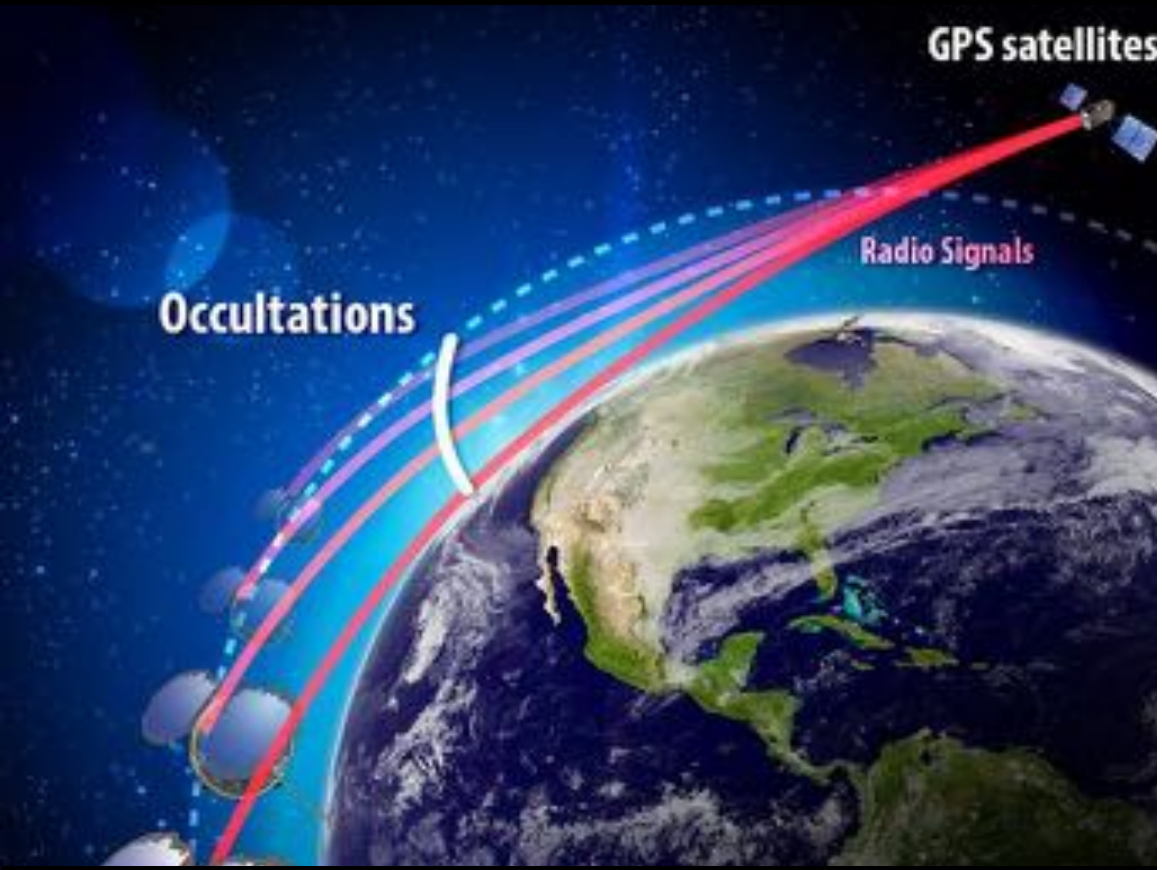
International Radio Occultation Working Group 2021



12 April 2021
Session 2: Climate

obs4MIPs v3.0:

A Multi-Mission GNSS-RO Dataset for Climate Monitoring and Model Assessment

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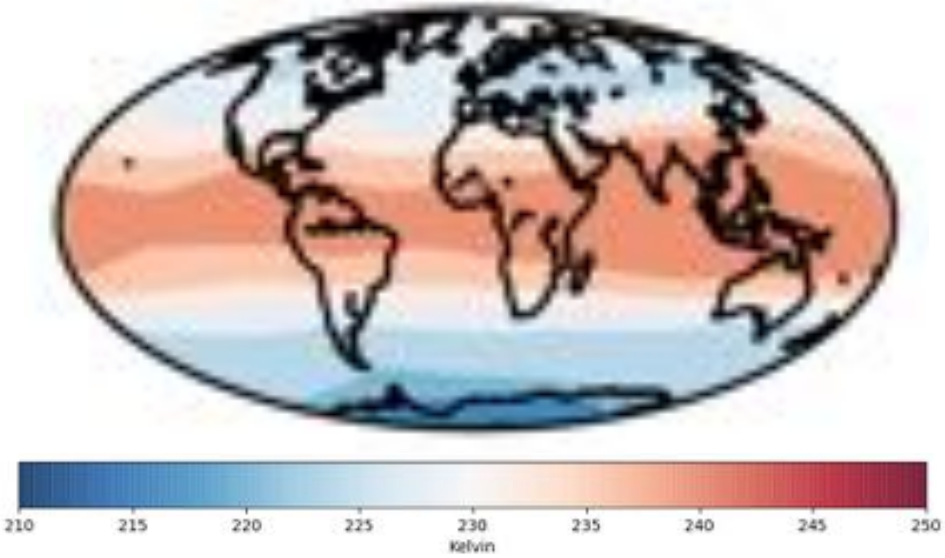
Overview (Outline)

- RO in Observations for the Model Comparison Project
- Evaluation of obs4MIPs products with ERA-5, MERRA-2, NCEP
- Temperature Variability and Trends
- Planetary Oscillations (QBO, ENSO)
- Conclusions

RO in Observations for Model Intercomparisons Project

obs4MIPs: Gridded climate record of observations targeted at climate/model intercomparison.

The obs4MIPs has now expanded to include contributions from a broader community and satellite products, including RO.



obs4MIPs
Observations for Model Intercomparisons Project

SCAN ME

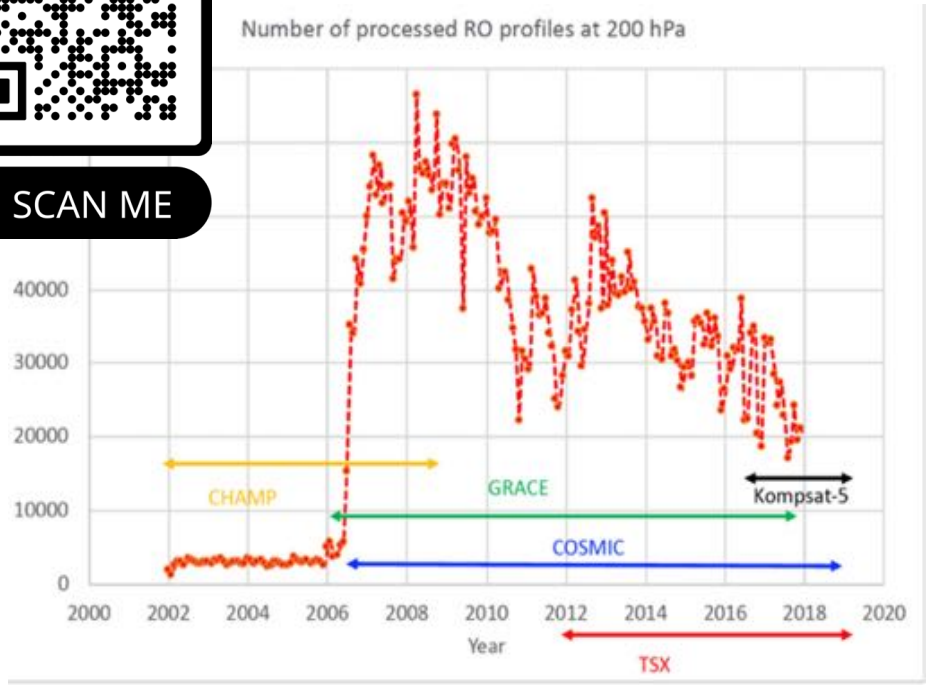
Product Availability:

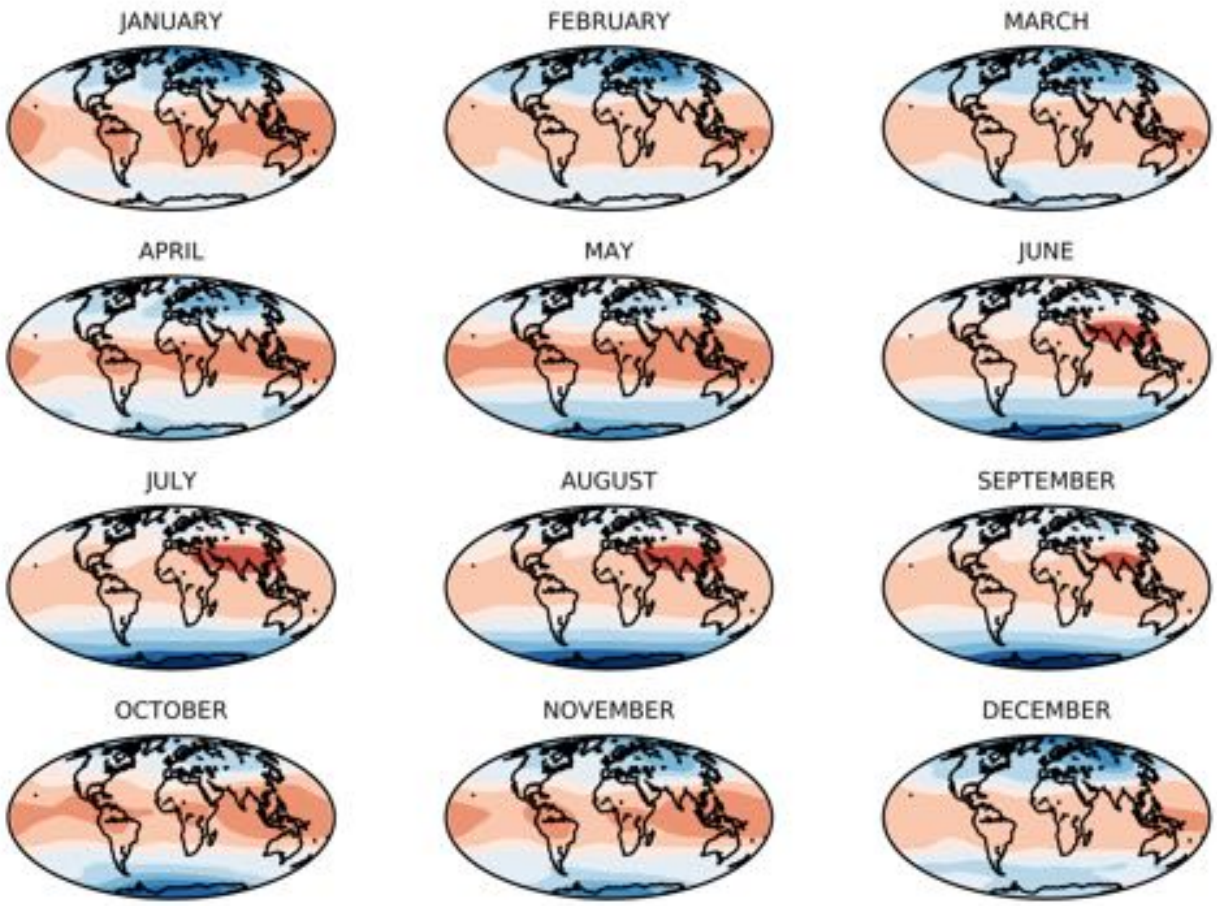
- ✓ Level 3 data
- ✓ Geopotential Height
- ✓ Wet Temperature
- ✓ Refractivity (Pending)
- ✓ Pressure-based Products
- ✓ 5°×5° latitude-longitude grids
- ✓ Can downloaded from ESGF and JPL-Genesis .

RO in Observations for Model Intercomparisons Project (Cont.)

- Combines missions processed at JPL: Champ, COSMIC-1, Grace, Kompsat-5, TerraSAR-X
- Products produced using the Bayesian Interpolation Method with Spherical Harmonic [Leroy et al. 2012, 2021].
- **v3** extends the dataset to December 2018 and uses MERRA-2 profiles as a-priori for the retrievals.

SCAN ME



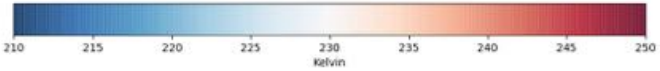


Example of monthly averaged products on the left

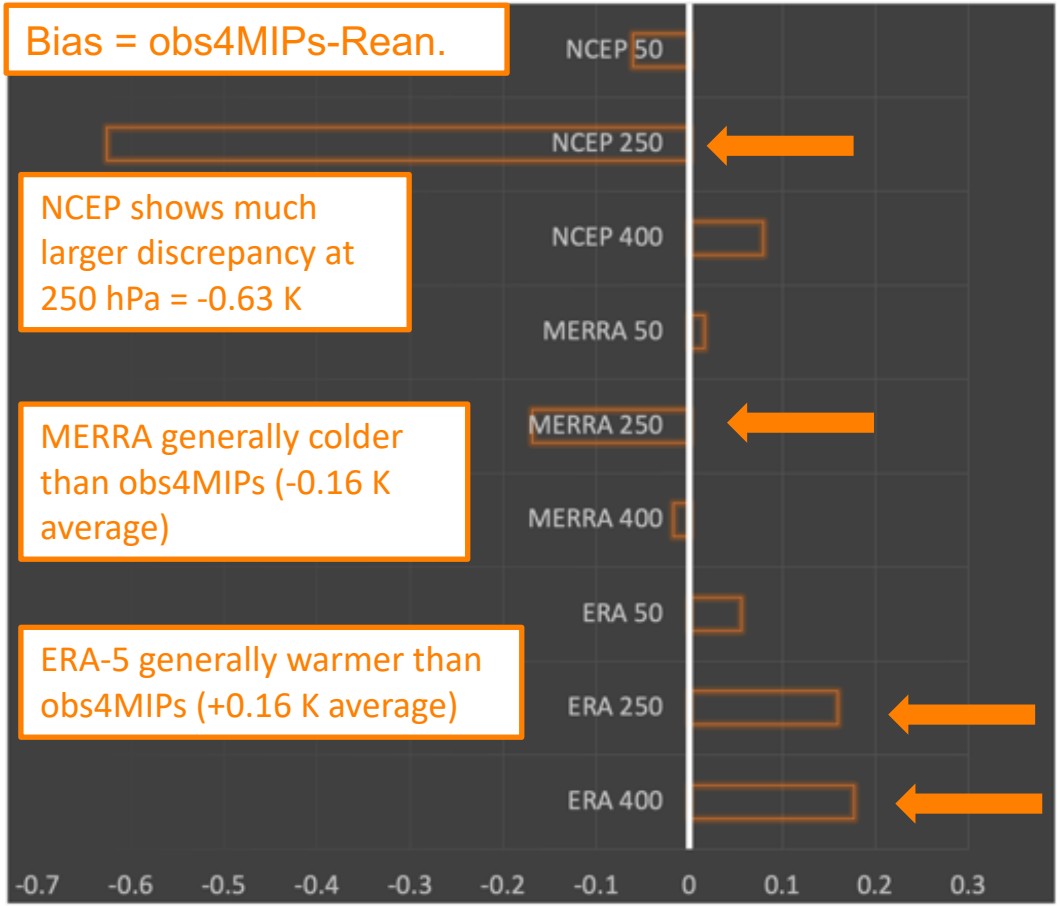
Product Availability from 400 to 50 hPa at 5 hPa res.

High Vertical Resolution from mid-Troposphere to Lower Stratosphere: unachievable by IR and MW sounders

200 hPa



Comparisons of obs4MIPs vs. Reanalyses

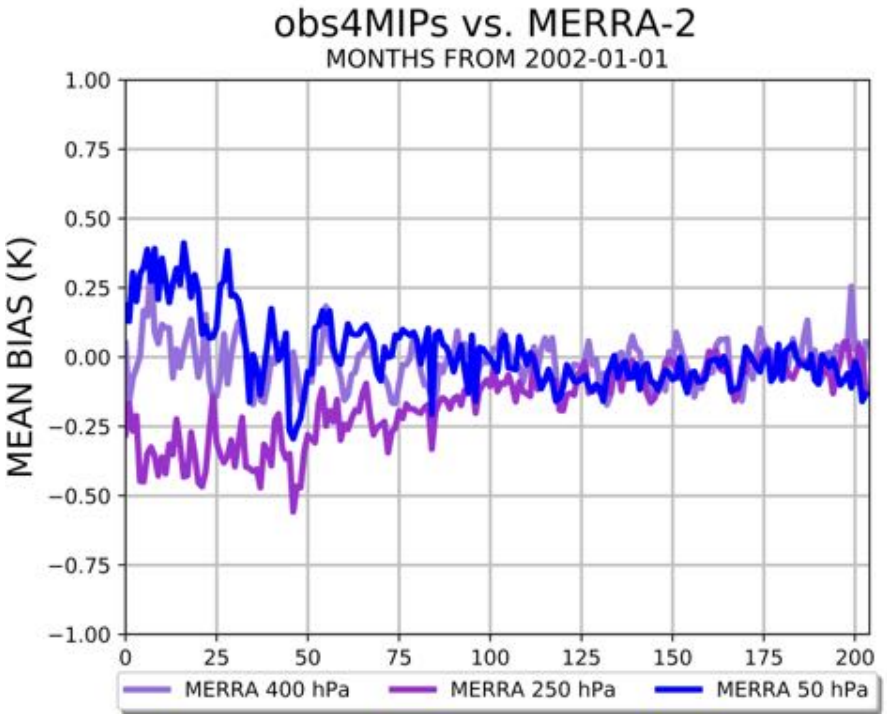


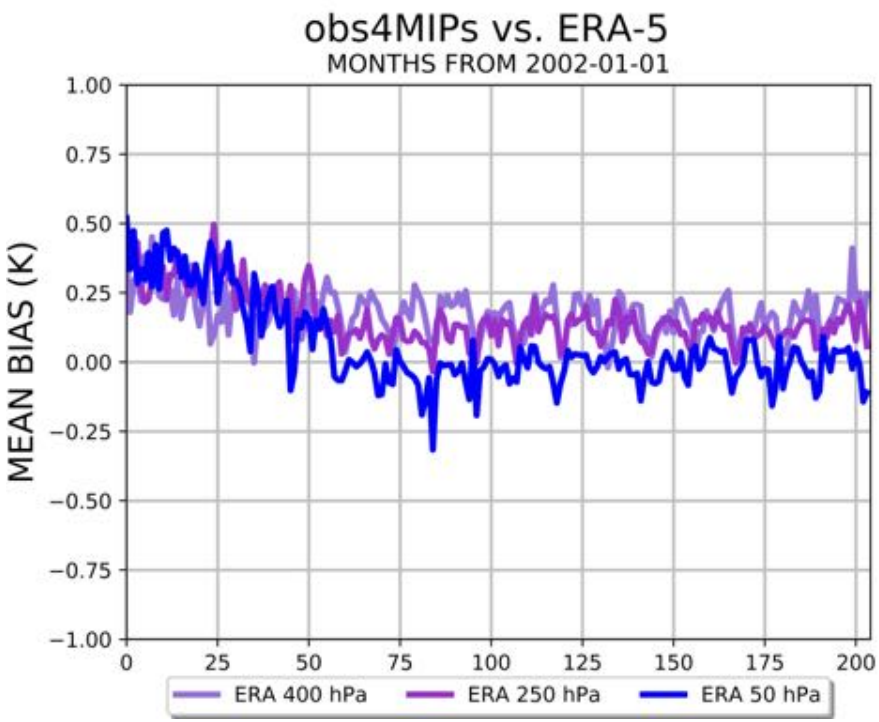
17 years (2002-2018) of monthly averaged ERA-5, MERRA-2 and NCEP-DOE reanalysis used as a reference in the evaluation of the obs4MIPs products at various levels (400 hPa, 250 hPa, 50 hPa shown)

- Analysis :
  - Averaged biases 2002-2018 (Left)
  - Time Series of Monthly Biases (Next slide)
  - Geographical Distribution (Next slide)

Overall, 2002-2018 period averages show relatively small biases.

Evaluation of obs4MIPs Products





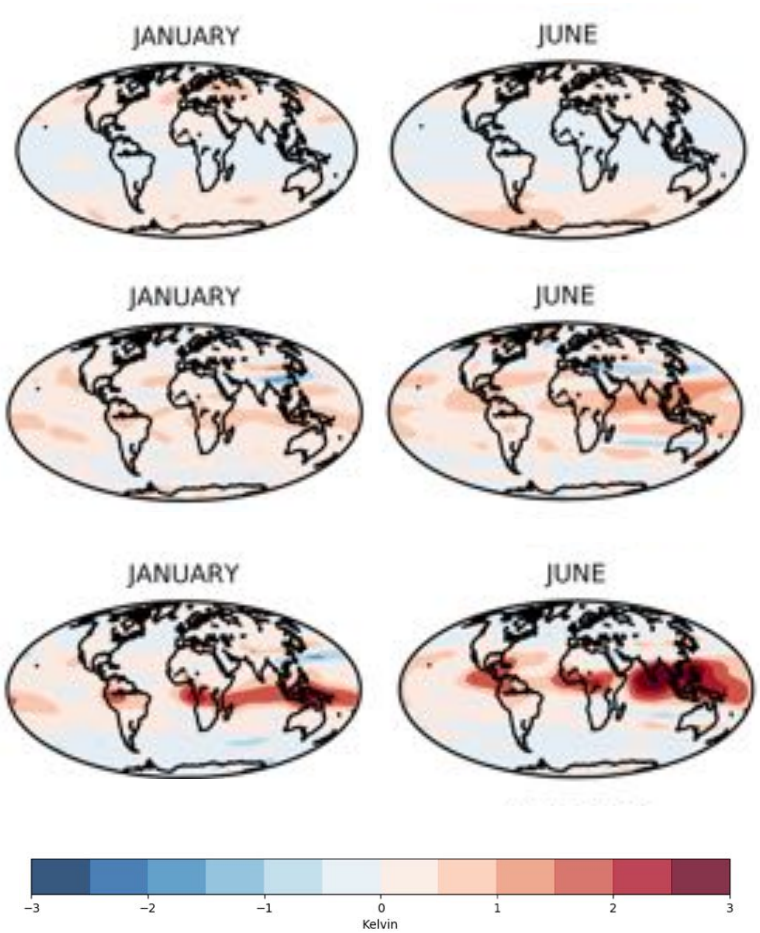
ERA-5

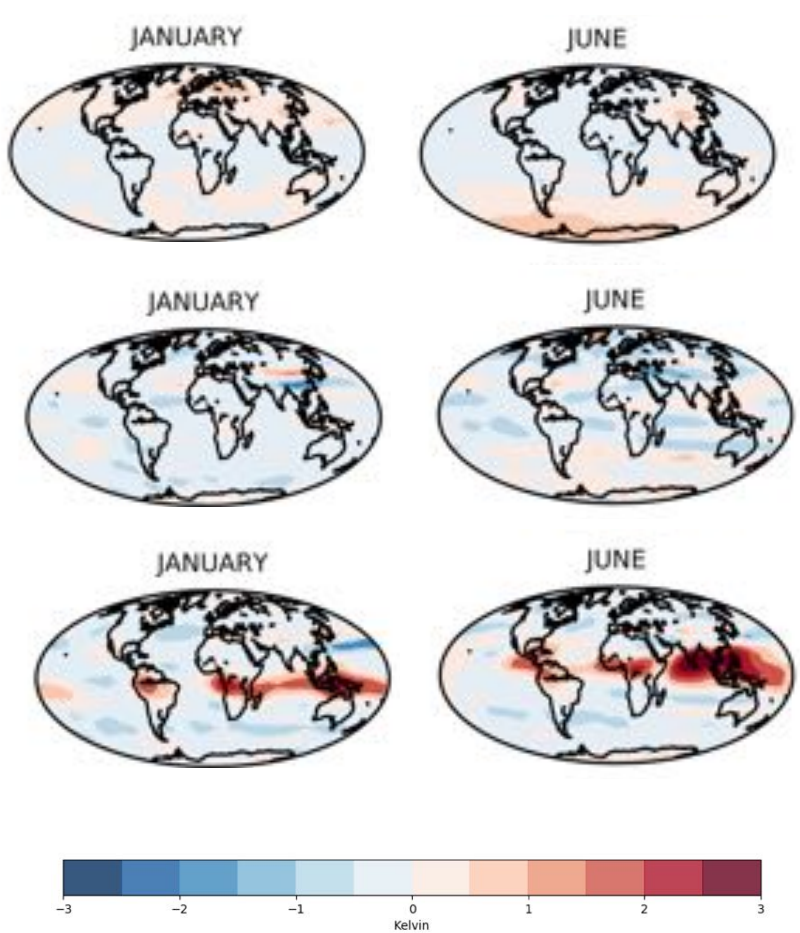
MERRA-2

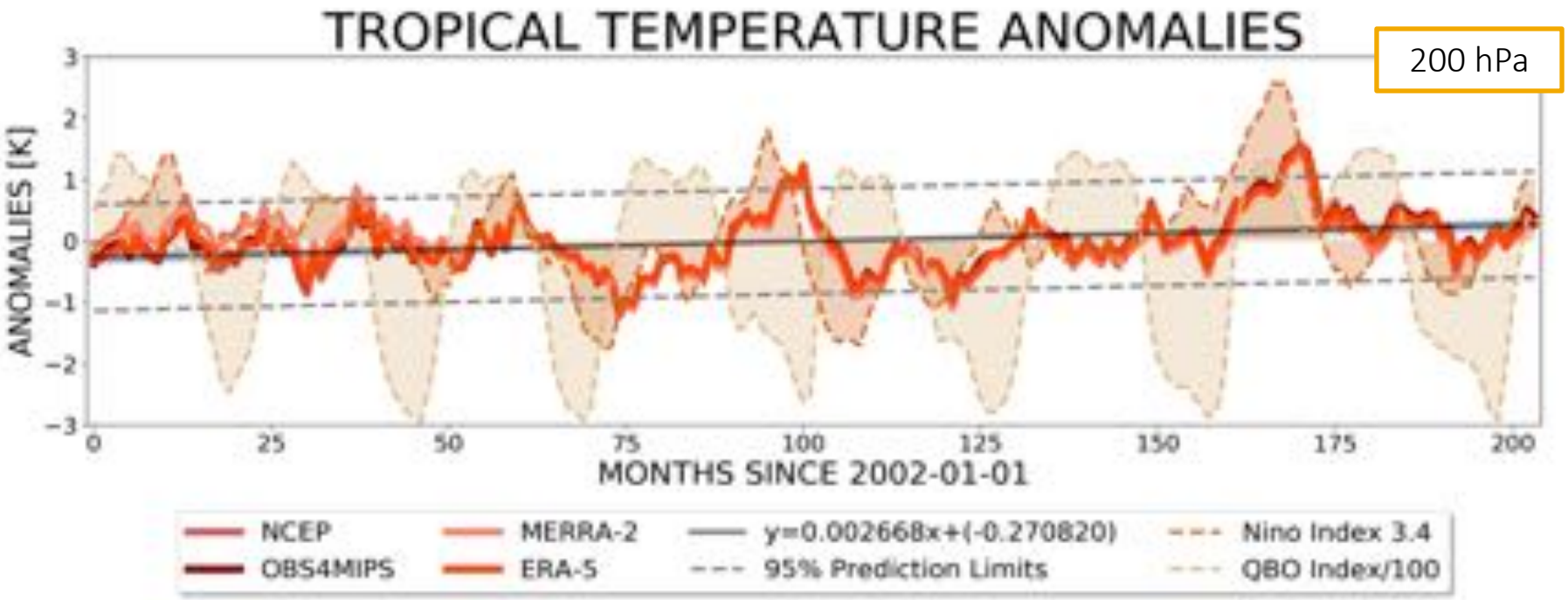
50 hPa

250 hPa

400 hPa



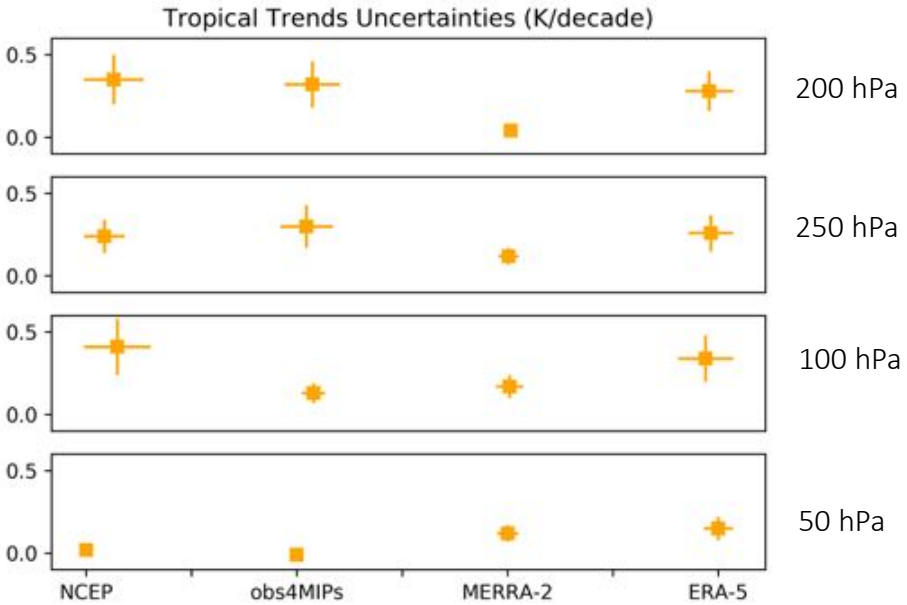




UTLS: Temp anomalies at 200, 250, 100 and 50 hPa, along with corresponding trends from NCEP, MERRA-2 and ERA-5 reanalyses. MERRA-2 shows the largest departure from all other datasets in the pre-COSMIC era

NCEP	0.24	±0.10
Obs4MIPs	0.30	±0.13
MERRA-2	0.12	±0.05
ERA-5	0.26	±0.11

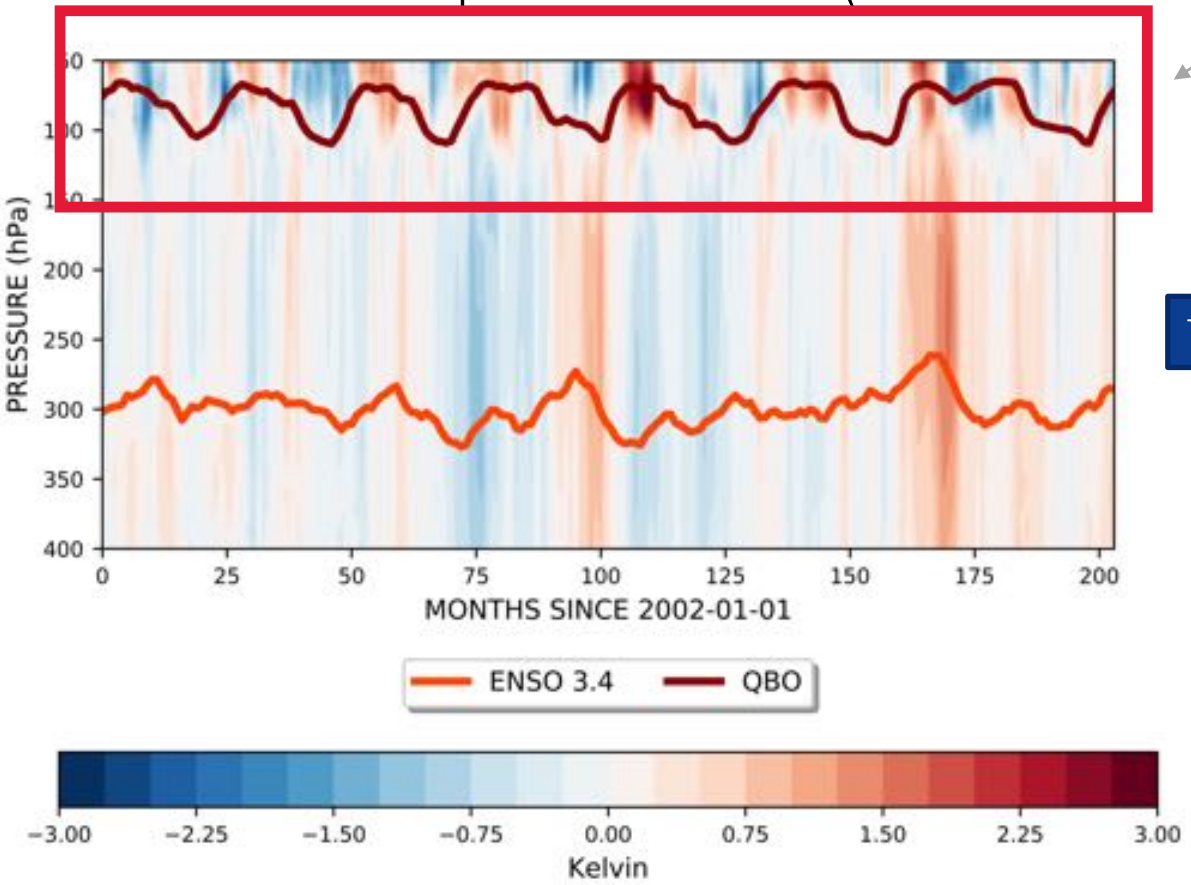
Trends per decade (K/decade) for each dataset and its corresponding 2σ uncertainty (UTLS = 200 and 250 hPa; Stratosphere = 100 and 50 hPa).



- Tropical Trends are consistent with those Vergados et al. 2021.
- MERRA-2 has the smallest temperature trends compared with other datasets (0.04 ± 0.02 K/decade at 250 hPa, 0.12 ± 0.05 K/decade at 200).

For reference: GISTEM v4 ~ 0.20 K/decade in UTLS

Zonal Mean Temperature Anom (22.5°S – 22.5°N)



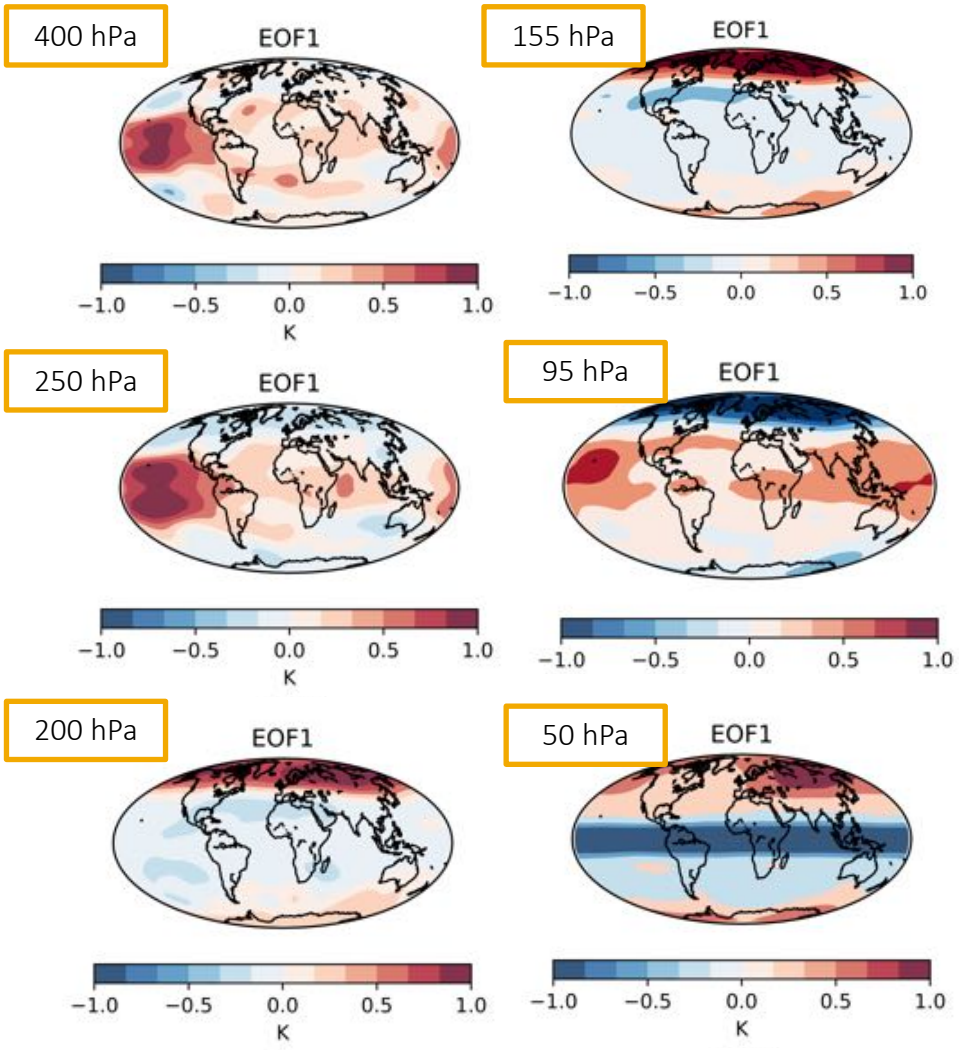
Strato: Downward-propagating QBO pattern in the lower Stratosphere.

Neg Temp Anom =Westerlies
Pos Temp Anom = Easterlies

The Highest Variability -> Transition from Westerlies to Easterlies

Several El Niño events are revealed during the GNSS RO time period: 2002–2003, 2004–2005, 2006–2007,and 2009–2010, 2014–2016.

The La Niña events 2007–2008, 2010–2011, and 2011–2012 can also be observed.



- Empirical Orthogonal Functions (EOFs) constructed from 17-years of obs4MIPs temperature and GPH data to extract major modes of spatial and temporal variations.
- In the the troposphere, warming signals in the Pacific Ocean can be observed from -> ENSO
- The separation at the tropopause can also be seen in the 200 hPa, where tropics seem to be dominated by cooling, while the primary mode of warming occurs in the Arctic.
- In the stratosphere, first PCs show the downward-propagating QBO pattern.
- While QBO and ENSO are the two primary triggers that dominate the global temperature variability, many other oscillations occur.

Summary

- obs4MIPs -> Gridded RO ”Climate Record” of observations targeted at Climate/Model Intercomparison.
- Generally, Obs4MIPs in good agreement against ERA-5, MERRA-2 and NCEP, largest differences in the tropics (400 hPa).
- 17 year average at at 250 hPa, show MERRA and ERA have similar magnitude biases with opposite sign (+/- 0.16), NCEP shows much larger discrepancy = -0.63 K
- RO Temperature Trends Time Series for 2002 – 2018 show temperature increase of 0.30 K/decade (Tropics) ~ 200 hPa.
- MERRA-2 trends significantly colder near TTL compared to other datasets.
- NCEP trends warmer than most in stratosphere.
- obs4MIPs RO only dataset to show expected stratospheric cooling at 50 hPa.
- RO captures ENSO, QBO, NAO and AO signals, using both temperature anomalies and vertically-resolved Empirical Orthogonal Functions.
- RO allows characterization of atmospheric lags between surface and UTLS warming during ENSO events.

Acknowledgements:

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Datasets:

- obs4MIPs RO: http://genesis.jpl.nasa.gov.
- ERA-5 Data: DOI: 10.24381/cds.6860a573
- NCEP Data: https://psl.noaa.gov/data/gridded/data.ncep.reanalysis.derived.pressure.html
- MERRA-2 Data: https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/

Selected References:

- Ao et al. 2015: https://doi.org/10.1002/2014JD022239
- Leroy et al. 2012: https://doi.org/10.1175/JTECH-D-11-00179.1
- Leroy et al. 2021: https://doi.org/10.1175/JTECH-D-20-0031.1

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