Multi-frequency analysis of modeled-versus-observed variability in tropospheric temperature

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Joint work with Benjamin D. Santer

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Research outcome

- Developed a statistical framework to compare the **spectral features** of TMT variability in climate model ensembles and satellite data under different analyst choices:
  - the satellite TMT dataset (RSS, STAR and UAH)
  - the climate model ensemble and type of simulation (HIST and CTL)
  - the method for separating signal and noise (MMA-r, LIN, QUAD and CUB)
  - the frequency range considered (ALL, HIGH, LOW)
  - the statistical model used to represent observed natural variability (AR, ARMA, FARIMA)

Objective

To explore whether the last two generations of climate models ***underestimate*** observed low-frequency variability of mid- to upper tropospheric temperature (TMT)

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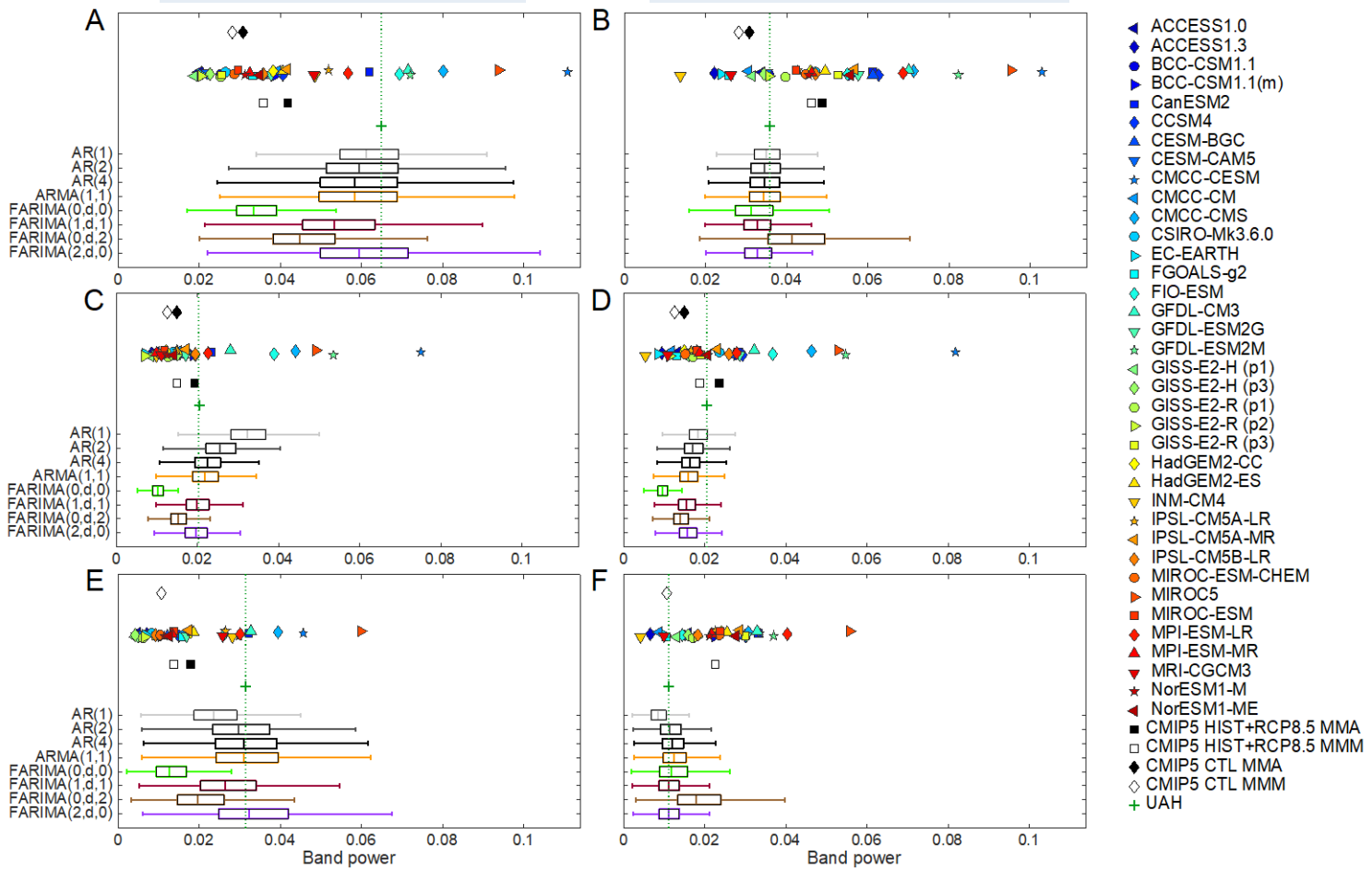
Distributions of band power values from the statistical models estimated on UAH dataset



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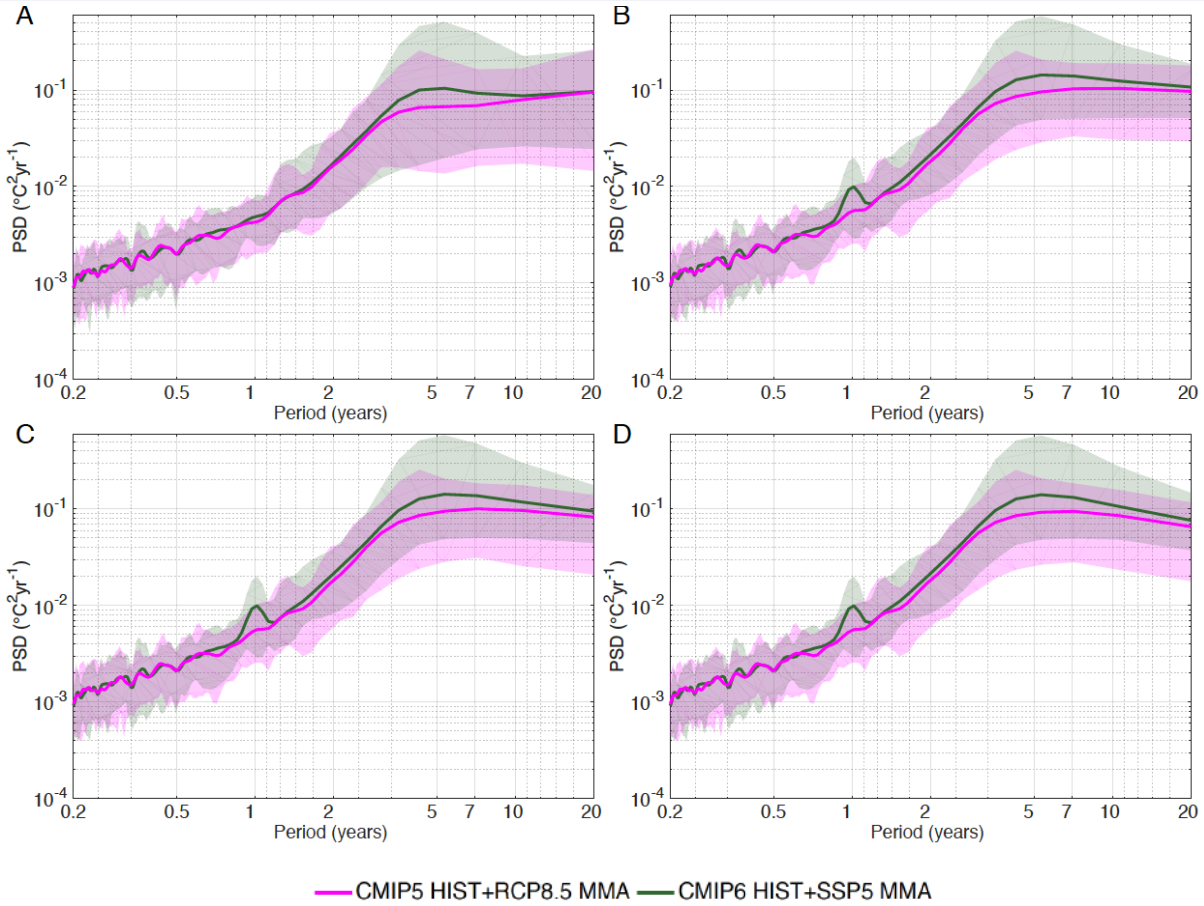
Comparing CMIP5 and CMIP6 spectra



A: MMA removal B: Linear detrending C: Quadratic detrending D: Cubic detrending

Comparison of the average spectra for the HIST+RCP8.5 simulations performed with 37 different CMIP5 models and for the HIST+SSP5 simulations performed with 21 different CMIP6 models.

All spectra were calculated for TMT data spatially averaged over 82.5N-82.5S.
The analysis period is from January 1979 to December 2018.

The shaded areas represent the 5-95% variability intervals on the power spectral densities.

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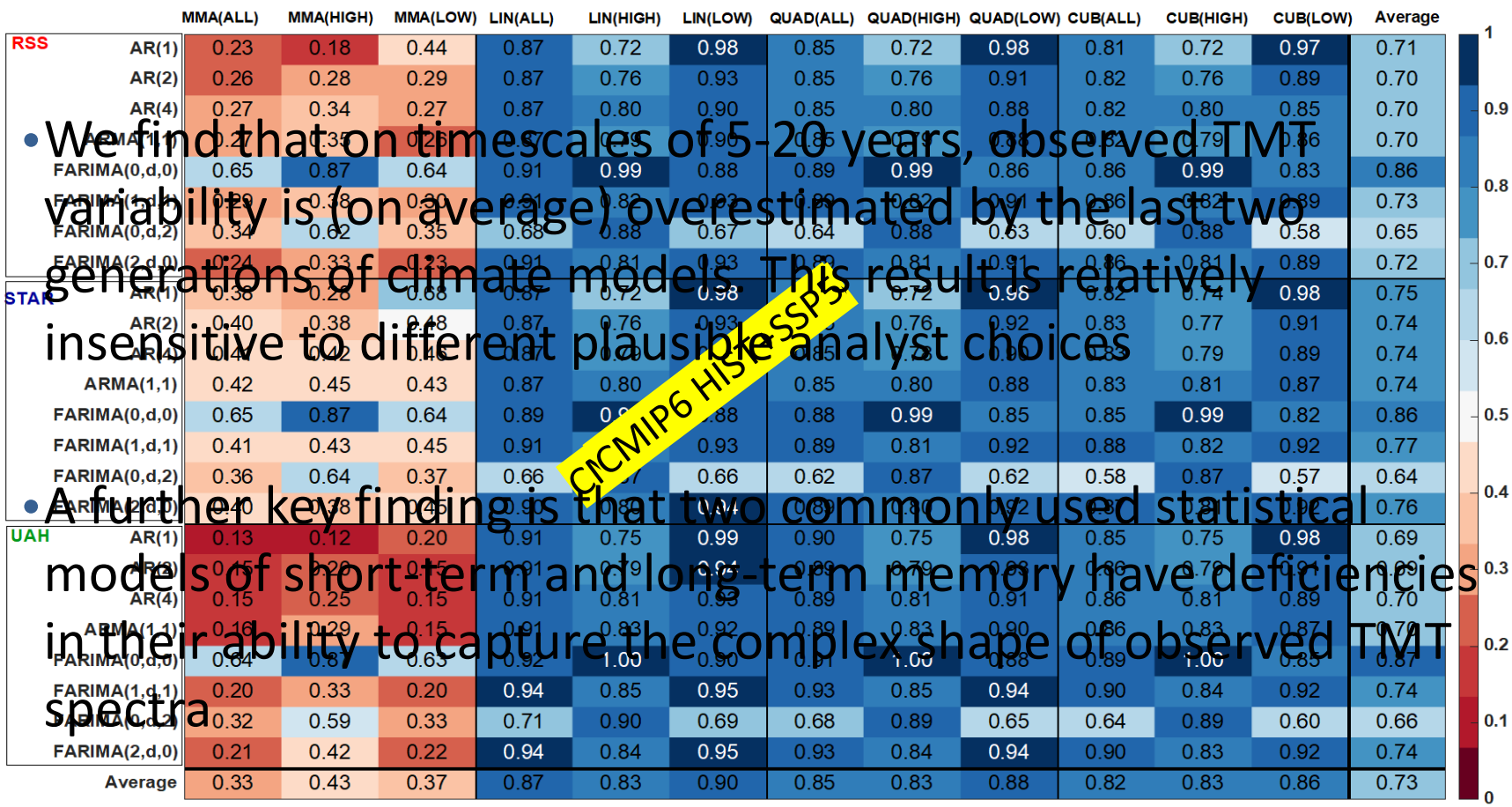
Probability that CMIP HIST simulations have *larger* band power than observations

Impact



- We find that on timescales of 5-20 years, observed TMT variability is (on average) overestimated by the last two generations of climate models. This result is relatively insensitive to different plausible analyst choices
- A further key finding is that two commonly-used statistical models of short-term and long-term memory have deficiencies in their ability to capture the complex shape of observed TMT spectra

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Future work

- We operate on “signal removed” TMT data. We will investigate the use of raw data and study its impact on the estimated observed natural variability
- We also intend to expand our suite of signal removal methods:
  - scaled MMA removal
  - Energy Balance Models (EBMs) for estimating “noise free” anthropogenic signals from observations in the presence of uncertainties in ECS and anthropogenic aerosol forcing
- We plan to use of large initial condition ensembles (LEs) for comparing the efficacy of signal removal approaches