Cold-point tropopause temperature bias in reanalyses modulated by equatorial waves

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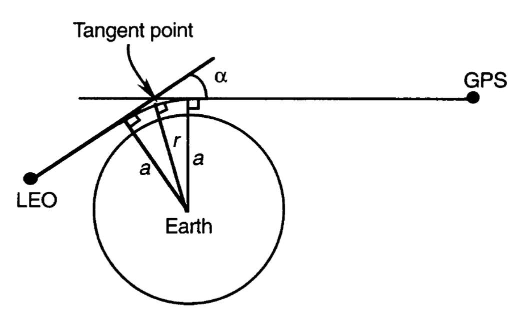
1 - Motivation

The cold-point tropopause in the tropics controls the amount of water vapor in the stratosphere, affecting dehydration and stratospheric entrainment. A recent reanalysis intercomparison found that all modern reanalyses have a cold-point temperature (CPT) warm bias compared to observations, which maximizes at the Equator (Tegtmeier et al., 2020).

The CPT is known to be modulated by equatorial waves (e.g. Kim and Son, 2012), and since late 2006 GNSS radio-occultations (GNSS-RO) provide a dense global coverage of temperature measurements with high vertical resolution. Ideal to study CPT variability related to equatorial wave anomalies directly from observations.

We test whether reanalysis CPT bias is affected by the presence of equatorial waves, quantifying its variations and how do recent reanalysis datasets compare to each other.

2 - GNSS-RO and reanalysis data



Kursinski et al. (1996): GPS radio occultation measurement technique.

Temperature profiles from **GNSS-RO** missions: CHAMP, COSMIC, GRACE, Metop-A, SAC-C, TerraSAR-X ('wetPrf'). ~2500 profiles/day globally on a 100 m vertical grid.

CPT from GNSS-RO gridded on daily 5° x 5° longitude-latitude grid following Pilch Kedzierski et al. (2020).

CPT from reanalysis model-level data:
ERA5, ERA-Interim, JRA-25, JRA-55, MERRA, MERRA-2, CFSR(v1).

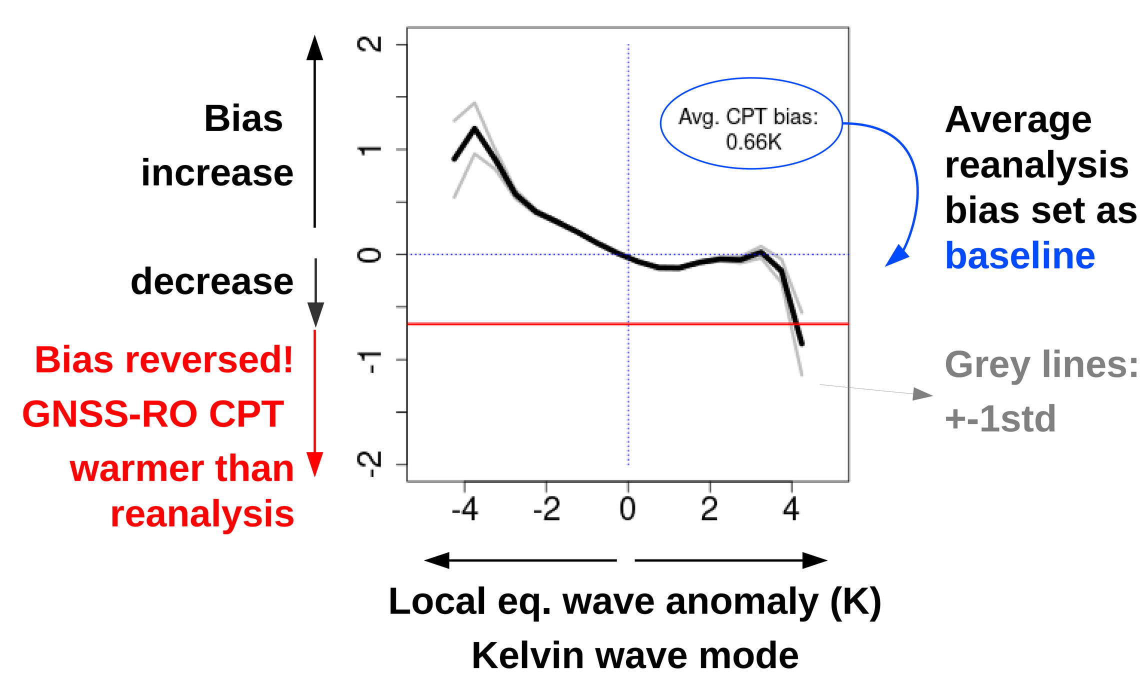
Preliminary period 2007-2011 analyzed, restricted to 15°N -15°S.

3 - Method and example

Reanalysis CPT is first interpolated on the same 5° x 5° daily grid as GNSS-RO.

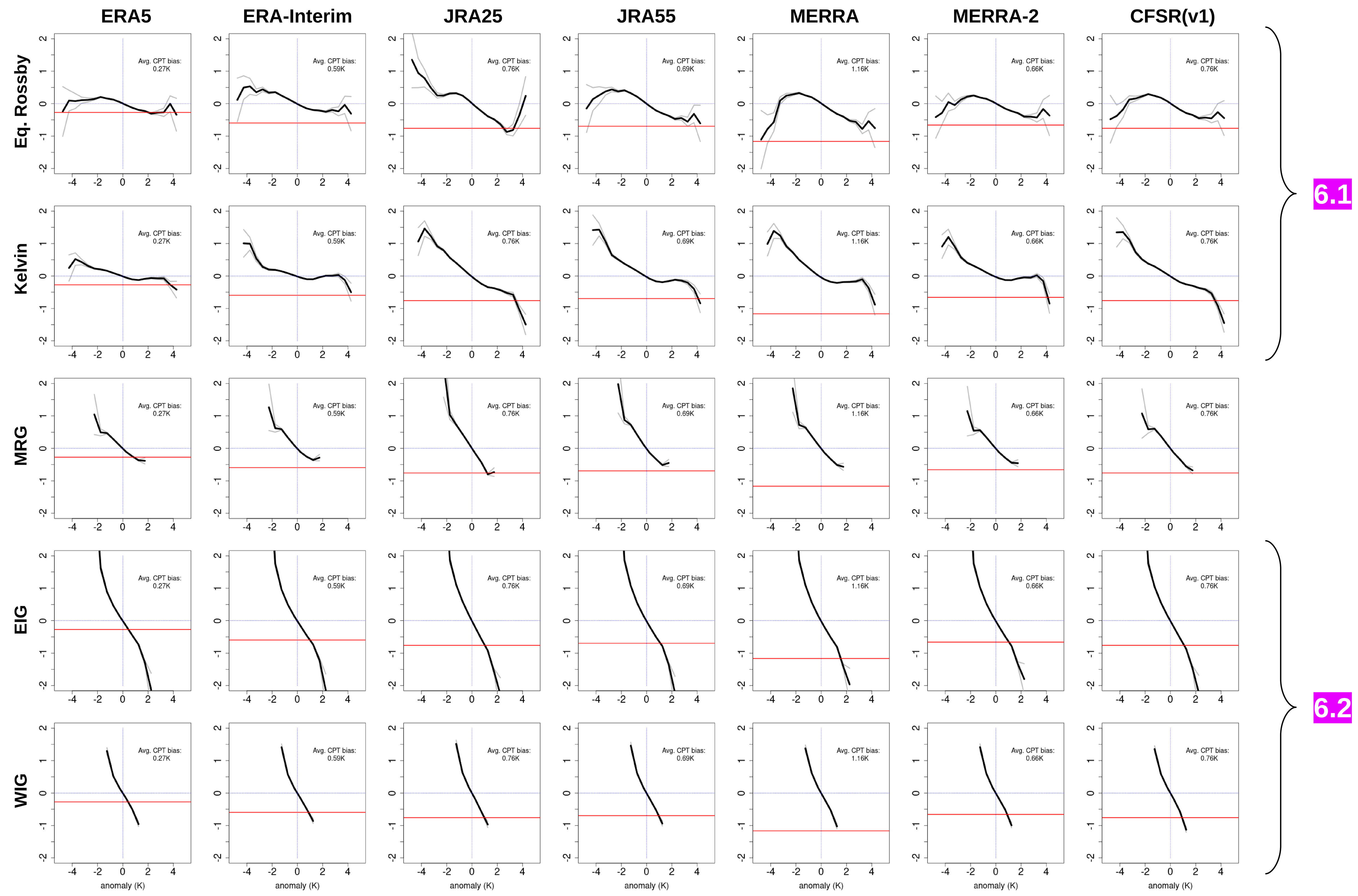
Equatorial waves are filtered from the gridded GNSS-RO CPT, similarly to Wheeler and Kiladis (1999). Non-overlapping wavenumber-frequency domains are used for every equatorial wave mode filter, obtaining CPT anomalies (again 5° x 5° daily) for the following modes: **equatorial Rossby**, **Kelvin**, mixed Rossby-gravity (**MRG**), and both eastward and westward-propagating equatorial inertia-gravity waves (**EIG** and **WIG**).
(!) Only waves with periods of 2 days or more are filtered, due to the daily resolution.

Collocated reanalysis differences from GNSS-RO CPT are binned and averaged relative to the local temperature anomaly of each filtered equatorial wave mode. An example diagram for MERRA-2 CPT bias variation relative to Kelvin wave anomalies is shown below.

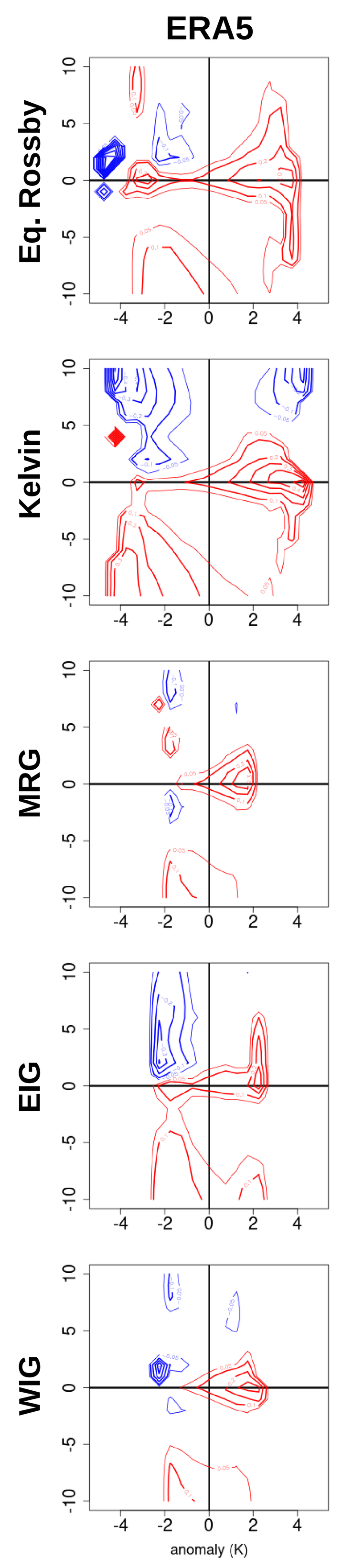


A panel containing the same diagram for all reanalyses and against every filtered equatorial wave mode is shown in section 4.

4 - CPT bias modulation by equatorial waves



5 - Temp. increments



Work in progress
Analysis – 12h forecasts
Warming or cooling in K/day

Model level above forecast CPT

Roughly ±3km around CPT

Shows what data assimilation in ERA5 is trying to do, bringing model and obs. as close as possible; relative to each equatorial wave mode's local anomaly.

Current effort: check the temp. increments on the rest of reanalysis products and compare forecast vs analyzed CTP.

6.3

6 - Conclusions

6.1: The relatively slower equatorial Rossby and Kelvin wave modes already hint at modulating reanalysis CPT bias: e.g. cold phase of Kelvin wave increases CPT bias by up to an additional 1K, while warm phases see the opposite. Slight variations among reanalyses: less effect in the newest.

6.2: The faster equatorial inertia-gravity waves (EIG and WIG), despite having lesser amplitudes, modulate CPT bias by ±1.5-2K. All reanalyses see a near-identical modulation, regardless of their different mean CPT biases. MRG shows an intermediate effect.

6.3: Initial results looking at the effect of data assimilation suggest temperature increments around the reanalysis CPT are also strongly modulated by equatorial waves. Differences in the range of several 1/10 of K per day.

6.4: Given the similarities among reanalysis products, is there potential for a one-fits-all bias correction tool in the future?

A paper for the S-RIP special issue in ACP is in preparation.

Acknowledgments:
This study was funded by GEOMAR Helmholtz Centre for Ocean Research in Kiel. The authors thank the CDAAC and reanalysis data servers for the freely available GNSS-RO and reanalysis datasets.

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