The ROM SAF RO climate data records: plans and applications

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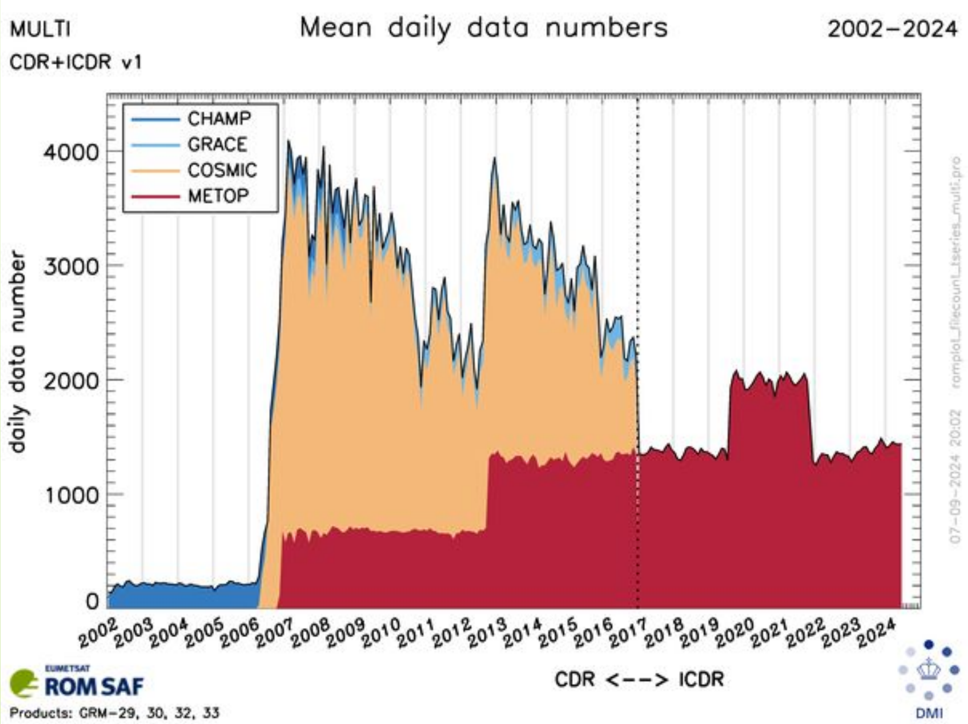
Outline

- The ROM SAF climate data records
- Applications of ROM SAF climate data records
- Development plans

ROM SAF climate data records

– from reprocessing #1 –



Climate data record (CDR v1)

- CHAMP, GRACE, COSMIC-1, Metop, MULTI
- Reprocessed 15+ years, Sep-01 to Dec-16
- Released in February 2019

Interim climate data record (ICDR v1)

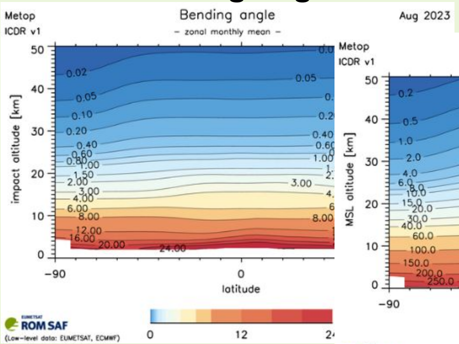
- Metop
- Processed 7+ years, Jan-17 to Jun-24
- First release in May 2019
- New data added monthly

The combined CDR + ICDR time series currently covers 22 full years, 2002 – 2023.

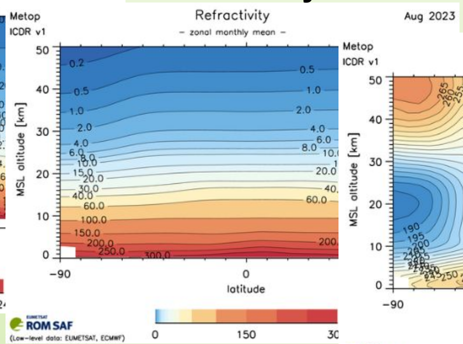
ROM SAF climate data records

– geophysical variables –

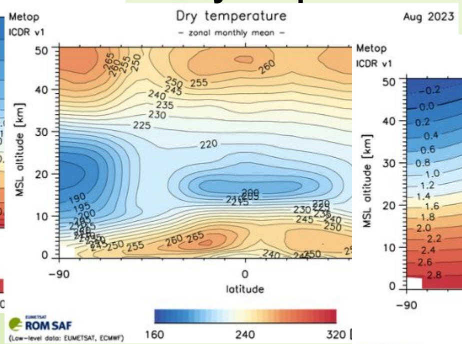
Bending angle



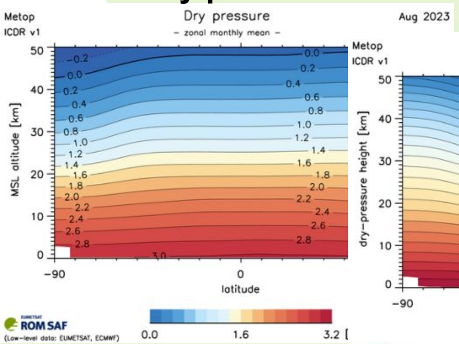
Refractivity



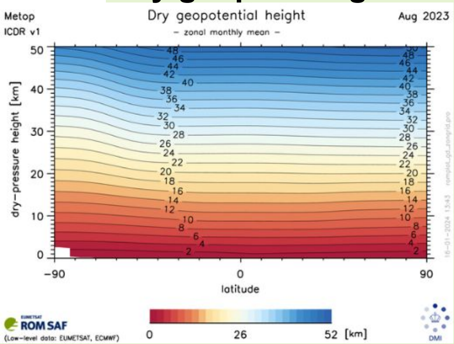
Dry temp



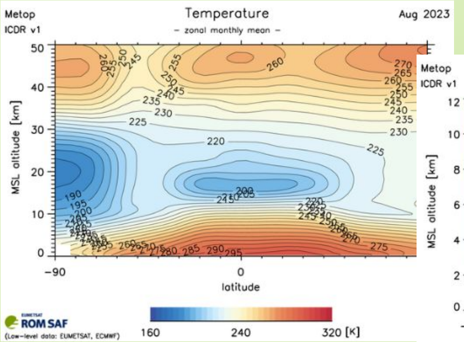
Dry pressure



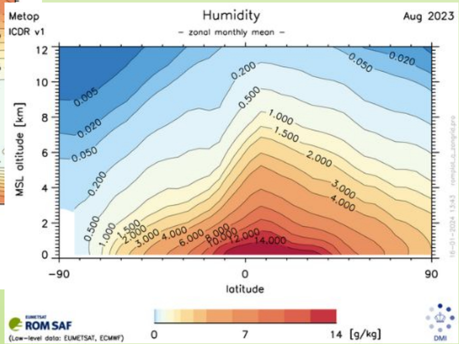
Dry geopot. height

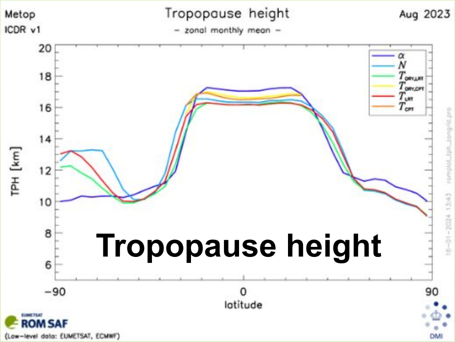


1DVar Temperature



1DVar Humidity





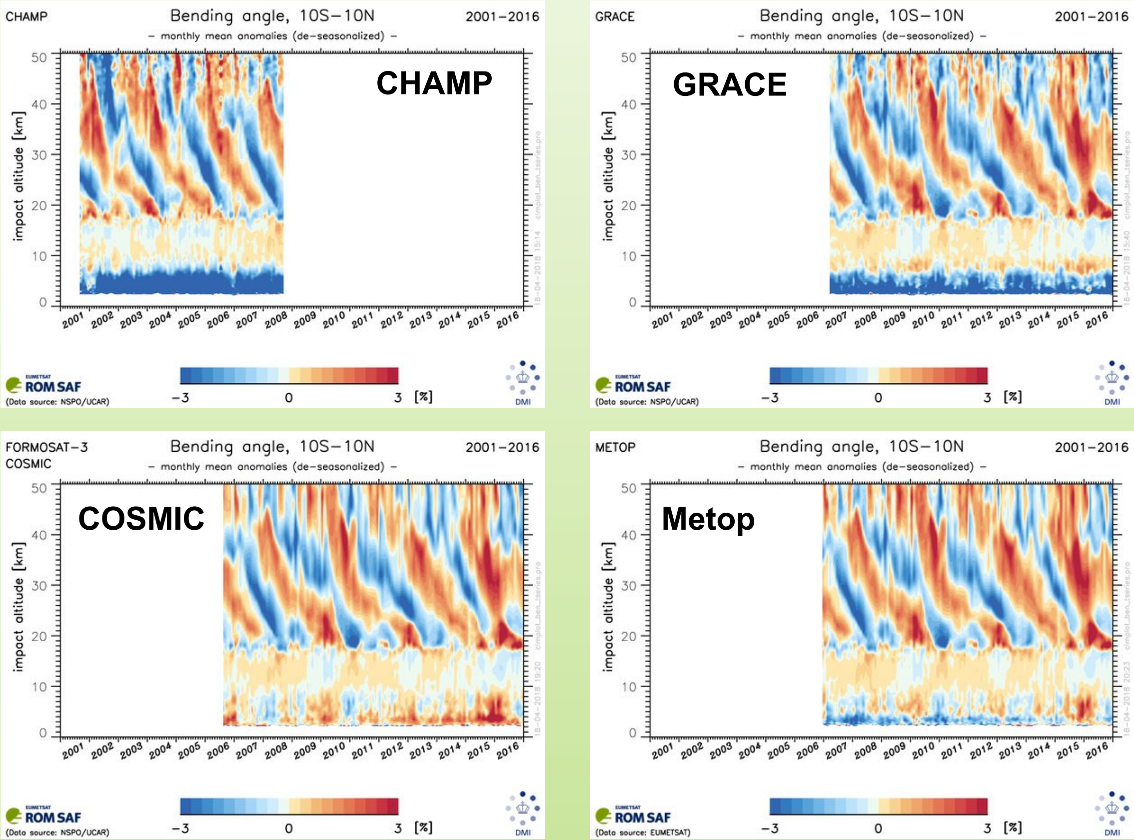
Tropopause height

+ 1DVar pressure profiles

+ 1DVar surface pressure

ROM SAF climate data records

– four RO missions –



Bending-angle anomalies computed for 4 different sets of data, using a common reference for the anomalies.

Fundamentally very similar. There are dif-ferences related to low-altitude biases below about 5-8 km, and the impacts of low data numbers are clearly visible in CHAMP and GRACE data. Closer inspection also reveal more subtle differences.

However, there is an excellent mission con-sistency within certain limits, and data from different missions can be combined into longer time series for use in climate studies.

ROM SAF climate data records

– four RO missions, global layer averages –

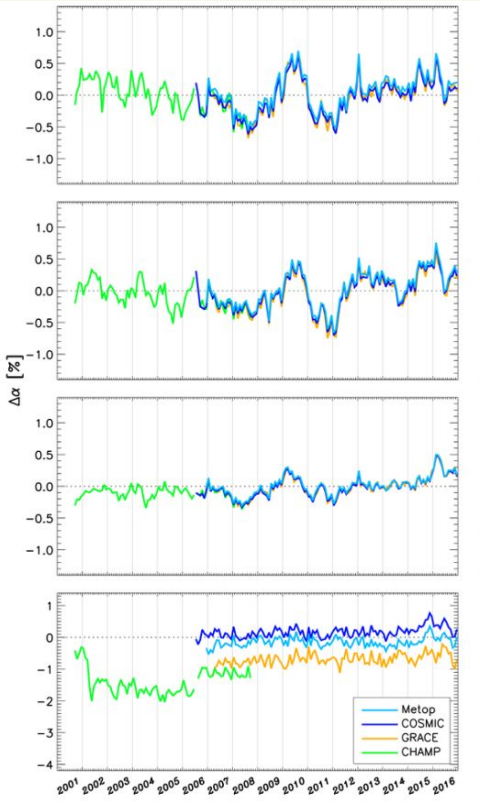
35-40 km

30-35 km

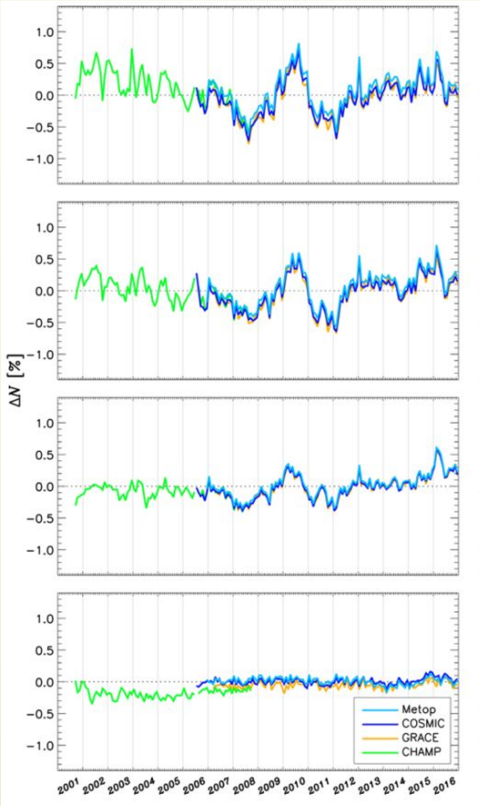
8-30 km

4-8 km

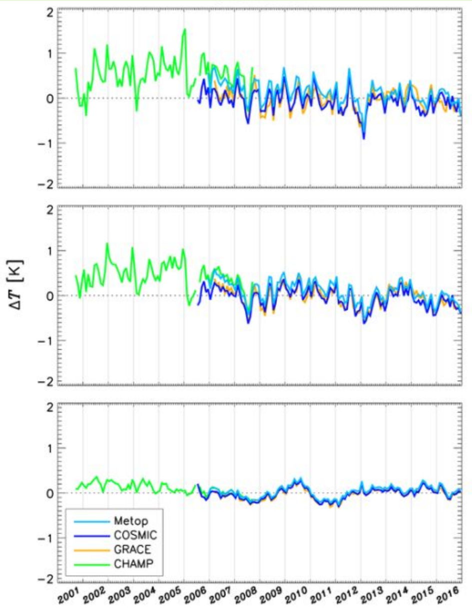
Bending angle



Refractivity



Dry temperature



Excellent mission consistency 8-30 km.

Consistency for bending angle and refractivity up to 40 km.

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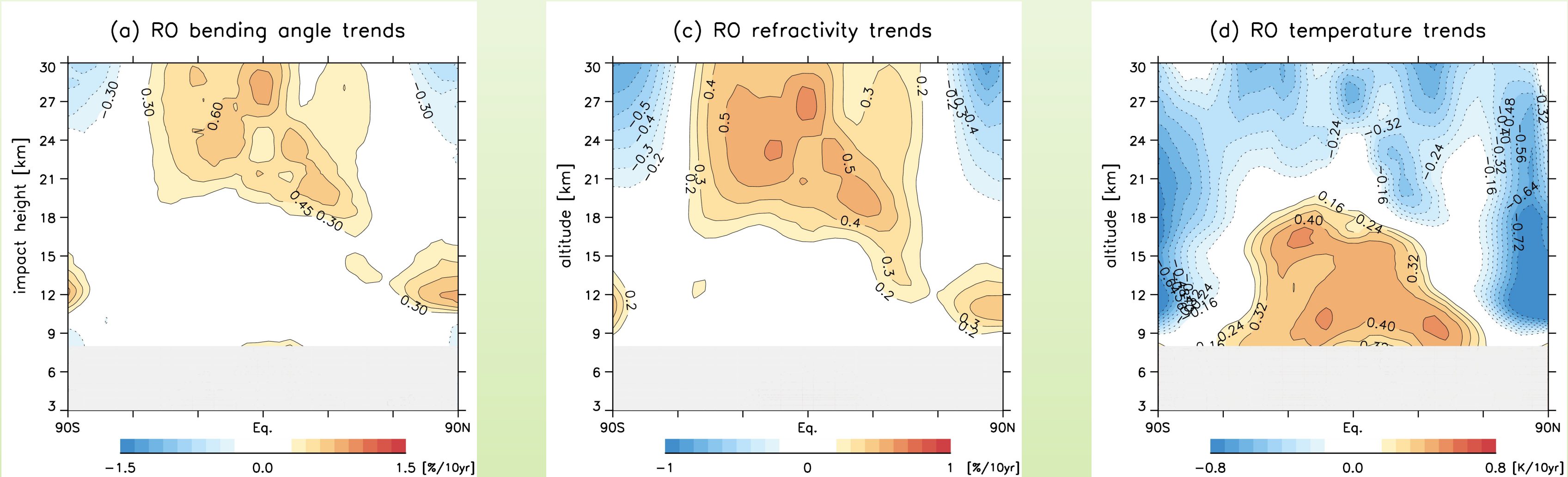
Use of ROM SAF climate data records

Examples of applications of ROM SAF climate data records are:

- *climate reanalysis*
- *atmospheric monitoring, climate time series*
- *evaluation of temperature time series from MW- and IR sounders*
- *evaluation of humidity time series from MW sounders*
- *equatorial stratosphere: QBO, zonal winds*
- ***atmospheric trends, contributions to the IPCC AR6 WG1 report***
- ***climate model testing***
- *migrating diurnal tides in the stratosphere*
- ***polar stratosphere: SSW events, conditions associated with ozone depletion***

Bending angle, refractivity, temperature trends

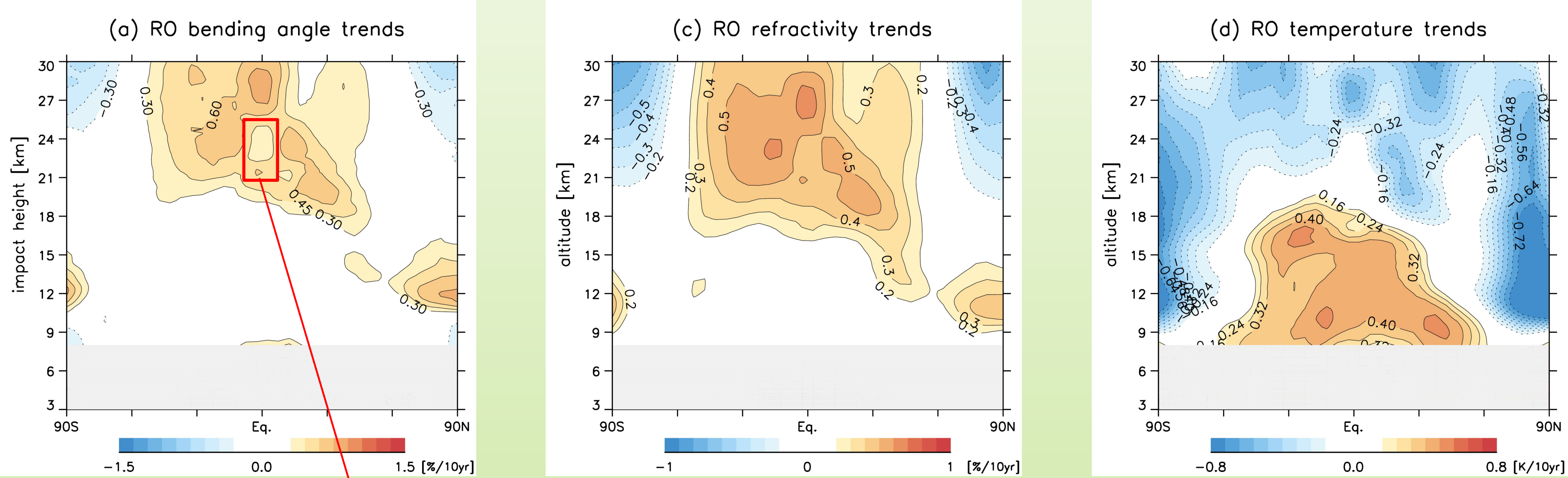


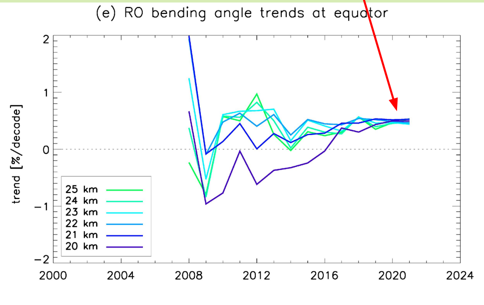
Decadal trends 2002-2020 in bending angle, refractivity, and temperature.

Temperature trends show a general stratospheric cooling and tropospheric warming, and a relatively sharp vertical change in trends near the tropopause.

The low- and mid-latitude RO trends are somewhat asymmetric in the UTLS region. Climate models do not show a systematic asymmetry similar to this.

Bending angle, refractivity, temperature trends





Observed trends have converged with 20 years of data. This length is enough to overcome the impacts of the natural variability on the trends in the low- and mid-latitude stratosphere.

In 2008, Ringer and Healy suggested, based on HadGEM1 climate model data, that trends in the tropical stratosphere bending angles would be clearly detected from around 16-20 years of data.

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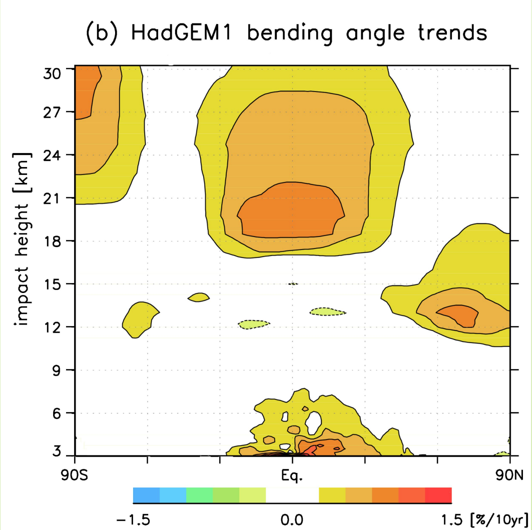
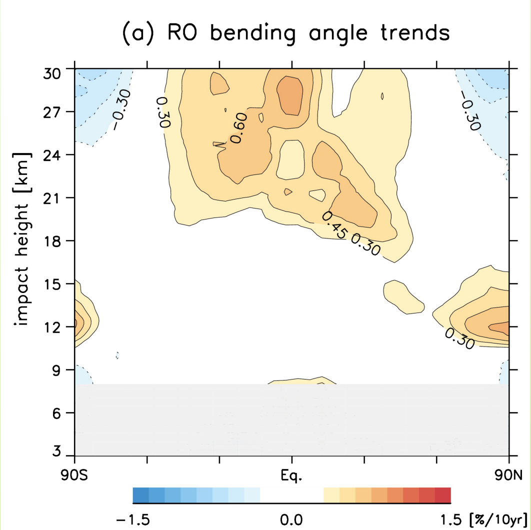
Bending angle trends

– comparison with climate models –



From Ringer and Healy (2008)



From Gleisner et al. (2022)

The observed trends at low- and mid-latitudes are structurally very similar to those predicted in the HadGEM1 climate model scenarios, with the observed trends being slightly smaller.

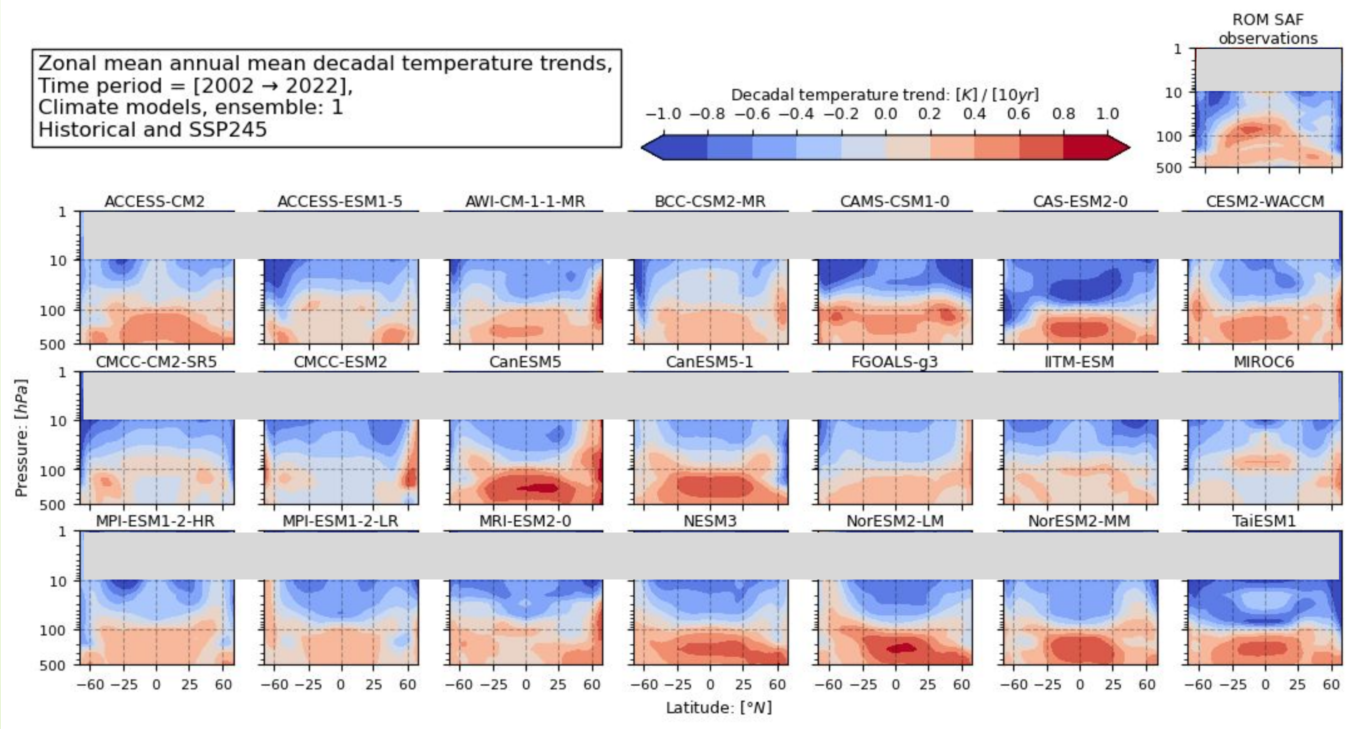
Observations and model differ near the poles, consistent with the higher varia-bility at high latitudes.

Bending angle changes from early 2000s to early 2020s. HadGEM1 climate model scenario integrations made in 2006.

Observed bending angle trends based on ROM SAF climate data records 2002–2020.

Temperature trends

– comparison with climate models –

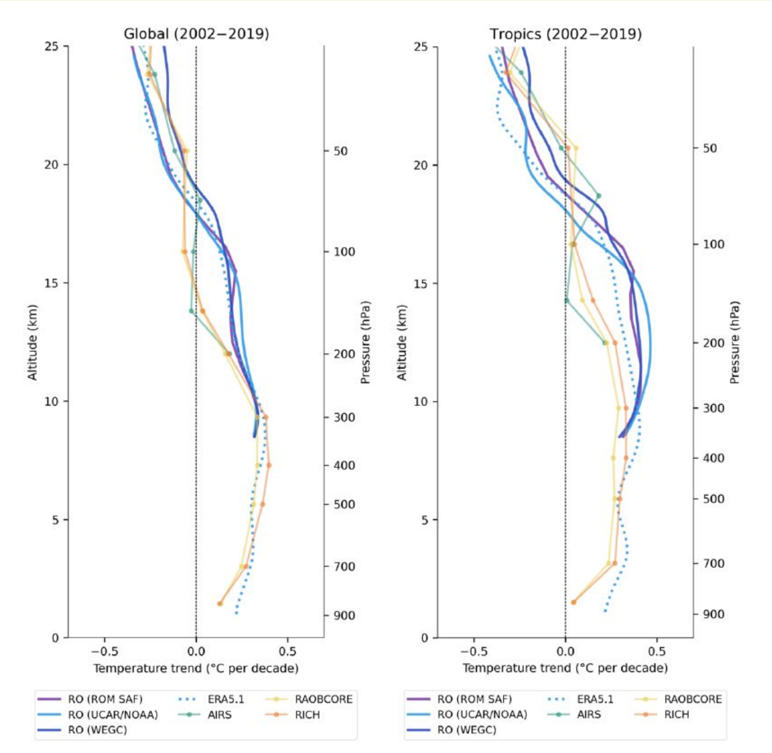


Temperature trends 2002-2022 for ROM SAF CDR+ICDR v1 and for 18 CMIP6 climate models: historical + scenario SSP2-4.5

The inter-model variability is caused both by actual model differences and the random differences between different realizations.

Contribution to the IPCC AR6 report

– observed temperature trends in the troposphere and UTLS –



From ROM SAF VS40 report (Florian Ladstädter)

Decadal temperature trends as function of height:

- RO data: ROM SAF, WEGC, UCAR/NOAA
- Radiosonde data: RAOBCORE, RICH
- IR-based data: AIRS
- Reanalysis: ERA5

There are *"faster temperature trends in the tropics in the upper troposphere than … near the surface."* Hence, we observe the tropospheric amplification expected from theory.

Another conclusion is that there is *"some spread be-tween different data types … near 15 km."* However,
it is also noted that *"these differences are reduced to near zero if a subset of radiosonde data … is used."* These differences are discussed in Steiner et al. (2020).

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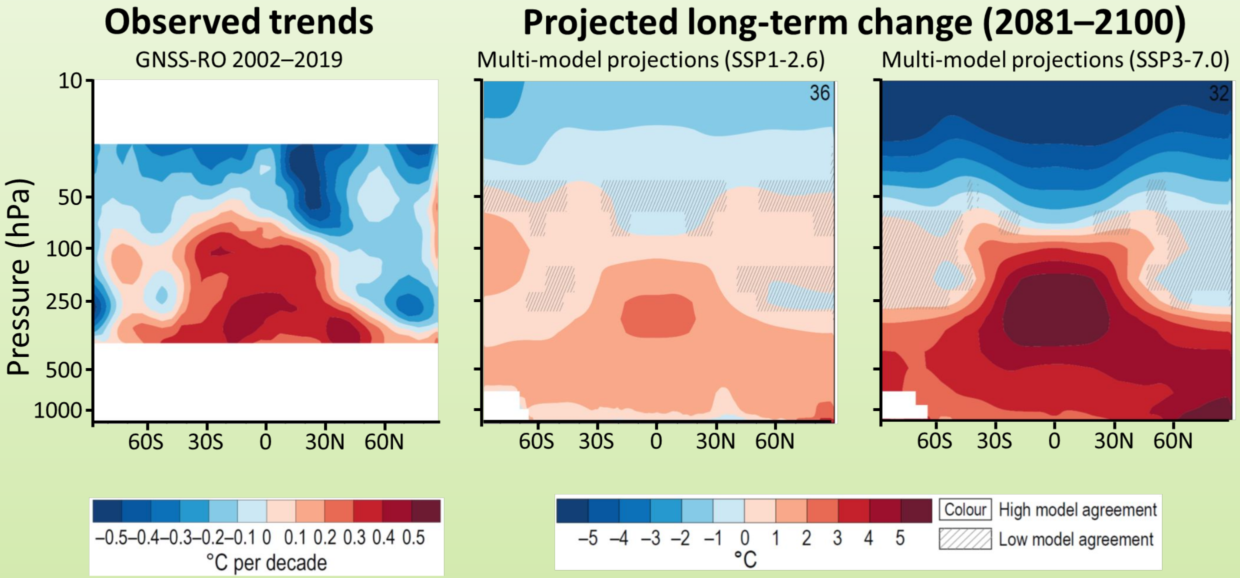
Contribution to the IPCC AR6 report

– observed and projected temperature trends –

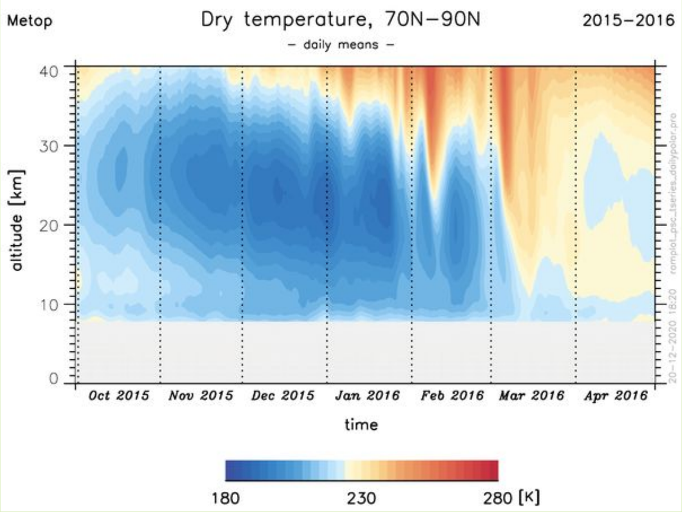


From IPCC AR6 WG 1, Technical Summary

Observed decadal trends in ROM SAF RO data (*left*) compared to projected temperature changes in CMIP6 models (*right*) over a roughly 85 year time period.

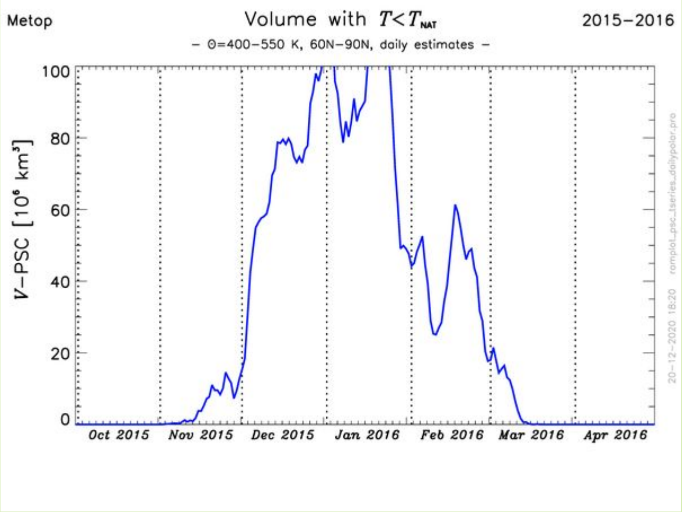
Two emissions scenarios: SSP1-2.6 (middle-low) and SSP3-7.0 (middle-high).

Monitoring Arctic stratosphere
– SSWs, PSCs, and ozone depletion –



Temperatures in the Arctic stratosphere were extremely low during the 2015-2016 winter, before breakup of the polar vortex.

Polar Stratospheric Clouds (PSCs) are associated with very low temperatures, below about -85 C at altitudes between 15 and 30 km.



Volume of air in the Arctic stratosphere with temperatures T lower than T_{NAT}. Associated with PSC formation and ozone depletion. Sun-light is also an important factor for the ozone chemistry.

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ROM SAF CDR development plans

Potential for improvements

- Data from more RO missions are available, to be included in future multi-mission CDRs.
- Reducing biases in bending angle, refractivity, and temperature in the middle/upper stratosphere
- Improving the stability, reducing bias shifts, in the 1D-Var solutions in the troposphere. Improve “climate quality” of humidity records.
- Improved error and uncertainty estimation, consistently implemented along the processing chain from low-level data (Level 0/1) to profiles (Level 2) and gridded data (Level 3).
- Enhancing the gridded RO data toward higher spatial resolution, specific synoptic times, etc.
- Enhancing the usefulness of the RO CDRs for the climate model community by provision of data on the right grids, in the right formats, and together with forward-mapping tools.

ROM SAF CDR development plans

Version 2 (planned release in 2025)

- Reprocessing of CHAMP, GRACE, COSMIC-1, Metop (other missions considered, *TBD*). Start of new Metop ICDR generation.
- Reduced high-altitude biases (kappa correction, improved orbit determination).
- Tropospheric data based on updated 1DVar processing using ERA5 reanalysis as background.
- Monthly mean grids on pressure levels, as an adaption to the climate model community.

Version 3 (tentatively in 2028)

- Additional satellite missions: Sentinel-6, COSMIC-2, Metop-SG, and possibly others. The precise list of missions is yet to be determined.
- New 1DVar humidity retrievals for climate applications, with improved long-term stability.
- Improved error and uncertainty estimation, consistently implemented along the processing chain from low-level data (Level 0/1) to profiles (Level 2) and gridded data (Level 3).
- Extended range of gridded data products, at higher temporal and spatial resolution and for specific synoptic times.

Conclusions

- RO data provide long-term stable remote sensing data with global coverage. 23 years of RO data now available for generation of climate data records.
- High consistency between different RO missions between around 5-8 and 30-35 km. Bending angle consistent up to around 40 km. Lower consistency in the lowest few kilometers. Humidity data records exhibit bias shifts propagated from the *a priori* data (currently, ERA5).
- RO provides important information for monitoring the climate, e.g., the rate of warming in the atmosphere. Complementary to that of other observation types because of the high vertical resolution. Testing climate models using RO is still under-explored.
- RO decadal trends as function of latitude and altitude included in IPCC Assessment Report 6, Working Group I (The physical science basis).
- RO data contributing to a range of applications important for climate: decadal trends, tropopause height variations, stratospheric winds, QBO, polar stratosphere, diurnal tides, etc.
- Firm commitment from the EUMETSAT ROM SAF to make RO based climate data records available. Next reprocessing planned for in 2024 to be released in 2025.
- Looking forward to contribute to IPCC AR7.

END