

Comparison and attribution of atmospheric temperature trends from LESFMIP simulations and observations

Matthias Stocker¹, Andrea K. Steiner¹, Stephen Po-Chedley², Aodhan Sweeney³ and Amanda C. Maycock⁴

¹Wegener Center, University of Graz ²Lawrence Livermore National Laboratory ³Planette.AI ⁴School of Earth and Environment, University of Leeds

1 Introduction

The strength and structure of atmospheric temperature trends are shaped by external forcings and internal variability. Using the Large Ensemble Single Forcing Model Intercomparison Project (**LESFMIP**) **single-forcing simulations together with radiosonde data and high vertical resolution satellite-based GNSS radio occultation (RO) observations** allows us to isolate individual forcing contributions and reassess remaining model–observation discrepancies.

2 Spatial Fingerprints and Forcing Contributions

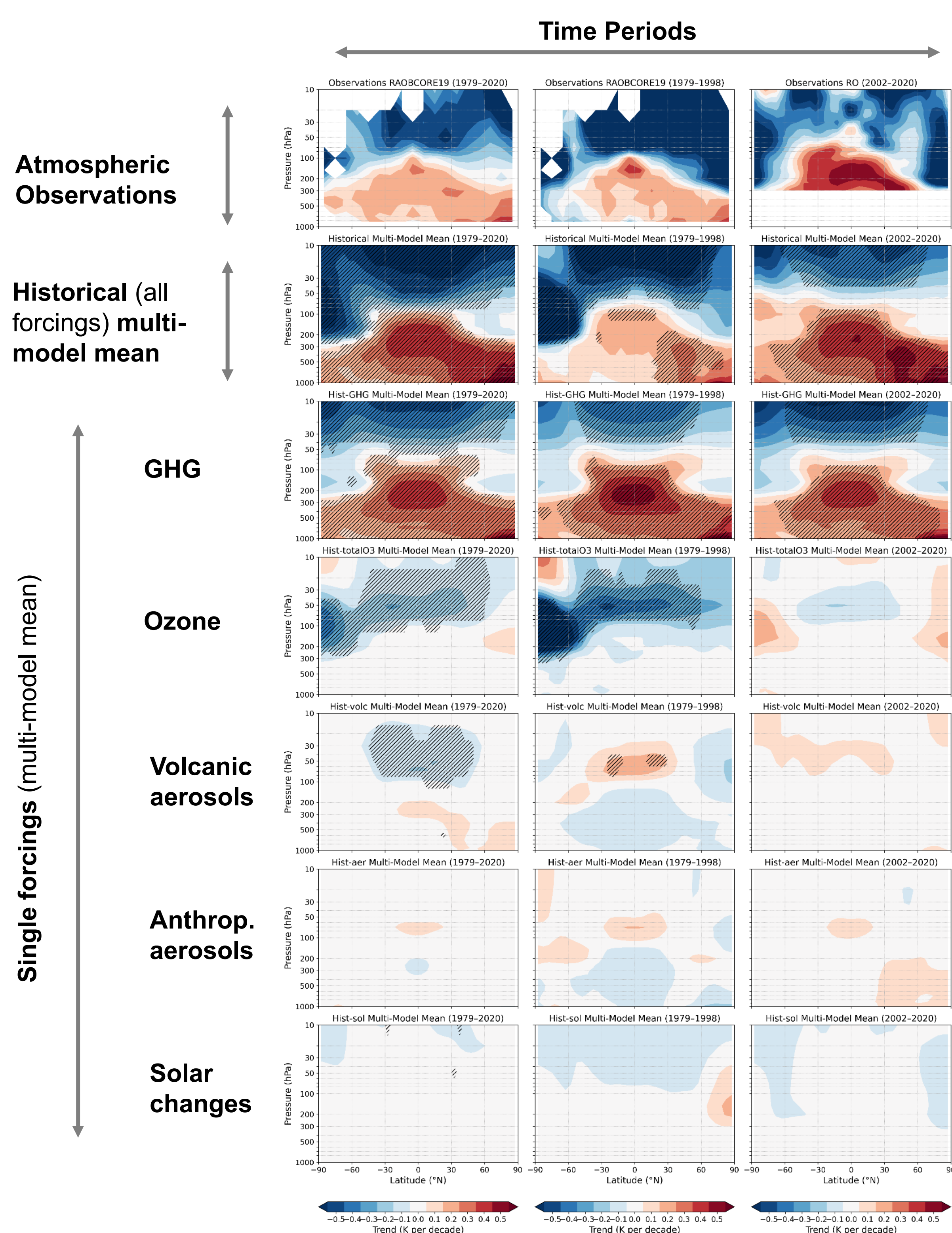
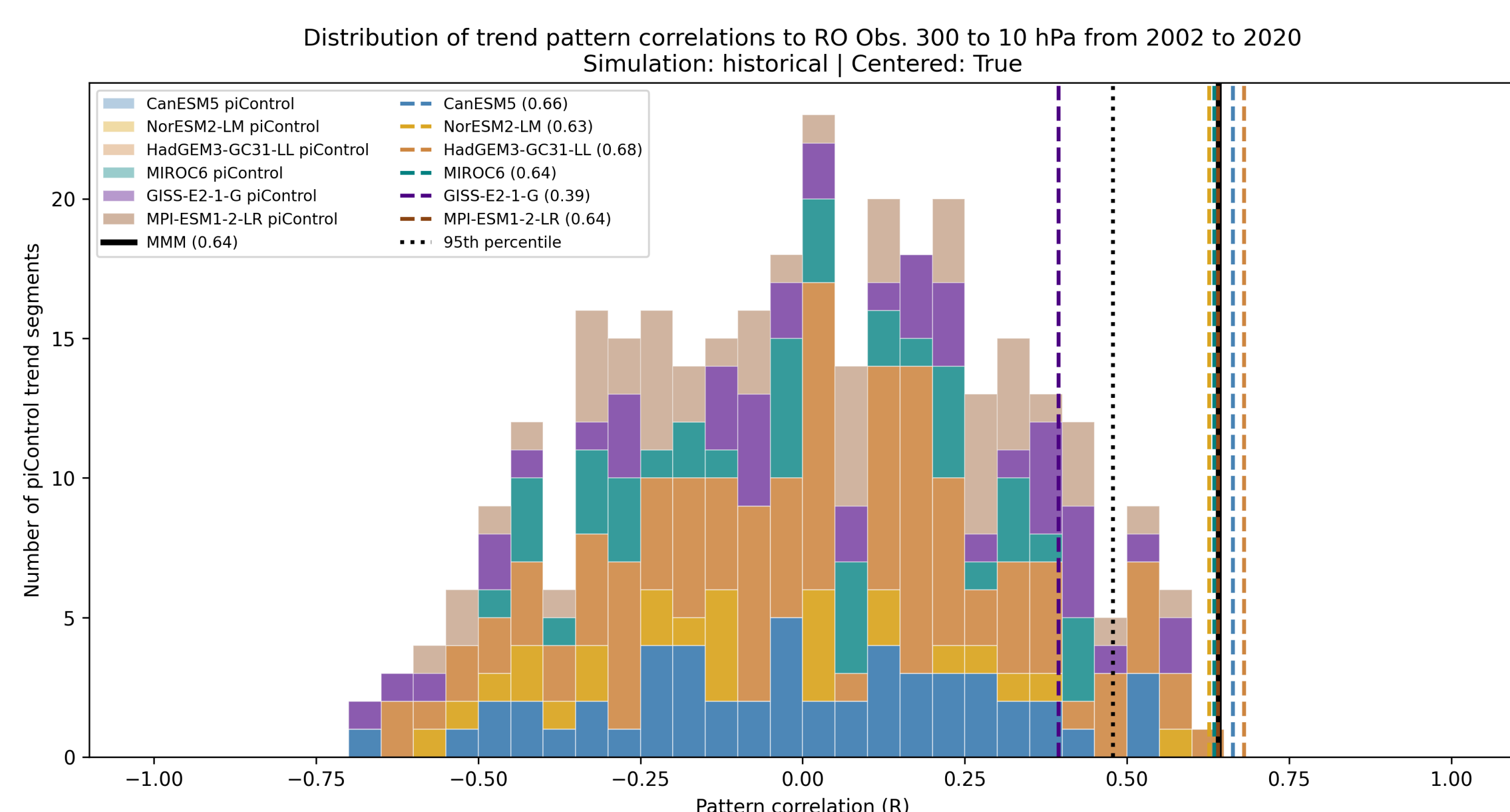


Fig. 1: Latitude-pressure temperature trends (K per decade). Columns: full period (1979–2020), ozone depletion period (1979–1998), ozone recovery period (2002–2020). Rows: observations, historical multi-model mean, greenhouse gases (GHG), stratospheric ozone, volcanic aerosols, anthropogenic aerosol, solar changes. Observations include RAOBCORE and radio occultation (RO). Hatched areas indicate where trends are outside the 95% range of piControl trends.

4 Trend Patterns vs. Internal Variability (2002–2020)

The **pattern correlation** compares the **observed temperature trend pattern** from satellite-based RO observations with **simulated patterns from internal variability (piControl)** and **different external forcings**, allowing attribution and assessment of model–observation consistency. For the historical simulations, the **multi-model mean and five of six model means exceed the piControl 95th percentile** (Fig. 3, vertical lines), indicating a forced contribution to the observed pattern. **Similar correlations for GHG-only simulations indicate that the observed trend pattern is primarily shaped by GHG forcing.**

(a) Historical trend pattern (2002–2020): $R = 0.64$



(b) GHG trend pattern (2002–2020): $R = 0.68$

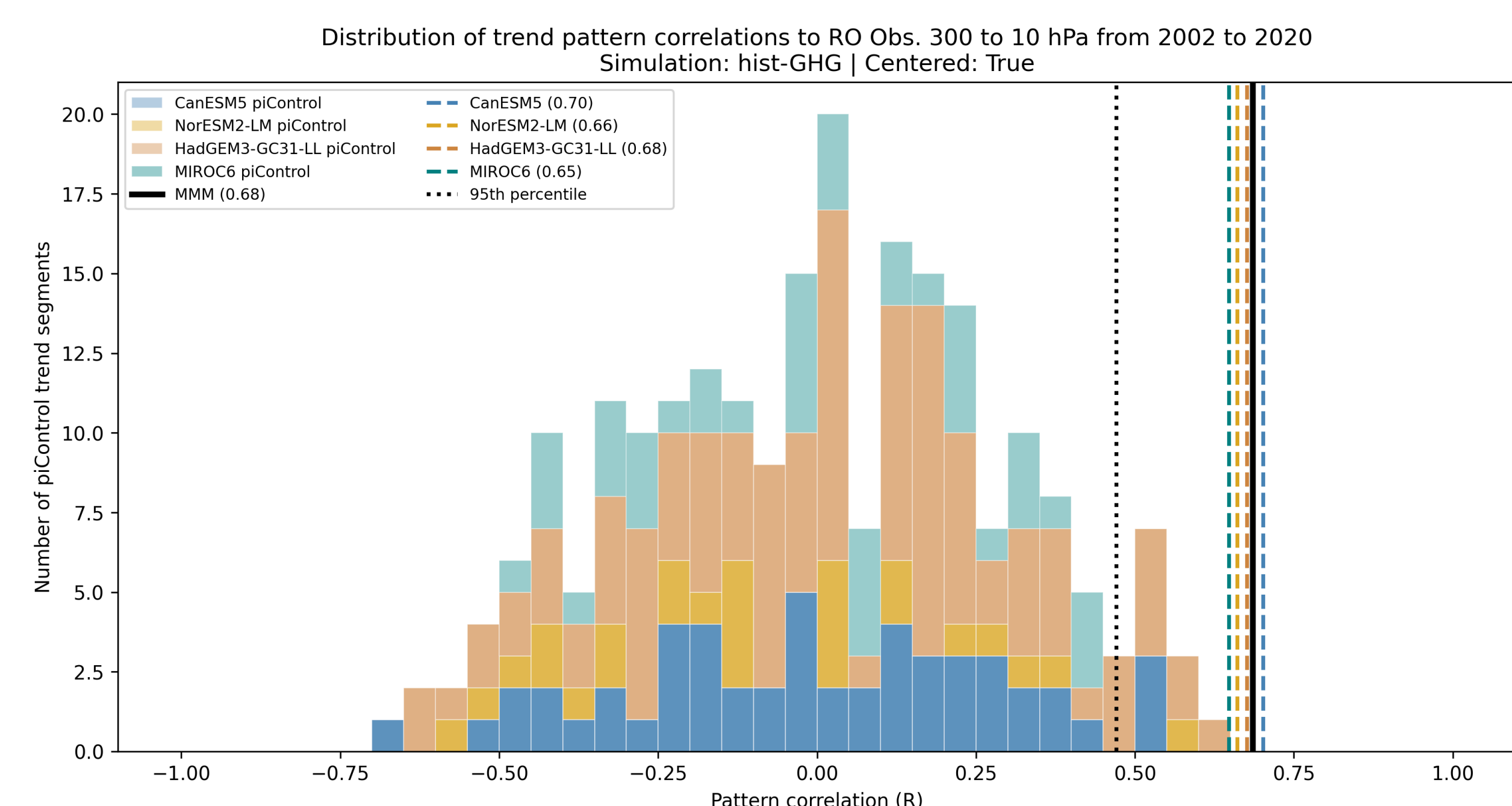


Fig. 3: Centered pattern correlations with RO for 2002–2020 (300–10 hPa). Histograms show the distribution of 19-year piControl segments. Colored dashed lines show individual model means and the solid black line the multi-model mean. (a) Historical simulations. (b) GHG only simulations.

3 Vertical Trend Structure

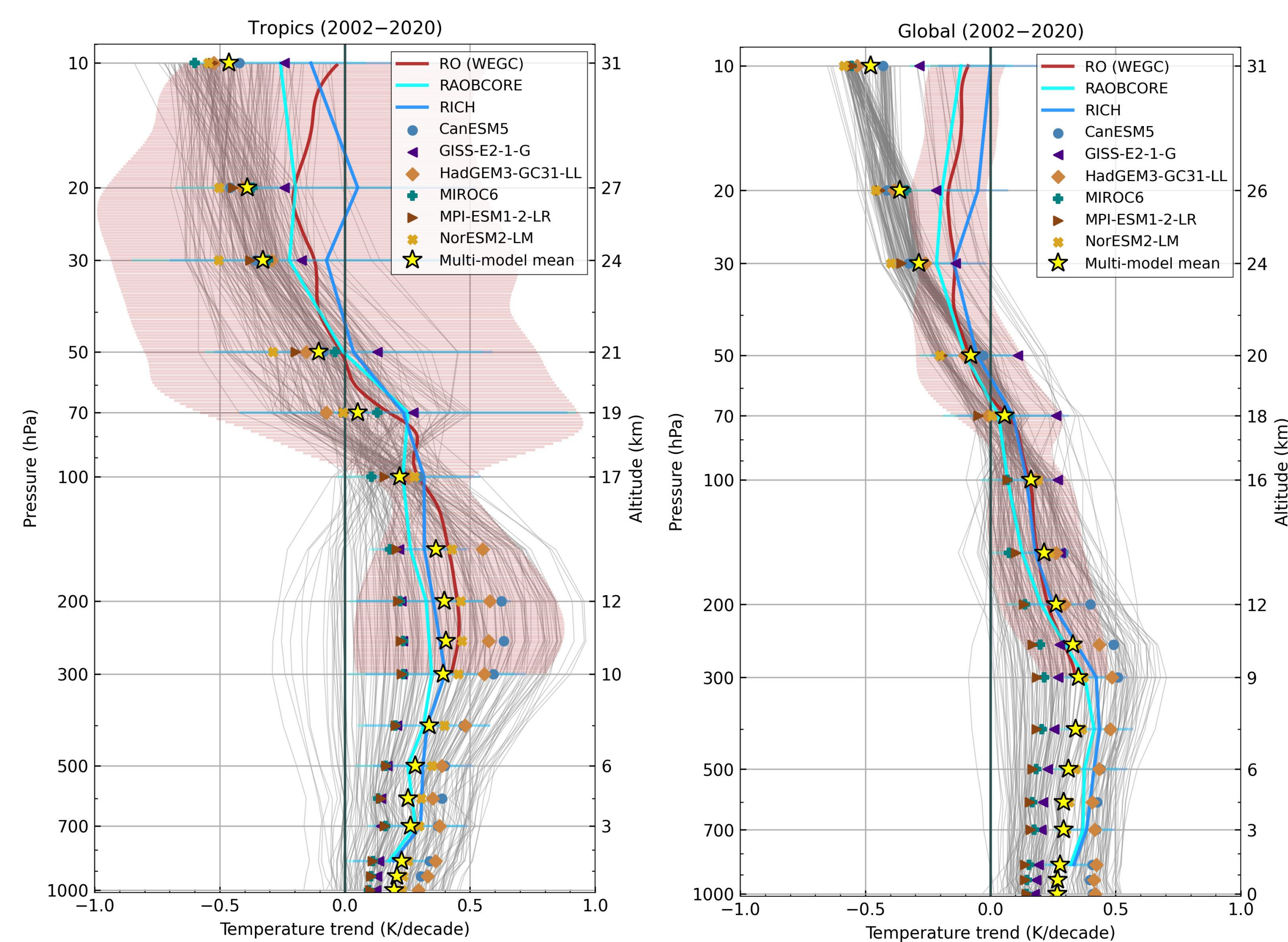


Fig. 2: Temperature trends for the radio occultation (RO) period (2002–2020), averaged over the tropics (left) and the globe (right). Colored lines represent observations, including RO and radiosondes (RICH, RAOBCORE). Symbols indicate individual model means. Yellow stars denote the multi-model mean. Gray lines indicate the individual ensemble members.

Key Takeaways

The **multi-model mean broadly agrees with observations across all periods** (Fig. 1), with **particularly good agreement with RO during 2002–2020**. However, **substantial spread among individual models is visible** (Fig. 1 and Fig. 2).

During the **ozone recovery period**, the multi-model mean shows **SH polar lower-stratospheric warming**, whereas **observations show cooling** (Fig. 1). This **difference may reflect internal variability and/or may be linked to a simulated ozone recovery response**. GHG forcing dominates the simulated temperature trends, followed by stratospheric ozone changes (Fig. 1).

Pattern correlation of historical simulations show substantially higher agreement with observations than those from internal variability alone (Fig. 3). GHG-only simulations indicate that the **post-2000 observed trend pattern is primarily due to greenhouse-gas forcing**.