Connections between the TTL and sea surface temperatures: interannual variability and trends

Chaim I. Garfinkel[1,2], Margaret Hurwitz[3], Darryn W. Waugh[2], Luke Oman[3] Lei Wang[1,4]
[1]Johns Hopkins University [2]Hebrew University [3]NASA GSFC [4]Lamont-Doherty
Correspondence: chaim.garfinkel@mail.huji.ac.il

(1) Introduction and Conclusions

●Trends and variability of temperature, water vapor, and ozone in the TTL and lower stratosphere significantly impact earth's radiative budget and energy budget.

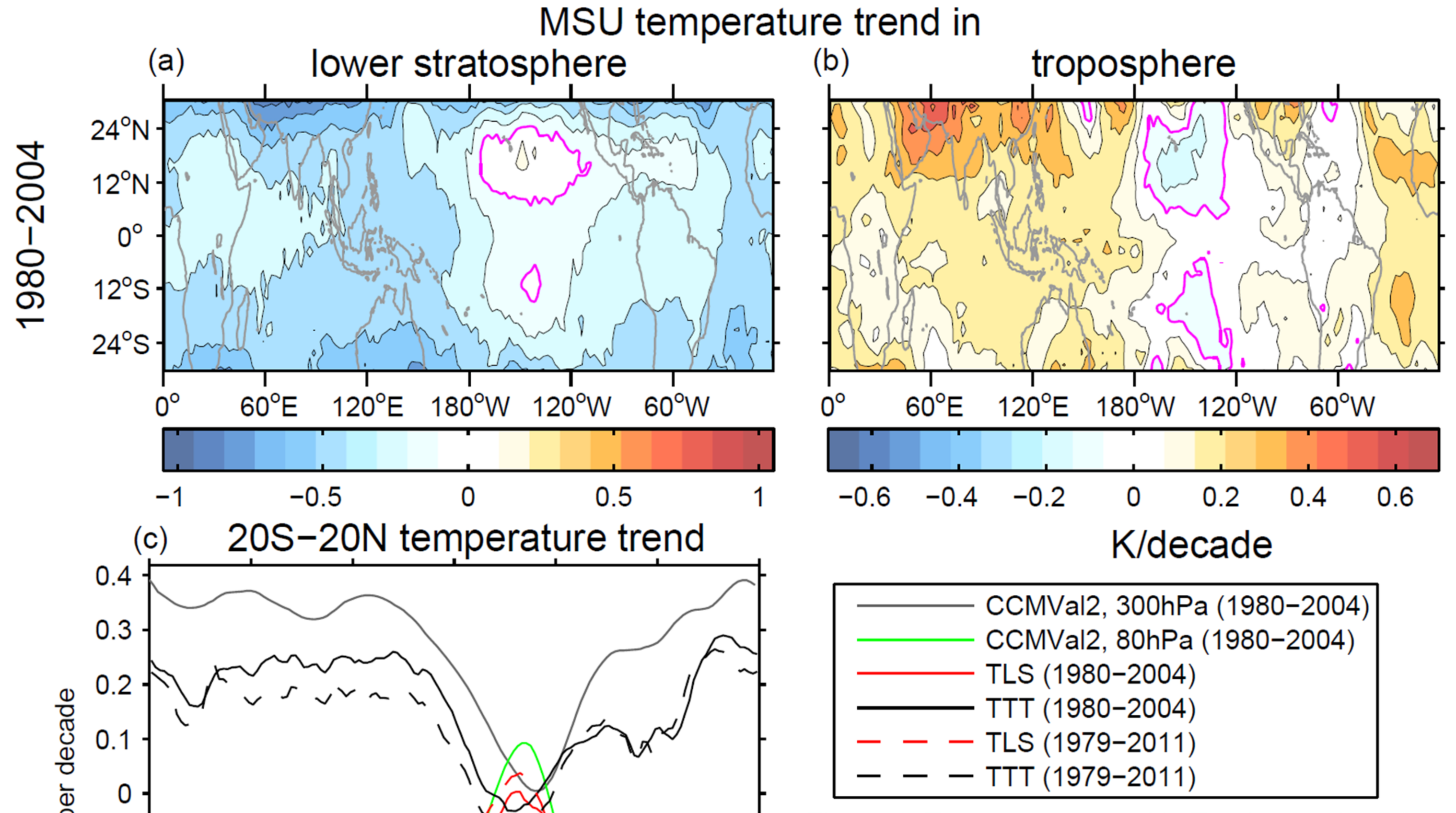
●Sea surface temperatures (SSTs) can impact these regions directly on a wide range of timescales.

●This work uses satellite data and targeted model experiments with the GEOSCCM to show that:

1. Over the satellite era, rising SSTs in the Indian Ocean and Warm Pool region have led to a circulation response that extends up to 70hPa that includes local cooling in the TTL. Future changes in SST are projected to lead to similar changes. This leads to tropical ozone trends that are highly zonal; in addition, because cold point temperatures decrease, the stratosphere dehydrates (2-6).

2. El Nino leads to stratospheric dehydration, though the magnitude of the dehydration is highly sensitive to the nature of the El Nino event and seasonality (7-9).

(2) Jan.-March Tropical Temperature Trends



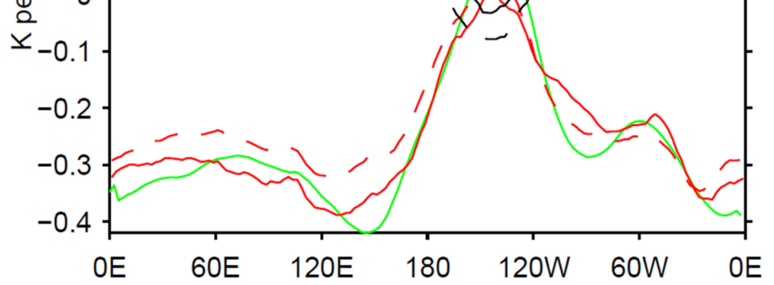


Figure 1: Temperature trend in Tropics for the RSS (a) lower stratosphere (TLS) and (b) troposphere (TTT) channels during JFM. The zero line is magenta, and the contour interval is 0.15K/decade for TLS and 0.1 K/decade for TTT. (c) Summary of the tropical temperature trends in JFM in the satellite data, in the CCMVal2 multi-model mean, and upon changing the starting and ending points of the linear best fit used to calculate the trend.

●Regions in the troposphere that have cooled relative to the zonal mean have warmed in the lower stratosphere, and vice versa. The cooling in the lower stratosphere was strongest in the warm pool region and weakest in the eastern Pacific.

●This effect is present in both the satellite record and in the multi-model mean of the CCMVal-2 models in the historical forcings scenario. This effect is robust to excluding individual CCMVal-2 models, and it is insensitive to changing the end points of the trend.

(3) Trend Model Experiments

●Six member ensemble of AMIP-style integrations with GEOSCCM v2, 2°x2.5° resolution, 72 levels from surface to 0.01hPa.

●The only external forcing is that SSTs follow those observed from 1980-2006. We thus isolate the impact of changing SSTs only.

(4) Vertical Structure of Temperature Trends

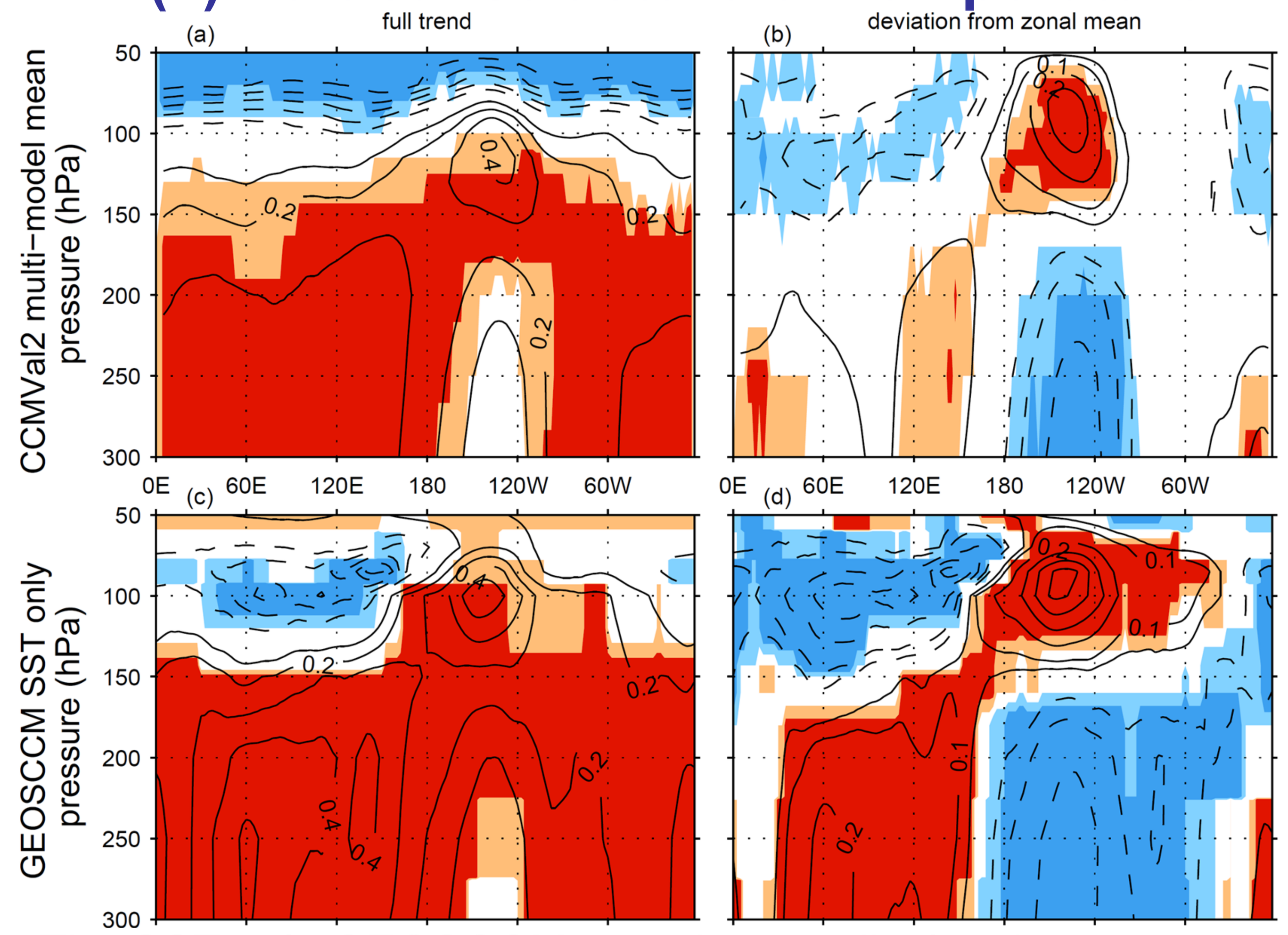


Figure 2: Vertical structure of the trend in JFM in the Tropics (20S-20N) in (top row) the multi-model mean of the CCMVal2 models. (a) full trend, (b) deviation from the zonal mean. (c,d) like (a,b) but for the GEOSCCM SST only experiments. The contour interval is 0.1K/decade, and the ±0.05K/decade contour is added for (b) and (d). The zero contour is omitted. Regions in which the trend is robust among the ensemble members are indicated by red and blue.

●The SST only GEOSCCM experiments display the same vertical/zonal structure found in the CCMVal2 models, strongly suggesting that SST trends have driven these UT and LS trends.

(5) Drivers of the Temperature Trend

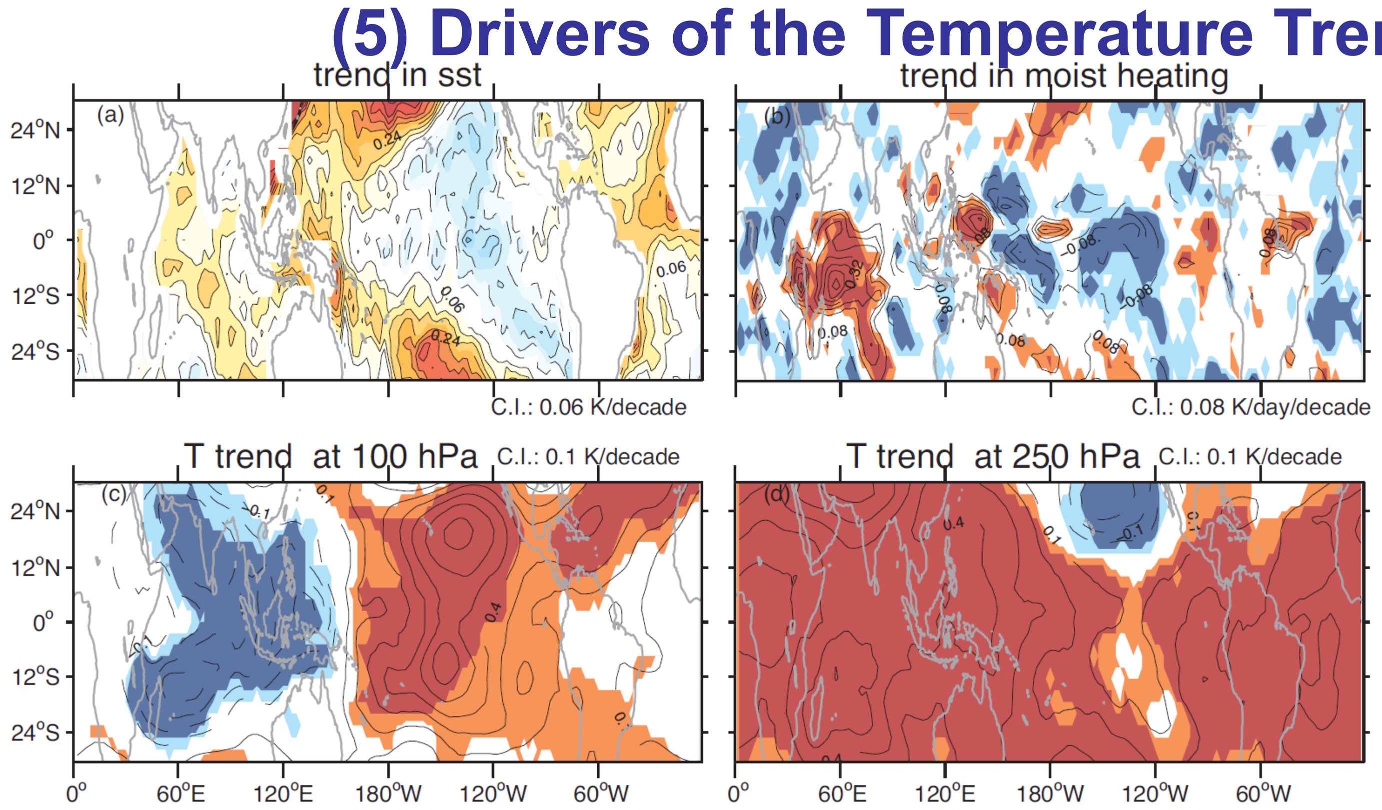


Figure 3: Trend in JFM in the ensemble mean of the SST-only GEOSCCM ensemble. (a) sea surface temperatures; the contour interval is 0.06 K/decade, (b) moist heating pressure weighted from 500hPa to 150hPa; the contour interval is 0.08 K/day/decade except that the 0.02 K/day/decade contour is added, (c-d) lower stratospheric and upper tropospheric temperature; the contour interval is 0.1K/decade, The zero contour is omitted. Statistical robustness of the trend is indicated by red and blue.

●SSTs have warmed over the Indian Ocean and warm pool region, driving increased convection locally and a large scale Gill response in the UT and TTL.

(6) Impact on Ozone and Water Vapor

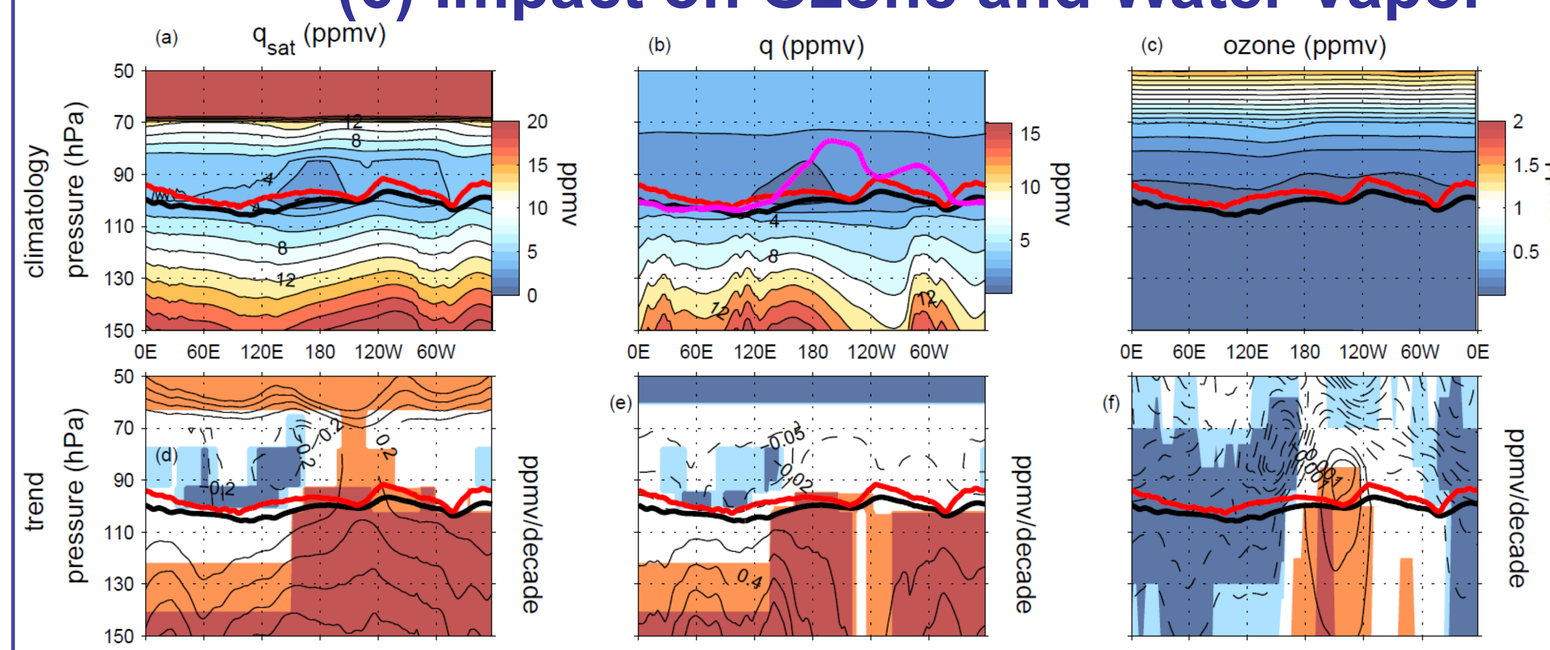


Figure 4: The climatology and trend in JFM in the ensemble mean of the GEOSCCM SST only ensemble for (a,d) saturation vapor pressure, (b,e) moisture, and (c,f) ozone. The climatological location of the tropopause is indicated with a thick black line for the mean climate.

●These changes leads to lower saturation vapor pressure in the cold point region in the western Pacific, and thus to less stratospheric water vapor.

●These changes also lead to strong ozone anomalies due to anomalous vertical motion.

(7) ENSO Model Experiments

●Four 50-year AMIP-style integrations with GEOSCCM which differ only in the imposed SSTs: NTRL, EPW, CPW, and CPWideal.

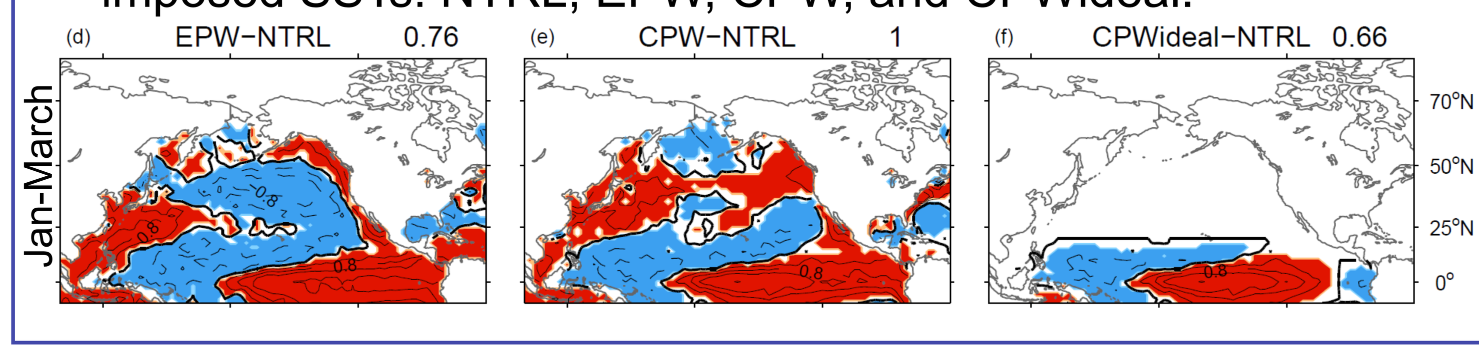


Figure 5: JFM SST used to force the perpetual ENSO GEOSCCM integrations, as compared to the neutral ENSO experiment. Contours are shown at ±0.4, ±0.8, ±1.2, ±2, and ±3K. Anomalies greater than 0.1K are shaded.

(8) ENSO: Tropical Water Vapor

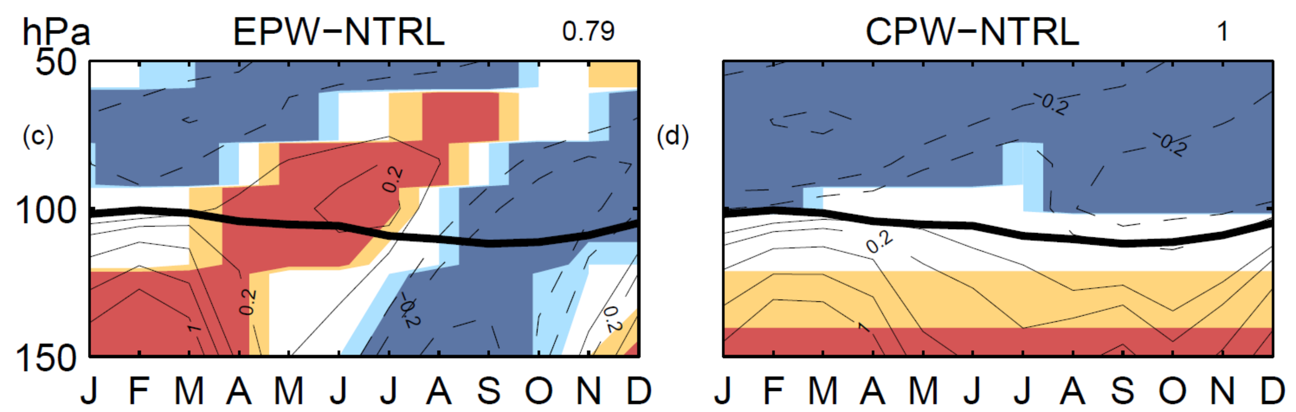


Figure 6: Tropical water vapor (20S-20N) in the perpetual CPW and EPW GEOSCCM integrations over the course of the year. Contours are shown at ±0.1, ±0.2, ±0.4, ±0.7, ±1ppmv, and regions with anomalies significant at the 90% (99%) level are colored orange(red) or light blue (dark blue). A solid black contour indicates the climatological tropopause.

- In the annual average El Nino leads to less stratospheric water vapor.
- EPW leads to more stratospheric water vapor than CPW.
- Both variants lead to maximum lower stratospheric water vapor in the springtime after the El Nino events has peaked. The anomaly then propagates upwards, consistent with the tape recorder effect.

(9) ENSO: Temperature at 100hPa

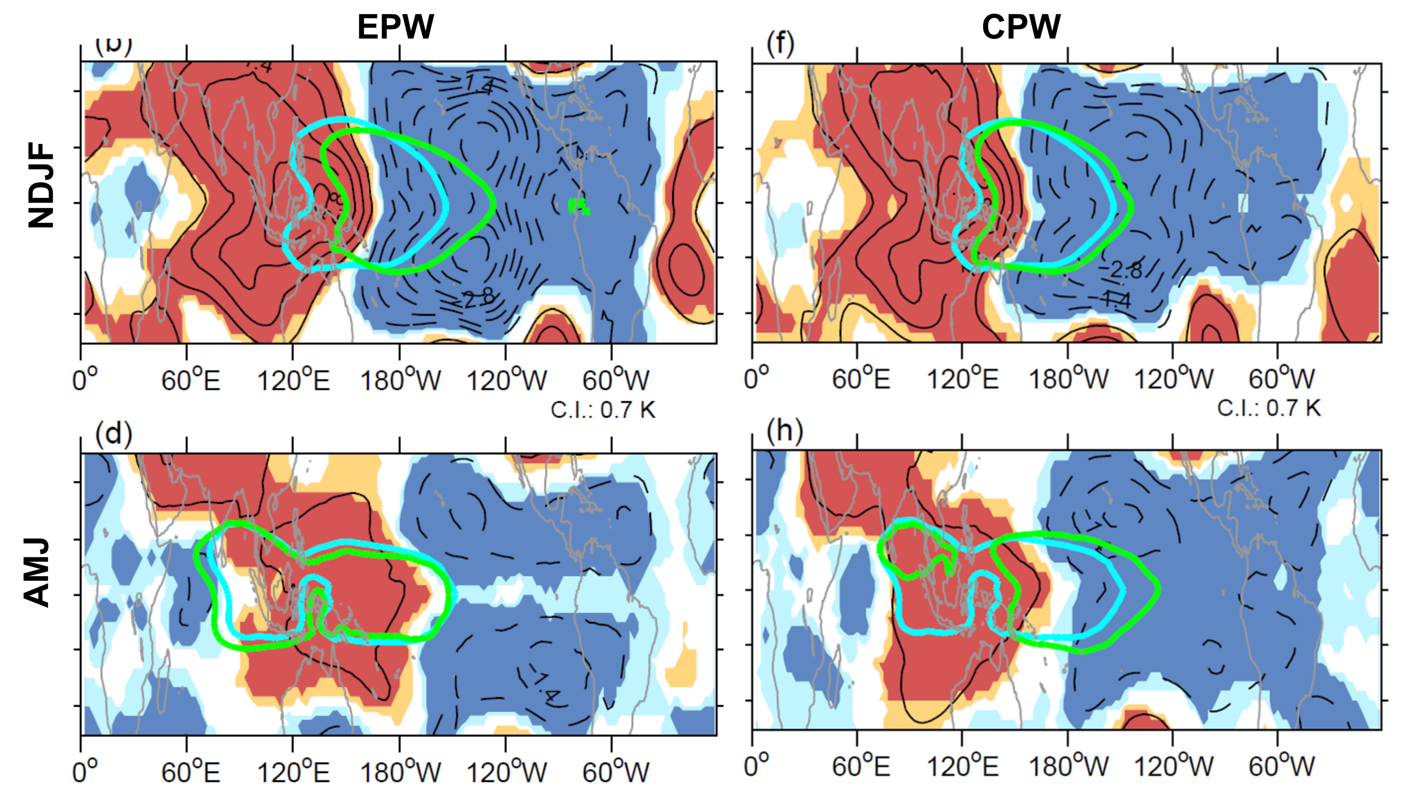


Figure 7: Temperature anomalies at 100hPa during EPW and CPW in midwinter (top) and in spring (bottom). Color indicates regions in which the model responses are robust . The cyan contour represents the cold point region during Neutral ENSO, and the green contour represents the cold point region during El Nino. The cold point region represents the region water vapor must pass through before it enters the stratosphere, and it shifts to the west towards India during AMJ.

●During midwinter, temperature changes in the cold point region are non-uniform: the western half warms, but the eastern half cools. The net effect is that the cold point region cools during both EPW and CPW.

●In springtime, the temperature anomalies are locally of smaller magnitude, but nearly the entire cold point region warms during EPW. During CPW, the warming is shifted to the east, and thus the net temperature change is small.

●Similar response in the 6 member ensemble discussed in the middle column and in the CPWideal experiment.

References, and for Additional Details

Garfinkel, C. I., M. M. Hurwitz, L. D. Oman, D. W. Waugh (2013), Contrasting Effects of Central Pacific and Eastern Pacific El Nino on Stratospheric Water Vapor, GRL, 40, 4115--4120, doi: 10.1002/grl.50677.

Garfinkel, C.I., D. W. Waugh, L.D. Oman, L. Wang, and M.M. Hurwitz, (2013). Temperature trends in the tropical upper troposphere and lower stratosphere: connections with sea surface temperatures and implications for water vapor and ozone, Journal of Geophysical Research: Atmospheres, 118(17), 9658-9672, doi: 10.1002/jgrd.50772