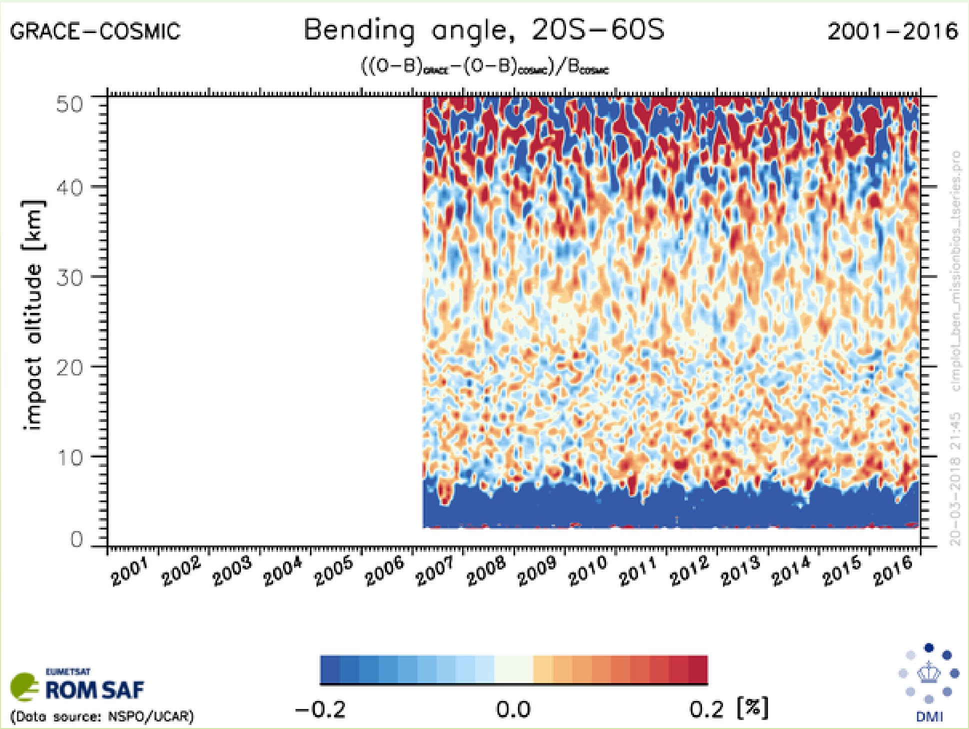
Mission differences: removing sampling effects

example: GRACE-COSMIC

No correction



Sampling-error corrected

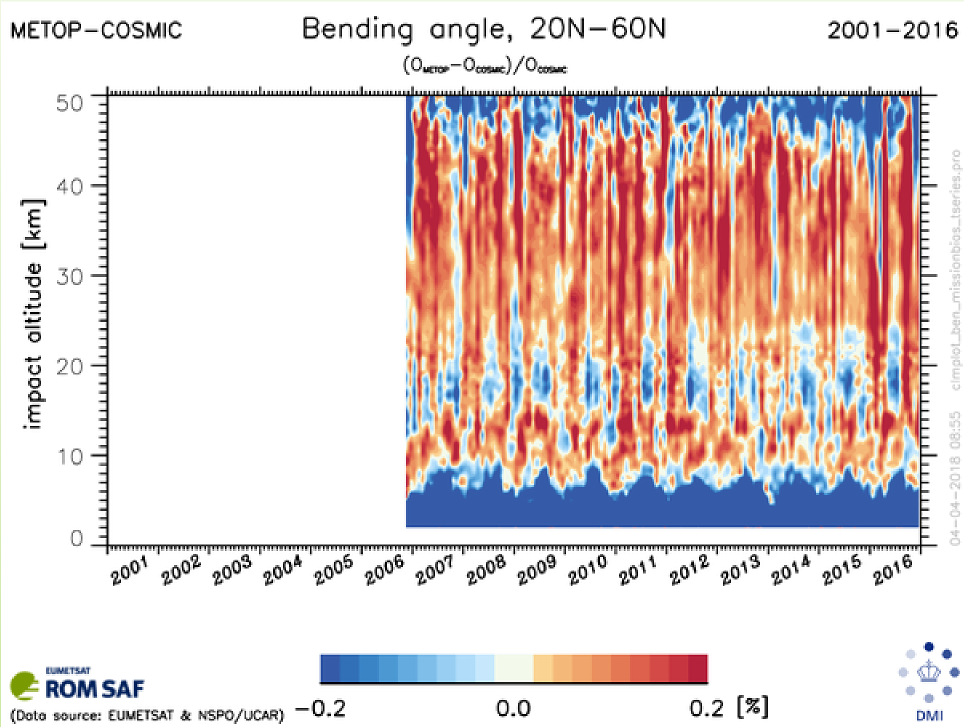


Differences due to random errors, and due to systematic errors from input data or processing, remains. When the systematic errors are small, the differences appear as a “quasi-random” pattern.

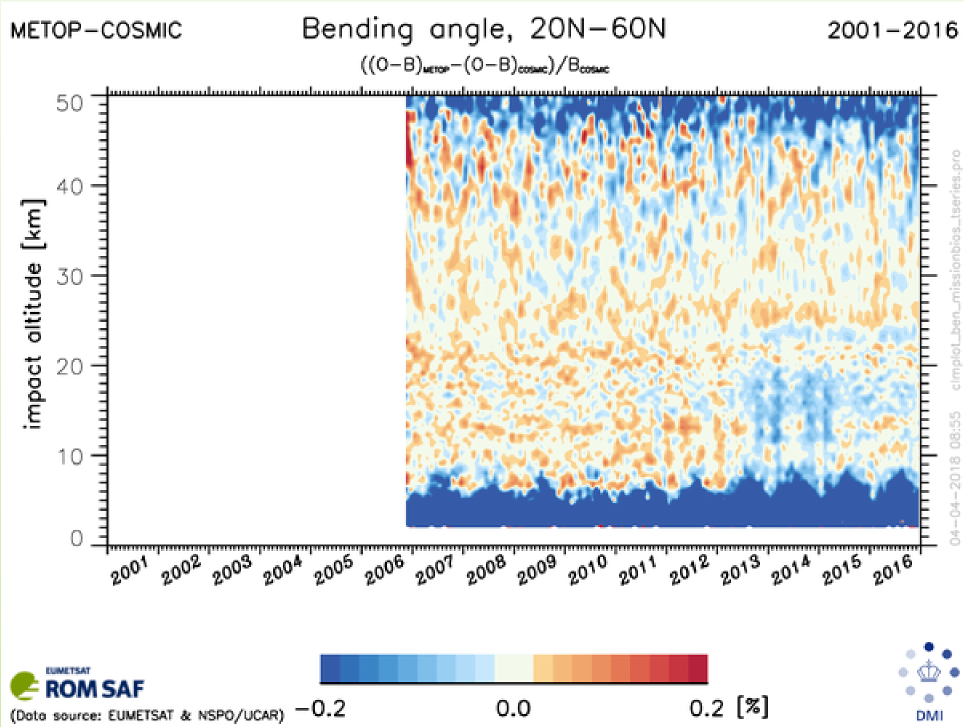
Mission differences: removing sampling effects

example: Metop-COSMIC

No correction



Sampling-error corrected



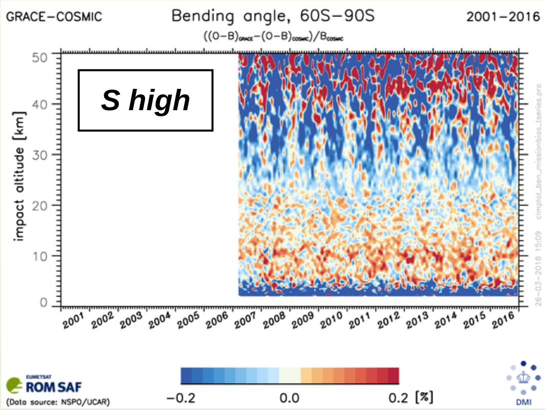
When the dominating sampling effects are removed, the remaining systematic differences due to processing or input data stand out more clearly from a “quasi-random” background.

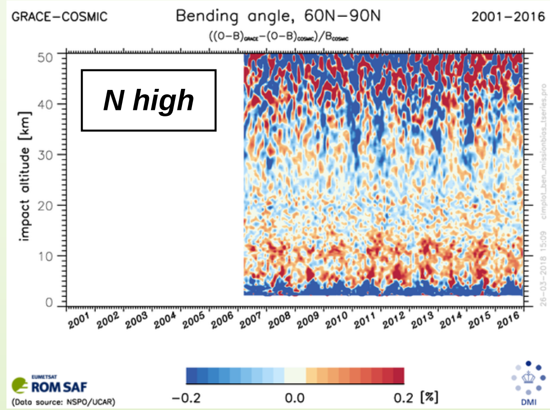
MISSION DIFFERENCES

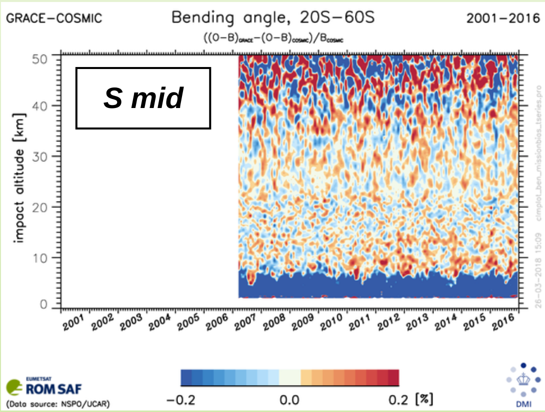
BENDING ANGLE IN DIFFERENT LATITUDE BANDS

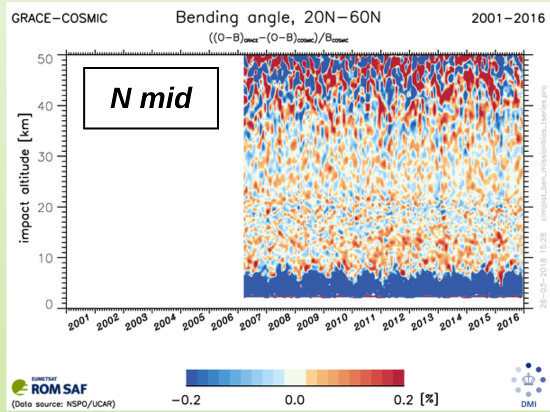
GRACE – COSMIC

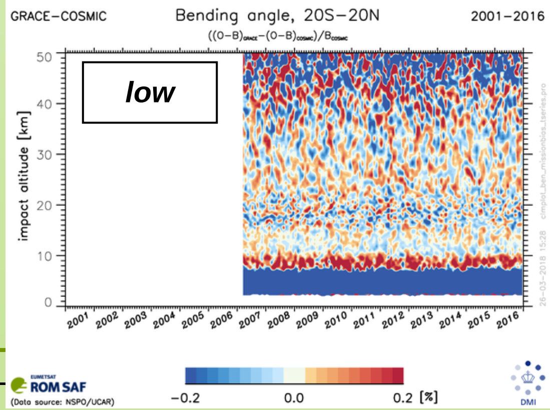
Input from UCAR









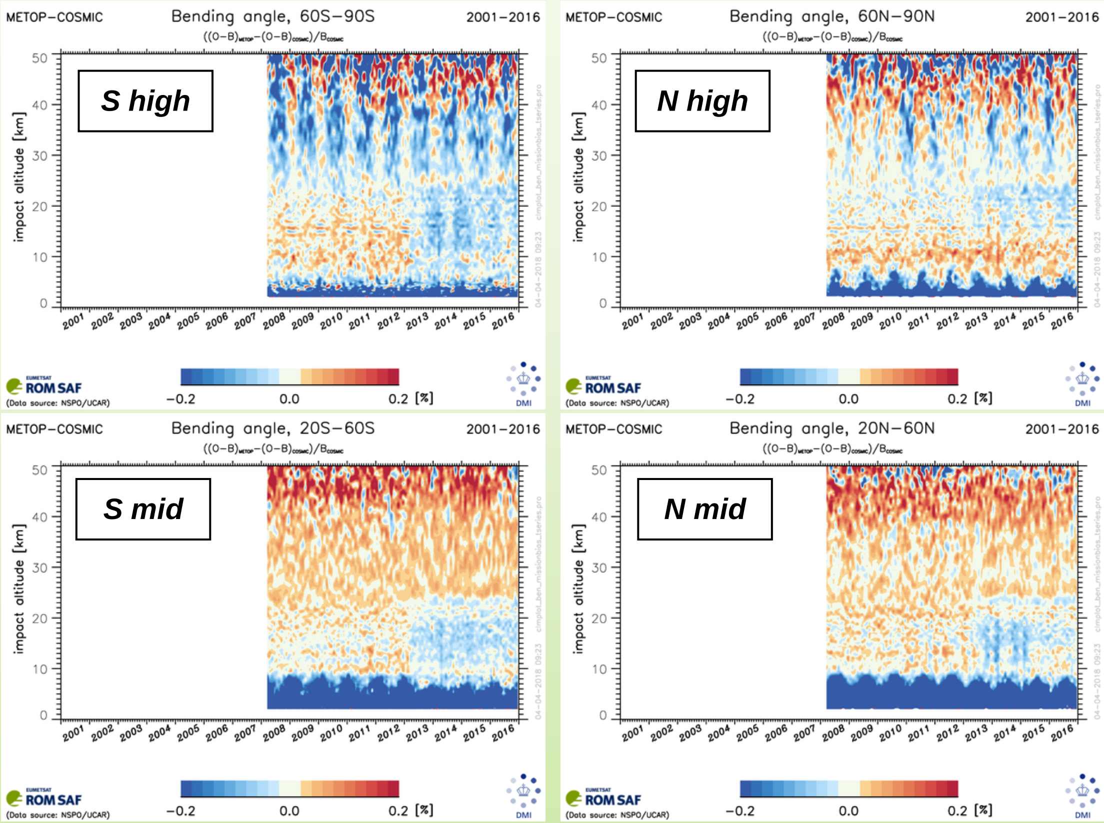


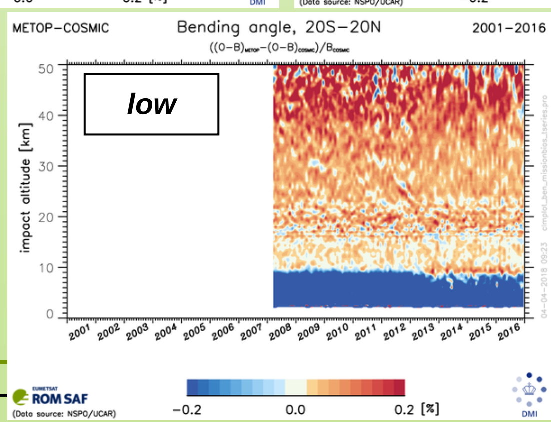
Findings:

- Random errors, minimum around 20 km, increasing upward;
- Lower-tropospheric biases, smaller at high latitudes;
- Seasonally varying biases at high latitudes above 30 km (*not* due to “high-altitude initialization” since we use the raw ionospheric corrected bending angles).
- Tendency to remaining sampling errors at low latitudes (diurnal cycle effects, easier to see in vertically averaged data).

Metop – COSMIC

Input from UCAR

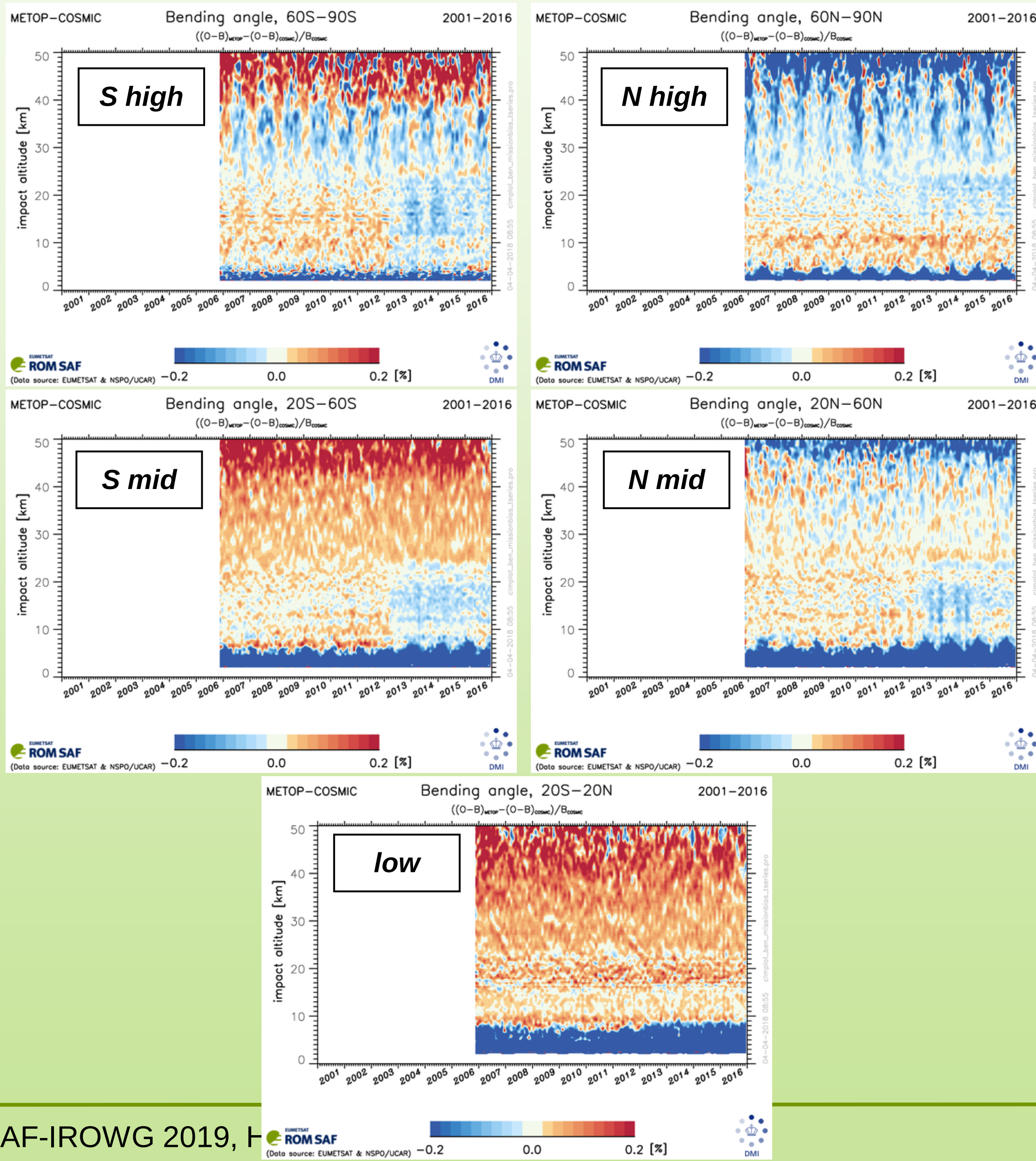




Additional findings:

- Bias change between 10–20 km in 2013 (L2 extrapolation issue related to a GRAS firmware update);
- Metop–COSMIC bias at mid- and low latitudes, 0.1% around 40 km increasing upward;

Metop – COSMIC



COSMIC input from UCAR

Metop input from EUMETSAT

Additional findings:

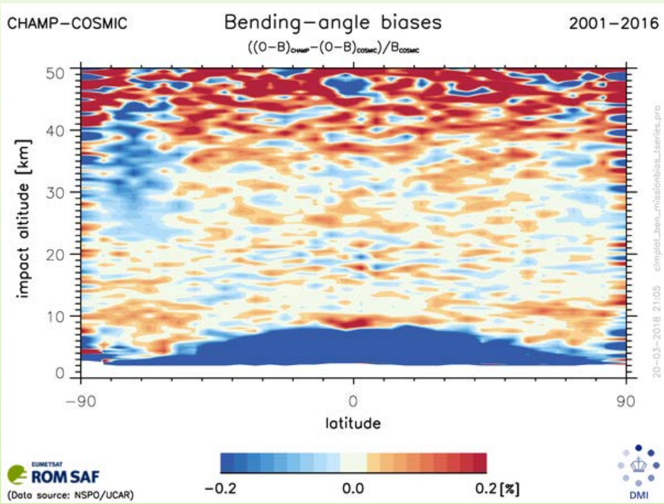
- North-south asymmetric bias on the order of 0.1% above 35-40 km, and increasing upward. Most likely related to subtle differences in LEO satellite orbits from the two sources of input data.

RO mission differences

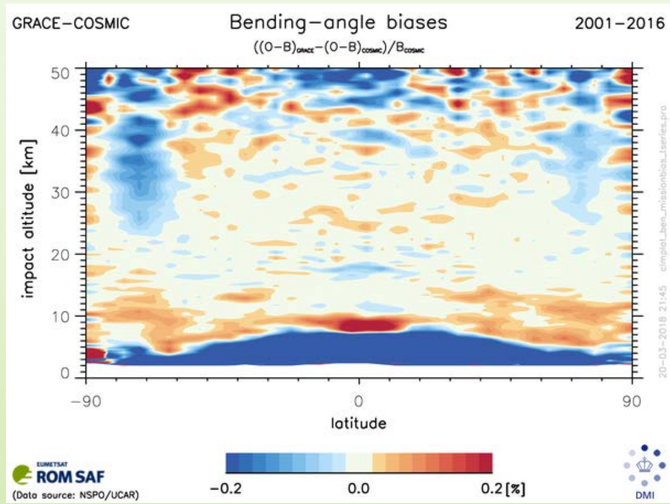
– bending angle differences –

Input from UCAR

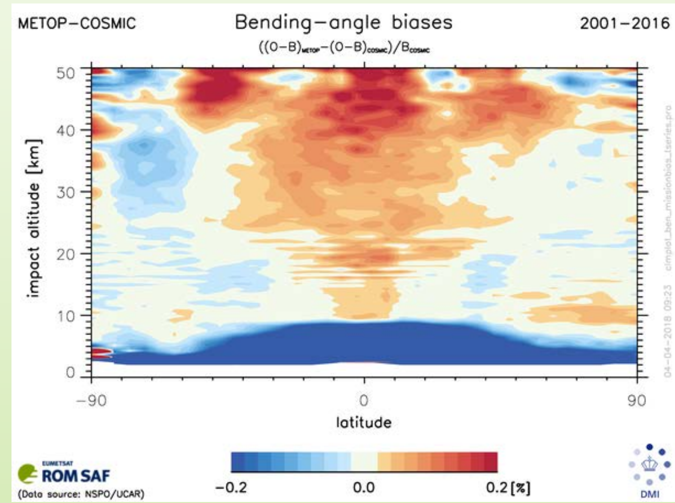
CHAMP – COSMIC



GRACE – COSMIC



Metop – COSMIC

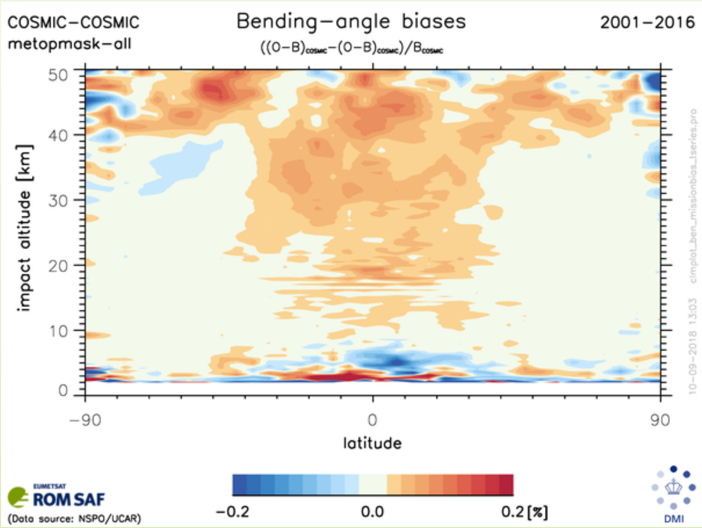


- Random errors increasing upward – largest magnitude in CHAMP-COSMIC.
- Positive bias structure at mid- and low latitudes in Metop-COSMIC and increasing upward. Believed to be related to under-sampling of the diurnal cycle in combination with an imperfect sampling-error correction. Is there a tendency to this in CHAMP-COSMIC and GRACE-COSMIC as well?

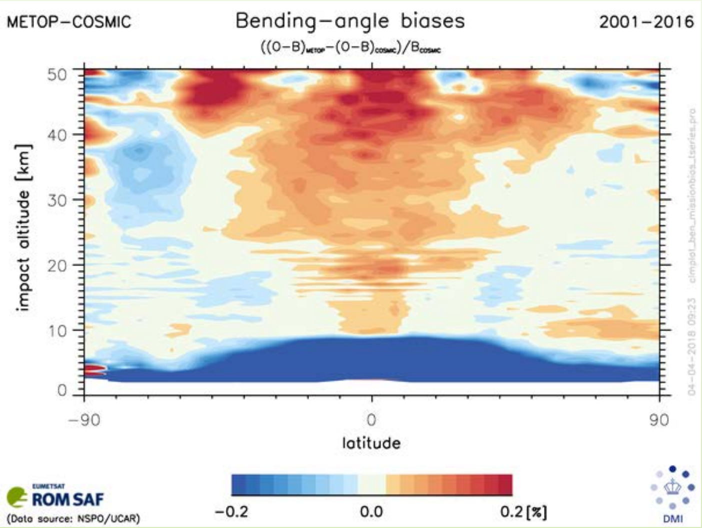
RO mission differences

– residual error from under-sampling of the diurnal cycle –

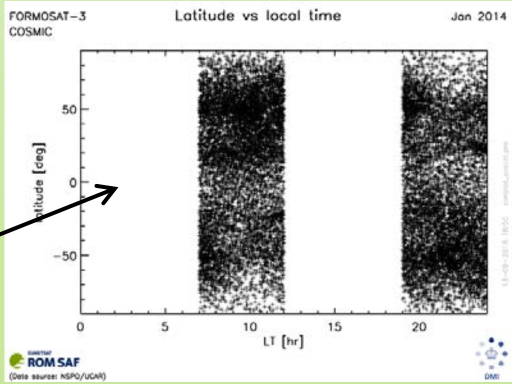
maskCOSMIC – COSMIC



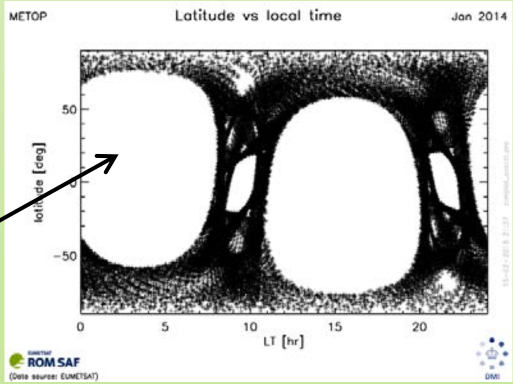
Metop – COSMIC



masked COSMIC



Metop



ANOMALIES & ANOMALY DIFFERENCES

BENDING ANGLE, GLOBAL AVERAGES

Anomalies and anomaly differences

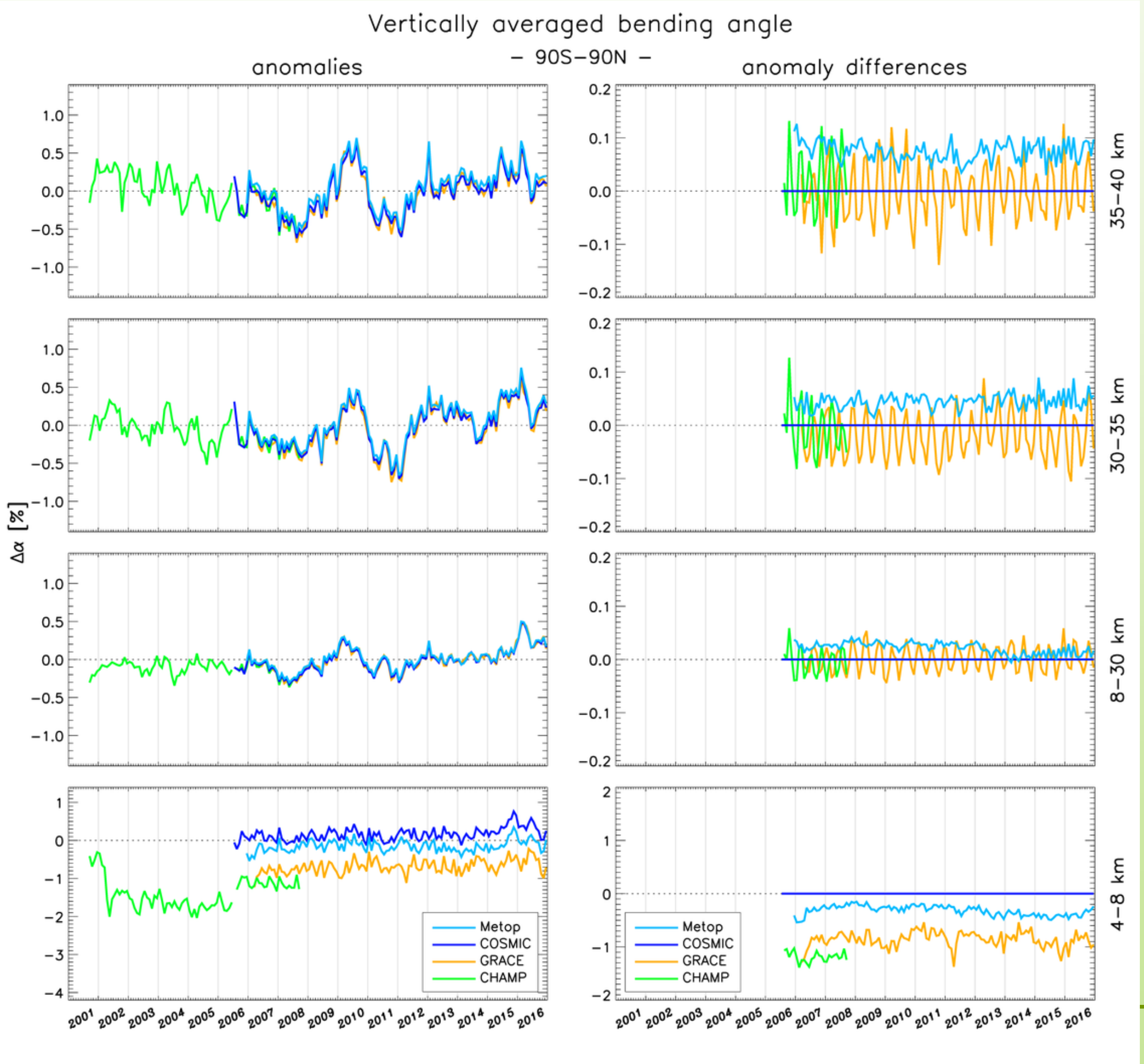
– bending angle, global –

35-40 km

30-35 km

8-30 km

4-8 km



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Anomalies and anomaly differences

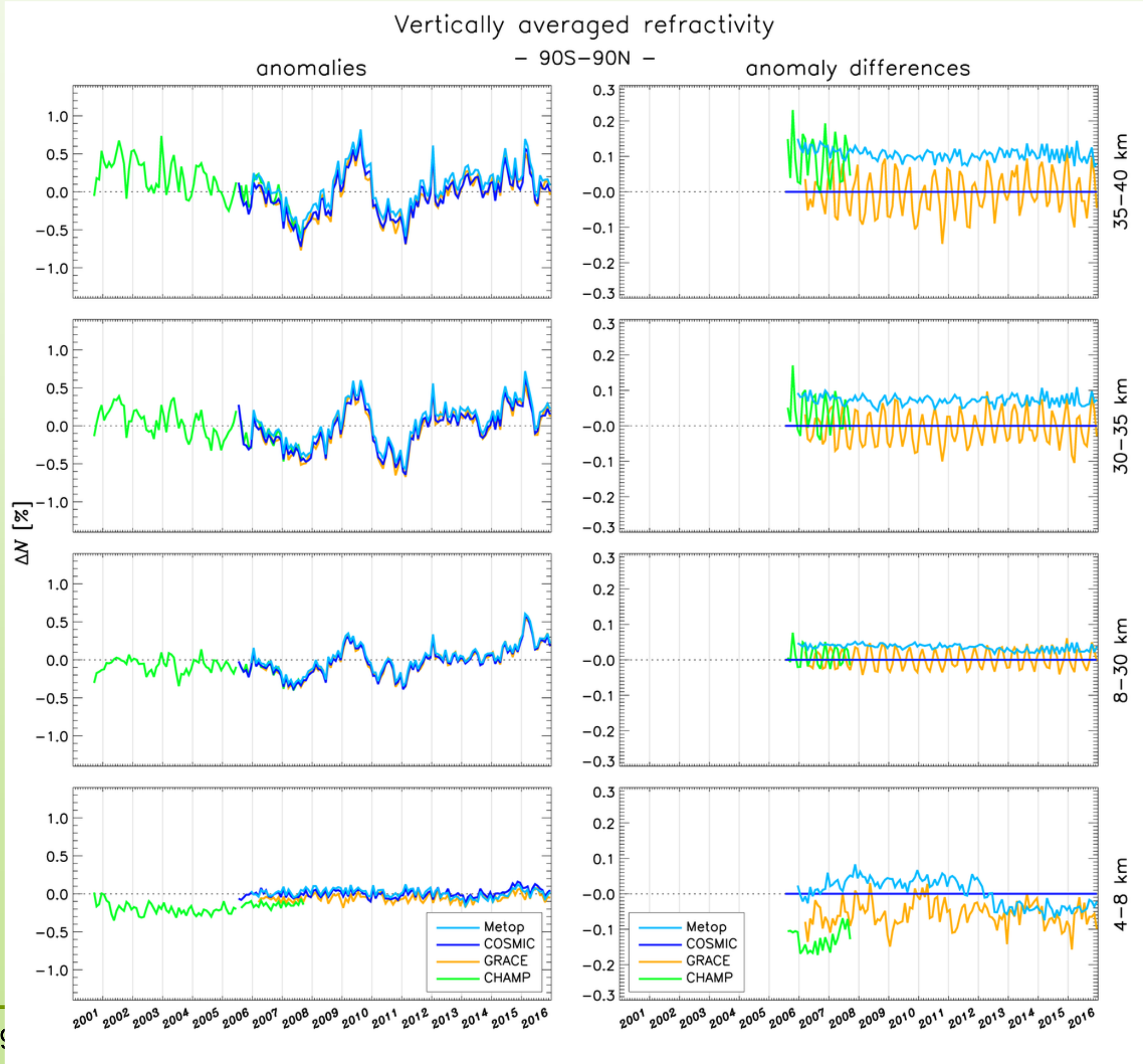
– refractivity, global –

35-40 km

30-35 km

8-30 km

4-8 km



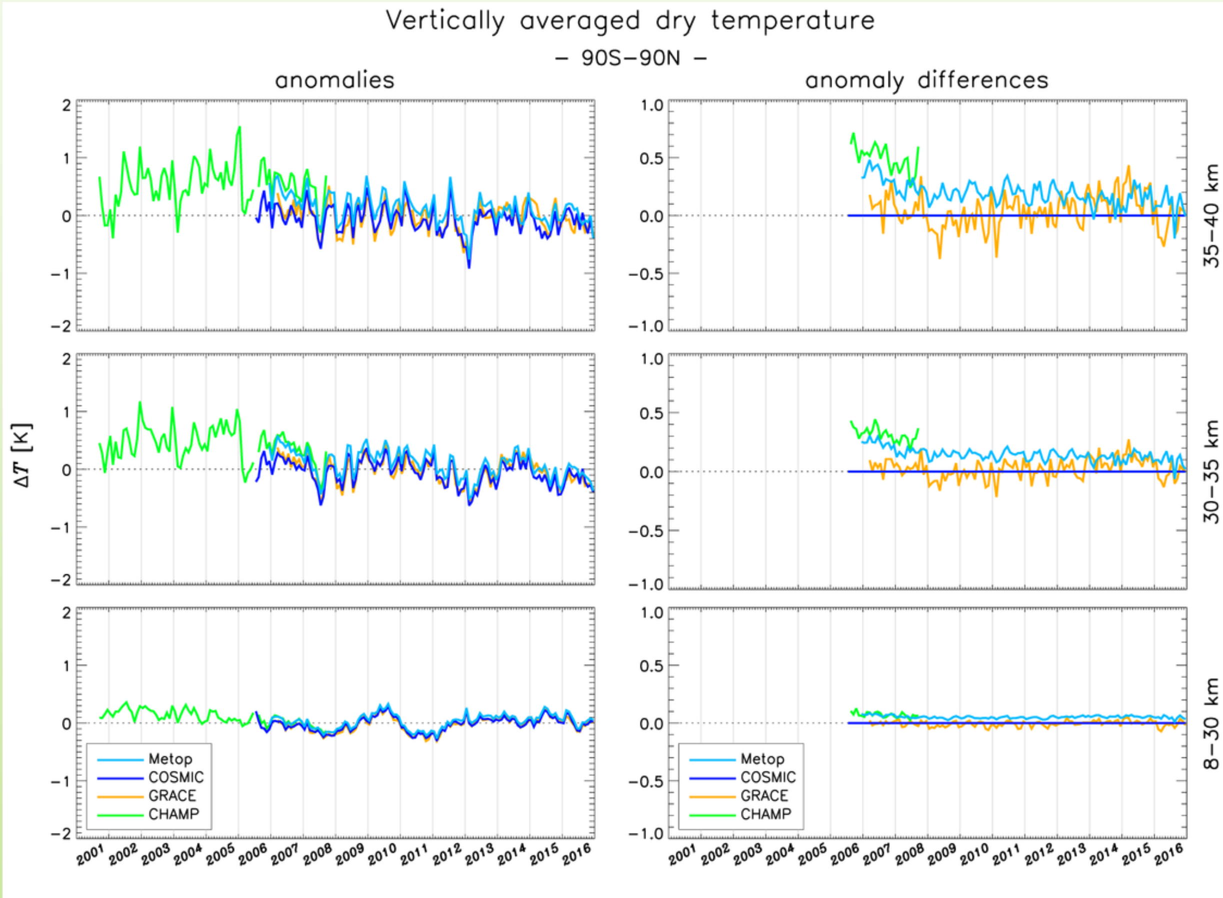
Anomalies and anomaly differences

– dry temperature, global –

35-40 km

30-35 km

8-30 km

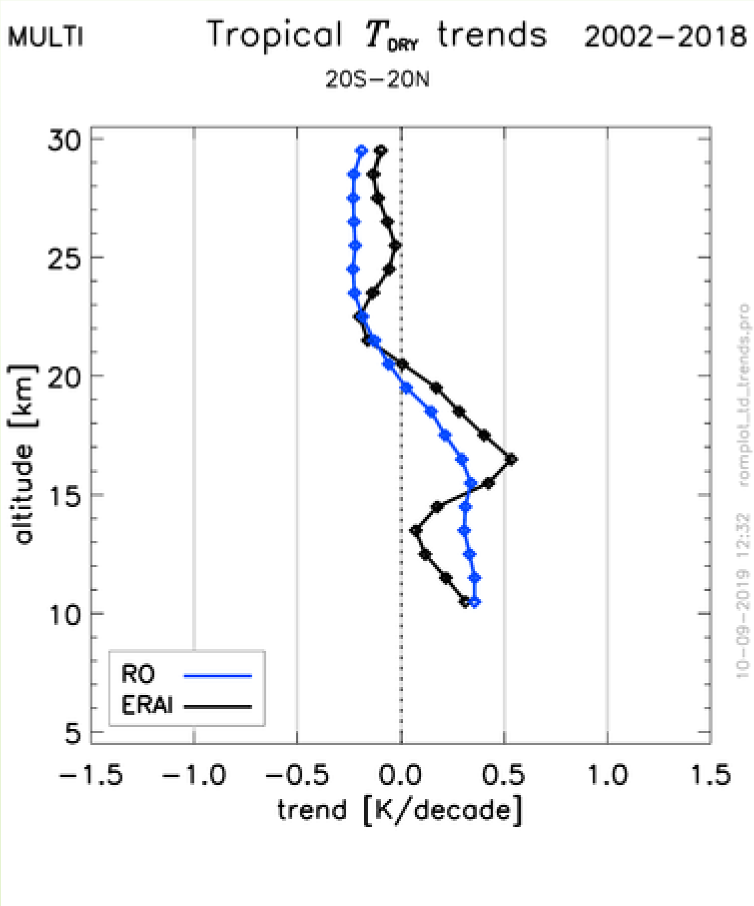


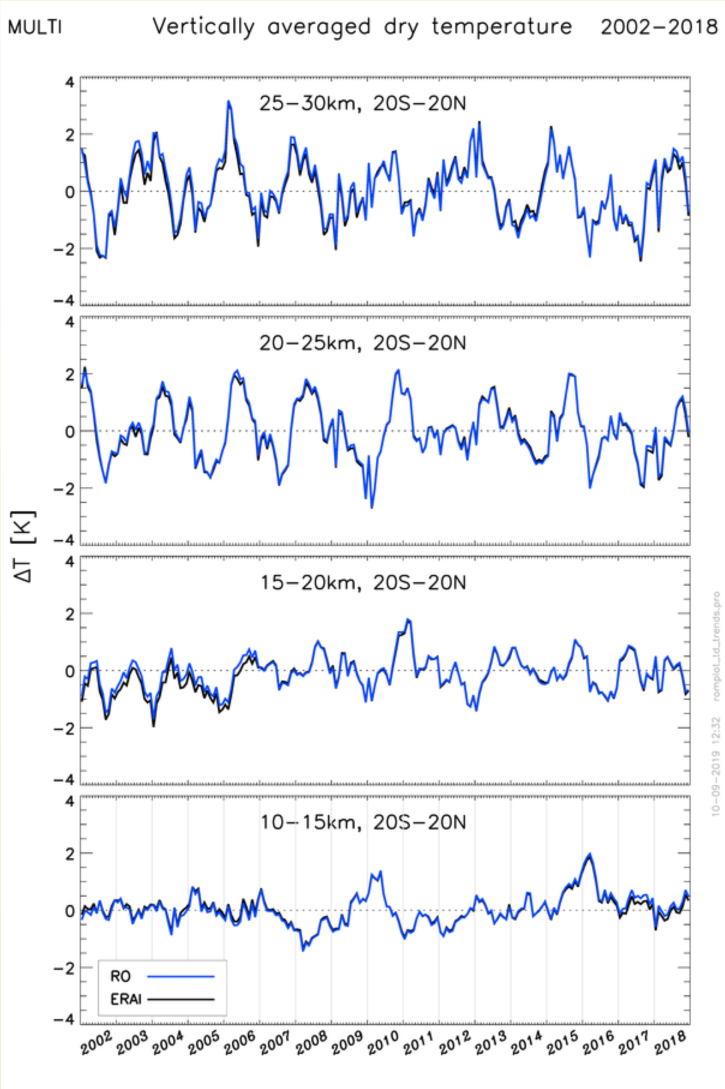
Metop – COSMIC differences in global averages

	Bending angle	Refractivity	Dry temp.
40-50 km	0.10 %	0.15 %	0.25 K
35-40 km	0.07 %	0.10 %	0.16 K
30-35 km	0.05 %	0.07 %	0.12 K
25-30km	0.04 %	0.06 %	0.08 K
20-25 km	0.02 %	0.04 %	0.06 K
12-20 km	0.01 %	0.02 %	0.04K
8-12 km	0.01 %	0.02 %	0.02 K

These differences reflect both errors propagated from the profiles, and residual sampling errors.

Tropical temperature trends

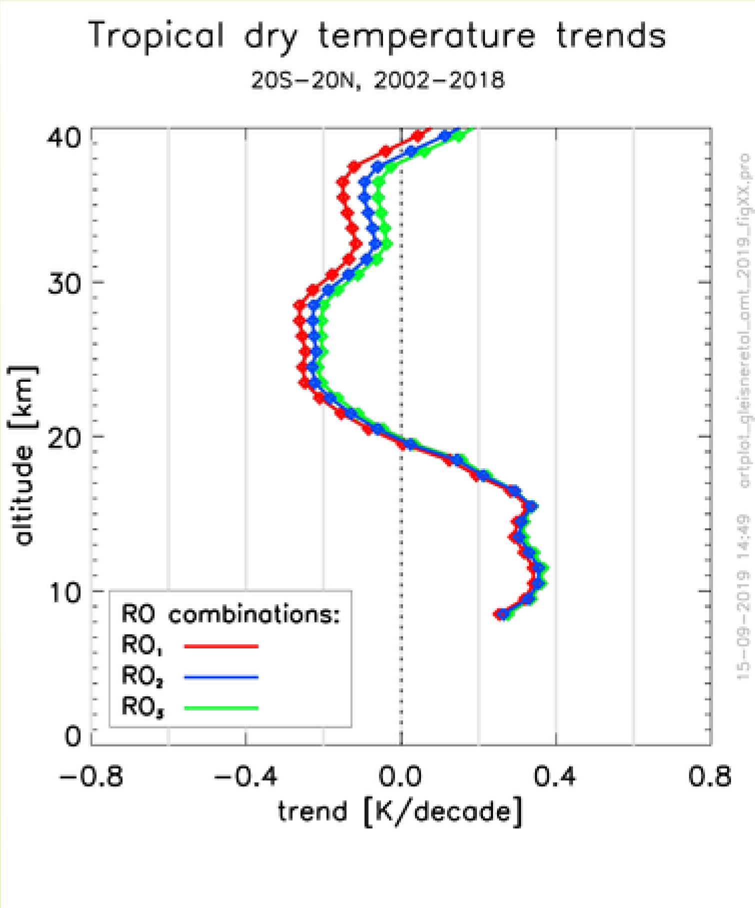




Tropical dry-temperature anomaly trends, 2002-2018, from ROM SAF (blue) and ERA-Interim (black).

EUMETSAT ROM SAF

Impact of RO mission differences on trends



Three different RO time series constructions

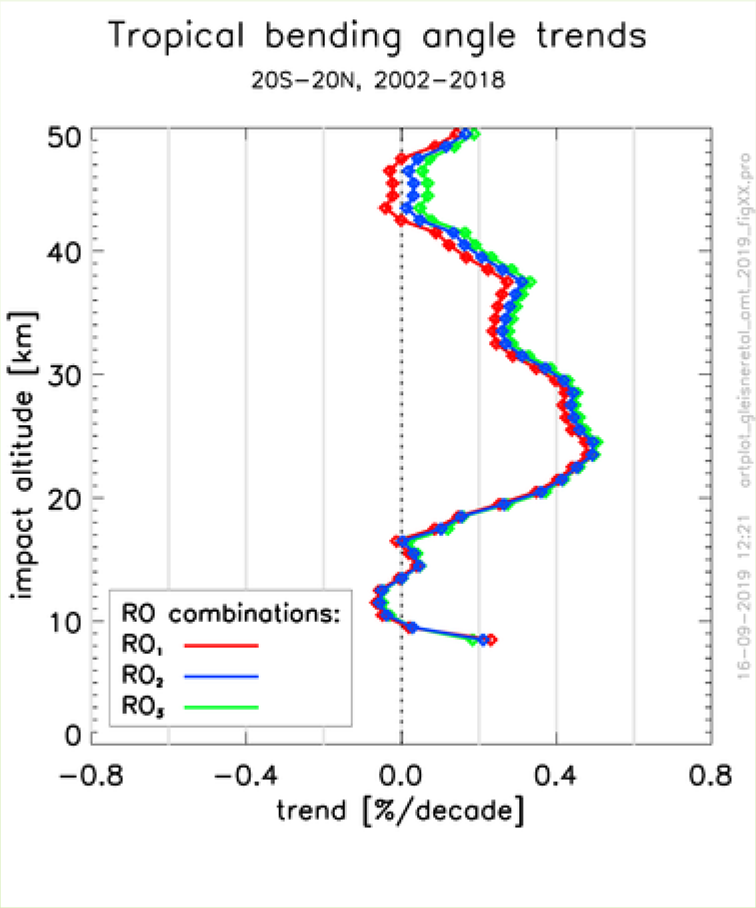
- Sep 2001 to Dec 2006: CHAMP, COSMIC
- Jan 2007 to Dec 2016:
  - RO_1: COSMIC only
  - RO_2: MULTI (all RO missions)
  - RO_3: Metop only
- Jan 2017 to Dec 2018: ICDR based on Metop

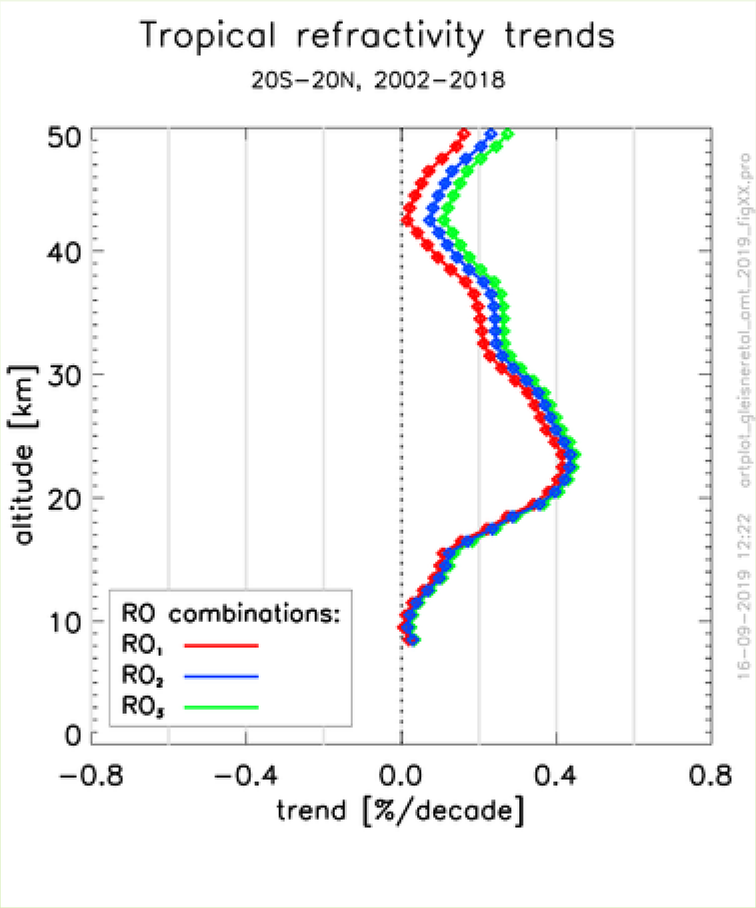
Different combinations of RO missions lead to slightly different trends. The differences increase upward.

The changing weight of COSMIC in relation to Metop over the 10-year period 2007-2016, in combination with a small but systematic difference between these two missions, adds an error to the trend.

The fundamental cause is that we slowly get a stronger weight of Sun-synchronous data, and our sampling-error correction does completely correct for this.

Impact of RO mission differences on trends





Different combinations of RO missions lead to slightly different vertical trend profiles.
At least a part of this range is due to an imperfect correction of sampling errors.

Main conclusions

- High consistency between the RO missions between about 6-8 km and 30-35 km.
- Biases between the missions in the lower troposphere, below about 6 km.
- Seasonal biases between the missions at high altitudes, high latitudes.
- Subtle biases related to processing system, firmware changes, and input data differences can be identified in the climatologies.
- Model-based removal of sampling effects is quite efficient, but leaves residuals due to local time effects. For sun-synchronous missions like Metop, this results in a constant bias, while for precessing orbits the biases are oscillating.
- Impacts on long-term trends in the tropical atmosphere:
  - error in dry-temperature trend around 0.1 K/decade above 30 km,
  - error in refractivity and bending angle trends around 0.05%/decade above 30 km, and 0.1%/decade above 40 km.

END