Global Water Vapor variations in the Upper Troposphere and Lower Stratosphere in two coupled stratosphere-troposphere-ocean models

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1. Introduction and Motivation

Water vapor and ice are known to exert a key influence on the radiative and dynamical balance of the upper troposphere and lower stratosphere (UTLS). Recent research has demonstrated that observed variations of the global water vapor into the lower stratosphere (Figure A) are an important driver of decadal global surface climate change (Solomon et al., 2010). Therefore, variations of the water vapor into the lower stratosphere can provide a source of decadal variability for the climate system. However, there is still a need to improve the representation of the UTLS water vapor distribution and its variations in climate models.

Purpose: The the modeled UTLS water vapor distribution, its interannual and inter-decadal variability is examined in a long-term simulation performed with a coupled troposphere-stratosphere-ocean model and compared with global observational datasets. The model has a well-resolved stratosphere with a high vertical resolution and is fully coupled to a dynamical ocean model.

Questions:

•Which are the mecahnisms controlling the distribution and variability of UTLS water vapor in the models?

•Is there any impact of ocean coupling, high vertical resolution and the representation of the tropical stratospheric dynamics on the modeled UTLS water vapor?

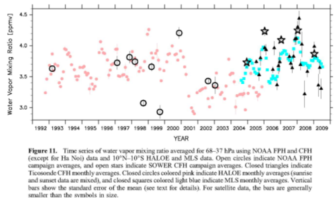
2. The models and the simulations

CMIP5 historical and preindustrial simulations are here analyzed from:

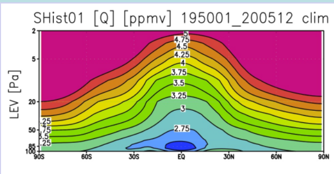
High-Resolution CMCC-CMS coupled atmosphere-ocean model with a well-resolved stratosphere: T63L95 (spontaneous QBO) Simulations are named SHist01 and sec001.

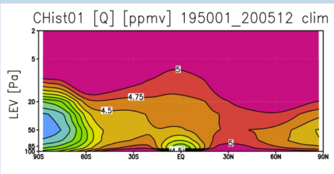
Low-Resolution CMCC-CESM coupled atmosphere-ocean plus biogeochemistry and vegetation model with a well-resolved stratosphereT31L39) Simulations are named CHist01 and cec002

Figure A: Time series of water vapor mixing ratio averaged for 68–37 hPa using NOAA FPH and CFH (except for Ha Noi) data and 10°N–10°S HALOE and MLS data. From Fujiwara et al., 2010



3. The Climatology





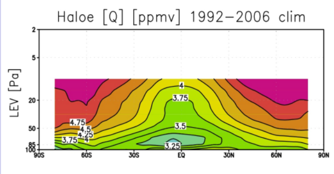
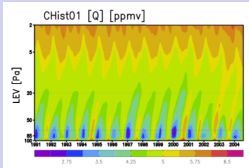
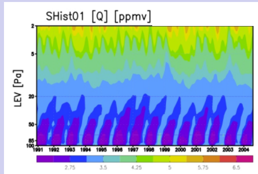


Figure 1. Long-term annual mean distribution of zonal mean water vapor in the stratosphere as reproduced by the two model simulations and Haloe data. Units [ppmv]. The lower resolution model shows an excess of H2O stratosphere

4. Intraseasonal variations: The tape recorder





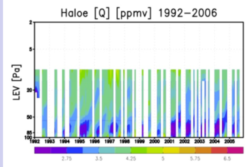
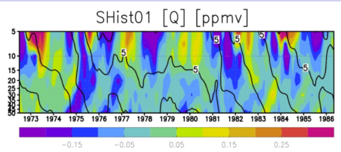


Figure 2. Time series of month-pressure distribution of water vapor mixing ratio for the 1992-2005 period form the models and Haloe at 10N-10S. Units [ppmv]. The tape recorder from the higher-resolution model is in better agreement with Haloe

5. Interannual variations: QBO and ENSO



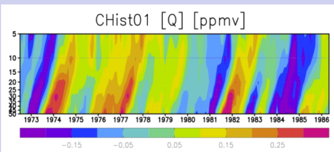
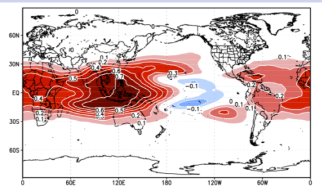


Figure 3. Time series of month-pressure distribution of 25-yrs water vapor mixing ratio for the two models between 50hPa and 5hPa. Units [ppmv]. The signal of the QBO is seen in the higher-resolution model which internally generates the QBO and modulates downward propagating H2O anomalies. This modulation of the tape recorder is completely absent in the lowe-resolution model



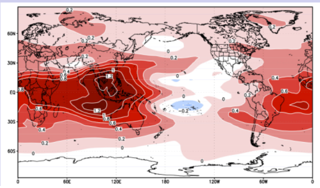


Figure 4. Composite analysis of the 100hPa H2O on the ENSO index, based on the NINO3 SSTs time series. The Figure shows the H2O anomaly for warm ENSO years (when the index is larger than 1STD) w.r.t. cold years. The anomalies for the lower-resolution model are almost twice the higher-resolution model. This could partially explain the positive bias found in the climatologies of the low-resolution model.

6. Long-term decadal to interdecadal variations

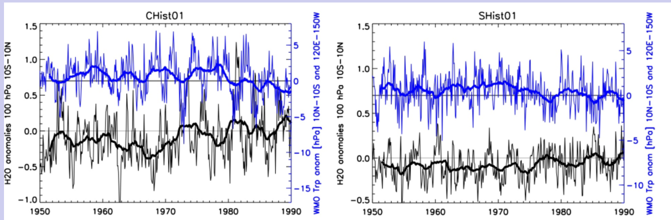


Figure 5. Time series of 100hPa water vapor anomalies w.r.t. 1950-2005 average (black) at 10N-10S and WMO tropopause height (blue) averaged between 10N-10S and 120°-150W. A 36-month running mean is overimposed (thick line). Units [ppmv]. Interannual and loger-term variations of the water vapor entry show a very good coherence with variations of the tropopause height (and hence temperature) in the Tropical Western Pacific for the selected period (30 years)

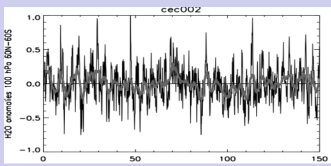


Figure 6. Near-global time series of 100hPa water vapor anomalies w.r.t. 150-yrs average (black) at 60N-60S. Units [ppmv]. The preindustrial simulation shows large natural interannual variability in the LS (same magnitude as observations) plus decadal variations

7. Role of the Asian Anticyclone? (Preindustrial simulation : 150 years)

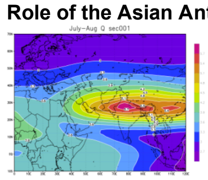
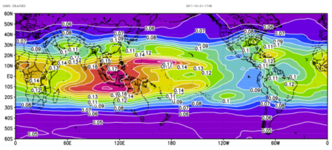
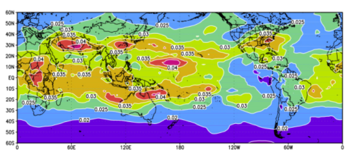


Figure 7 Top: 150 –yrs climatologies of sec001 water vapor (ppmv) at 100 hPa. Bottom (Left) Standard deviation of annual mean water vapor at 100 hPa; standard deviation of the 10-yr running mean of the same field. (Interannual variations in the water vapor are found in the Tropics, max in the west Pacific entry point; decadal variations have larger signal in the extra-tropics: possible role of the Asian monsoon anticyclone)





8. Summary

The vertical resolution and the representation of the tropical variability play a key role in representation of the water vapor distribution and short-term variability (ENSO and QBO)

Longer term variability of the same order of the observerd ones are found in the coupled model simulations

Interannual and longer-term tropical variations in the lower stratosphere are related to the tropical tropopause temperature and SSTs in the west Pacific.

Possible role of the anticyclonic monsoon region in the decadal extratropical H2O variations in the lower stratosphere remains to be estimated

Acknowledgments. This work was funded by the European Commission's 7th Framework Programme, under Grant Agreement number 226520, COMBINE project.