Dynamics of the ENSO impact on the tropical upwelling

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OBJECTIVE

We aim to investigate the El Niño-Southern Oscillation (ENSO) impact on the tropical upwelling in the Upper Troposphere/Lower Stratosphere (UTLS) region, and assess the importance of a well resolved stratosphere in this relationship

DATA AND METHODS

- European Consortium **EC-EARTH** coupled climate model *version 3.1*
- IFS cy36r4 **ATM** / NEMO3.3 ORCA1L46 **OCN**
- Fixed radiative forcing at year 2000
- El Niño3.4 region:
  5N-5S & 170W-120W

SIMULATIONS	RESOLUTION
HIGH-TOP (**HT**) 101 yrs	T255L91
NUDGED (**NUDG**) 101 yrs	T255L91 (nudging to climatology 10hPa)
LOW-TOP (**LT**) 101 yrs	T255L62

REANALYSIS (1958-2015)
HaddISST (Rayner et al. 2003)
JRA-55 (Ebita et al. 2011)

RESULTS

I. ENSO IN EC-EARTH

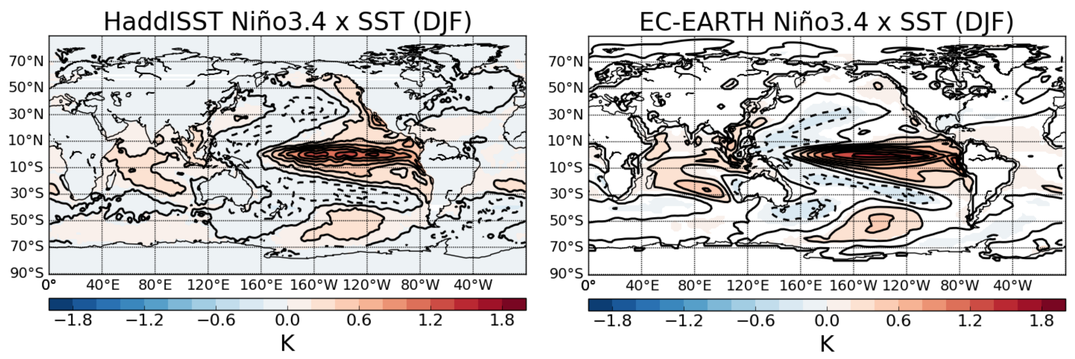


Figure 1. Regressions maps of December-January-February (DJF) sea surface temperature (SST) anomalies onto the Niño3.4 index for (left) HaddISST and (right) EC-EARTH.

- EC-EARTH realistically simulates the El Niño SST pattern in the tropical Pacific. This result does not depend on the vertical resolution, i.e., how the model resolves the stratosphere.
- The warm SST tongue is stronger in the model and slightly shifted to the central Pacific as compared to HadISST.

II. ZONAL-MEAN TEMPERATURE RESPONSE

- ENSO yieds a tropical tropospheric warming, particularly at the UT, and a tropical stratospheric cooling at the LS. The former is associated with the ENSO-related diabatic heating in the tropical Pacific and the thermal response along the tropical belt. The latter is associated with the intrusion of tropospheric warm anomalies into a relatively warmer environment in the stratosphere, that is a relative cooling.
- EC-EARTH reproduces the ENSO-related temperatura anomalies in the UTLS, in particular HT. In NUDG and LT, these anomalies are overestimated .

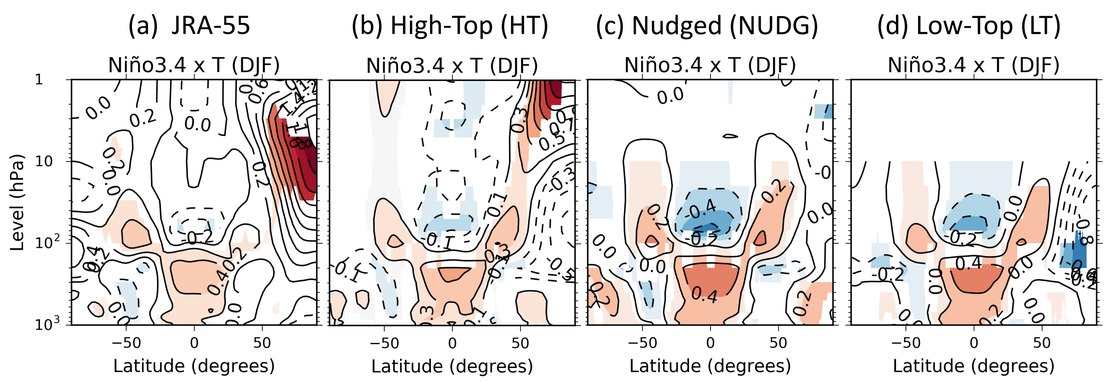


Figure 2: Latitude-height cross section regressions of zonal-mean temperature anomalies (K) onto the Niño3.4 index for: (a) JRA-55, (b) High-Top, (c) Nudged and (d) Low-Top simulations.. Only significant differences at the 95% confidence level are shaded.

III. LONGITUDE x LATITUDE TEMPERATURE AND STREAMFUNCTION

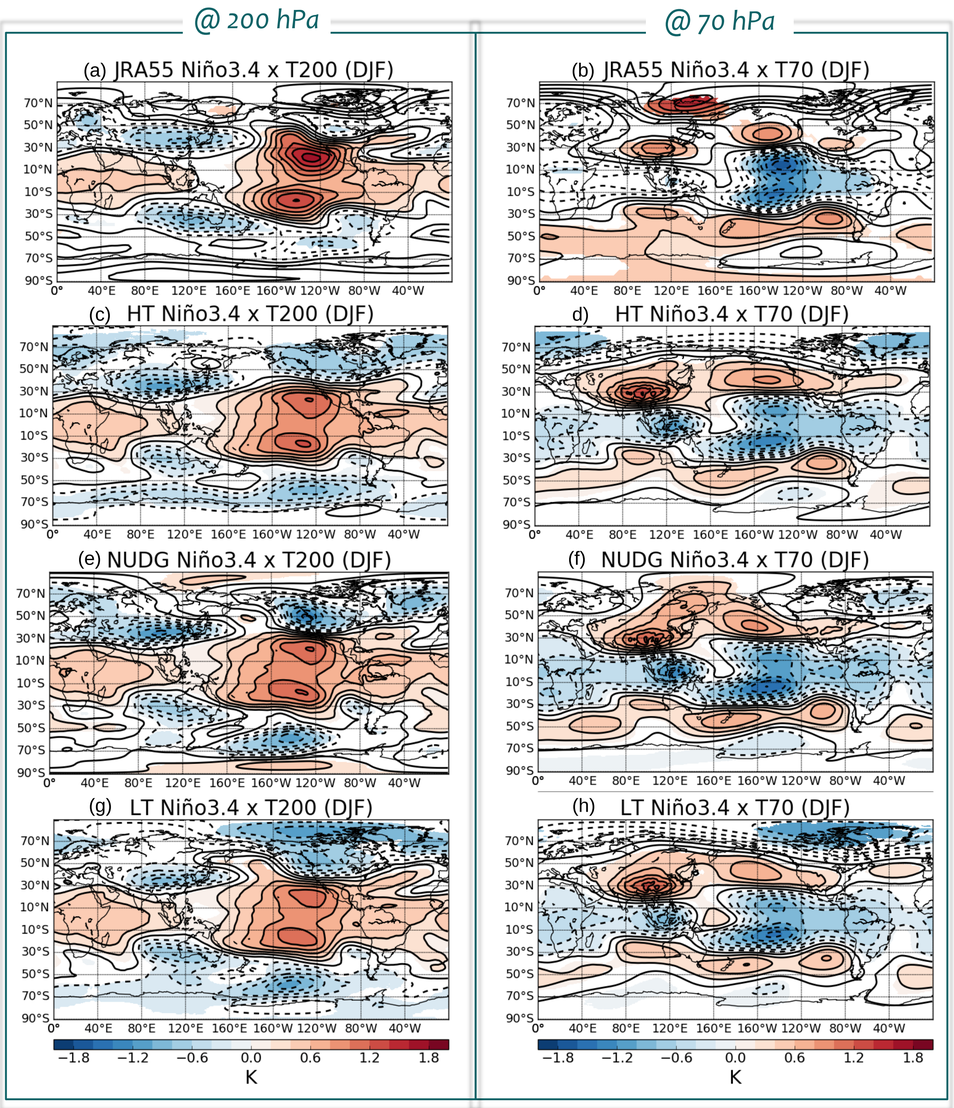


Figure 3: Regression maps of temperature anomalies onto the Niño3.4 index for at (left) 200hPa and (right) 70hPa for: (a,b) JRA-55, (c,d) High-Top, (e,f) Nudged and (g,h) Low-Top simulations. Only significant differences at the 95% confidence level are shaded.

- The regression maps of air-temperature emphasize the zonal asymmetries of the ENSO-related anomalies in the tropics. For T200: the warming lobes straddling the equator in the tropical Pacific illustrates the local Gill-type response to the ENSO diabatic heating (Matsuno 1966, Gill 1980); the off-equatorial cooling lobes in the Indo-Pacific region depicts the remote Gill-type response to the ENSO zonally-compensated diabatic cooling over the Maritime Continent (DeWeaver and Nigam 2004).
- The streamfunction anomalies at 200hPa show the circulation anomalies associated with both the local and remote Gill-type responses. These baroclinic structures involve upward and downward motions in the tropical Pacific and Indo-Pacific regions, respectively.
- The regression maps of T70 display the mirrored, opposite anomalies along the UTLS, which suggests that the vertical motions associated with the Gil-type responses remain at play.

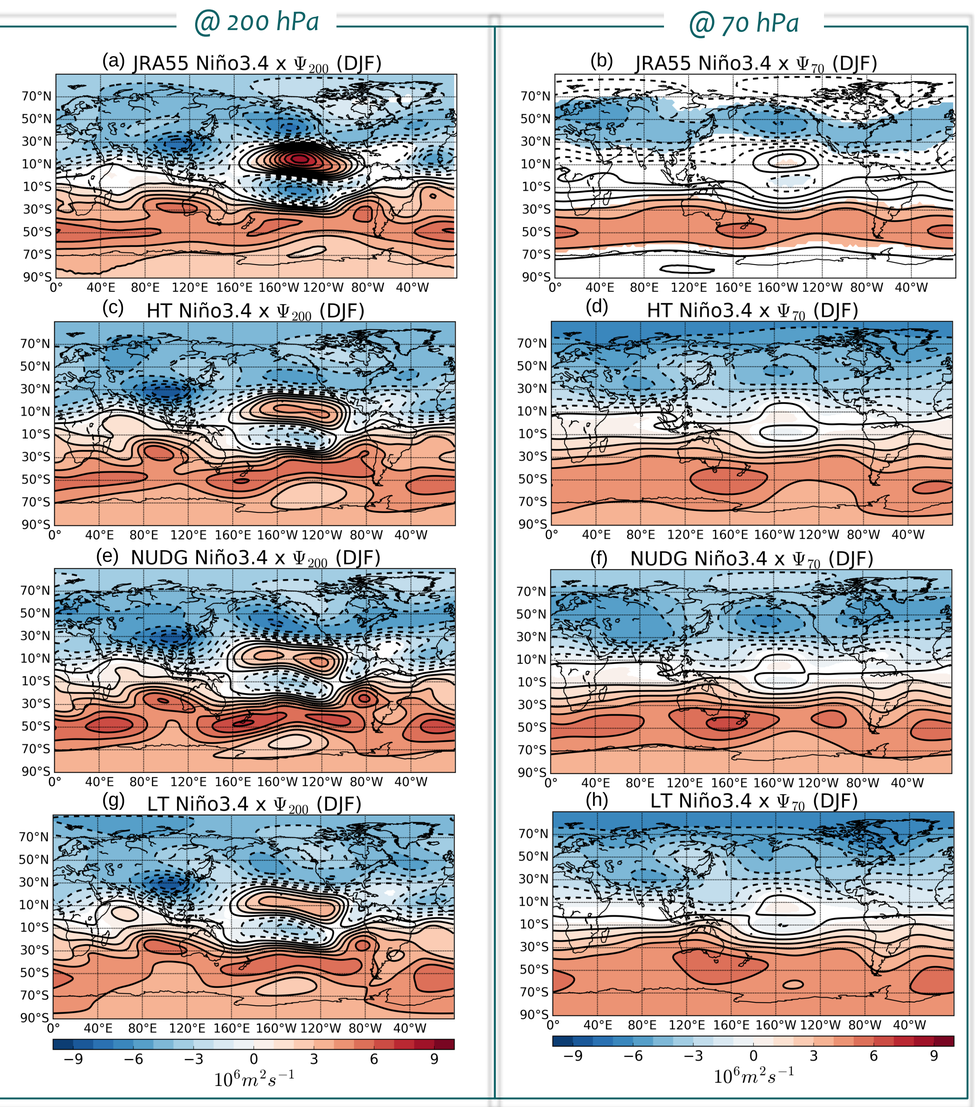
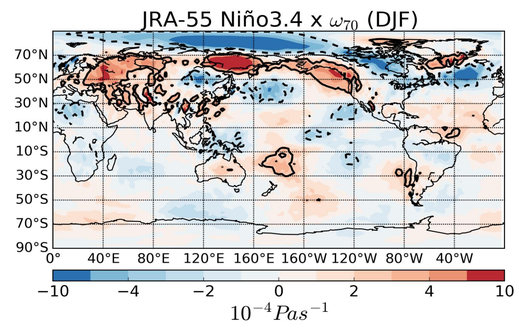


Figure 4. As in Figure 3 but for the streamfuncion anomalies.

TAKE HOME MESSAGES

- A well solved stratosphere is esential to obtain a realistic ENSO response in the UTLS region and the polar warming in the stratosphere.
- There are strong zonal asymmetries in the ENSO-related tropical temperature anomaly.
- The zonal-mean cooling in the lower stratosphere, is dominated by the dipole anomaly straddling the equator in the tropical Pacific and the monopole over the Maritime continent.
- How much of the upward motion in the UTLS is tropically induced via Gill-type response / extra-tropically induced via reinforcement of the Brewer-Dobson circulation? 🤔

Future work



Our preliminary results show two lobes of upward motion in the central Pacific in agreement with Figs. 3 and 4. However, there is an equatorial upwelling that cannot be explained with the Gill model and are presumably related to the Brewer-Dobson circulation.

Figure 3: Regression maps of the vertical velocity (omega) at 70 hPa onto the Niño3.4 index for JRA-55. Reddish (blueish) colors indicate downward (upward) motion. Only significant differences at the 95% confidence level are shaded.

References

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