Impact of the stratosphere on the winter tropospheric teleconnections between ENSO and the North Atlantic and European Region

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Chiara Cagnazzo and Elisa Manzini*, Centro Euro-Mediterraneo per i Cambiamenti Climatici, Bologna, Italy, (cagnazzo@bo.ingv.it)
•also at Istituto Nazionale di Geofisica e Vulcanologia, Bologna, Italy

1. Introduction and Motivation

The state and variability of the lower stratosphere may affect tropospheric climate (Baldwin and Dunkerton 2001; Thompson and Wallace 2000; among others). However, current climate models (coupled atmosphere ocean models as those used for climate projection, Randall et al 2007) usually include only a limited representation of stratospheric dynamics.

Purpose: To evaluate the role of the stratosphere in the teleconnection between ENSO and the North-Atlantic-European region (NAE) by means of simulations with atmospheric general circulation models. One of the models considered is the atmospheric component of a standard climate model (LOW TOP MODEL). The other model considered is a stratospheric resolving atmosphere model (HIGH TOP MODEL).

Implications: Contribute to determine the type of atmospheric models most appropriate for seasonal forecasting of the NAE winter climate.

2. Simulation and Methodology

Two 20-years ensembles of 9 simulations with prescribed observed SSTs and Sea Ice (1980-1999), respectively performed with:

(1) stratosphere-resolving atmosphere general circulation model: HIGH TOP MODEL, MAECHAM5, 39 vertical levels, surface to 0.01 hPa (Manzini et al 2006) (2) standard atmosphere general circulation model: LOW TOP MODEL, ECHAM5, 19 vertical levels, top at 10 hPa (Roeckner et al 2006)

Both MAECHAM5 and ECHAM5 employ T42 horizontal truncation and share the same physics, but for dissipation close to their respective model tops.

Monthly means of meteorological variables from each ensemble of simulations are combined into composites for extracting the response of the troposphere - stratosphere system to ENSO during the extended boreal winter season. ENSO anomalies = warm ENSO composite minus NEUTRAL composite.

Warm ENSO events considered: 1982/83, 1986/87, 1991/92, 1997/98. NEUTRAL= the 11 years, within 1980-1999, that are neither warm nor cold ENSO

3. Response of the troposphere -stratosphere system to ENSO

ENSO anomaly for the Zonal Mean T @ 70N, SSU/MSU satellite data

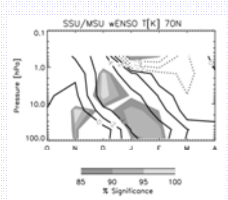

Figure 1. Impact of ENSO: polar warming of about 4 K in the lower stratosphere in late winter and spring. ENSO anomalies have been constructed as described above for the simulations

ENSO anomaly in the HIGH TOP and LOW TOP simulations for T @ 80N and U @ 60N

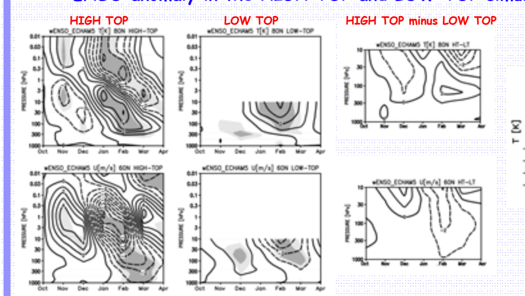

Figure 2. Polar warming and weakened polar vortex during ENSO. The U anomaly is significant down to the surface in Feb-Mar for the HIGH TOP. Shading: 95% and 99% statistical significance.

HIGH TOP(continuous) LOW TOP(dashed) @ 100 hPa

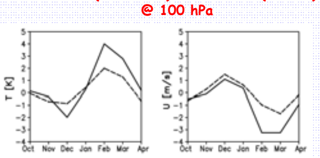

Figure 3. Cut of figure 2 at 100 hPa. The February temperature anomaly in the LOW TOP model is half the size than the HIGH TOP model. The polar vortex weakening in February and March is larger by a factor of 3 in the HIGH TOP with respect to the LOW TOP model.

ENSO anomaly in the geopotential height @ 50hPa FEBRUARY

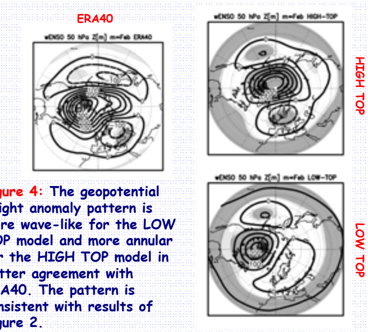

Figure 4: The geopotential height anomaly pattern is more wave-like for the LOW TOP model and more annular for the HIGH TOP model in better agreement with ERA40. The pattern is consistent with results of Figure 2.

4. ENSO and the Stratosphere: Sudden Stratospheric Warmings (SSWs)

Daily zonal mean zonal wind (m/s) at 60N, at 10 hPa and 70hPa (June to July)

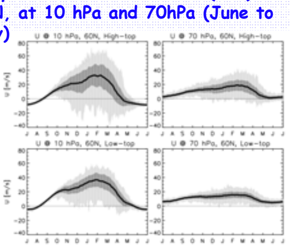

Figure 5. The mean behavior (climatological mean in black) is comparable for the HIGH TOP and the LOW TOP simulations, but the variability (dark grey=1 standard deviation) is significantly different and major SSWs are virtually absent in the LOW TOP model (light grey envelopes= individual maxima and minima).

Statistics of major SSWs for the HIGH TOP: frequency of occurrence by month over 9x20 years

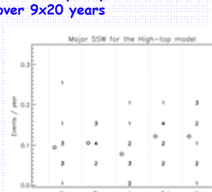

Figure 6: Black numbers= number of members with a given frequency. Diamonds=ensemble average frequency (9-member x 20-year time series). Realistic variability of the HIGH TOP (Charlton et al., 2007).

Daily zonal mean zonal wind (m/s) at 60N, at 10 hPa. Red thick curves = ensemble average stratified by ENSO (4 events). Red thin curves = time series of the 9 elements stratified by ENSO. Black curves and grey envelopes, as figure 5-left.

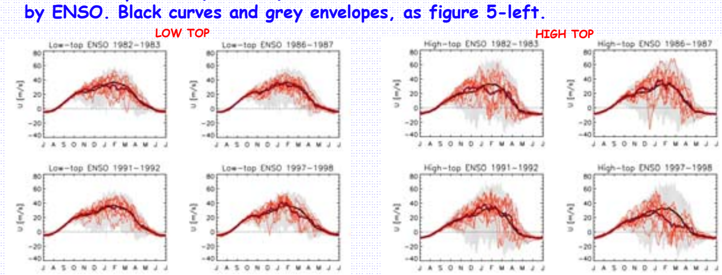

Figure 7: Strongest ENSOs: 1997-1998 and 1982-1983. For the HIGH TOP, results are consistent with Taguchi and Hartmann (2006): increased occurrence of SSWs during ENSO.

5. ENSO at the surface in late winter / early spring

February-March average of ENSO anomalies for the Sea Level Pressure (SLP), 1000 hPa Temperature and Precipitation

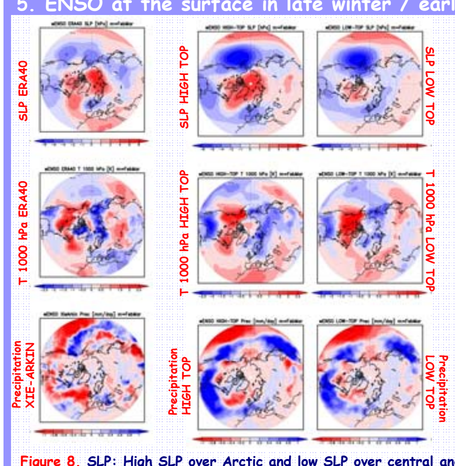

Figure 8. SLP: High SLP over Arctic and low SLP over central and west Europe. T 1000 hPa: low temperatures in North Europe, for the LOW TOP model the negative anomaly over Eurasia is confined North and the positive anomaly over the Arctic is virtually absent. Precipitation: increased precipitation over Southern Europe.

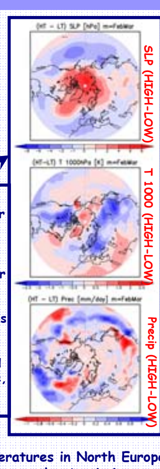

Figure 9. HIGH TOP minus LOW TOP: SLP= HIGH TOP shows higher pressures over the Arctic (+6hPa) and lower pressures over the Western Europe (-1hPa) and the North Pacific (-2hPa); more annular (or zonal) anomaly for the HIGH TOP model. Temperature: HIGH TOP anomaly is colder over Eurasia (-2 K) and warmer (1K) over the Arctic. Precipitation : 50% more for HIGH TOP in the West and South Europe, southward shift of the North Atlantic storm track

CONCLUSIONS

•The ENSO anomaly in the polar lower stratosphere (Figure 1) is reproduced also in the low top model (Figure 2), not including a well-resolved stratosphere. The zonal mean anomalies are however smaller in the low top model, in the lower stratosphere as well as in the troposphere (Figures 2 and 3). The reduced anomaly in zonal mean zonal winds for the LOW TOP model is consistent with a less annular (more wave-like) anomaly in geopotential height at 50 hPa during winter (Figure 4).

•The lack of SSWs in the LOW TOP model (Figures 5 to 7) demonstrates that planetary waves do not grow realistically enough, because they are subjected to artificial damping in the lower stratosphere. Lower stratospheric variability is therefore significantly reduced in the LOW TOP model.

•The more annular pattern of the ENSO anomaly is also found at the surface in SLP in February and March. Consistent anomalies in T1000 and precipitation (Figures 8 and 9) are also found.

•The picture that emerges it that of a stratospheric influence on the tropospheric ENSO-NAE teleconnection through downward propagation of zonal mean anomalies due to wave - mean flow interaction caused by SSWs.

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