WCRP
World Climate Research Programme

Wegener Center

UNI GRAZ

WCRP EPESC – LEADER Science Meeting

Evaluating Atmospheric Temperature Trends from LESFMIP Simulations and Observations

Andrea K. Steiner, Matthias Stocker, Wegener Center, University of Graz, Austria
Stephen Po-Chedley, Lawrence Livermore National Laboratory, USA
Aodhan Sweeney, University of Washington, USA
Amanda Maycock, University of Leeds, UK
Florian Ladstädter, Sebastian Scher, Wegener Center, University of Graz, Austria

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matthias.stocker@uni-graz.at

MOTIVATION & BACKGROUND

What are Atmospheric Temperature Trends Shaped by?

- Anthropogenic forcings (e.g., GHGs, aerosols)
- Natural forcings (e.g., volcanic eruptions, solar variability)
- Internal climate variability

Historical **discrepancies between observed and modeled temperature trends**, especially in the **tropical upper troposphere and lower stratosphere** (e.g. Mitchell et al., 2020)

LESFMIP provides a **new opportunity to analyze these discrepancies with a broad temporal and spatial coverage**

LARGE ENSEMBLE SINGLE FORCING MODEL INTER-COMPARISON PROJECT (LESFMIP)

Includes:

- Historical (all-forcing) simulations (1850 to 2014)
- Single-forcing experiments: GHG, aerosols, volcanic, ozone, solar (1850-2020)

Should help to:

- Isolate effects of individual external forcings
- Improve understanding of climate signal drivers

Note: Historical simulations (up to 2014) **extended using SSP2-4.5 scenario data** where available.

Unfortunately splicing of historical and scenario data results in (much) smaller subsample due to availability.

MODEL DATA AND OBSERVATIONAL DATA

Observational data:

- **Satellite-based:** MSU/SSU, GNSS-RO
- **Radiosondes:** RICH and RAOBCORE

LESFMIP data:

- **Historical and single forcing runs from different climate Models** (IPSL-CM6A-LR, CanESM5, CMCC-CM2-SR5, FGOALS-g3, NorESM2-LM, HadGEM3-GC31-LL, GISS-E2-1-G, MIROC6 and more incoming)

Vertical coverage: 1000 hPa to 1 hPa (**19** pressure levels)

Temporal coverage 1979 – 2020: Four time periods; **full time period**, **ozone depletion period** (pre-1998), **ozone recovery period** (post-1998) and **RO-period** (post 2002)

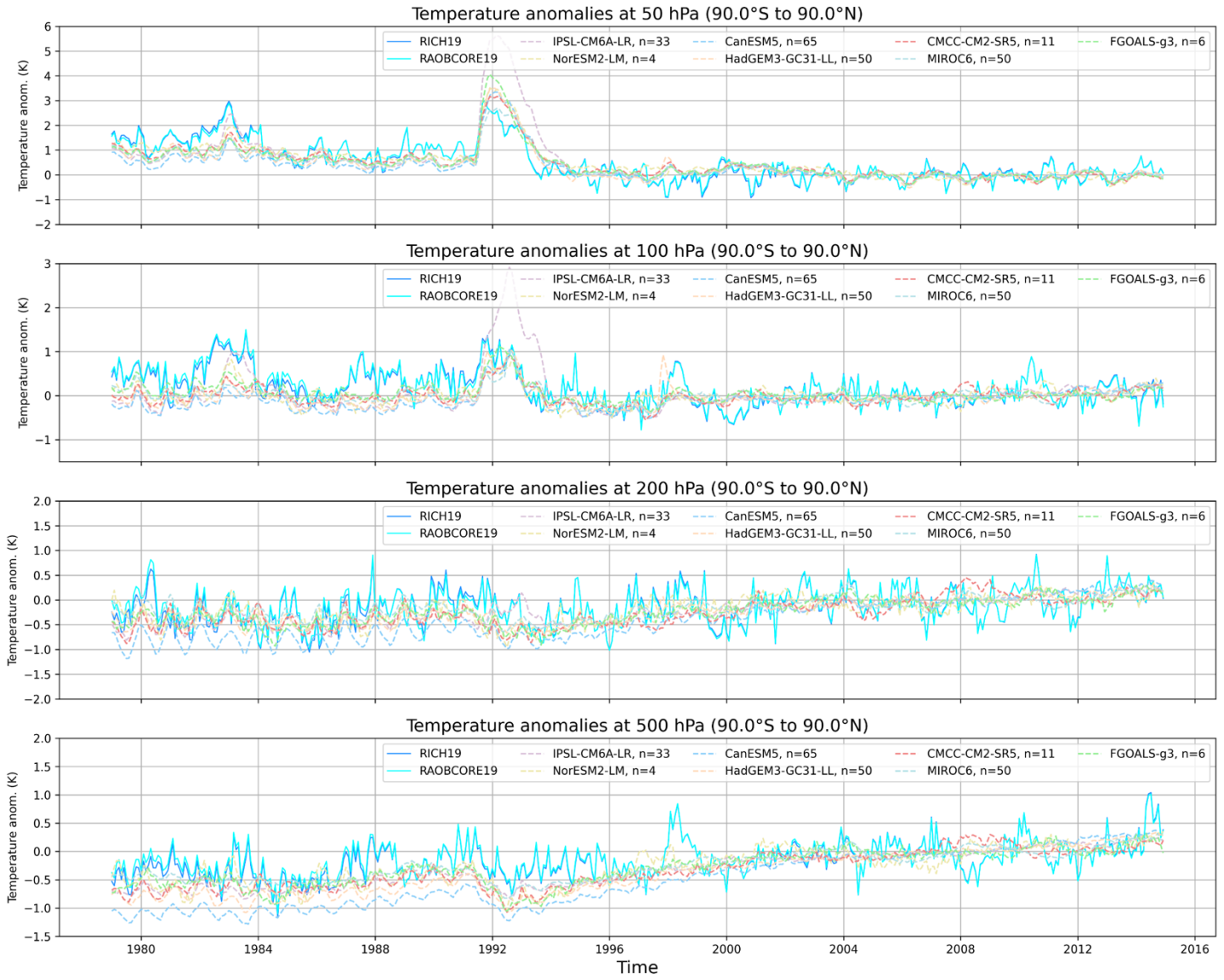
→ Assess the **agreement between simulated and observed** atmospheric temperature **trends**; **model spread vs. internal variability**; identify **contributions of single forcings** to biases

ANOMALIES - HISTORICAL RUNS (ALL FORCINGS)

Leader LESFMIP – Preliminary Results

Global Mean

- **Observations:** Radiosondes RICH v1.9, RAOBCORE v1.9
- Models: **Ensemble means** for IPSL-CM6A-LR, CanESM5, CMCC-CM2-SR5, FGOALS-g3, NorESM2-LM, HadGEM3-GC31-LL, MIROC6
- **2.5°-zonal mean temperature anomalies**
- Anomaly reference period 2000-2014



ANOMALIES - HISTORICAL RUNS (ALL FORCINGS)

Leader LESFMIP – Preliminary Results

Tropics

- **Observations:** Radiosondes RICH v1.9, RAOBCORE v1.9
- Models: **Ensemble means** for IPSL-CM6A-LR, CanESM5, CMCC-CM2-SR5, FGOALS-g3, NorESM2-LM, HadGEM3-GC31-LL, MIROC6
- **2.5°-zonal mean temperature anomalies**
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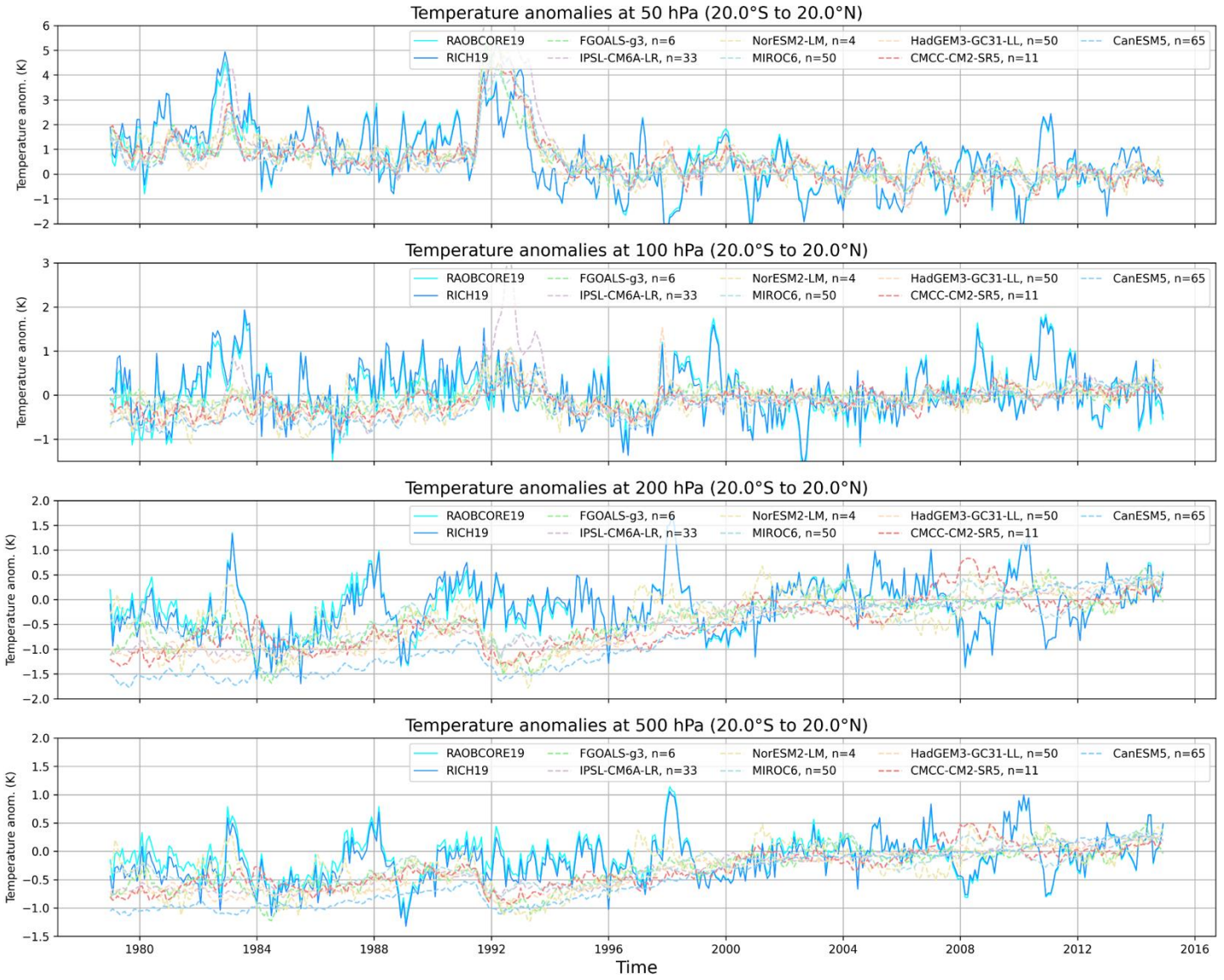
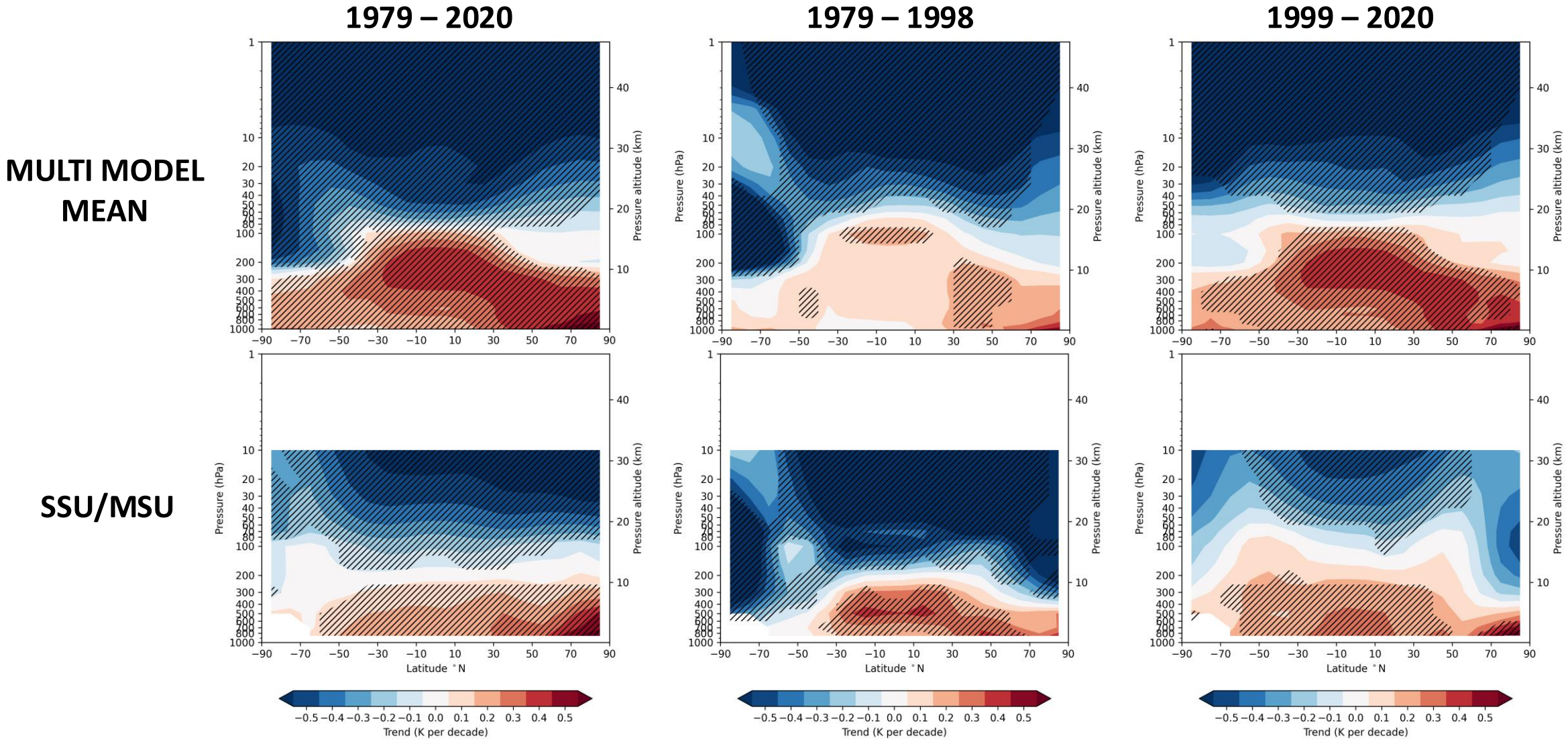


TRENDS - HISTORICAL RUNS (ALL FORCINGS)

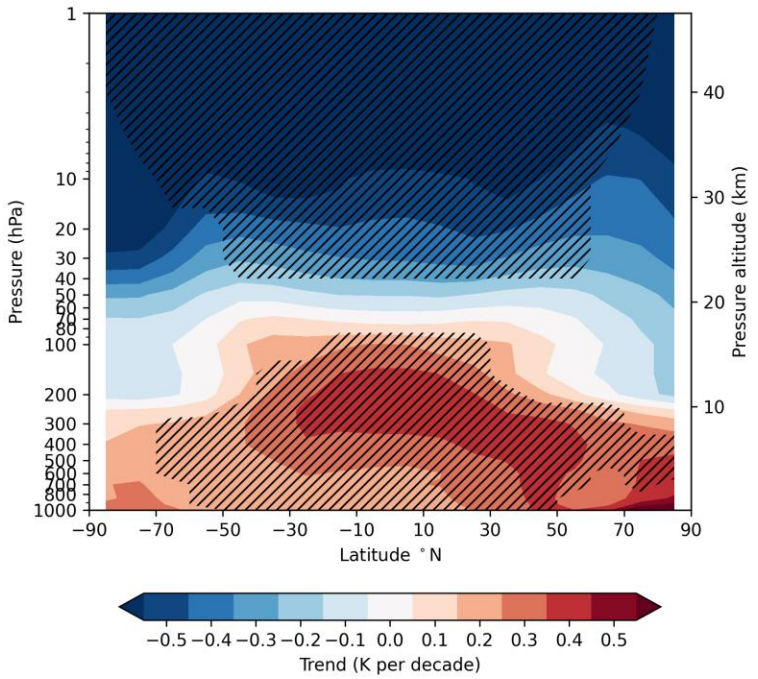
Multi Model Mean trends vs. SSU/MSU trends (RSS4 and SSU-AMSU). Hatching indicates where observed trends are outside the 5–95% range of trends from control simulations.



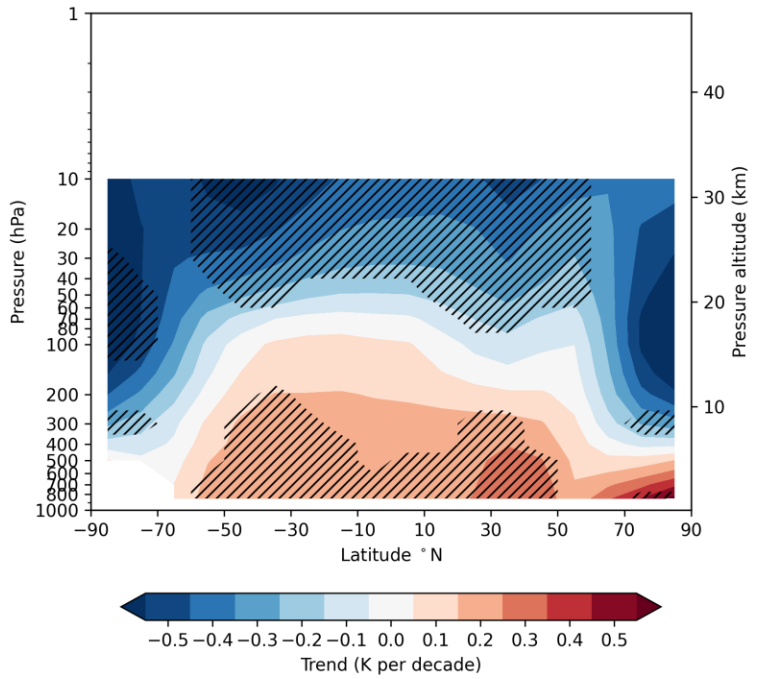
TRENDS - HISTORICAL RUNS (ALL FORCINGS)

GNSS-RO Period 2002 – 2020. Hatching indicates where observed trends are outside the 5–95% range of trends from control simulations.

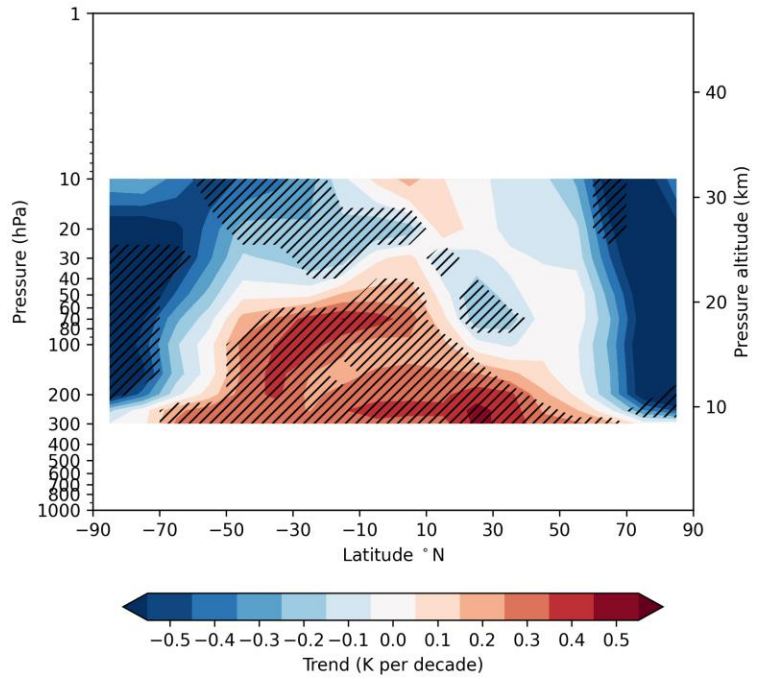
MULTI MODEL MEAN (2002-2020)



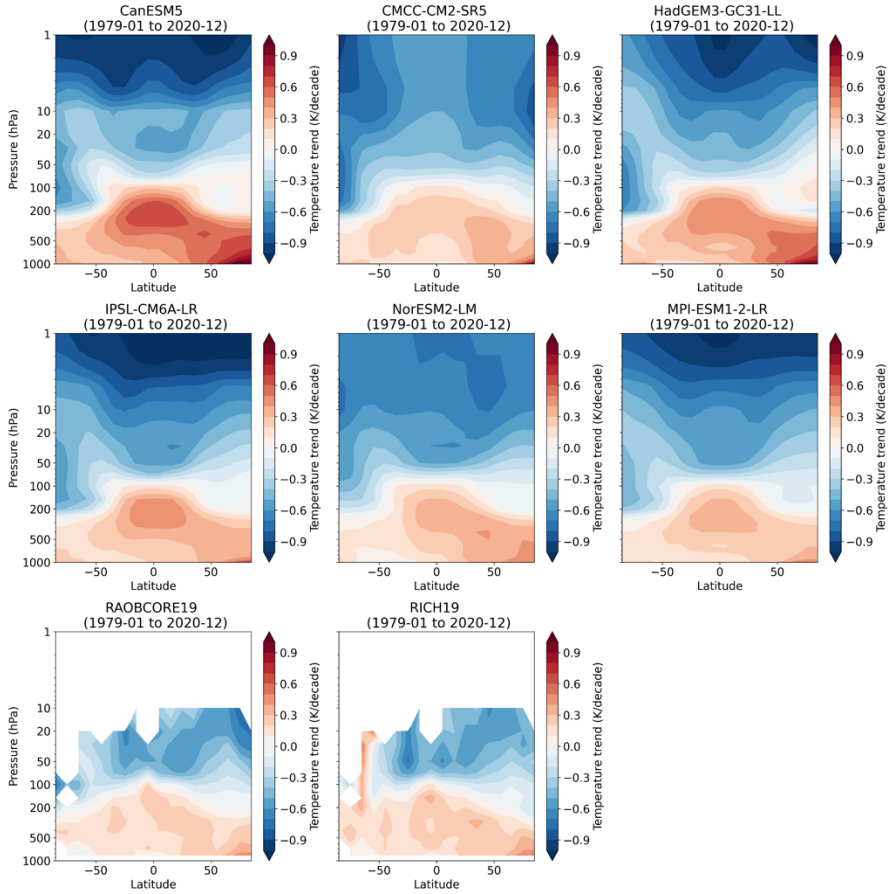
SSU/MSU (2002-2020)



GNSS-RO (2002-2020)

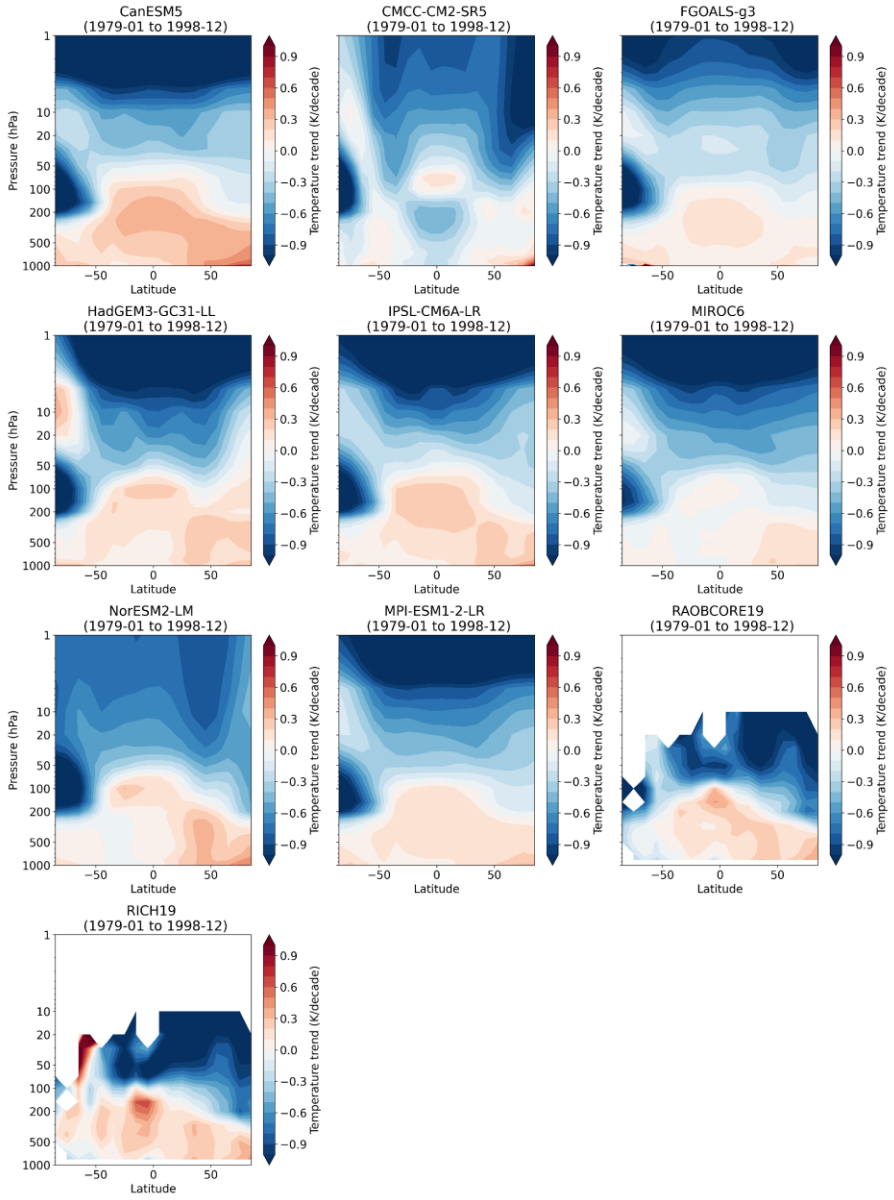


TRENDS FROM INDIVIDUAL MODELS



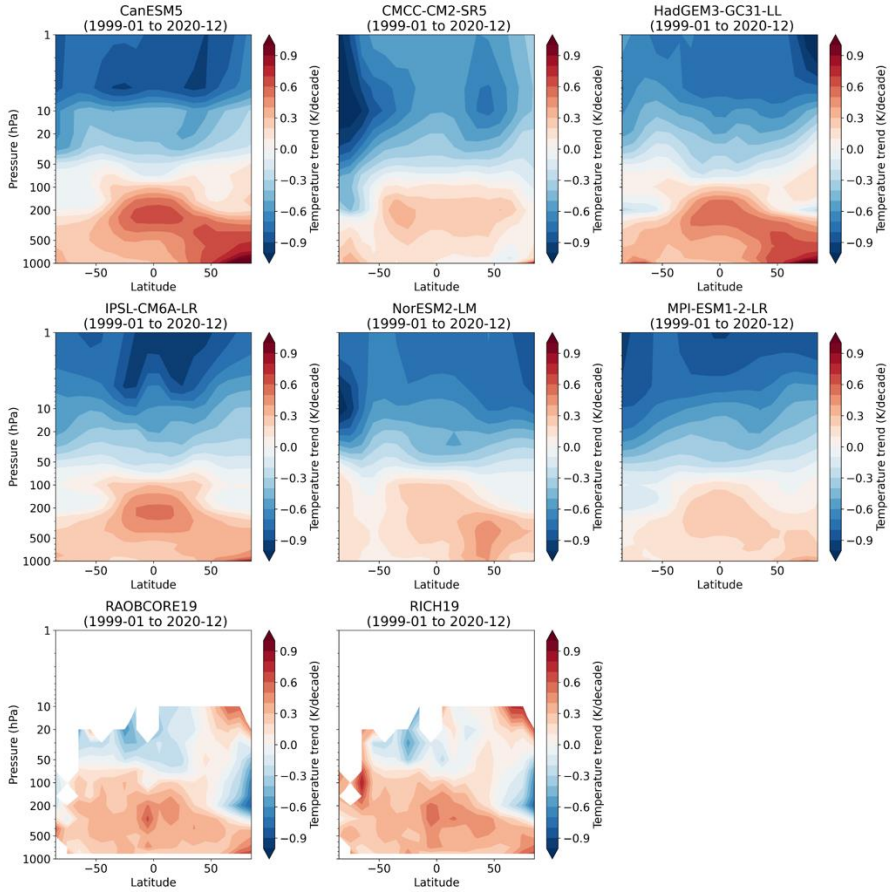
- **Full period (1979 – 2020)**
- Tropical upper tropospheric warming in modes tends to be larger than in observations (at least RS)
- **CanESM5, HadGEM3-GC31-LL and IPSL-CM6A-LR** show largest warming in the tropical troposphere compared to observations

TRENDS FROM INDIVIDUAL MODELS



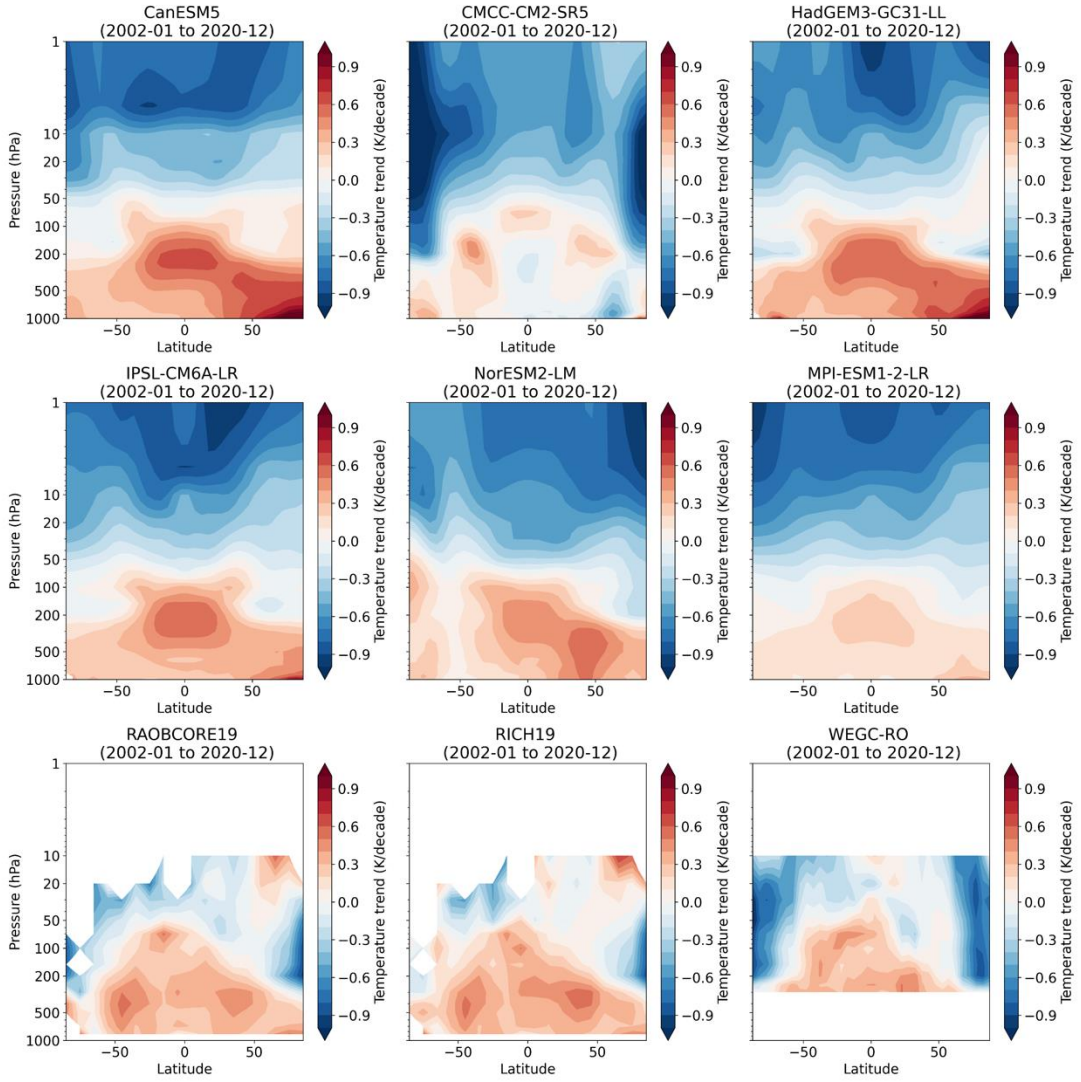
- **Ozone depletion period (1979 – 1998)**
- **CanESM5** shows much larger warming in the tropical upper troposphere compared to observations.

TRENDS FROM INDIVIDUAL MODELS



- **Ozone recovery period (1999 – 2020)**
- **CanESM5, HadGEM3-GC31-LL and IPSL-CM6A-LR** show **larger warming** in the **tropical upper troposphere** compared to observations.

TRENDS FROM INDIVIDUAL MODELS



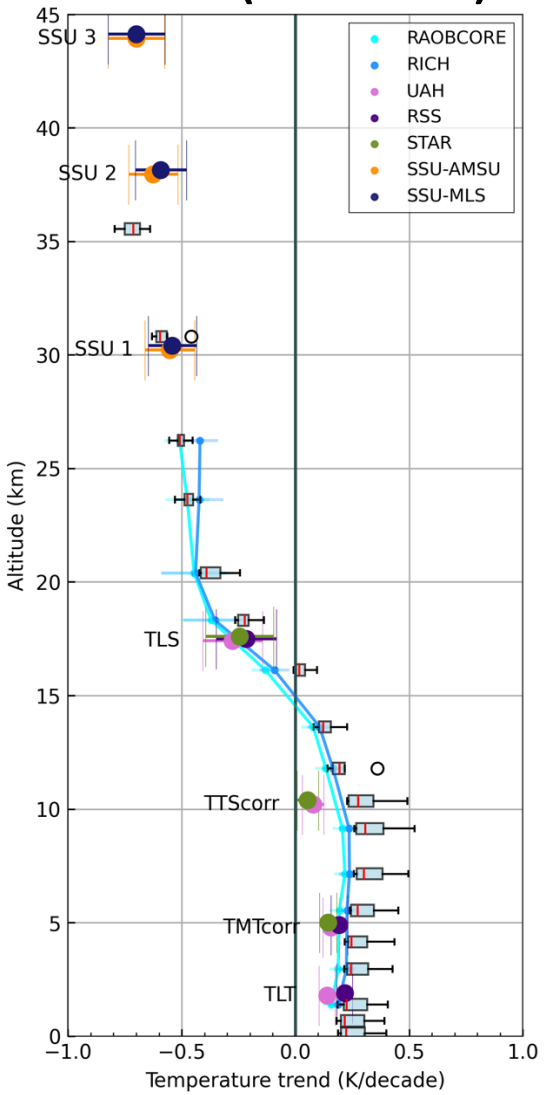
- **GNSS-RO period (2002 – 2020)**
- **CanESM5, HadGEM3-GC31-LL and IPSL-CM6A-LR** show **larger warming** in the **tropical upper troposphere** compared to observations.
- Asymmetric warming in the lowermost stratosphere (AWLS) not represented in models.

TRENDS - HISTORICAL RUNS (ALL FORCINGS)

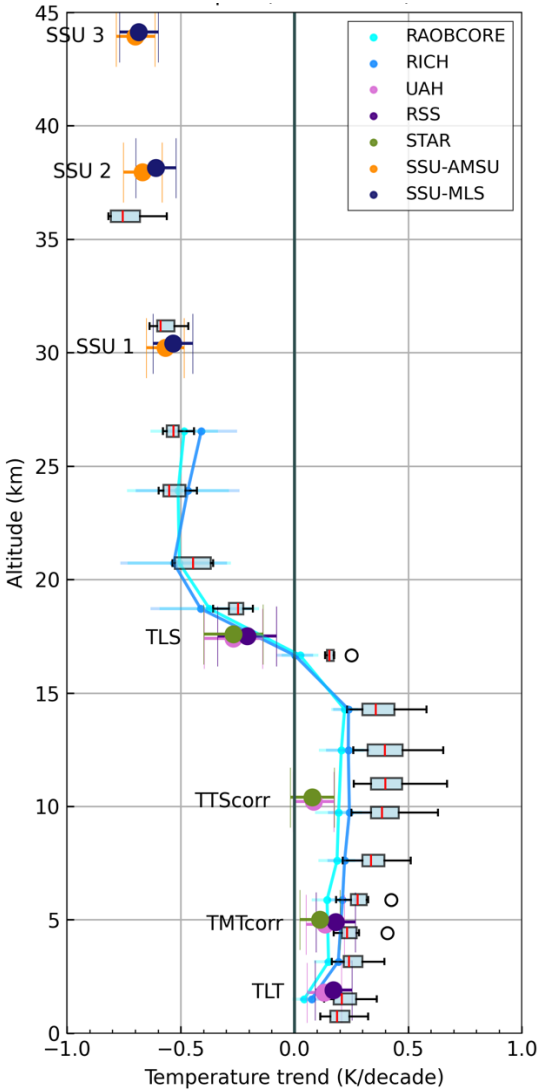
1979 to 2020 – Distribution of Model Trends (Ensemble Mean) vs. Observations

Boxes: Ensemble means for IPSL-CM6A-LR, CanESM5, CMCC-CM2-SR5, FGOALS-g3, NorESM2-LM, HadGEM3-GC31-LL, GISS-E2-1-G

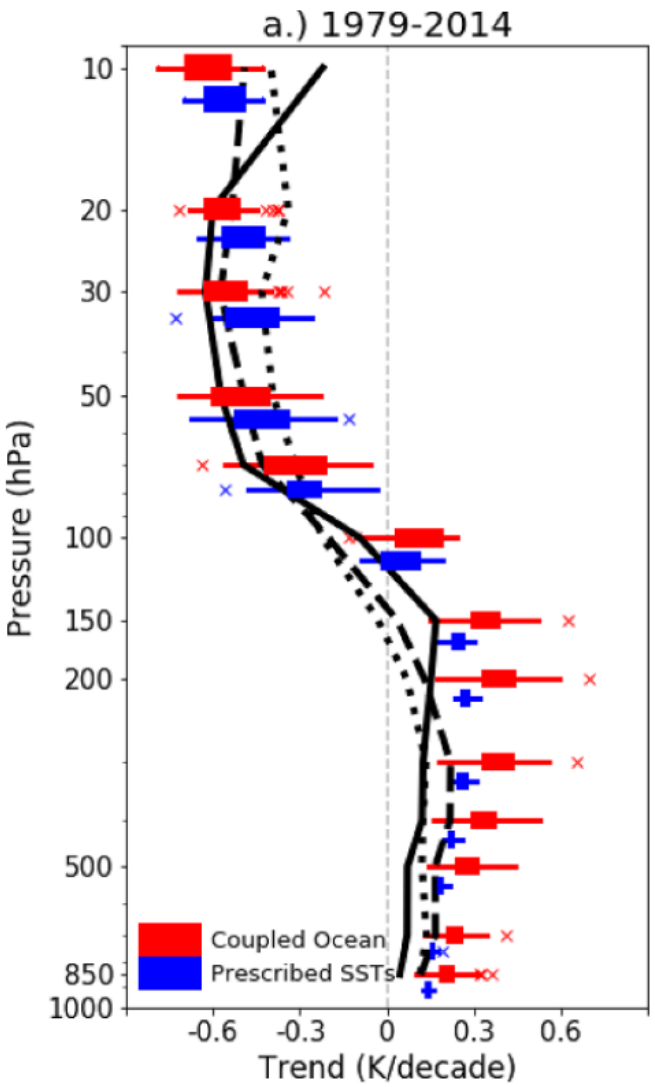
Global (1979-2020)



Tropics (1979-2020)

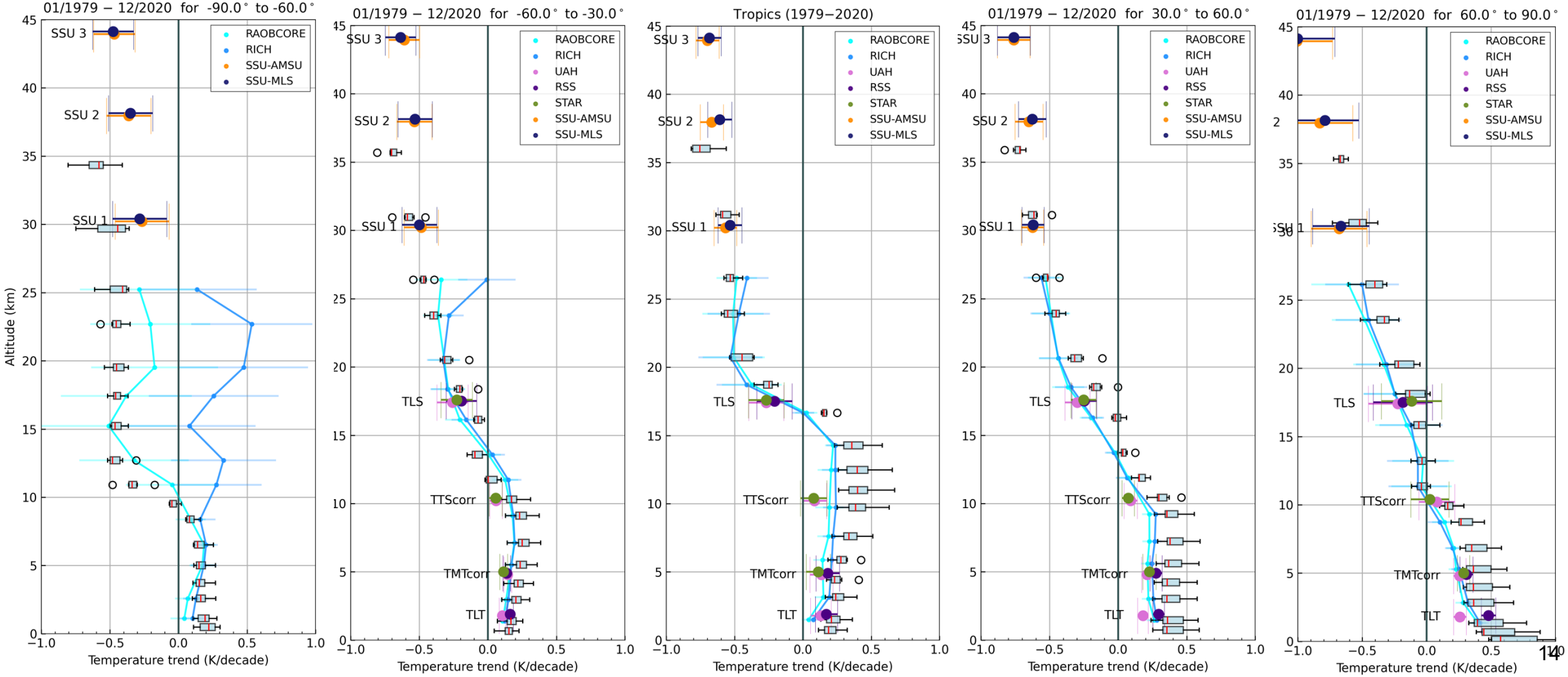


Mitchell et al. (2020)



PROGRESS – ATMOSPHERIC TEMPERATURE CHANGES

1979 to 2020 – Distribution of Model Trends (Ensemble Mean) vs. Observations



PROGRESS – ATMOSPHERIC TEMPERATURE CHANGES

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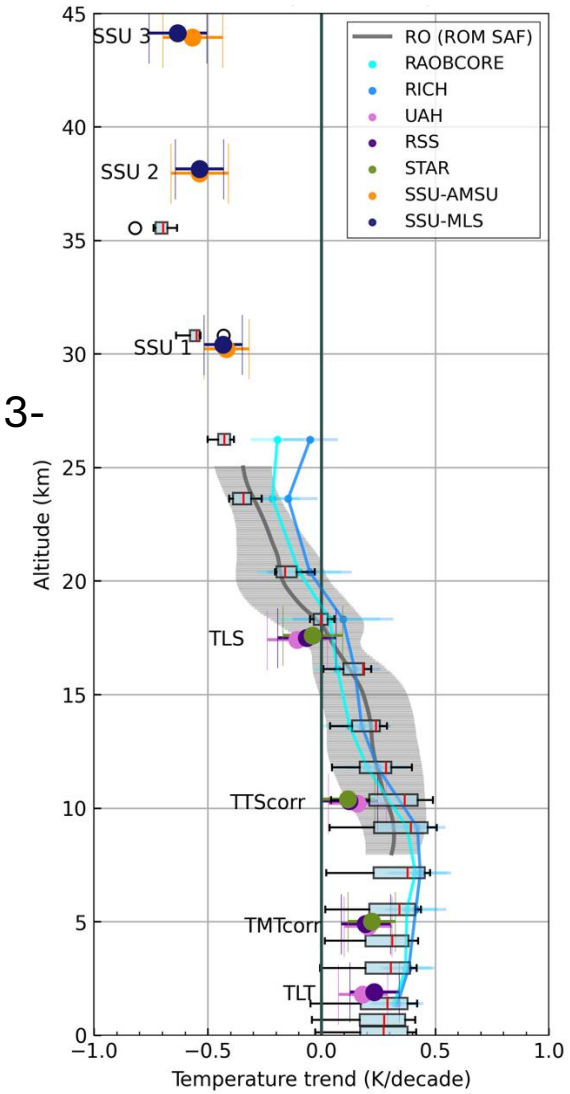
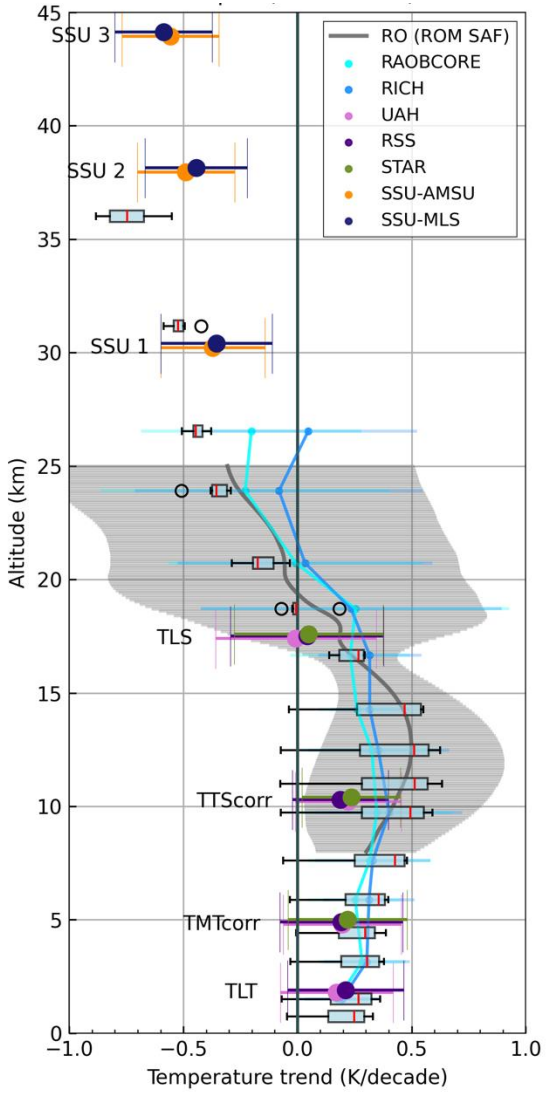
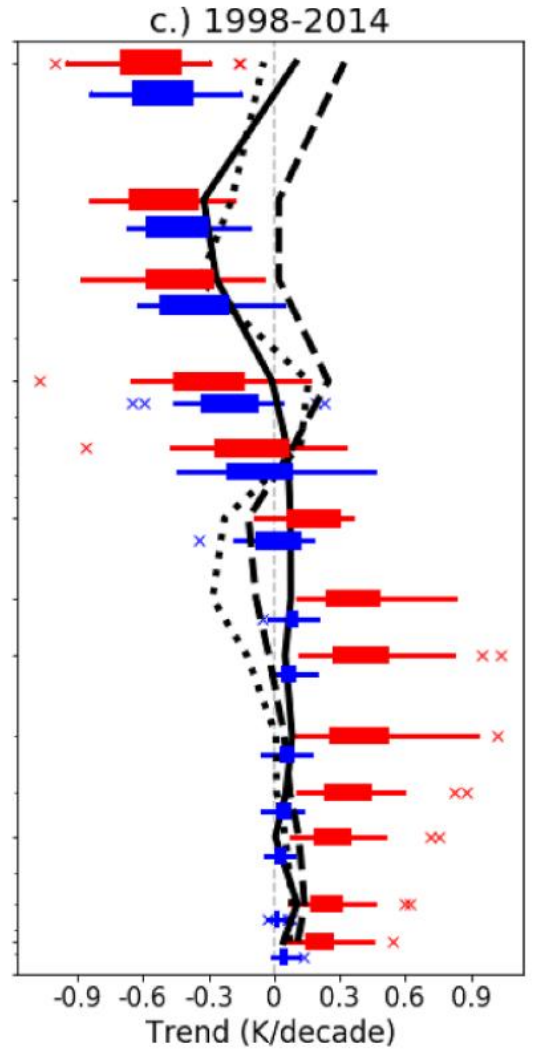


Tropics (2002-2020)



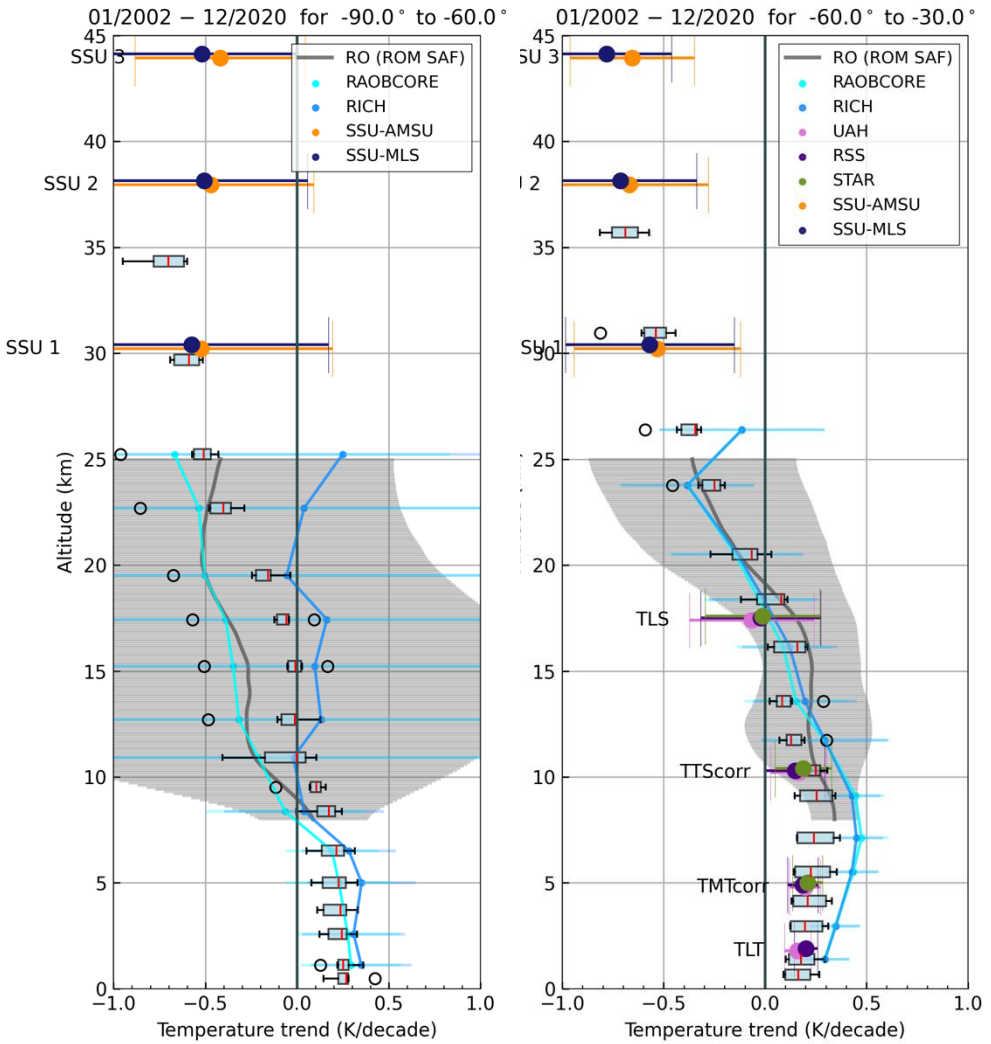
Mitchell et al. (2020)



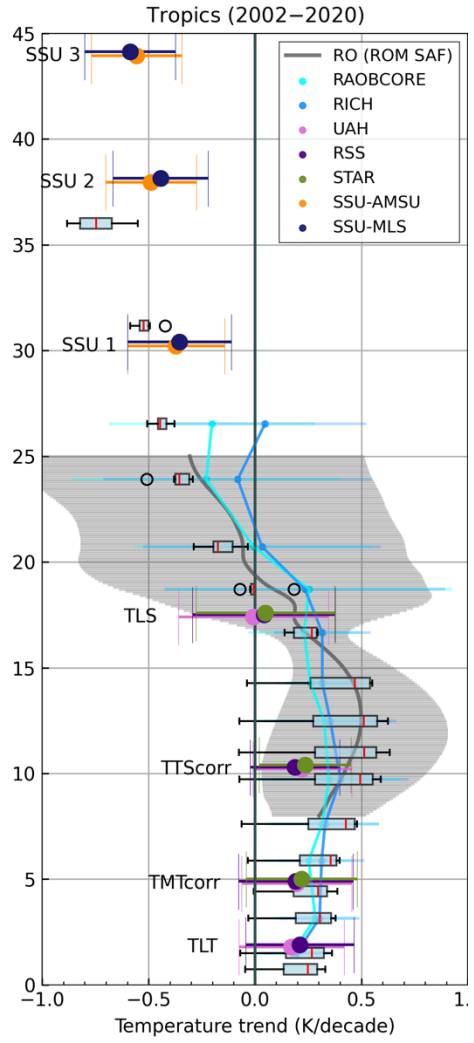
PROGRESS – ATMOSPHERIC TEMPERATURE CHANGES

2002 to 2020 – Distribution of Model Trends (Ensemble Mean) vs. Observations

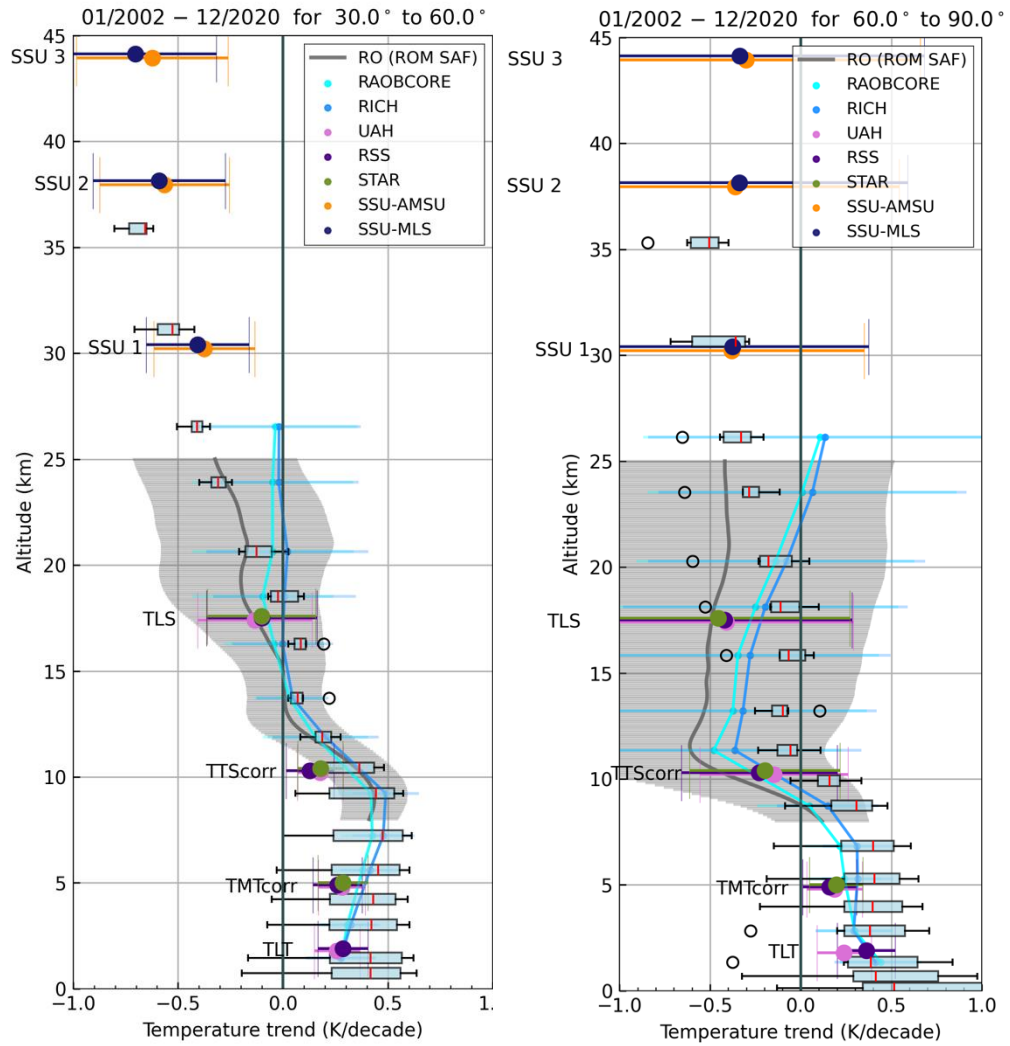
Southern Hemisphere



Tropics



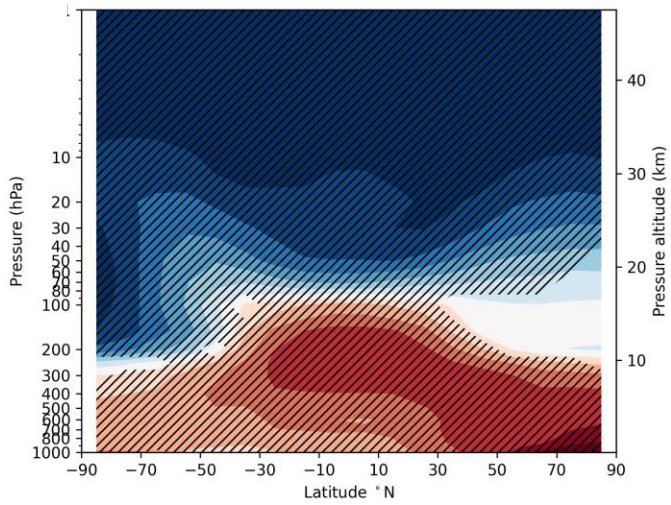
Northern Hemisphere



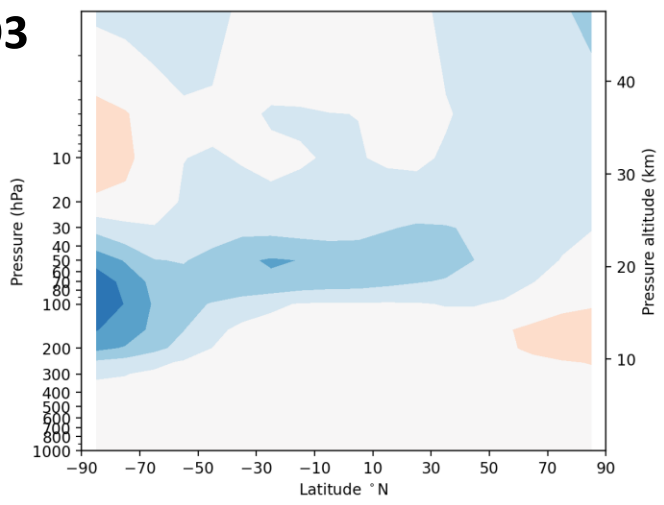
TRENDS – HISTORICAL VS. SINGLE FORCING

Multi Model Mean Trends (Full Period 1979 – 2020)

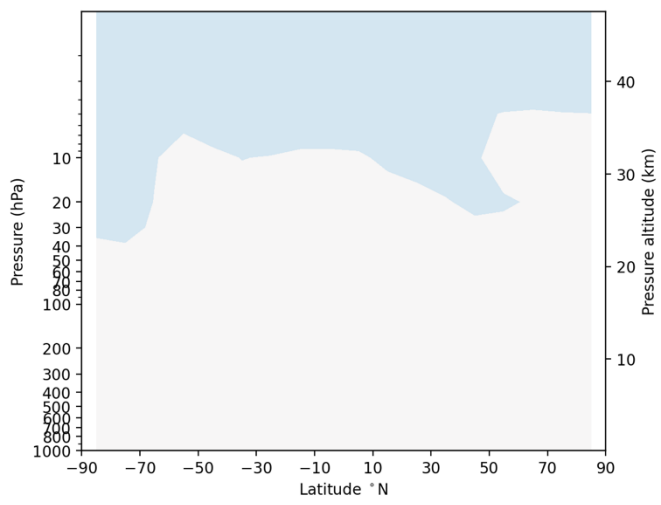
HIST.



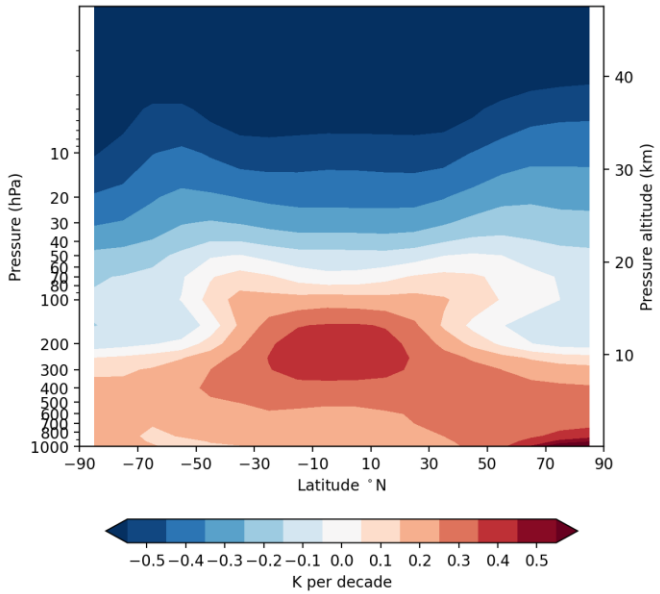
Tot. O3



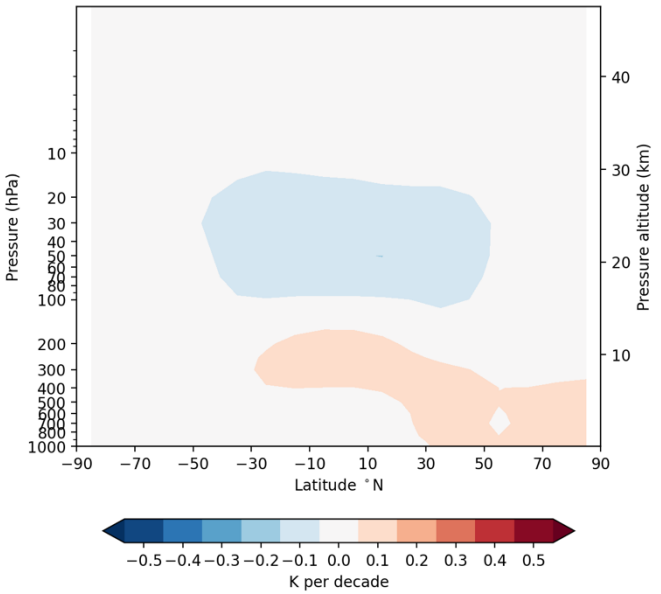
SOL.



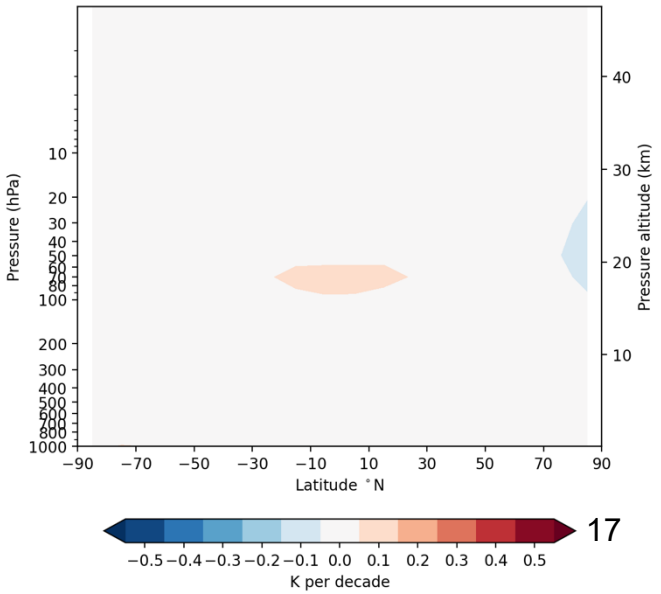
GHG:



Volc.



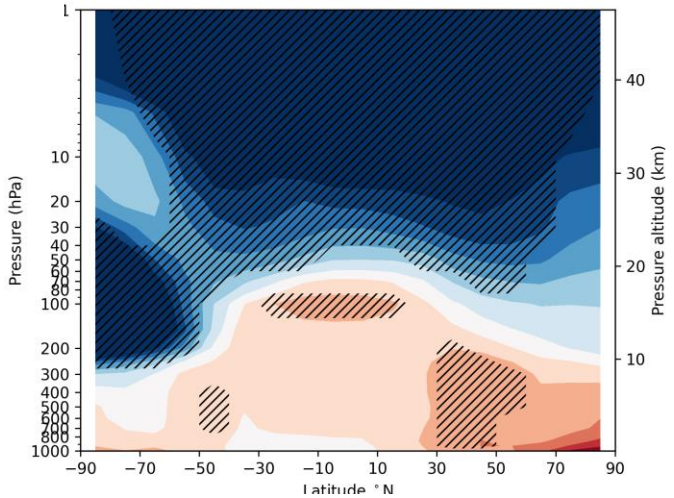
AER.



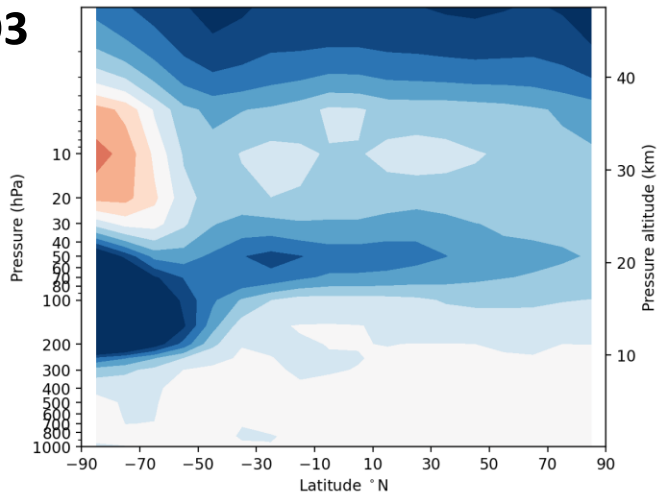
TRENDS – HISTORICAL VS. SINGLE FORCING

Multi Model Mean Trends (Ozone Depletion Period 1979 – 1998)

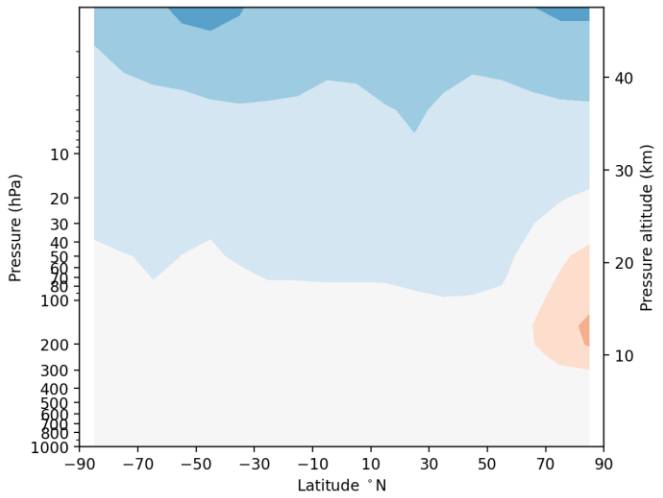
HIST.



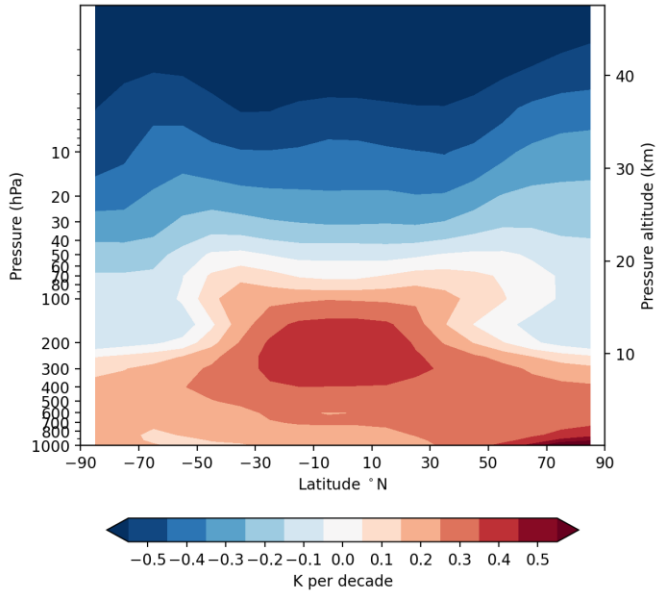
Tot. O3



SOL.



GHG:



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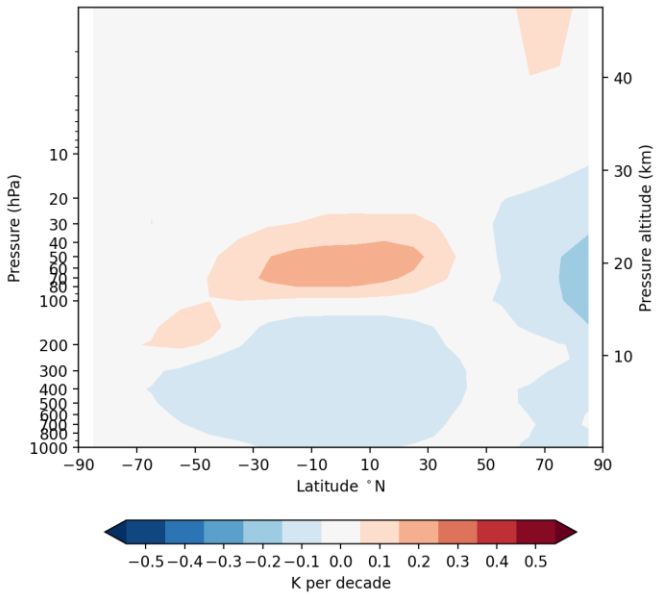

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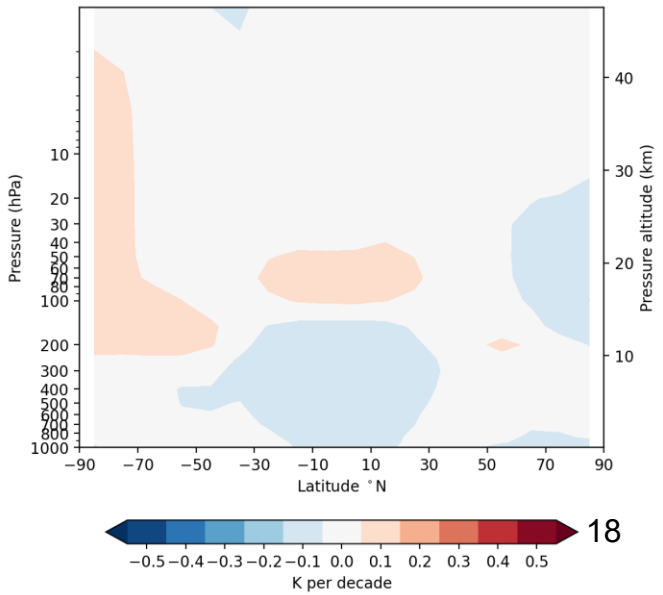
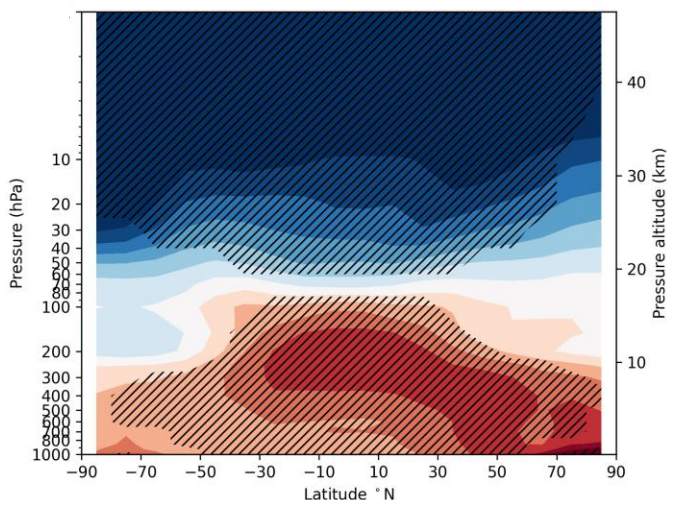


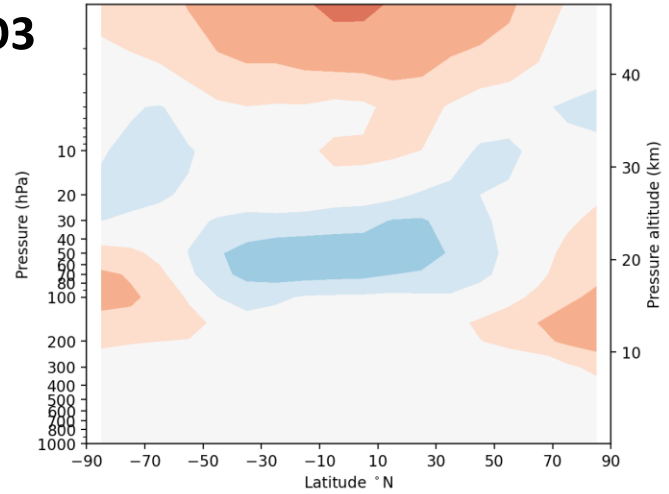
TRENDS – HISTORICAL VS. SINGLE FORCING

Multi Model Mean Trends (Ozone Recovery Period 1999 – 2020)

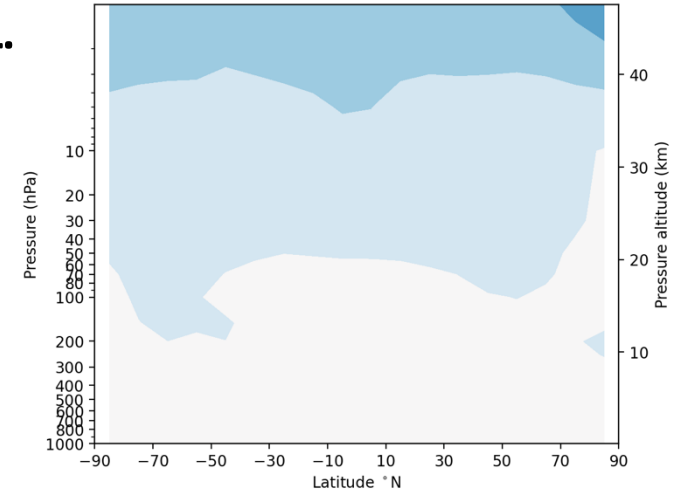
HIST.



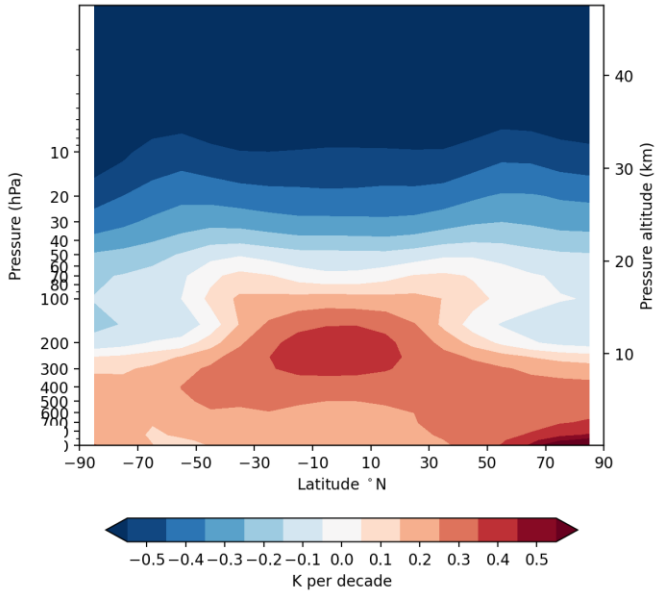
Tot. O3



SOL.



GHG:



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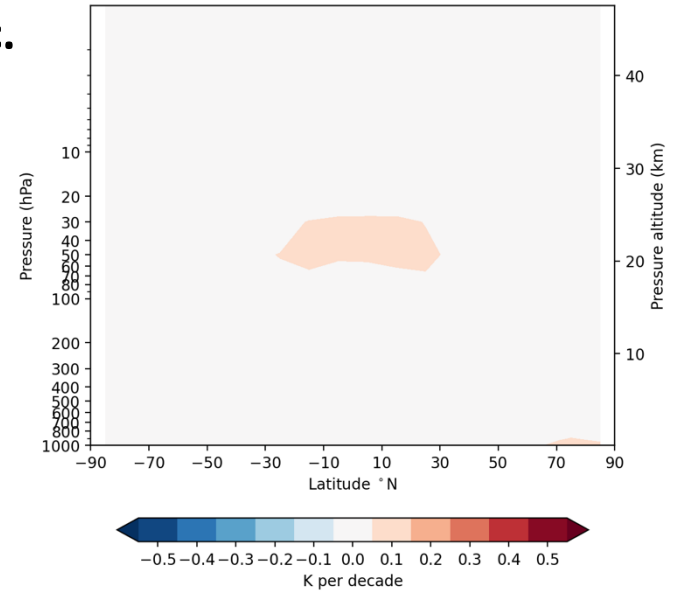

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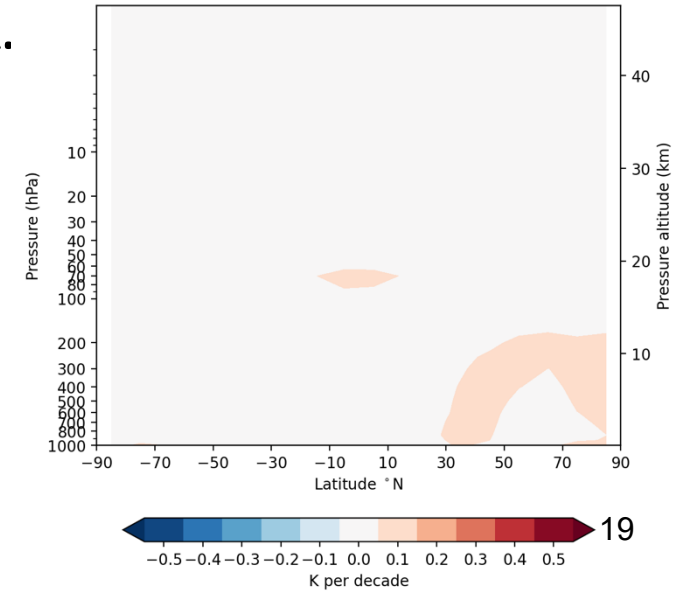
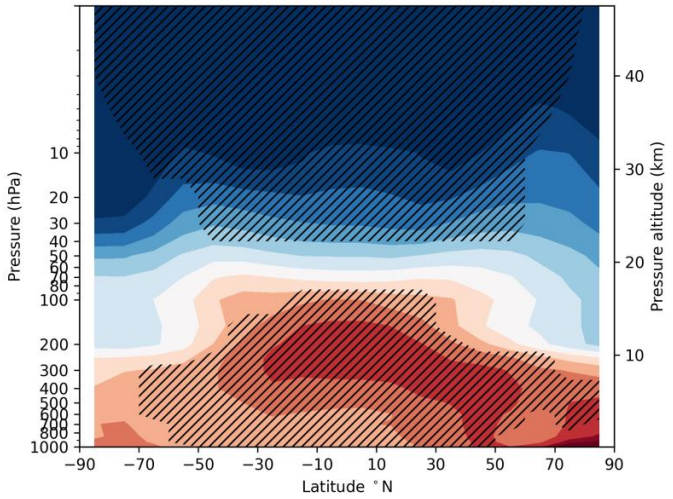


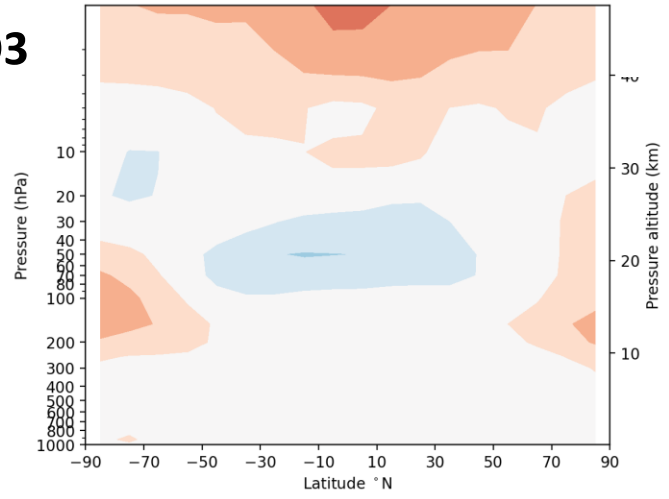
TRENDS – HISTORICAL VS. SINGLE FORCING

Multi Model Mean Trends (GNSS-RO Period 2002 – 2020)

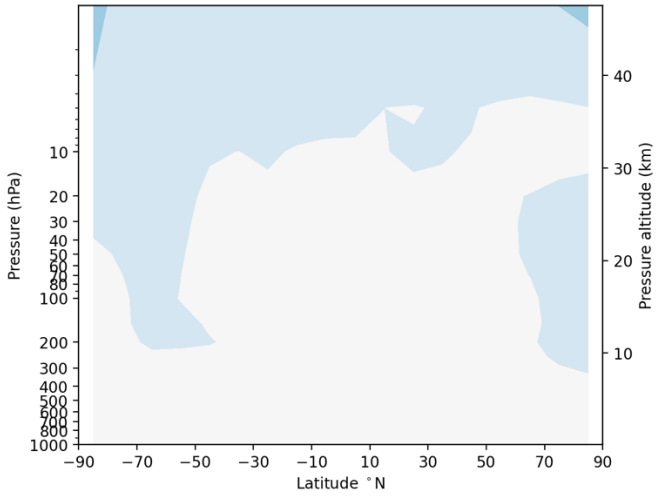
HIST.



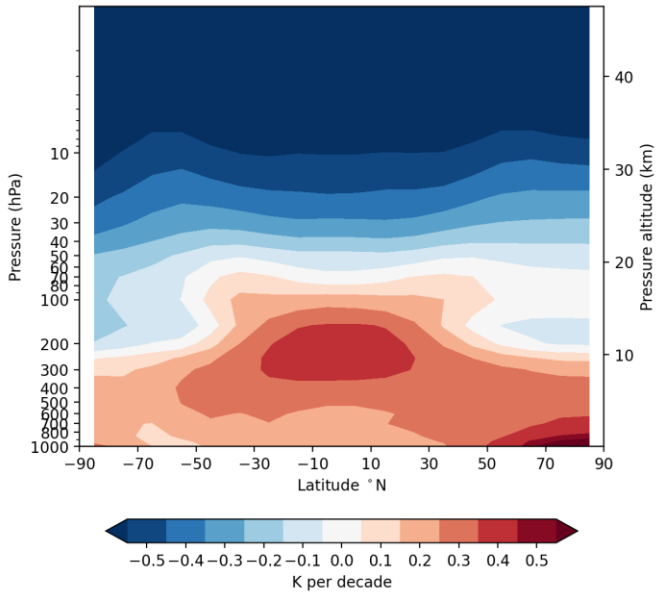
Tot. O3



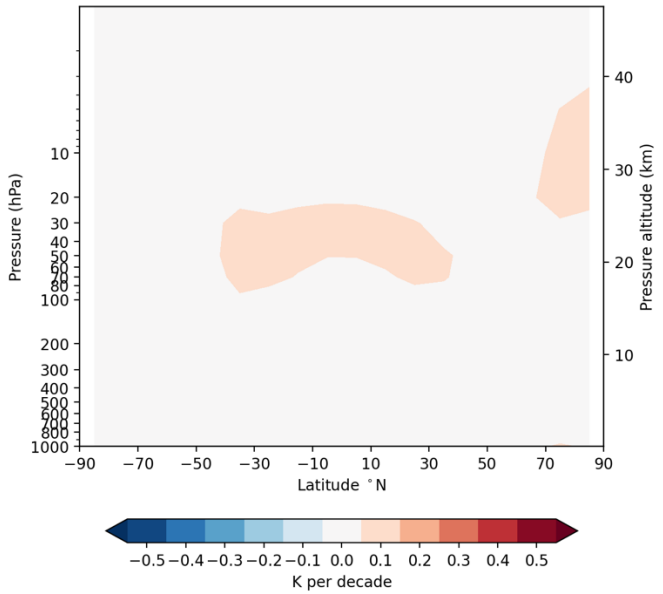
SOL.



GHG:



Volc.



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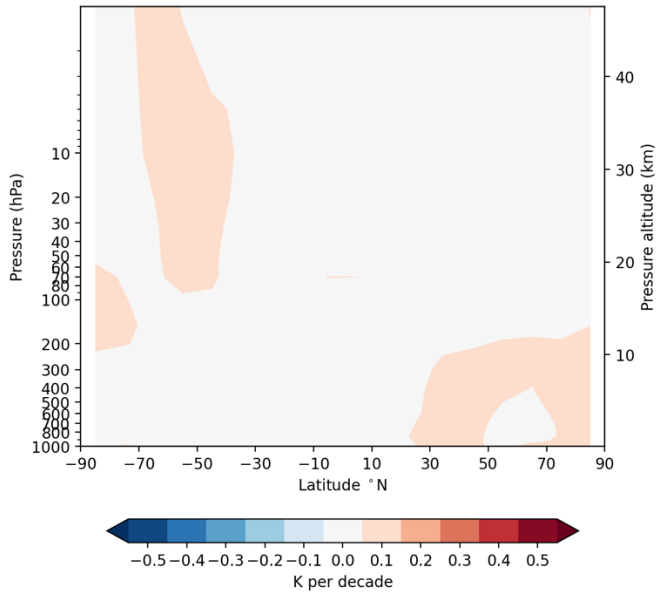

SUMMARY AND CONCLUSIONS (PRELIMINARY)

- Models show **good agreement with observations** for **global mean temperature trend** over the period **1979–2020**, as well as for the RO-period.
- **Discrepancies** are evident in the **tropical upper troposphere** and lower stratosphere and in high latitudes.
- Especially **CanESM5, HadGEM3-GC31-LL and IPSL-CM6A-LR tend to exhibit larger trends** in the tropical upper troposphere compared to observations.
- For the **RO period** (2002–2020), **modeled trends** are **higher than** those from **MSU and radiosonde datasets** in the tropics **but closely align with RO**-derived trends.

LOOKING FORWARD TO YOUR COMMENTS!!!