The ROM SAF RO climate data records

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- Homogenization of RO climate data records by sampling-error correction
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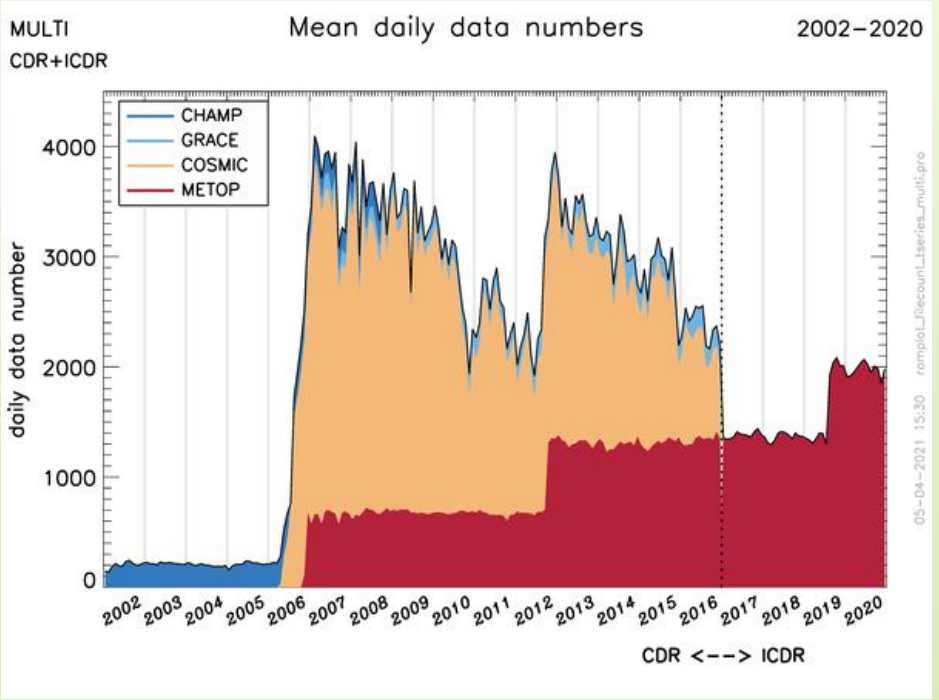
ROM SAF climate data records (CDR+ICDR)

Climate Data Records (CDR v1.0):

GRM-29-R1: **Metop** (2006–2016)
GRM-30-R1: **COSMIC** (2006–2016)
GRM-32-R1: **CHAMP** (2001–2008)
GRM-33-R1: **GRACE** (2007–2016)
GRM-28-R1: **MULTI** (2001–2016)

Interim Climate Data Records (ICDR v1.0, v1.1):

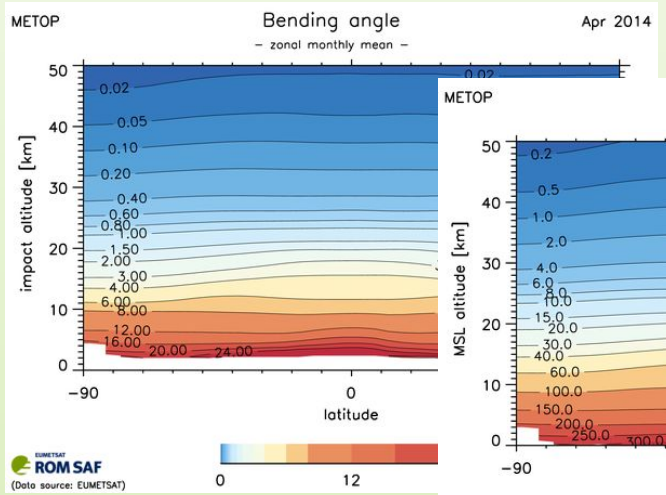
GRM-29-I1: **Metop** (2017 – present)

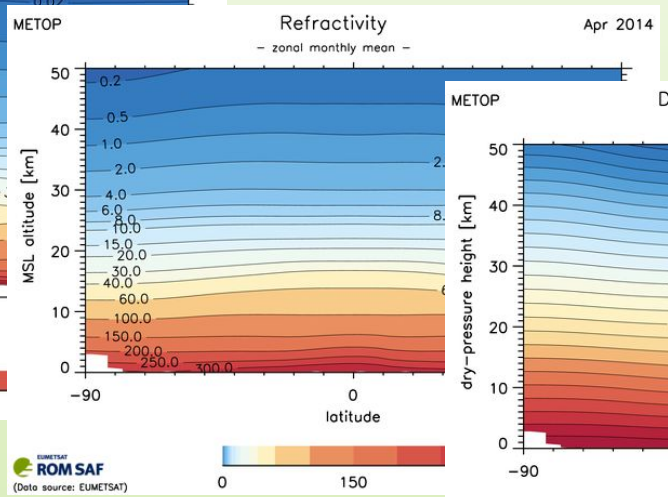


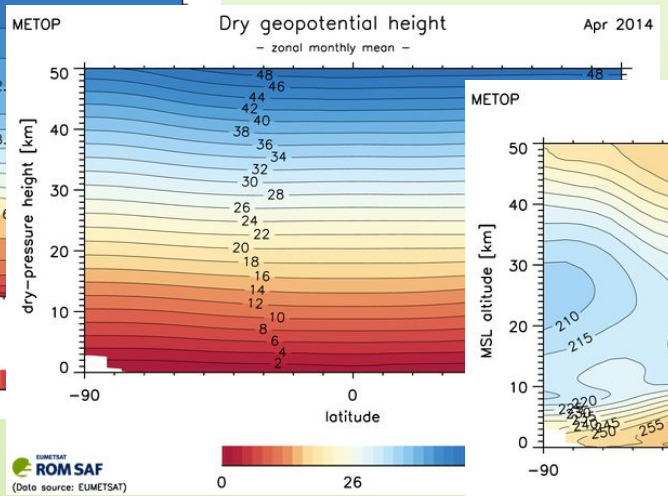
Contents:

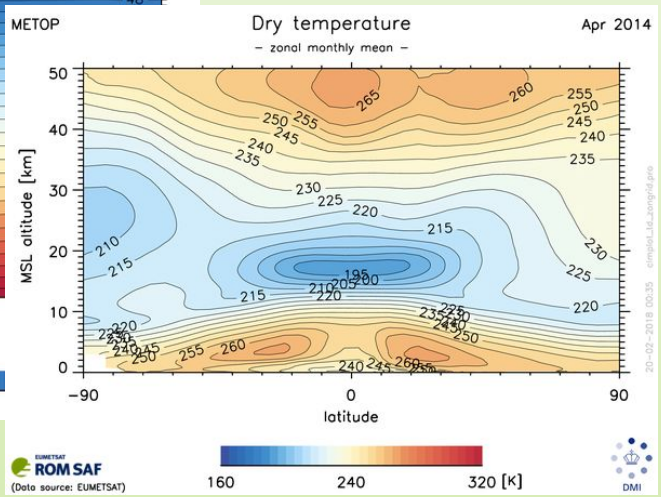
- Radio occultation bending angles, atmospheric refractivity, dry pressure and temperature
- Temperature, humidity, pressure, surface pressure, and tropopause height
- Monthly mean gridded data of all variables, including geopotential height
- In total: **16 RO data records per satellite mission**

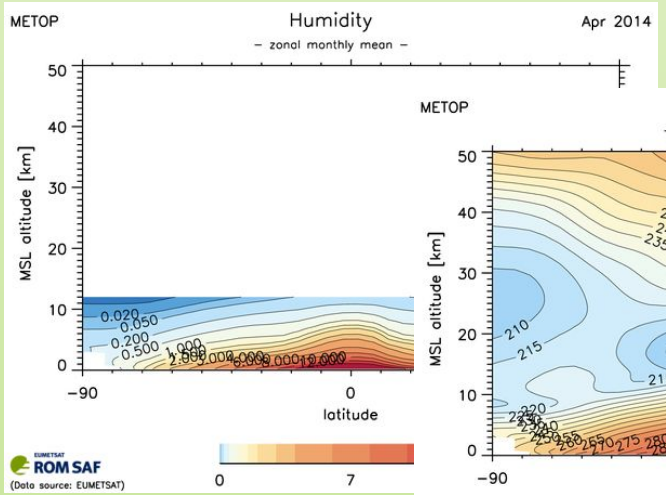
Geophysical variables available

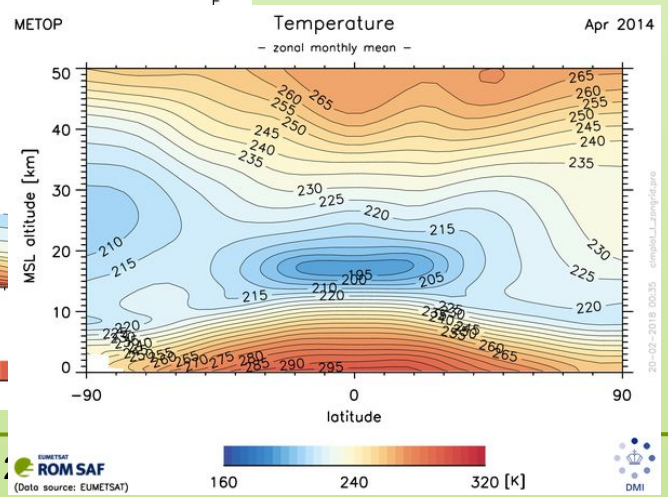


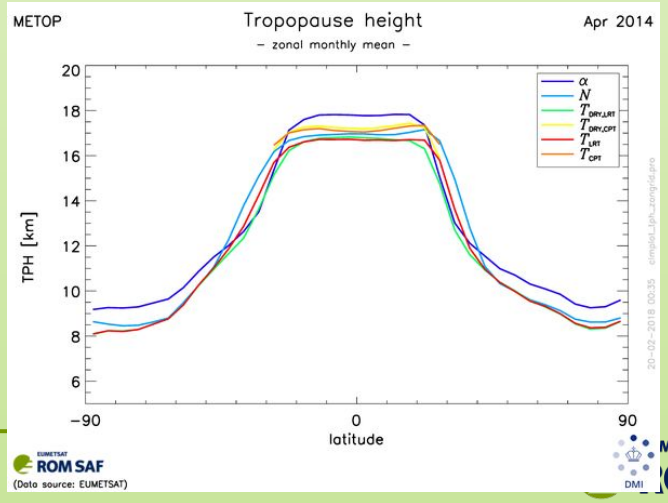












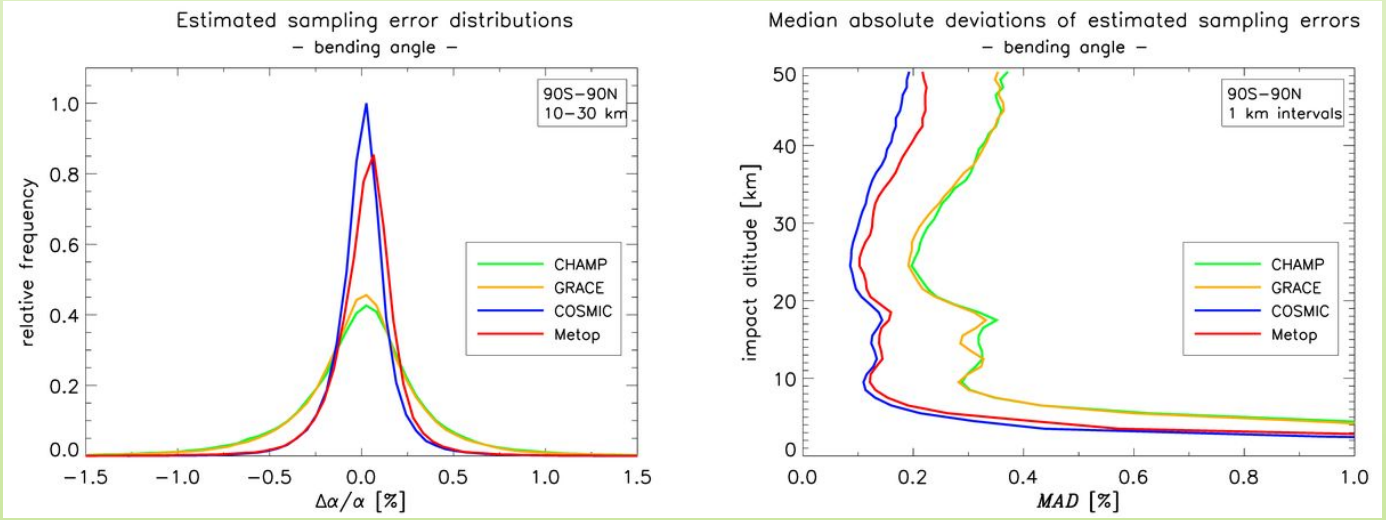
Estimation of sampling errors in gridded monthly means

Estimation of sampling errors from reanalysis short-term forecast fields:

$$\varepsilon_{\text{samp}} = \overline{B_i} - \overline{B_{\text{grid}}} + \Delta\varepsilon_{\text{samp}}$$

Sampled model mean

Whole grid mean (model "truth")



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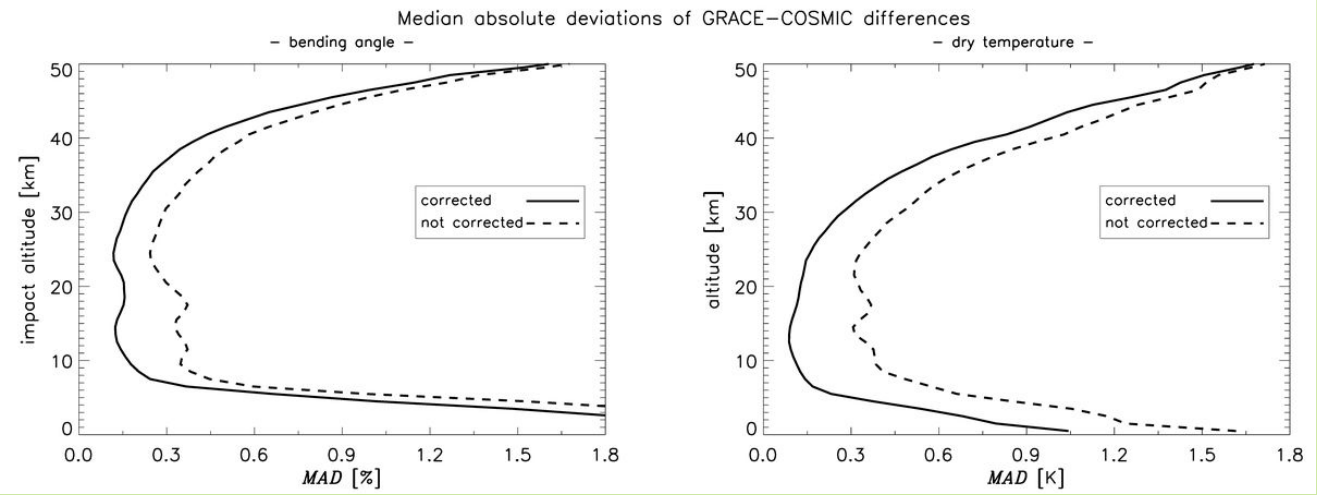
Reduced mission differences

The sampling error estimates are subtracted from the observed means

$$\overline{O}_{i,\mathrm{corr}} = \overline{O}_i - (\overline{B}_i - \overline{B_{\mathrm{grid}}})$$

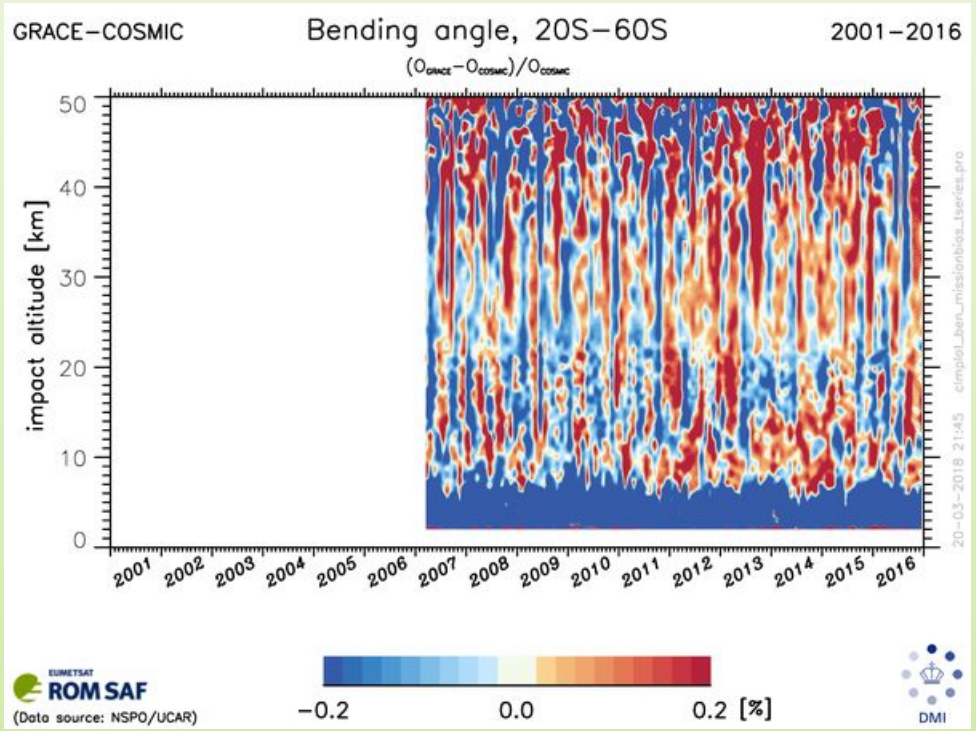
to obtain *homogenized* climate data records. Inhomogeneity of the time series caused by differences between RO missions with different sampling characteristics, but also sampling that changes with time.



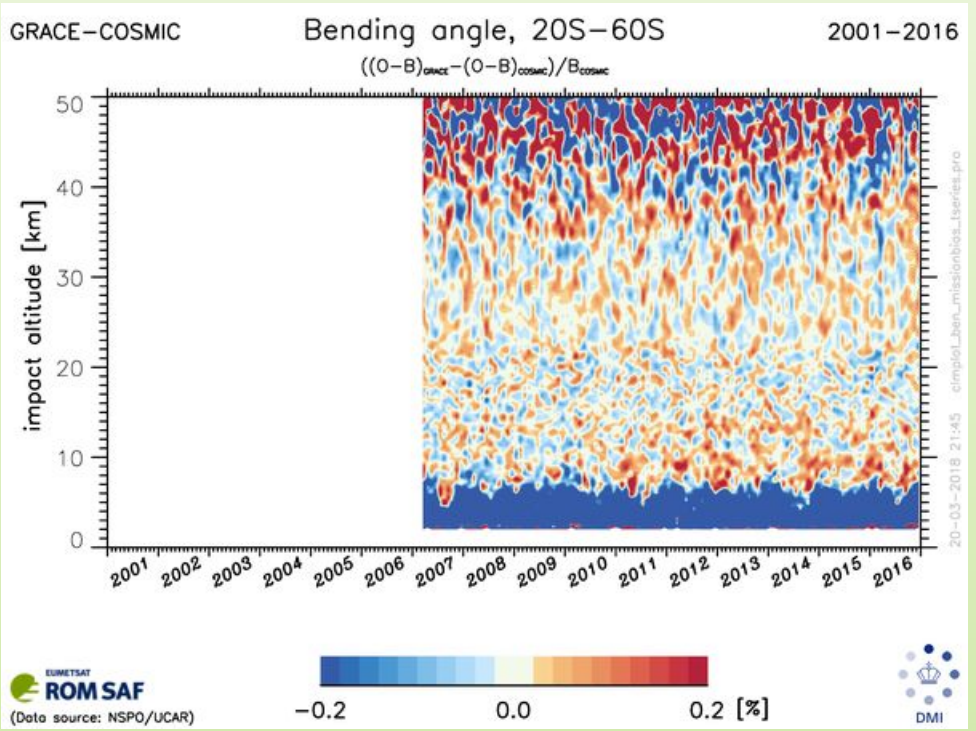
Reduced mission differences

example: GRACE-COSMIC

No correction



Sampling-error corrected

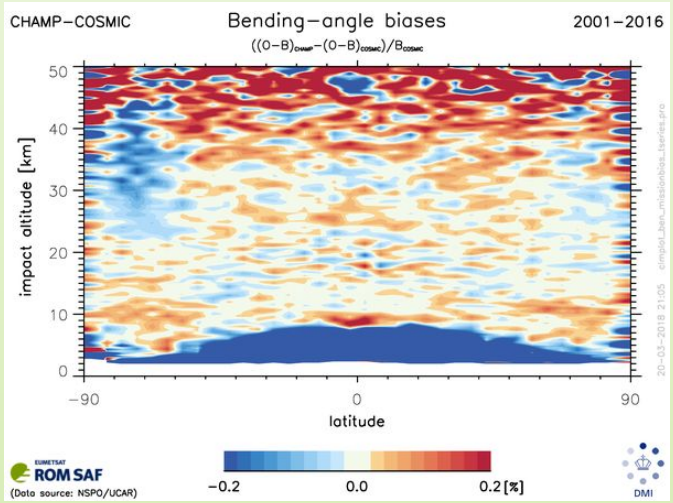


Differences due to random errors, and due to systematic errors from input data or processing, remains. When the systematic errors are small, the differences appear as a “quasi-random” pattern.

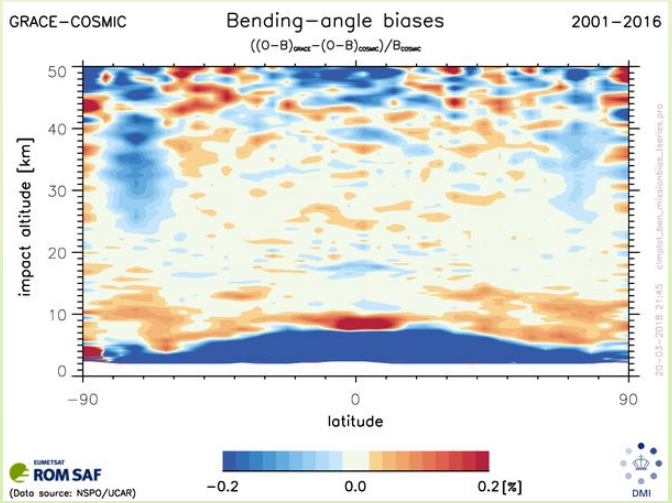
RO mission differences

– in bending angles –

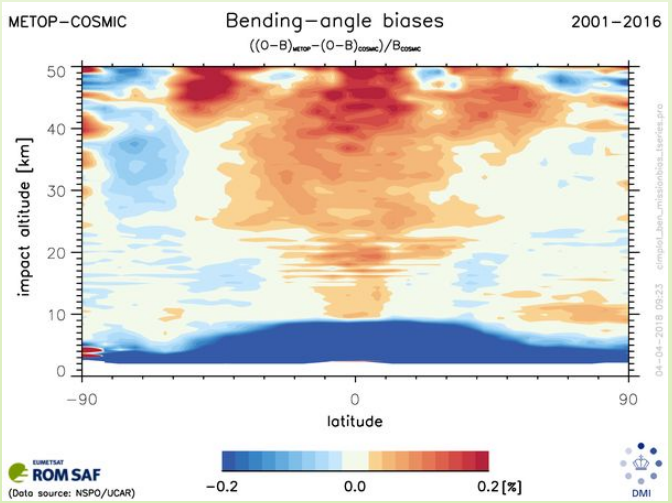
CHAMP – COSMIC



GRACE – COSMIC

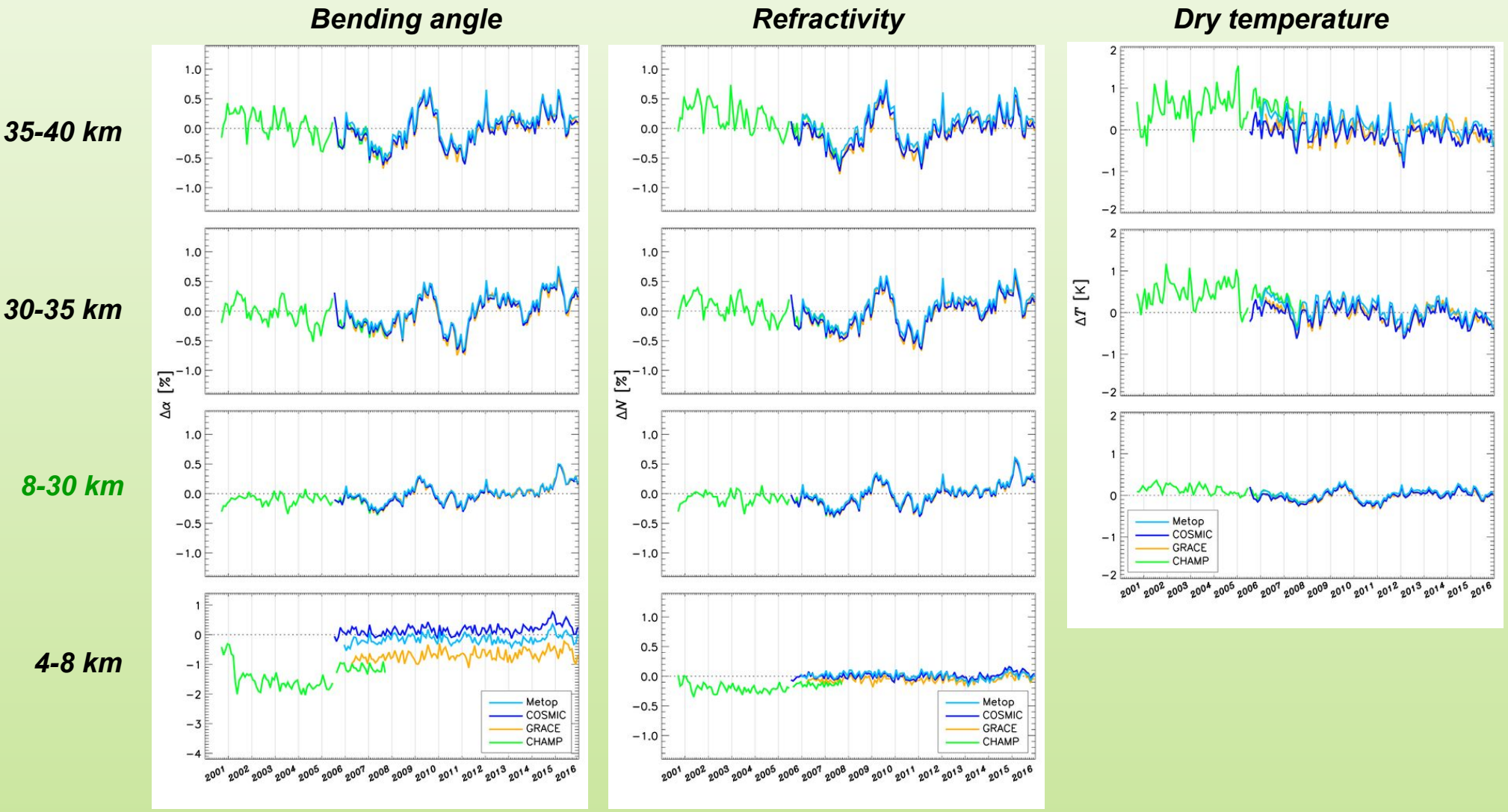


Metop – COSMIC



- 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.

Globally averaged anomaly data



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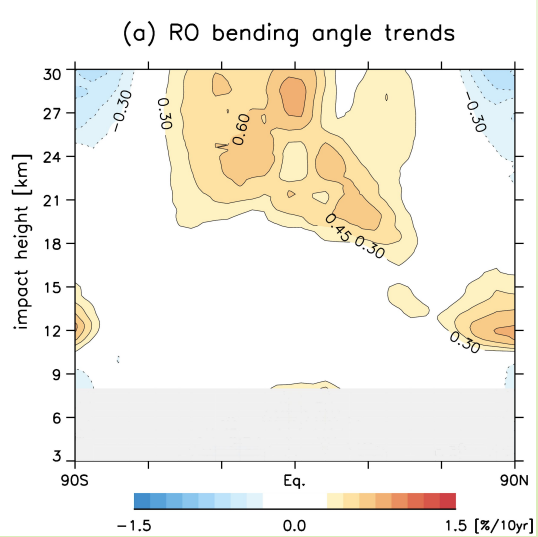
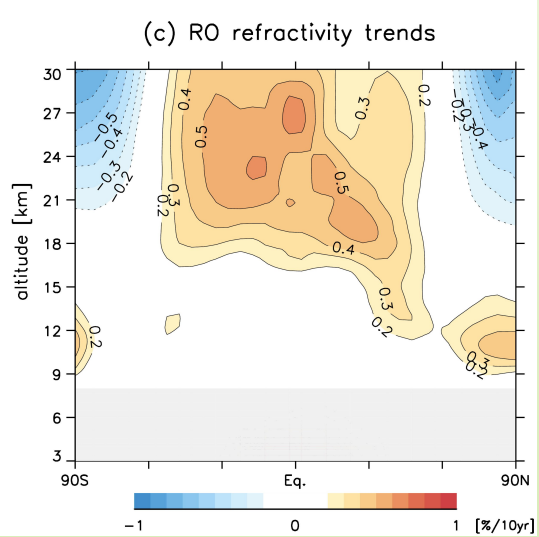
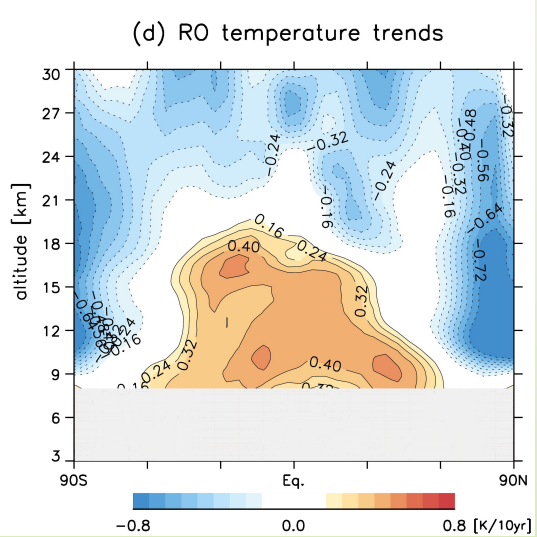
Atmospheric decadal trends

– bending angle, refractivity, dry temperature –







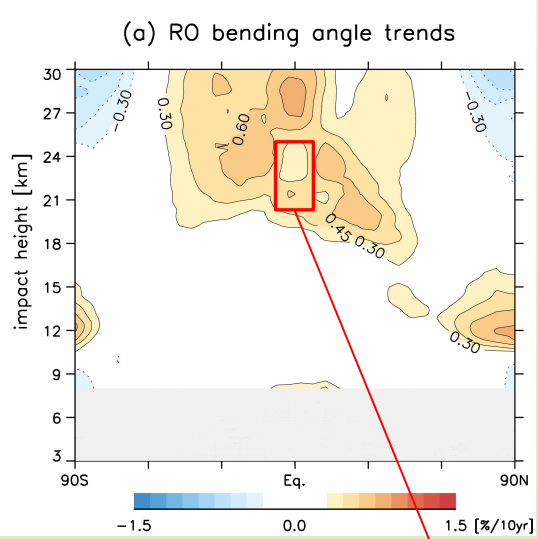
Observed trends in bending angle anomalies correspond to widespread lower-stratospheric cooling. Consistent pattern in refractivity.

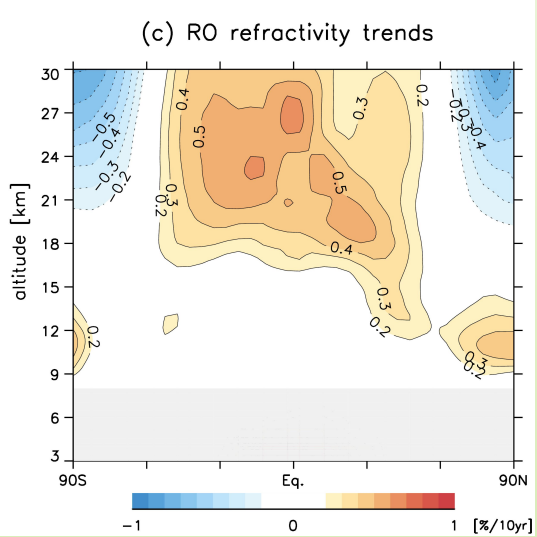
The temperature trends show tropospheric warming and a transition to stratospheric cooling across a relatively sharp vertical gradient associated with the tropopause region.

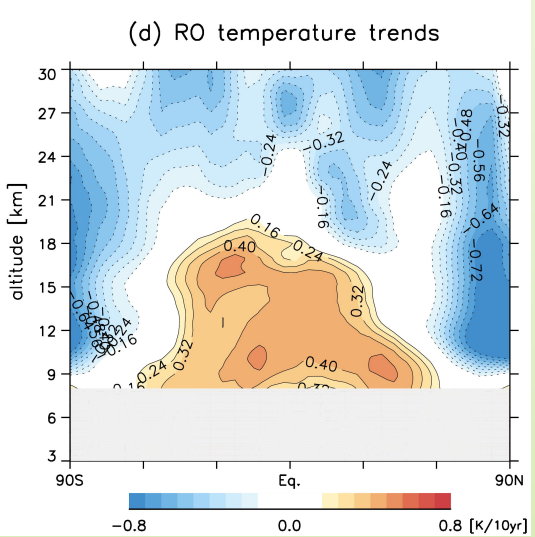
RO-based temperature trends contributed to the next IPCC Assessment Report (collaboration amongst several RO processing centers). In particular, the rate of warming in the tropical upper troposphere will be discussed, as the high vertical resolution of RO provides important information complementary to that of other observation types.

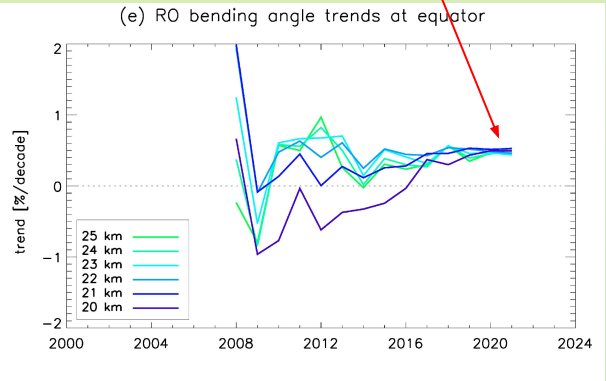
Atmospheric decadal trends

– bending angle, refractivity, dry temperature –









In 2008, Ringer and Healy suggested, based on climate model data, that climate trends in the tropical stratosphere bending angles would be clearly detected from 11–16 years of data.

Observed trends seems to have converged with the currently available 19 years of data.

The natural variability – mainly the QBO in the equatorial lower stratosphere – is larger in observed data than in climate models 15 years ago.

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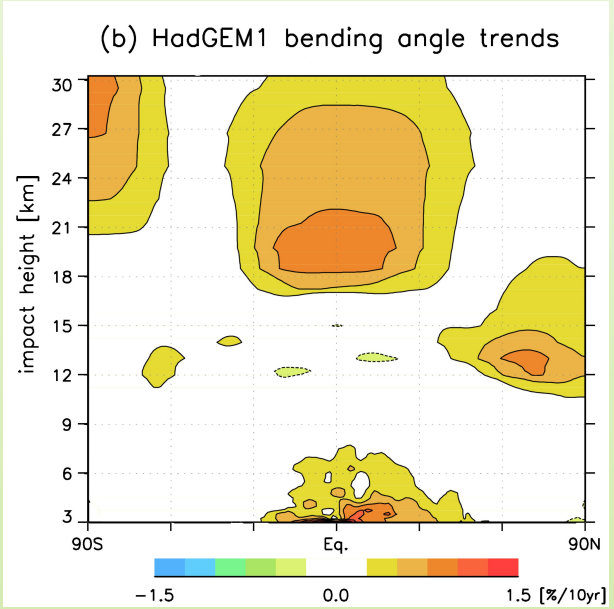
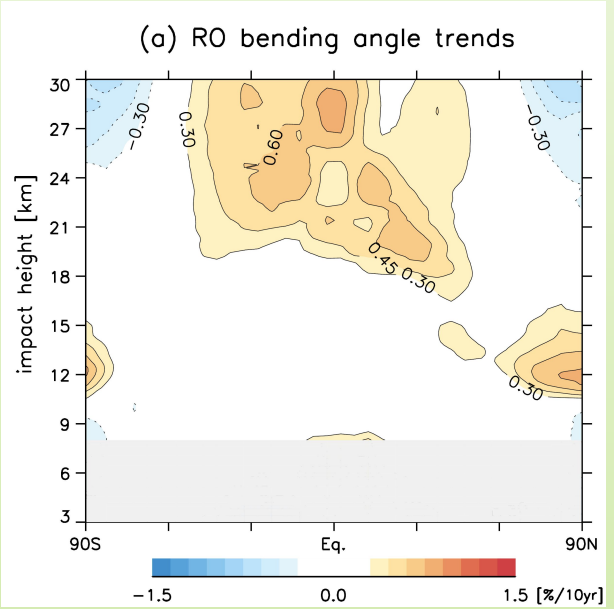
Atmospheric decadal trends

– Observed vs. modelled bending angle –





From Ringer and Healy (GRL, 2008)

Left: *Bending angle changes (per decade) early 2000s to early 2020s from HadGEM1 climate model scenario integrations made 15 years ago (Ringer and Healy, 2008).*

Right: *Observed bending angle trends based on ROM SAF CDR+ICDR data records 2002–2020.*

Summary

- Nearly 20 years of RO data available for generation of climate data records.
- Generation of long multi-mission time series requires homogenization of the data records through sampling error correction.
- High consistency between the RO missions between about 8 and 30-35 km. Bending angle consistent up to 40 km.
- 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 constant biases as evidenced by a small, but significant, offset between Metop and COSMIC in the middle and upper stratosphere.
- Observed RO trends represent well-understood responses to global warming. The observed bending angle trends closely match predictions made by climate models nearly 15 years ago.
- RO provides important information on the rate of warming in the tropical upper troposphere, complementary to that of other observation types because of the high vertical resolution. Contribution to the next IPCC Assessment Report.