Statosphere-Troposphere Coupling: Low frequency variability

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1. Introduction

The stratospheric flow is known to be characterized by considerable variability of dynamical origin at inter-annual time scales. Dynamical processes are responsible for the occurrence of Sudden Stratospheric Warming events (SSW) in the extra-tropics and the Quasi-Biennial Oscillation (QBO) in the Equatorial stratosphere. At longer timescales, the 11-yr solar cycle is a major driver of stratospheric variability. However, given the nonlinear nature of the climate system, there is also the possibility of dynamically driven inter-decadal variability of the stratospheric flow (e.g., Butchart et al 2000; Schimanke et al 2011). Here, the possibility of inter-decadal stratospheric variability is examined in a simulation with external forcing constant in time, done with a coupled atmosphere-ocean general circulation model that includes a well resolved stratosphere. The coupling to the ocean lets the troposphere - stratosphere evolution and variability to be consistent with the sea surface temperature evolution and variability. It is found that multi-decadal variability of the northern stratospheric flow reaches up to about a third of the total variability. The spatial and temporal characteristics of the decadal variations are presented.

2. Simulation & Model

261-years piControl experiment performed with the CMCC-CMS. The atmospheric component of the CMCC-CMS is ECHAM5, with top at 0.01 hPa and 95 vertical levels, T63 horizontal resolution and with the shortwave radiation scheme reported in Cagnazzo et al. (2007). It includes a well resolved stratosphere in the sense that stratospheric planetary wave – mean flow interaction leading to SSW is explicitly resolved and the effects of both orographic and non orographic gravity waves on the stratospheric and mesospheric large scale flows are parameterized (Manzini et al 2006). The version with 95 vertical levels also includes a spontaneously occurring QBO (e.g, Giorgetta et al 2006) . The ocean & seaice component of the CMCC-CMS is OPA-LIM, with 31 levels and horizontal resolution of 2°x2° with refinements around the Equator (Madec et al.1999; Timmermann et al. 2005) The coupling is described in Fogli et al. (2009).

3. Variability

Figure 3.1 (at right) November to March (NDJFM) zonal mean zonal wind standard deviation (STD): Ratio (in percent) between the STDs of the 11-year running and the inter-annual anomalies. Poleward of 30N (troposphere) and 60N (stratosphere) multi-decadal variability is 30% or more of the total variability.

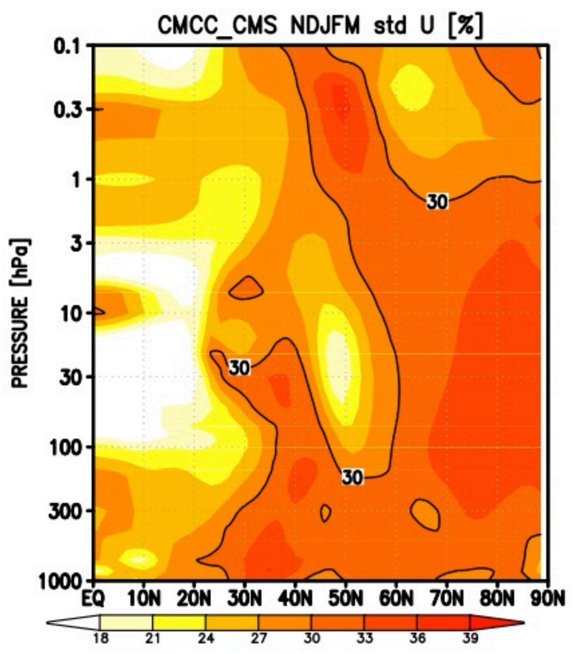
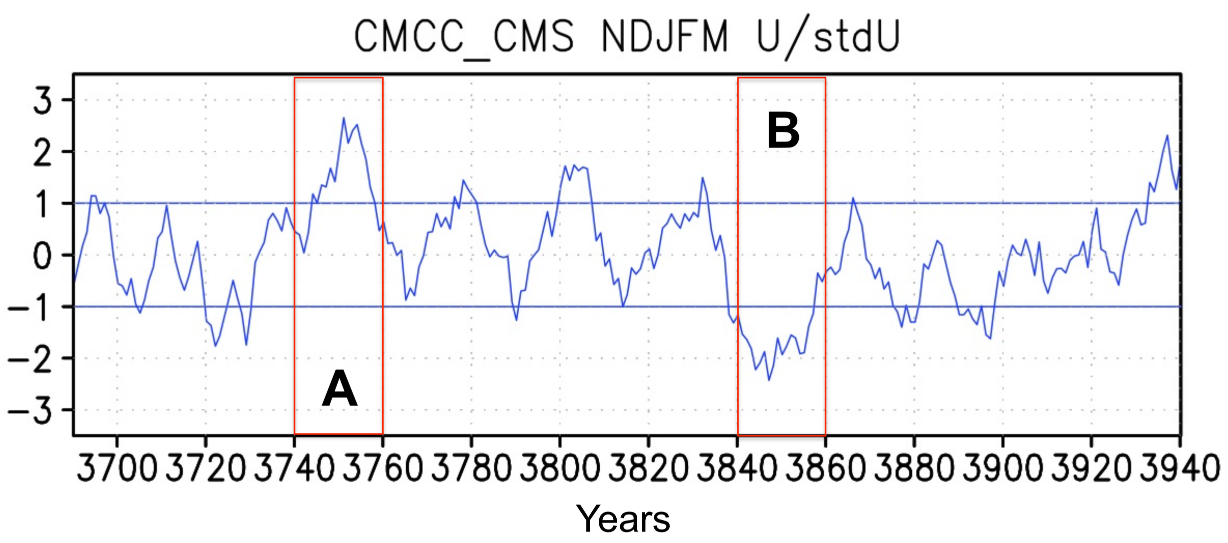


Figure 3.2 (below) Time series of the NDJFM zonal mean zonal wind anomalies (70N; 10 hPa). The time series is smoothed with an 11-year running mean and standardized.



A: strong vortex
B: weak vortex

Long lasting (>20 years) anomalies in zonal wind, identifying two anomalous time intervals, one with a strong polar vortex (**case A**, *years: 3740-3760*) and one with a weak stratospheric polar vortex (**case B**, *years: 3840-3860*): *How do the troposphere & stratosphere look like for such long lasting periods?*

4. Spatial and temporal characteristics: Composites for the A and B long lasting anomalies in NDJFM zonal mean zonal winds identified in Figure 3.2

Figure 4.1 Zonal mean zonal wind anomalies, strong vortex (A, left) and weak vortex (B, right).

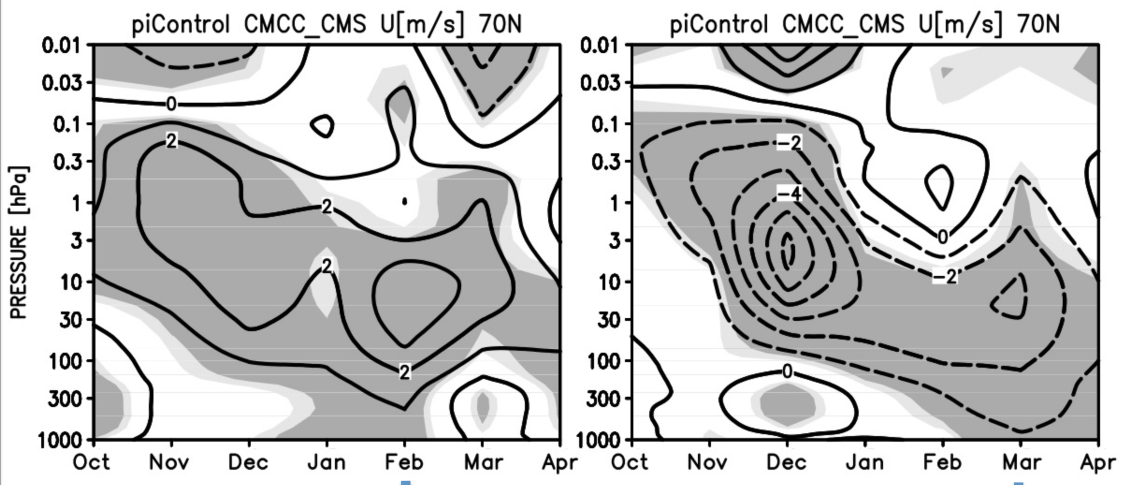
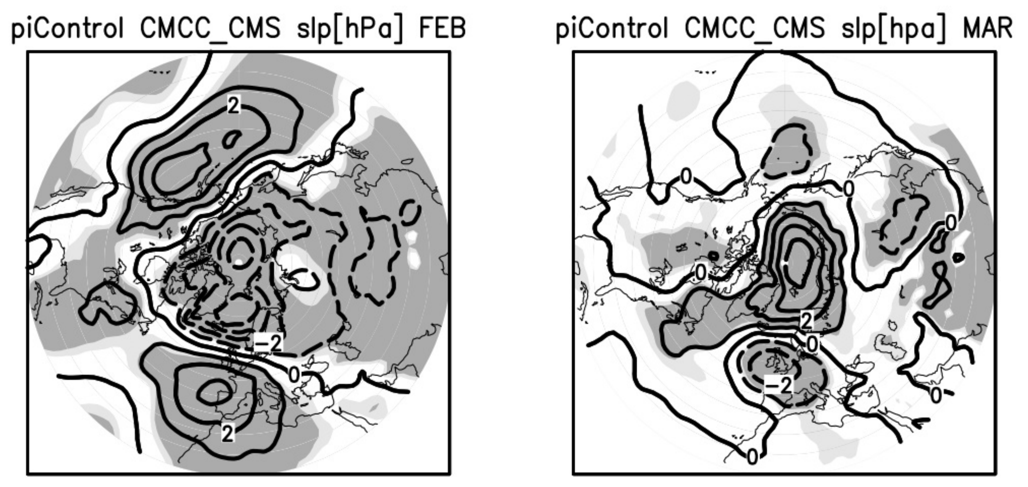


Figure 4.2 Mean sea level pressure anomalies for February, case A (left) and March, case B (right)



Light (dark) shading 95 (99) % stat sign level

Figure 4.3 Surface temperature anomalies for February, case A (top) and March, case B (bottom). Sown only for stat sign above 99% level

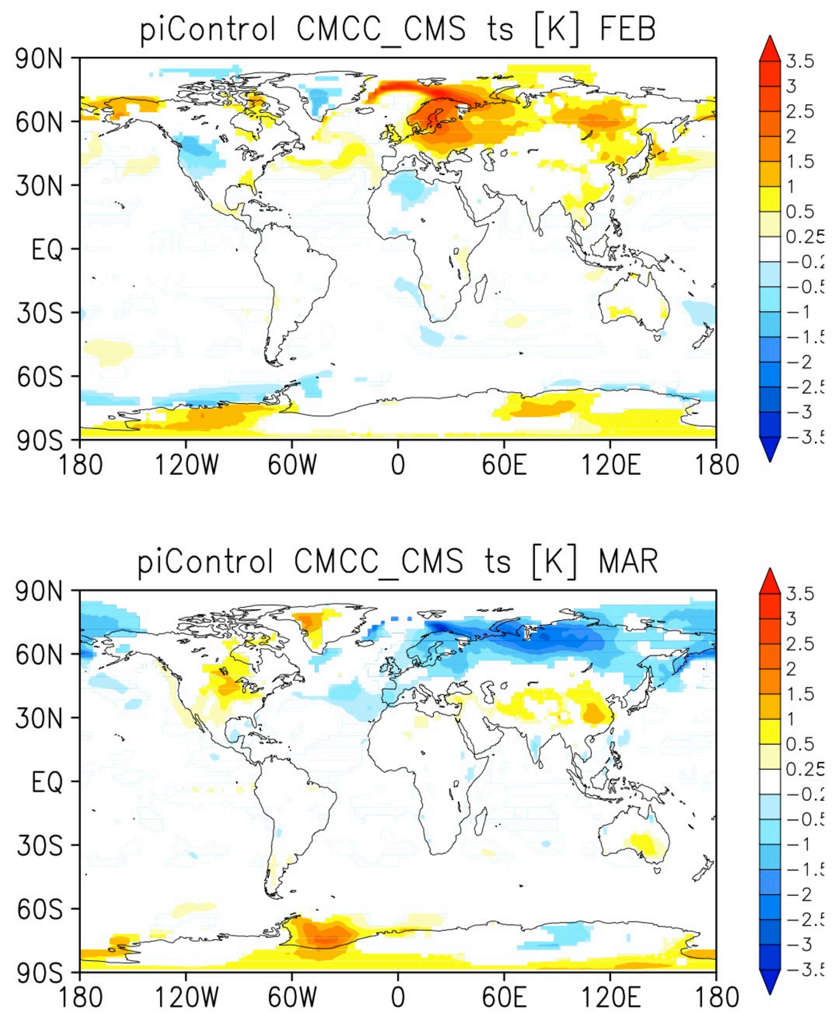
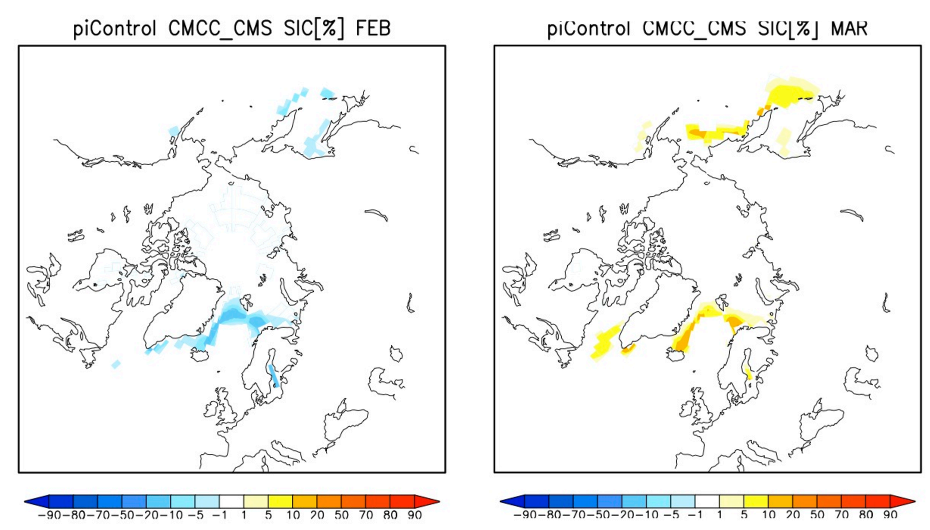
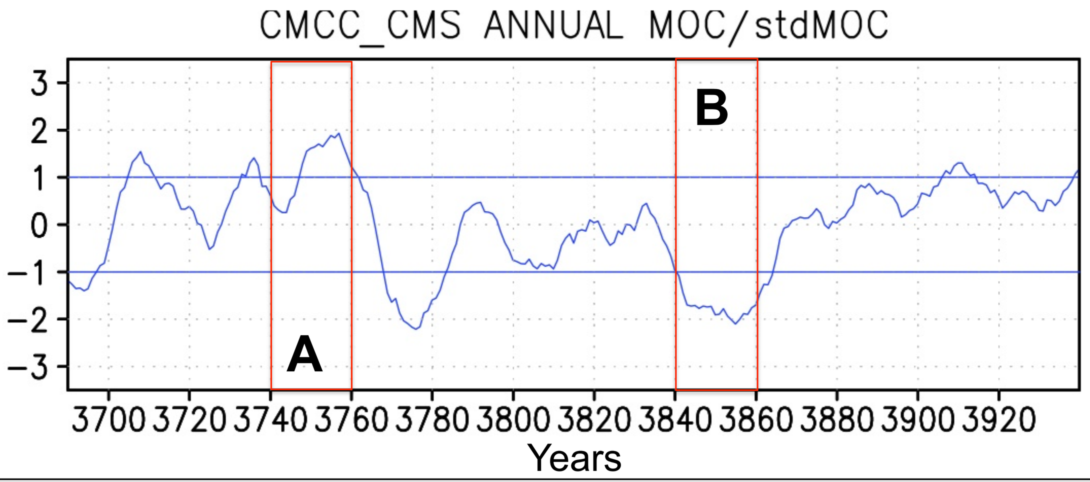


Figure 4.4 Sea ice cover anomalies for February, case A (left) and March, case B (right).



Sown only for stat sign above 99% level

Figure 4.5 Time series of the annual mean Atlantic Meridional Overturning Circulation (MOC) maximum anomalies. The time series is smoothed with an 11-year running mean and standardized.



5. Conclusions

- Long lasting (>20 years) anomalies of the polar vortex exist in the piControl run of an atmosphere-ocean sea-ice coupled model with a well resolved stratosphere. These variations are due to a change in the frequency of SSW events in the relative decades (about twice as much in the weak vortex, case B, wrt the strong vortex, case A; not shown).

- Multi-decadal stratosphere - troposphere system anomalies show coherent stratospheric / early winter to tropospheric & surface / late winter connections
  ➔ Potential for decadal predictability is suggested.

- Given the change in SSW frequency in the decades considered, inter-annual variations are also responsible for the stratosphere/troposphere connections at the multi-decadal scales.

- The connection to the mean sea level pressure, sea surface temperature and sea ice cover is indicative of the atmospheric forcing of the Atlantic meridional overturning circulation (Deshayes and Frankignoul 2008; Gastineau and Frankignoul 2011).

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SEVENTH FRAMEWORK PROGRAMME

MAX-PLANCK-GESELLSCHAFT