Volcanic Eruption Signals in Large Ensembles

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Abstract: Volcanic eruptions are the largest natural cause of climate change, on time scales from seasonal to interannual to decadal. Large ensembles offer the opportunity to examine these responses and compare them to the impacts of random weather and climate variability driven from atmospheric chaos, and the impacts of El Niño Southern Oscillation impacts. The Community Earth System Model Large Ensemble (LE) has produced 42 ensemble members of simulations for 1920-2100, and the Decadal Prediction Large Ensemble project (DPLE), has produced decadal simulations starting with actual initial conditions for each year for 1954-2015, with 40 ensemble members for each year, both using the same CAM5 climate model at 1° horizontal resolution. In addition there are 10 ensemble members each from runs with the same model with specified sea surface temperatures, either global (AMIP goga – global ocean global atmosphere) or tropical only (AMIP toga – tropical ocean global atmosphere). The forcing from the three largest volcanic eruptions in this period, 17 March 1963 Agung, 4 April 1982 El Chichón, and 15 June 1991 Pinatubo, as well as smaller eruptions, are included in all these runs. To examine the responses to the Agung, El Chichón, and Pinatubo eruptions in the following years, results of the DPLE runs starting on 1 November of 1962, 1981, and 1990, the LE simulations for the same periods, which were not initialized with actual initial condition, and the AMIP goga and AMIP toga runs are compared to observations. In particular, the "winter warming" surface air temperature pattern in the following Northern Hemisphere winter is examined. The average anomaly response for each ensemble is calculated by comparing to the average of the previous five years, but for DPLE, the LE mean from the previous five years was used. Examples of each ensemble member for the Northern Hemisphere winter following the 1982 El Chichón eruption are shown for the DPLE, AMIP goga and AMIP toga runs.

Uncertainties: The volcanic forcing in the ensembles was not interactive with the model and the CAM5 climate model only had 30 levels with limited resolution in the stratosphere. Therefore, these results should serve as a comparison to future runs that would start with the same initial conditions at the time of the eruption for each ensemble member, to examine the importance of initialization and interactive stratospheric aerosols.

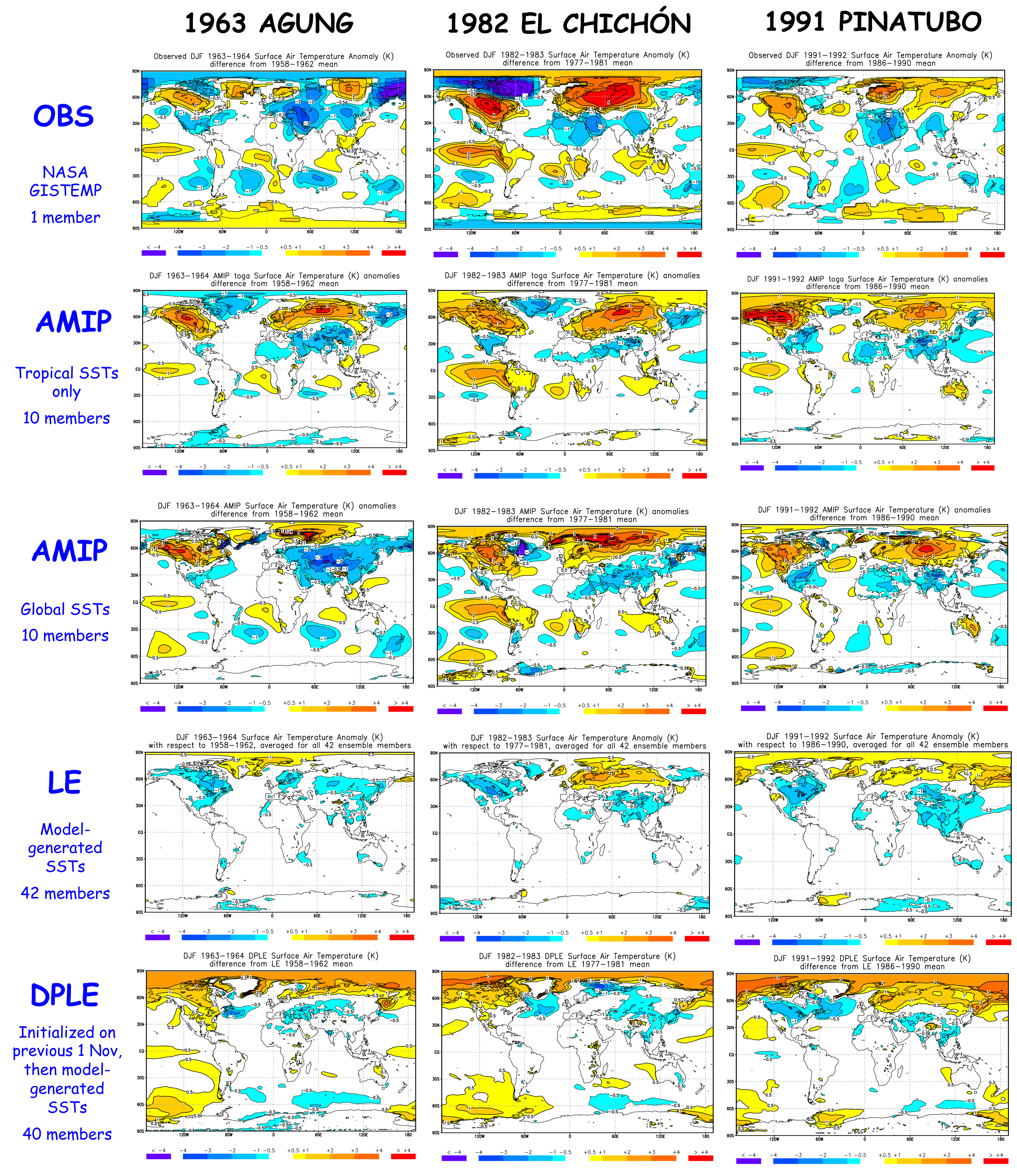

Fig. 1. DJF surface air temperature anomalies after the 1963 Agung, 1982 El Chichón, and 1991 Pinatubo eruptions, with respect to the average of the previous 5 years. **Top row:** Observed; data from GISTEMP team (2019). **Second row:** AMIP toga Large Ensemble (Lehner et al., 2018). **Third row:** AMIP goga Large Ensemble (Lehner et al., 2018). **Fourth row:** CESM Large Ensemble (Kay et al., 2014). **Fifth row:** CESM Decadal Prediction Large Ensemble (Yeager et al., 2018).

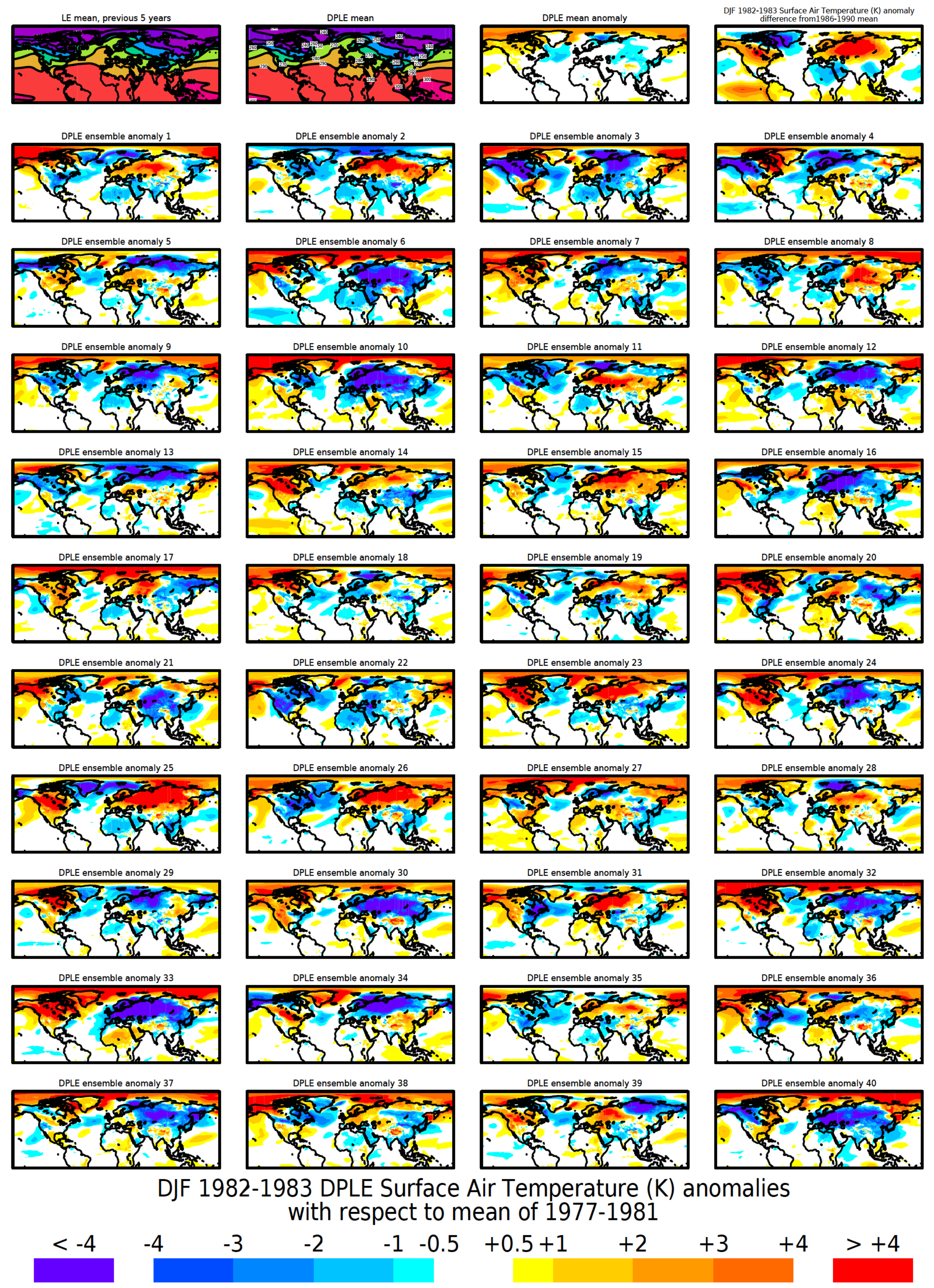

Fig. 4. DPLE DJF individual ensemble anomalies for El Chichón with respect to the previous 5 years.

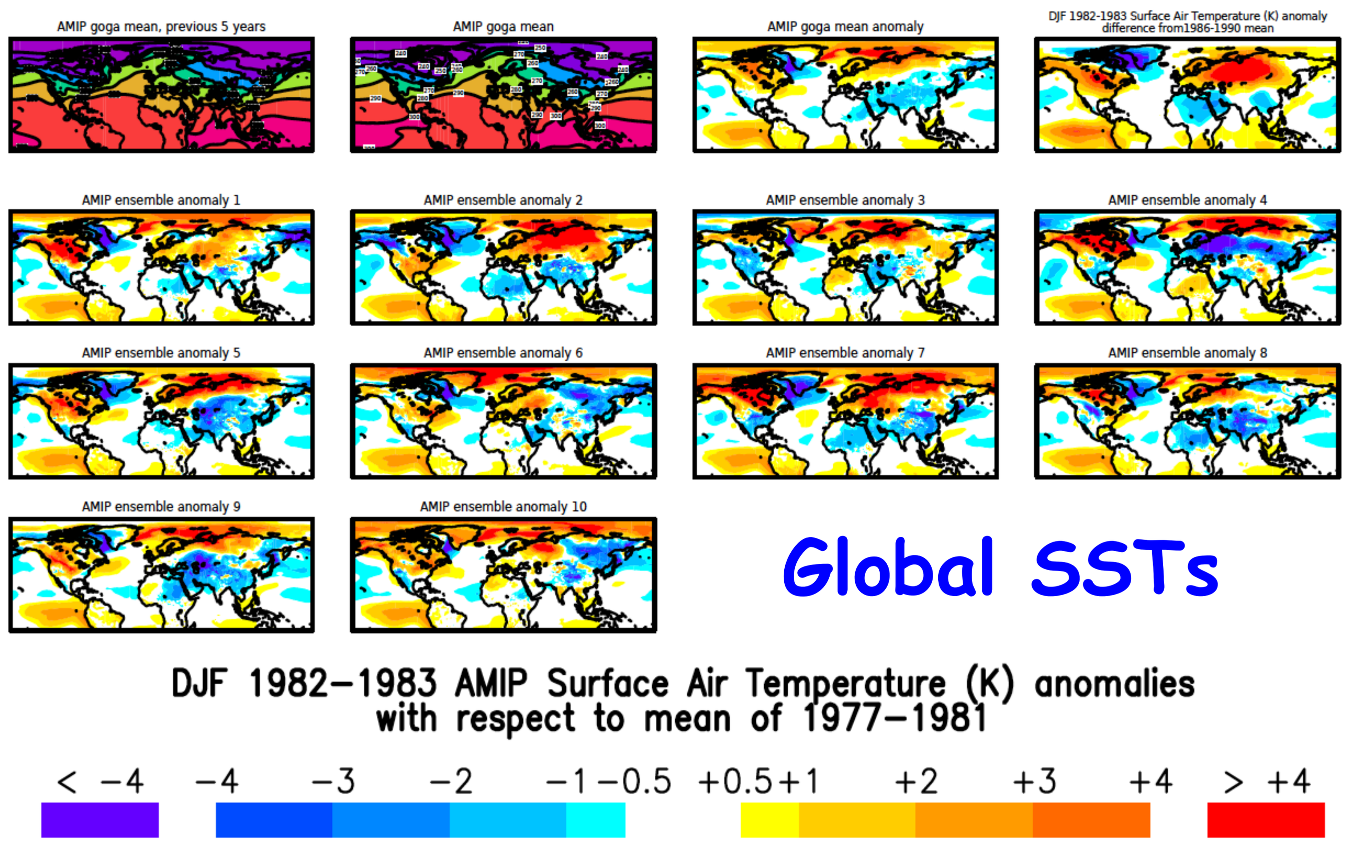

Fig. 2. AMIP DJF individual ensemble anomalies for El Chichón with respect to the previous 5 years, using **global** sea surface temperatures.

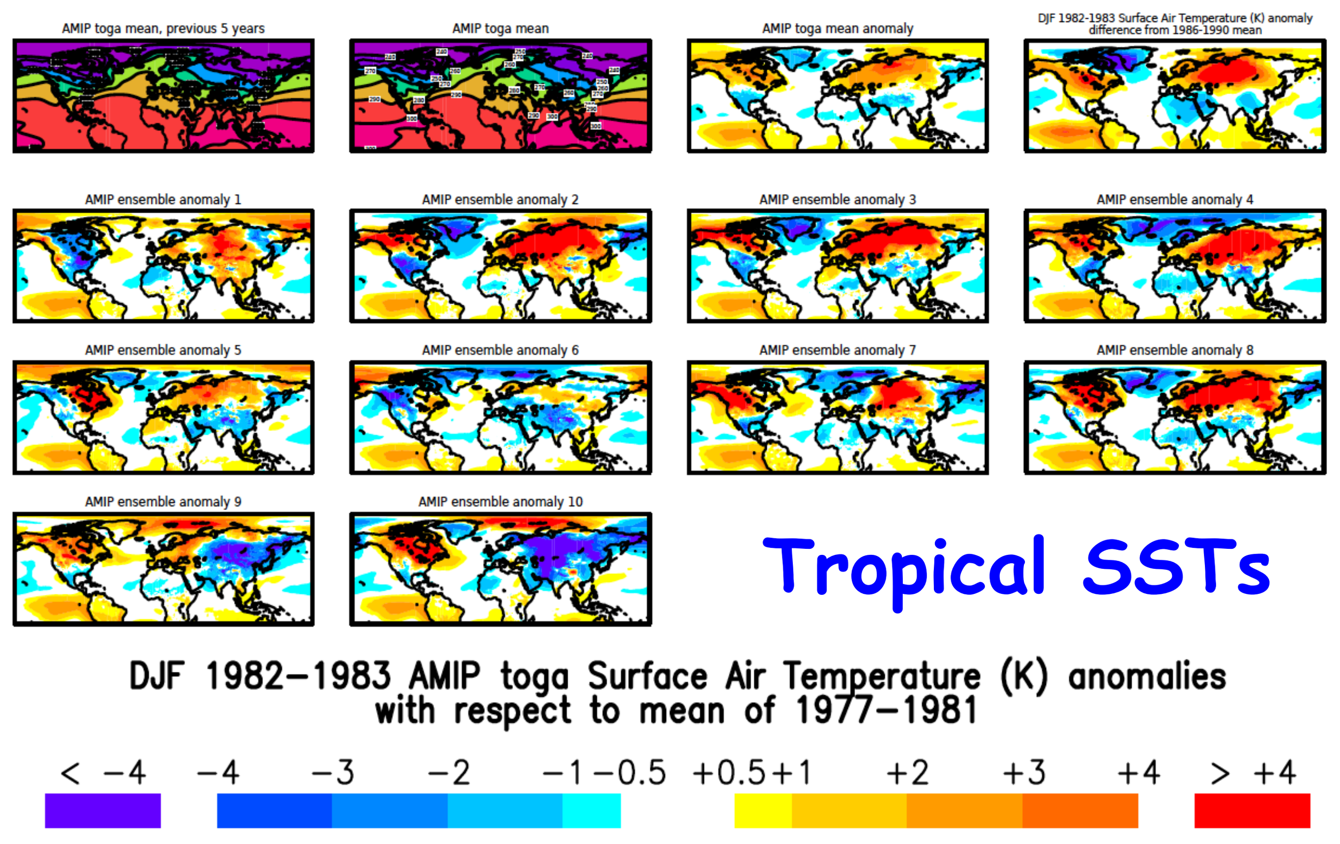

Fig. 3. AMIP DJF individual ensemble anomalies for El Chichón with respect to the previous 5 years, using **tropical** sea surface temperatures.

Results and Conclusions

- AMIP simulations, with specified sea surface temperatures (SSTs), either tropical only or global, do a good job of simulating observed winter warming after large volcanic eruptions. This is surprising, as Oehrlein et al. (2019) found that El Niño is associated with a negative Arctic Oscillation in the absence of volcanic eruptions. This requires further investigation.
- The Large Ensemble simulations with free running oceans do not simulate the observed El Niño after each eruption, and only produce weak winter warming as shown previously by Polvani et al. (2019).
- The DPLE simulations, even though initialized with observed SSTs on 1 November of the year before the eruptions, do not simulate the observed El Niños.
- While the observations show warming east of the Antarctic Peninsula for all the volcanic eruptions (Verona et al., 2019), none of the ensembles reproduce it.
- Next steps: add statistics and look at precipitation.

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