# Short- and long-term fluctuations of stratospheric water vapor and ozone in CCMI simulations of EMAC


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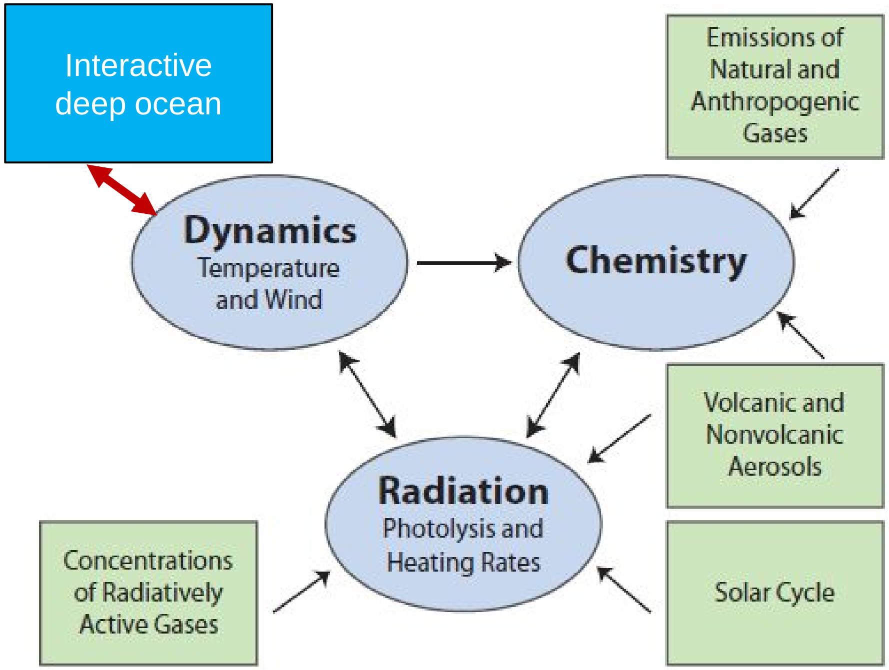
# The Chemistry-Climate Model EMAC

European Centre for Medium-Range Weather Forecasts - Hamburg (ECHAM) / Modular Earth Submodel System (MESSy) Atmospheric Chemistry (**EMAC**) model

- is based on ECHAM 5,
- using a full set of stratospheric and tropospheric chemistry;
- resolution: T42/L90 (T42: 2.8° x 2.8°, L90: 0-80 km).




(Detailed description: Jöckel et al., 2016.)

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# Strategy for CCM simulations

Three types of numerical model simulations covering the middle atmosphere and troposphere have been defined, as recommended by the IGAC/SPARC Chemistry-Climate Model Initiative (CCMI):

(1) A hindcast simulation with specified dynamics, i.e. nudged to observed meteorology from 1979 to 2013 (referred to RC1SD),

(2) a free-running hindcast simulation representing the past (from 1950 to 2013; referred to RC1), and

(3) a combined hindcast and forecast simulation (from 1950 until 2100; referred to RC2 and, in addition, RC2-O, i.e. with interactive ocean).

For the EMAC RC1SD simulation,

- forcing: 6 hourly ERA-Interim with vertically varying relaxation time constants,
- the middle and upper stratosphere (>30 km) and mesosphere is free running.

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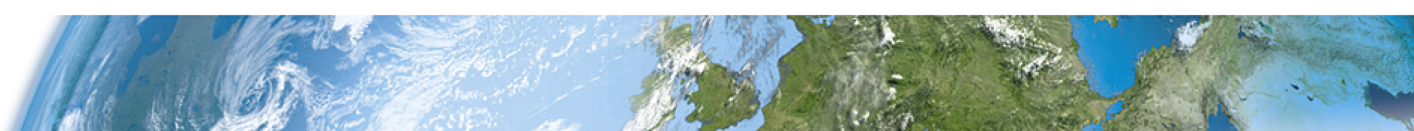
# Scientific challenges, questions and tasks regarding stratospheric ozone

- Detection of ozone return/recovery in the next 5 to 10 years due to the regulation of CFCs. It has to be investigated if the recovery of ozone in the upper stratosphere is consistent with our expectations based on $Cl_y$, temperature, and other factors.
- Prediction of the future evolution of the stratospheric ozone layer in a changing climate, determining the dependence of ozone recovery in space (latitude and altitude) and time, especially investigating the evolution of the ozone layer in polar regions (ozone hole) as well as in the tropics.
- How will ozone concentrations develop depending on the assumed climate scenarios (RCPs: Representative Concentration Pathways), e.g. detecting higher stratospheric ozone values (‘super-recovery’) as an indicator of climate change?



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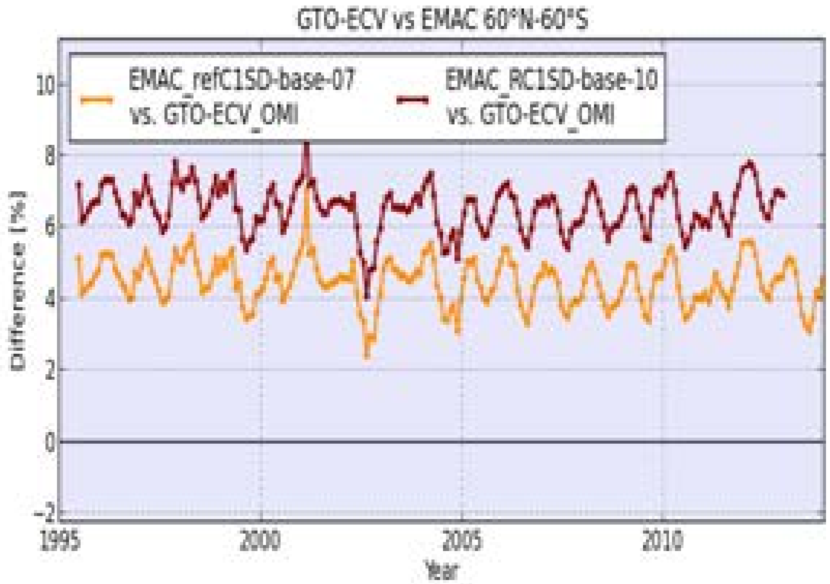
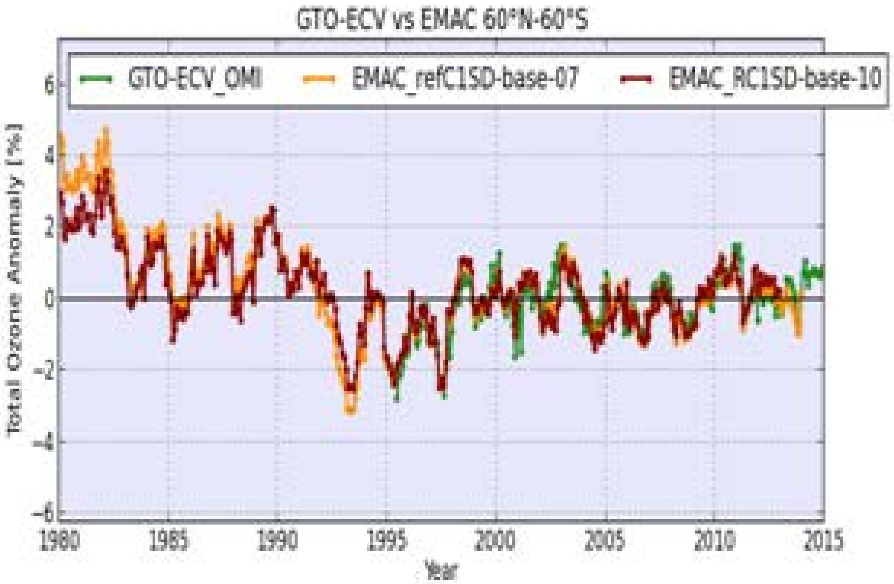
# Ozone anomalies (1995-2013): 60°S-60°N

Comparison of satellite-instrument- and model data



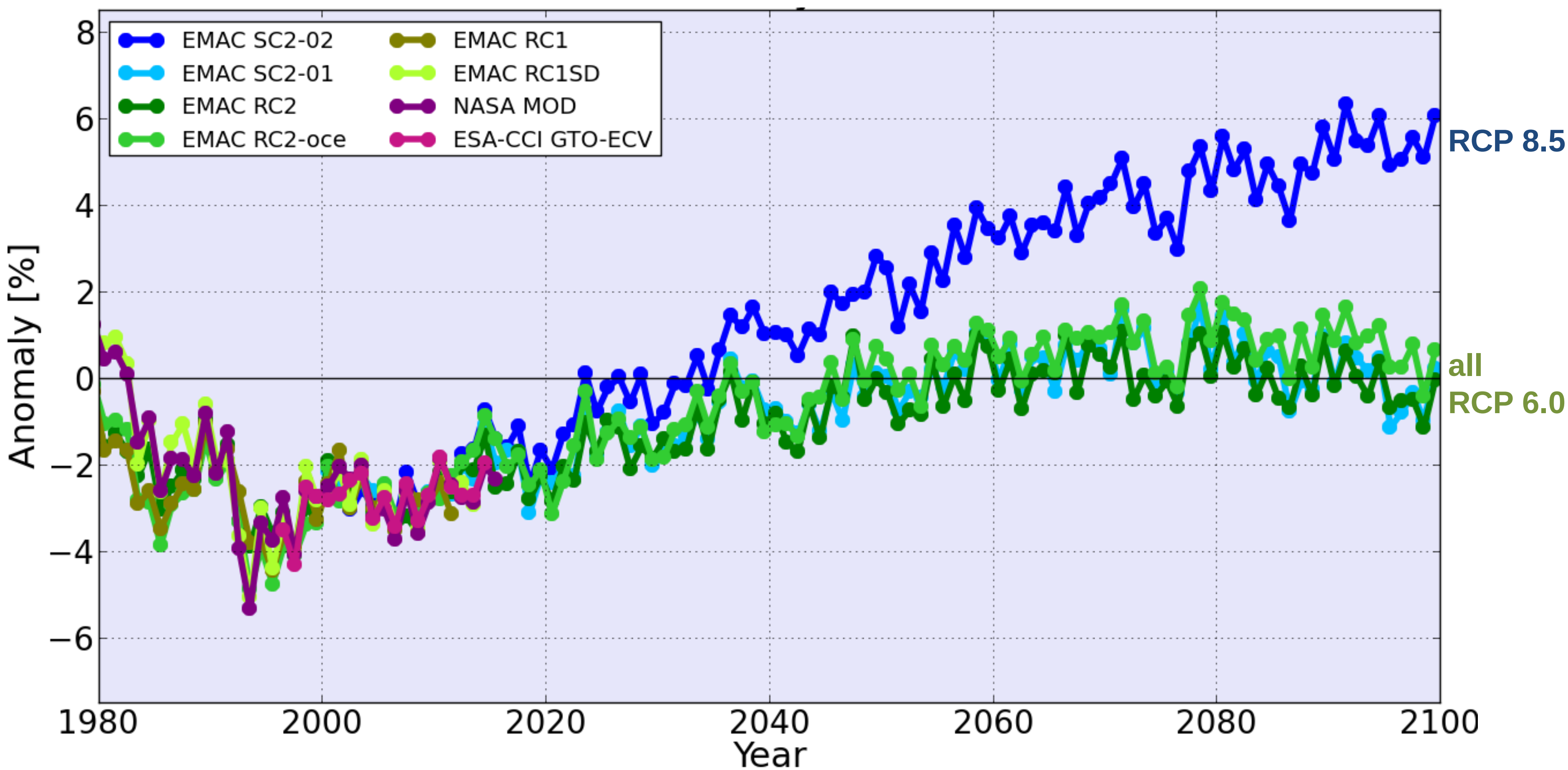




<u>Near global mean</u>:

ESA Ozone-cci data set (since 1995) compared with two different RC1SD simulations (red/orange: without/with nudging of the mean temperature)

# Ozone anomalies (1960-2100): 60°S-60°N

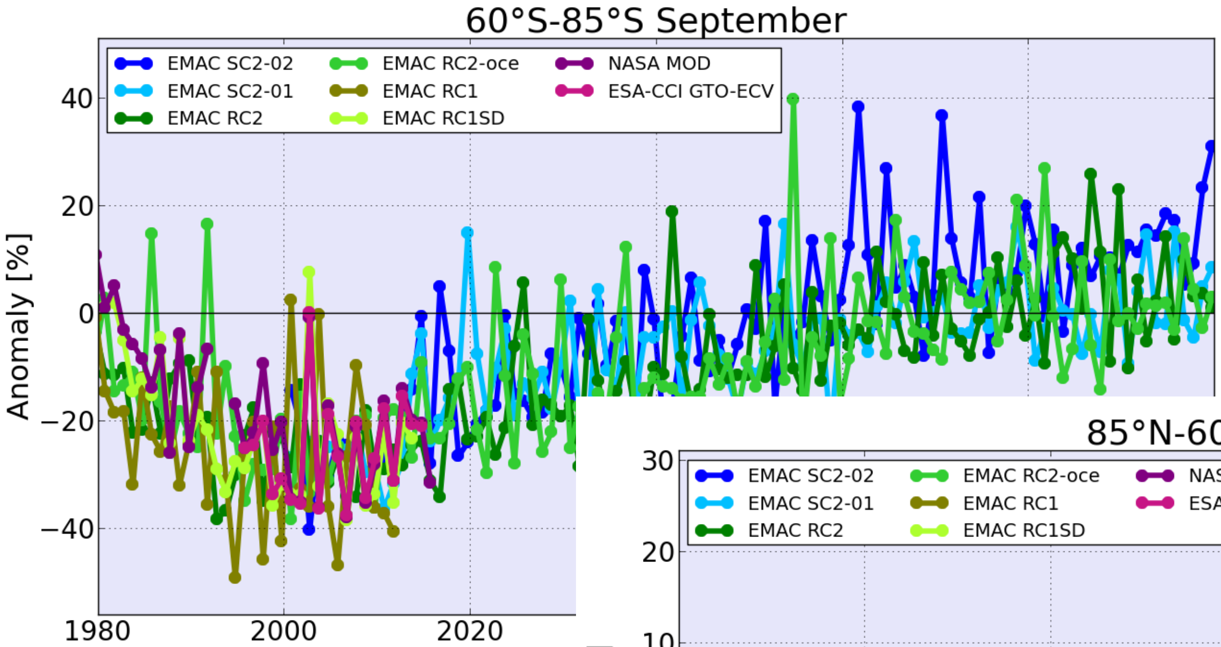
Comparison with satellite data and model prediction




update of Jöckel et al., 2016

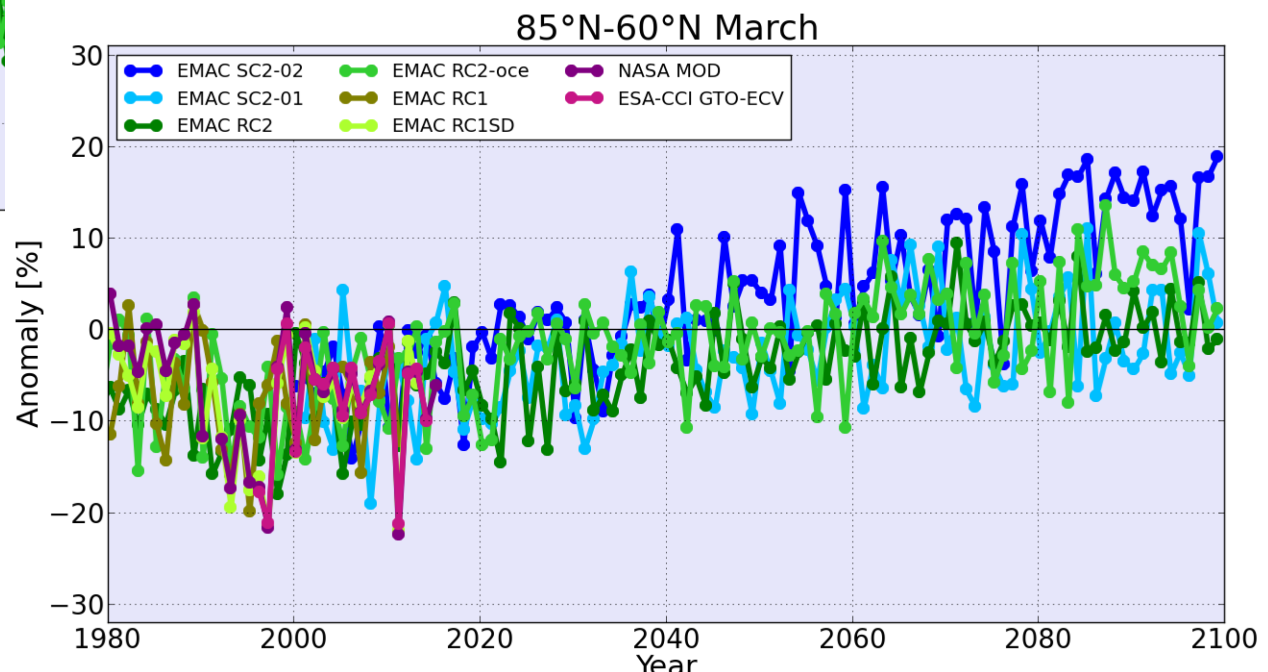
# Ozone anomalies (1960-2100): polar regions

## Comparison with satellite data and model prediction



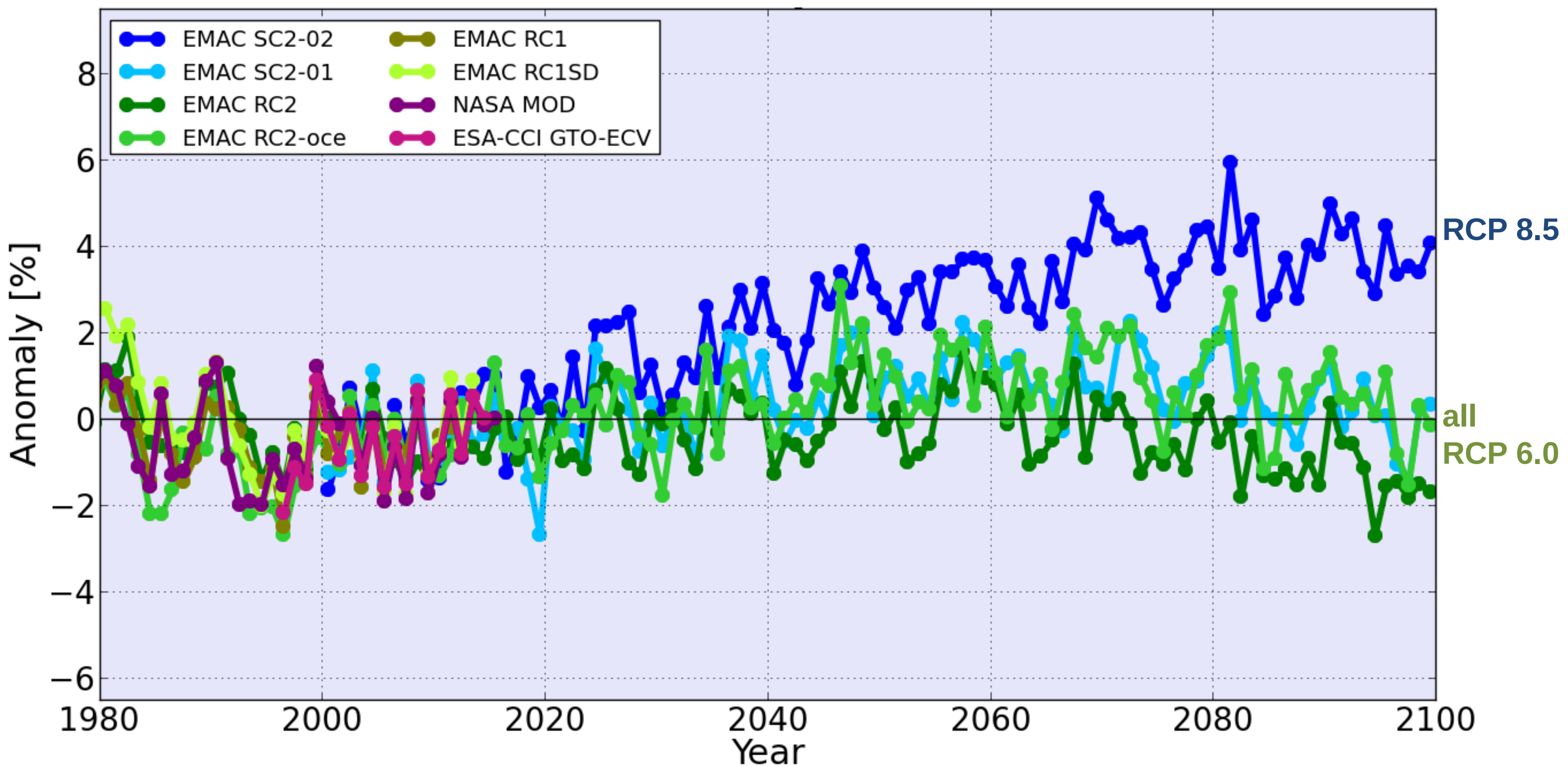

RCP 8.5

all
RCP 6.0

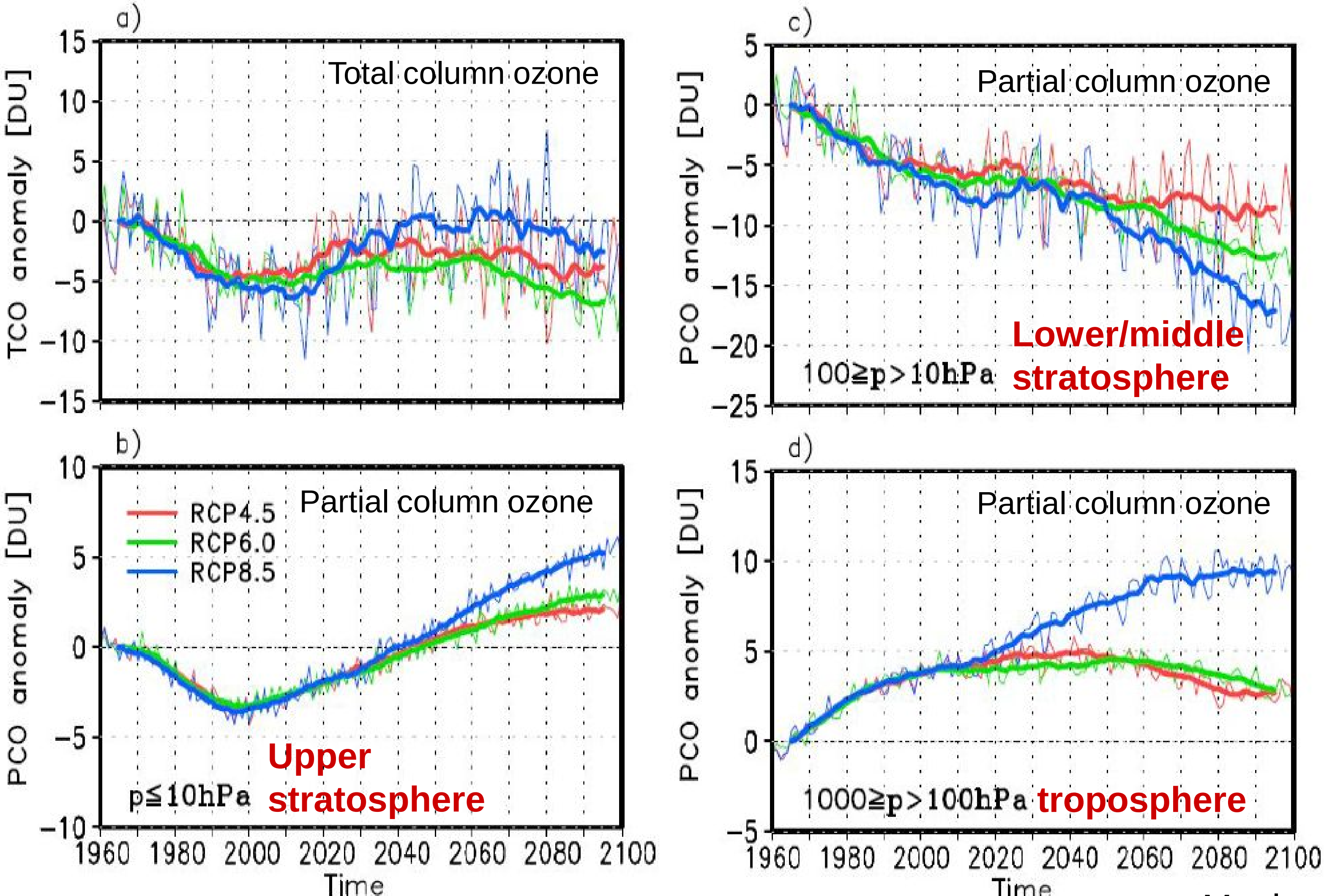


# Ozone anomalies (1960-2100): 20°S-20°N

Comparison with satellite data and model prediction



# Evolution of the tropical stratospheric ozone layer

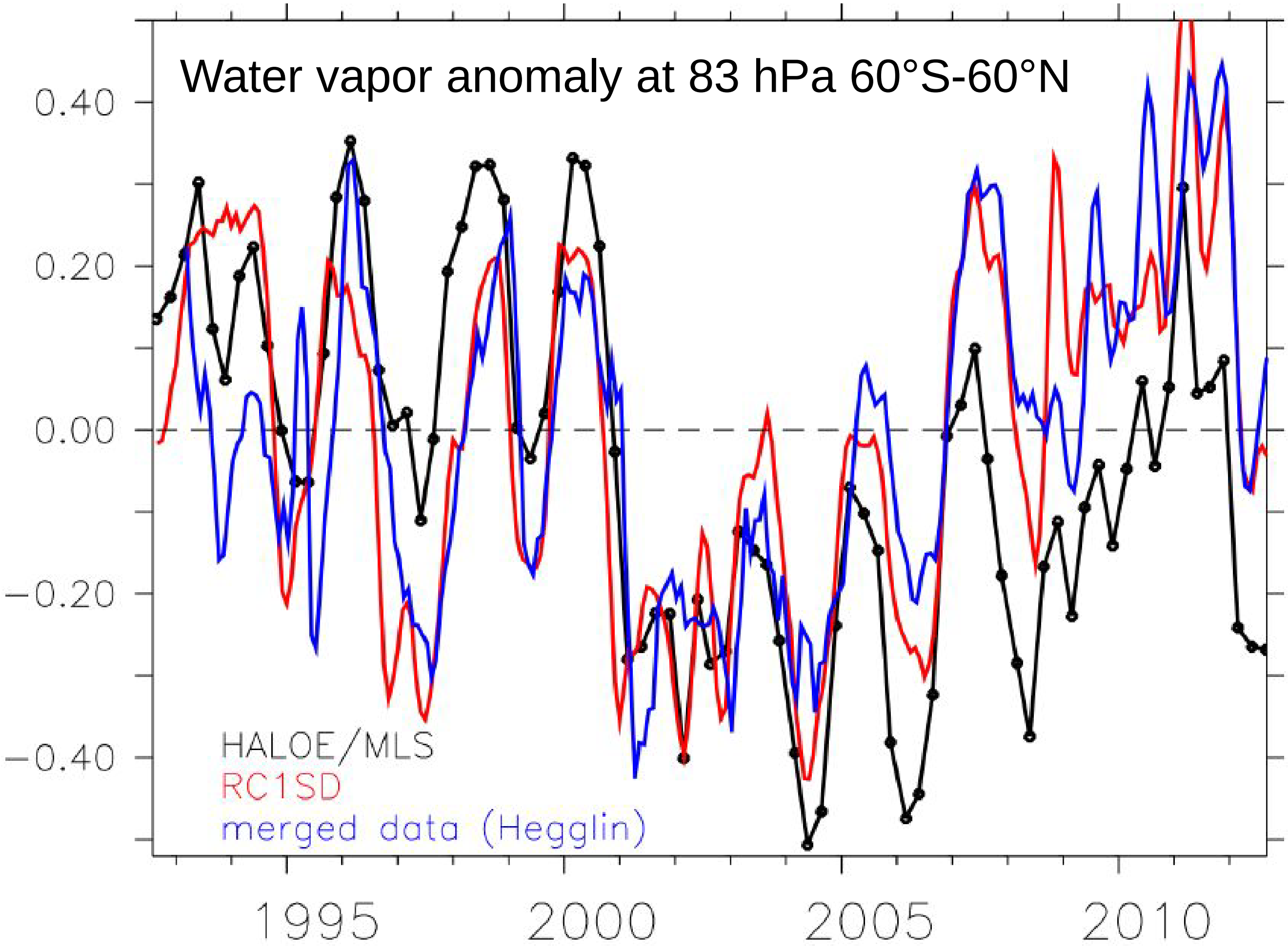



Meul et al., 2016

# Scientific challenges, questions and tasks regarding stratospheric water vapor

- Explain short- and long-term fluctuations of stratospheric water vapor on the basis of comprehensive data sets together with appropriate CCM simulations.
- How good are the relevant processes described in the CCMs?
- What are the dominant drivers for observed (strong) fluctuations?
- Can we determine significant long-term trends in the past?
- What do the CCMs predict for the 21$^{th}$ century?

# Example: Explanation of the millennium water drop




Brinkop et al., 2016

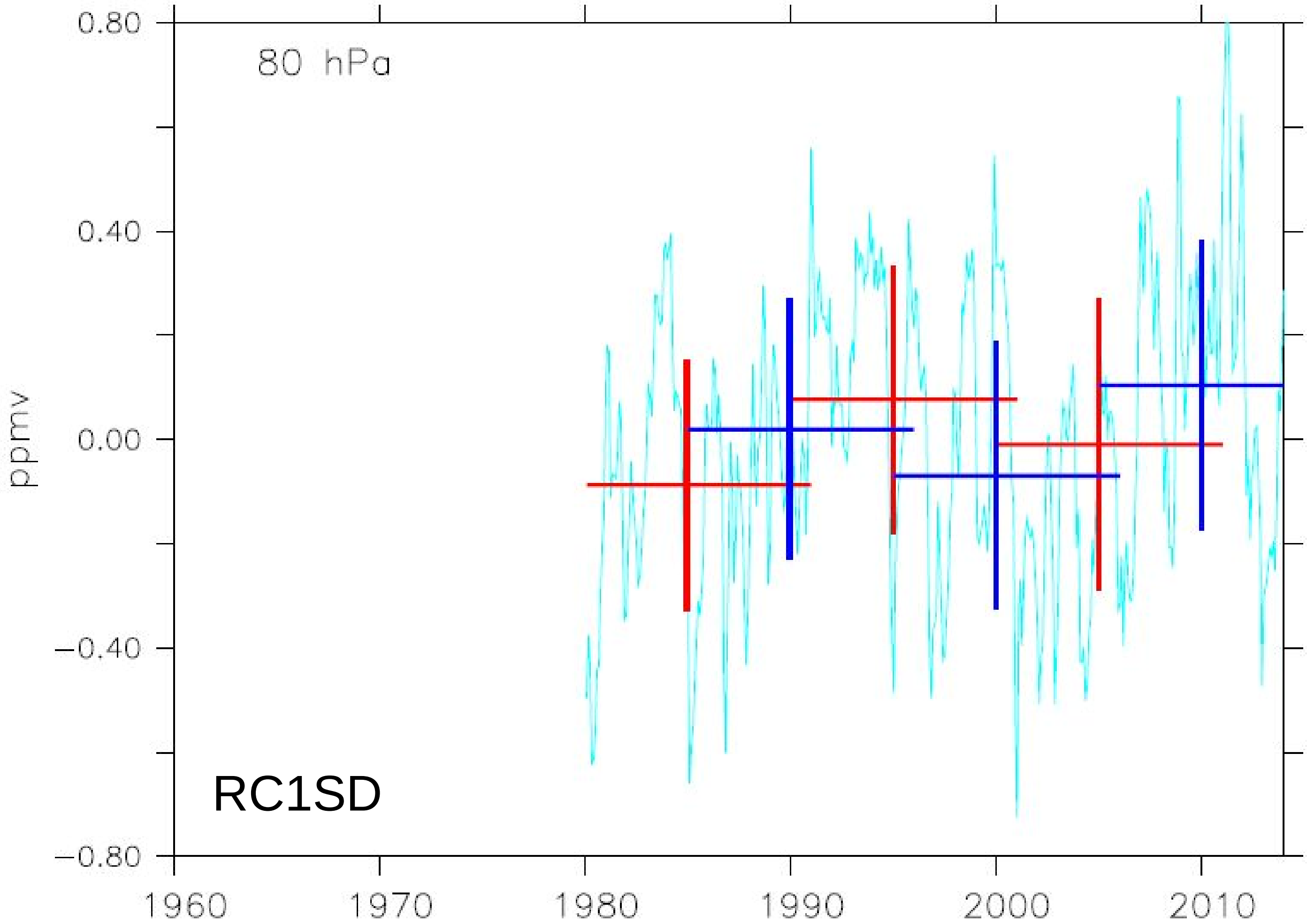
Correct (observed) tropical SSTs are very important for triggering the strong decline in water vapor!

SST changes due to a coincidence with a preceding strong El Niño-Southern Oscillation event (1997/1998) followed by a strong La Niña event (1999/2000).

This event is supported by the change of the westerly to the easterly phase of the equatorial stratospheric quasi-biennial oscillation (QBO) in 2000.

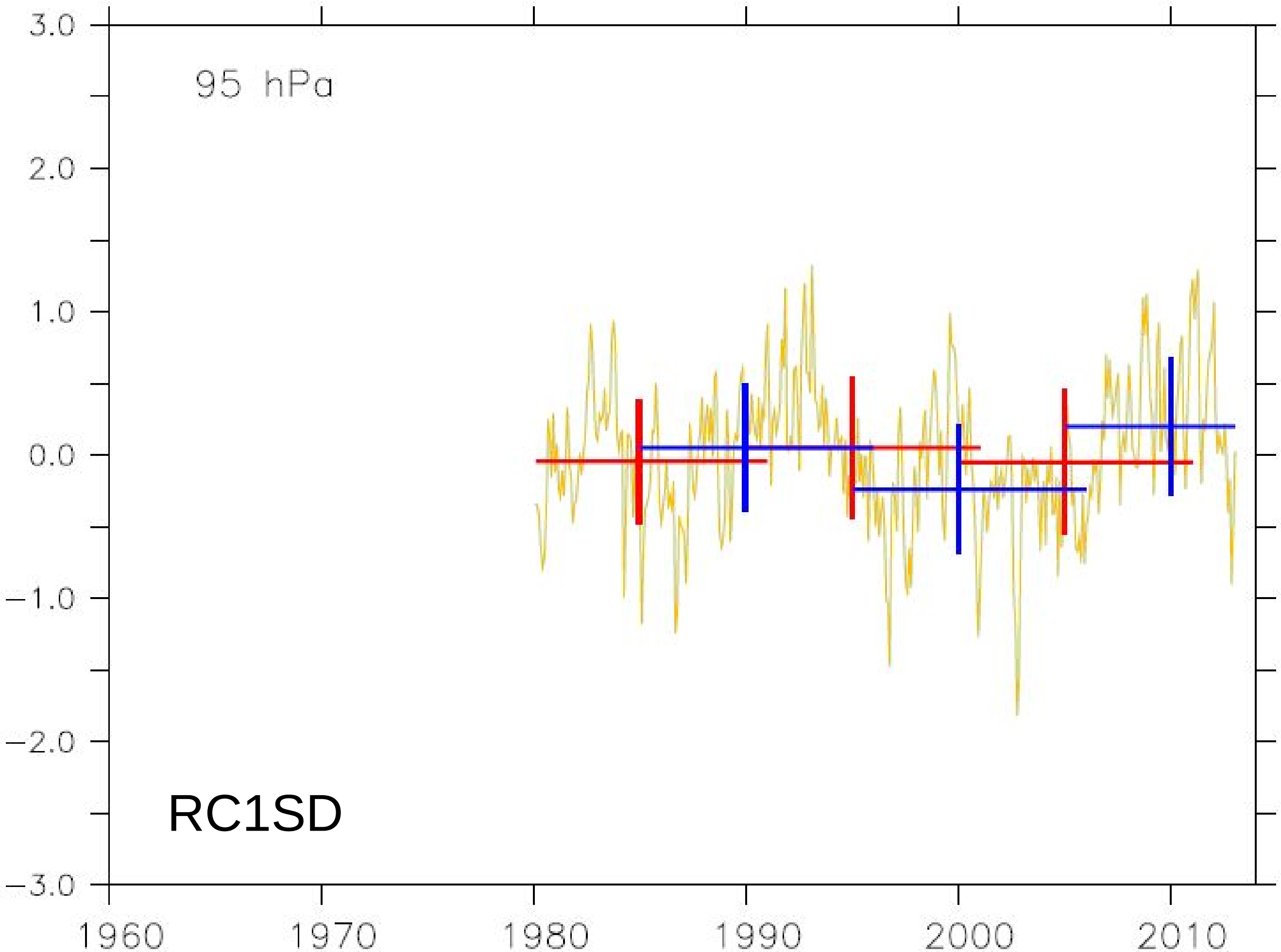
# Stratospheric water vapor: fluctuations and trends

- Tropics (30°N-30°S), lower stratosphere (80 hPa)



# Stratospheric temperature: fluctuations and trends

- Tropics (30°N-30°S), lower stratosphere (95 hPa, near TP)



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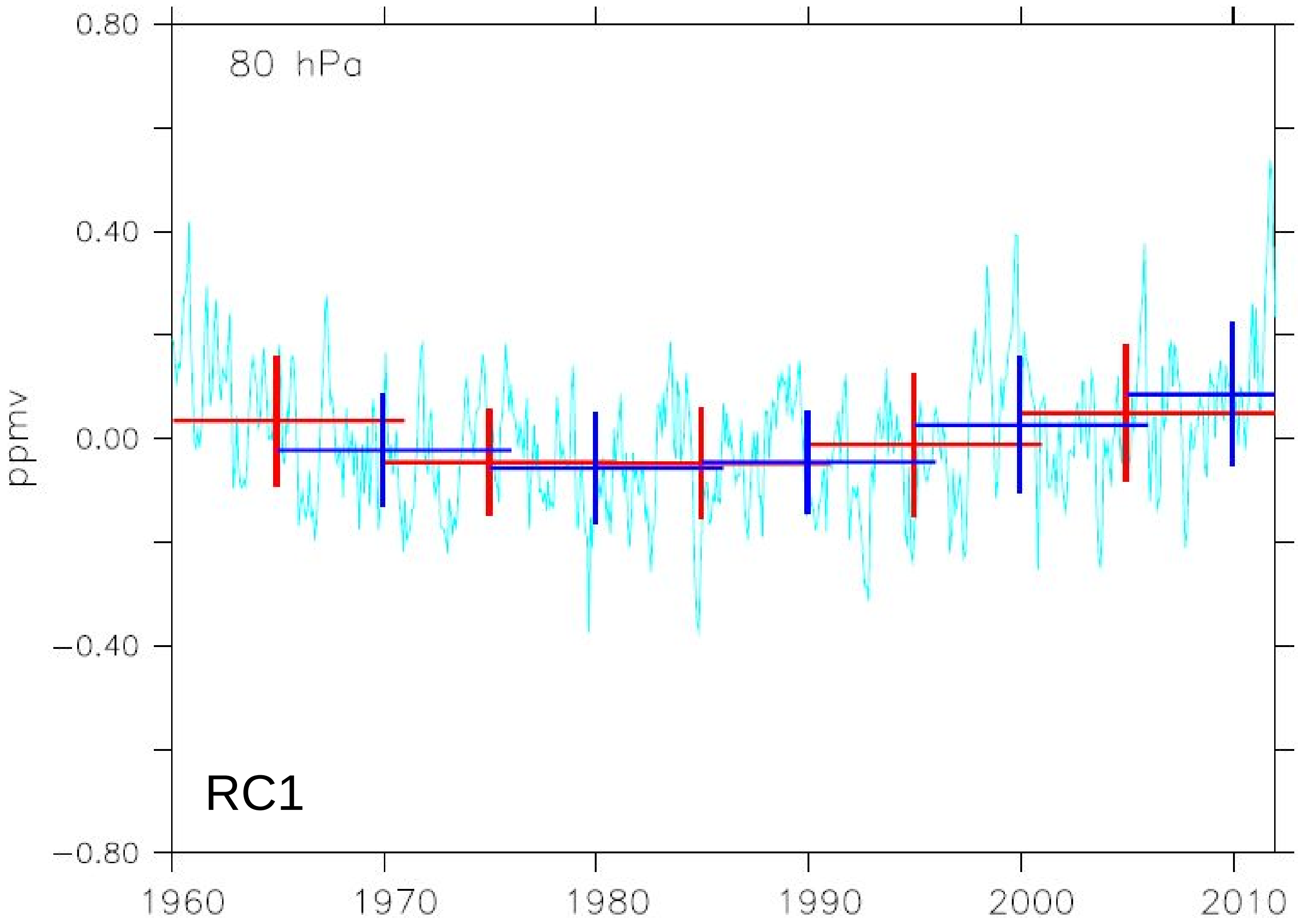

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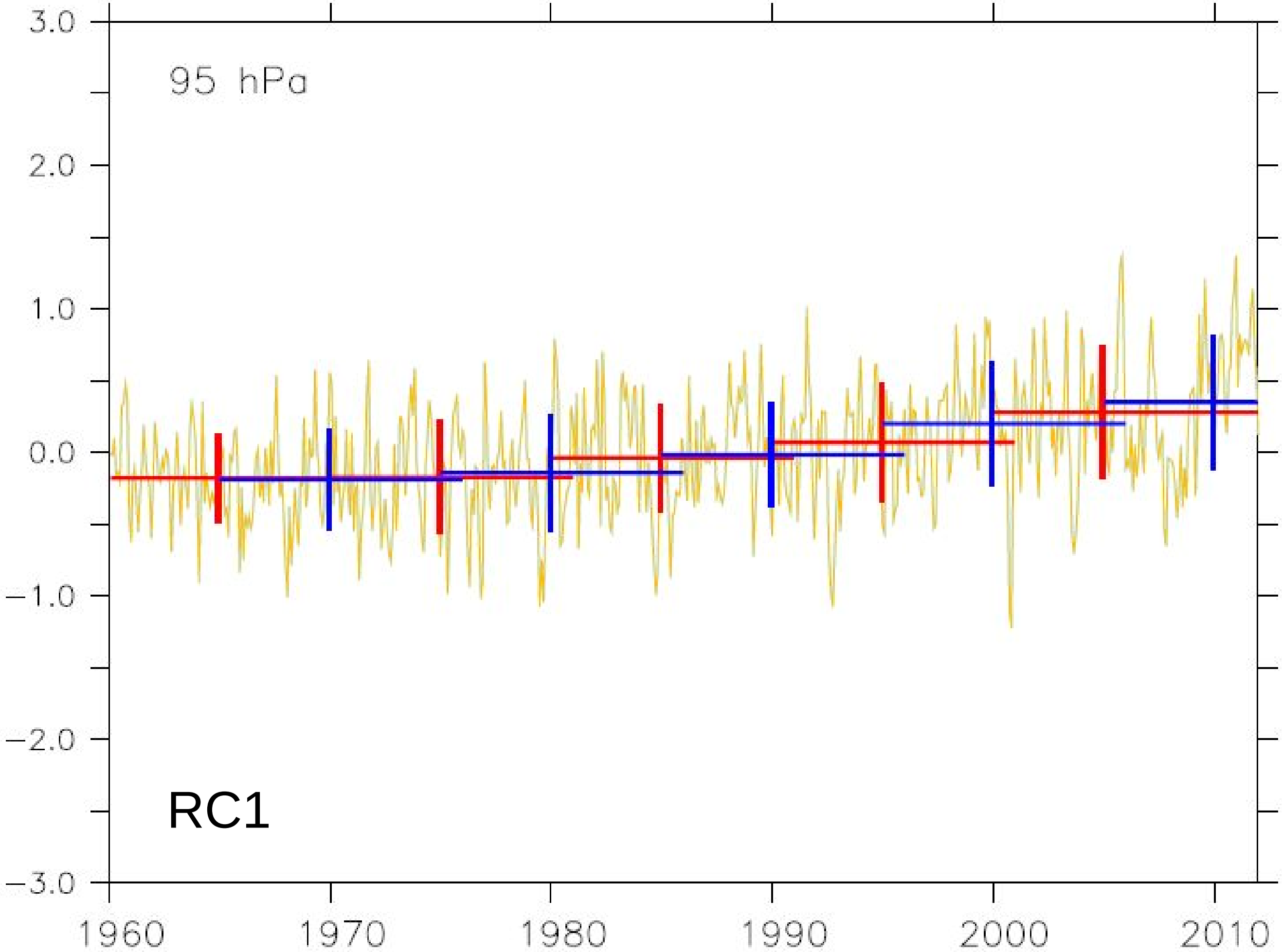

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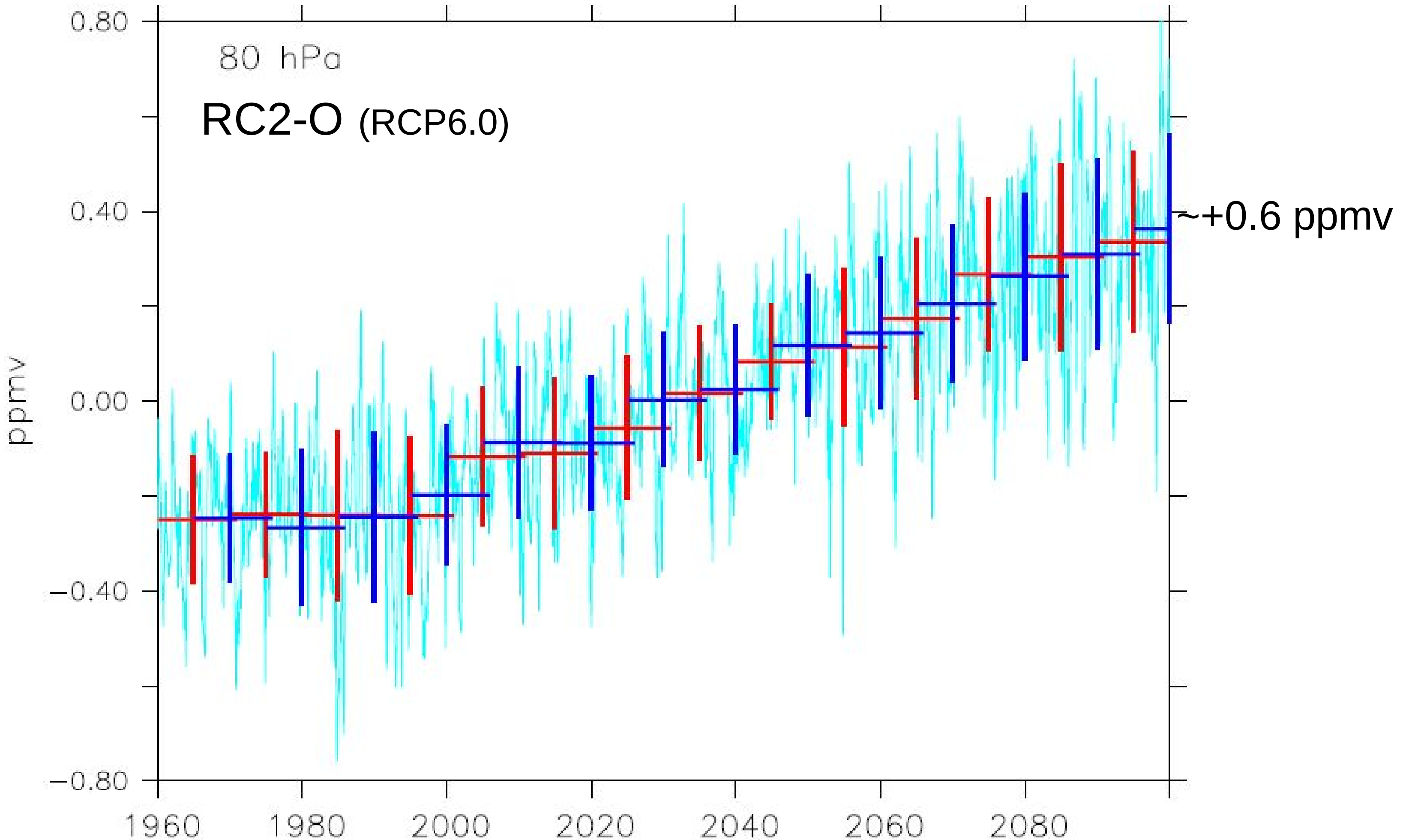

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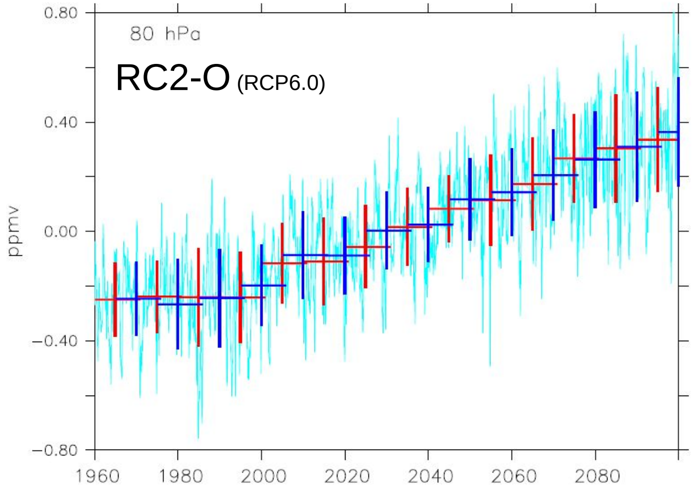
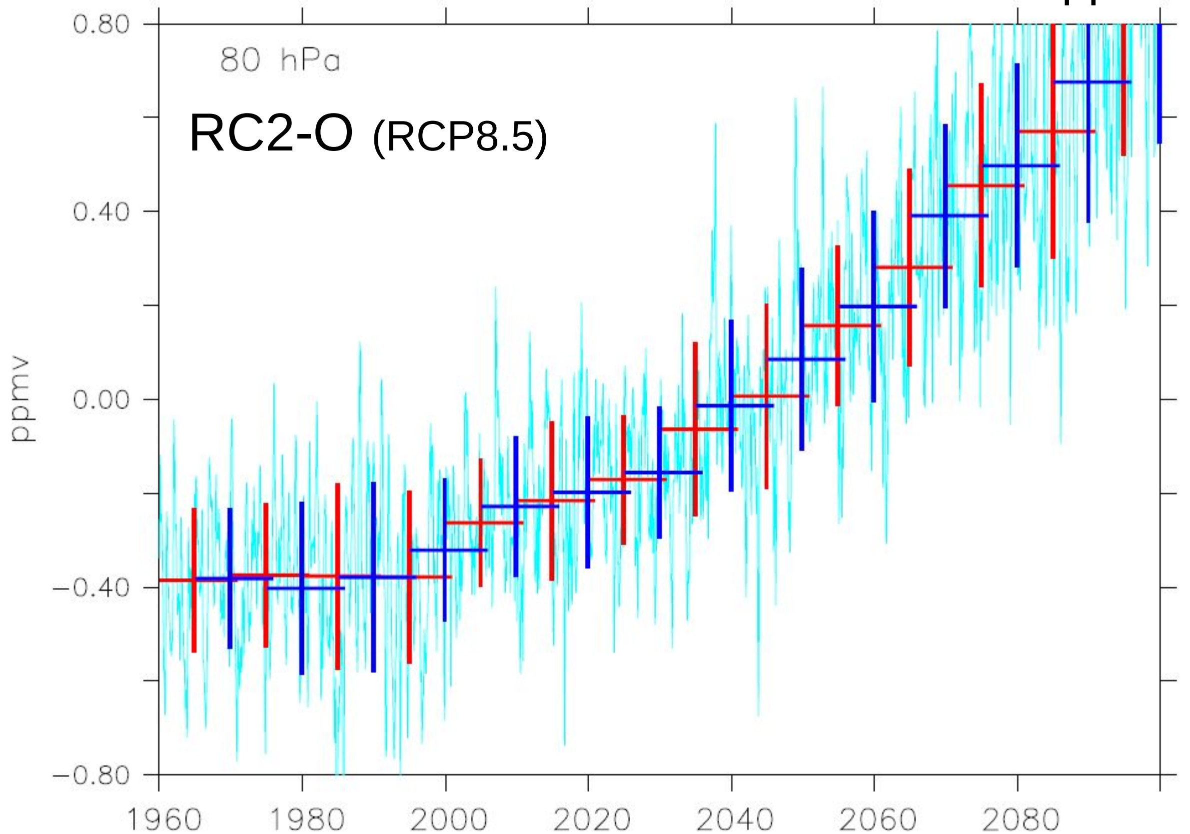



~+0.6 ppmv

~+1.2 ppmv



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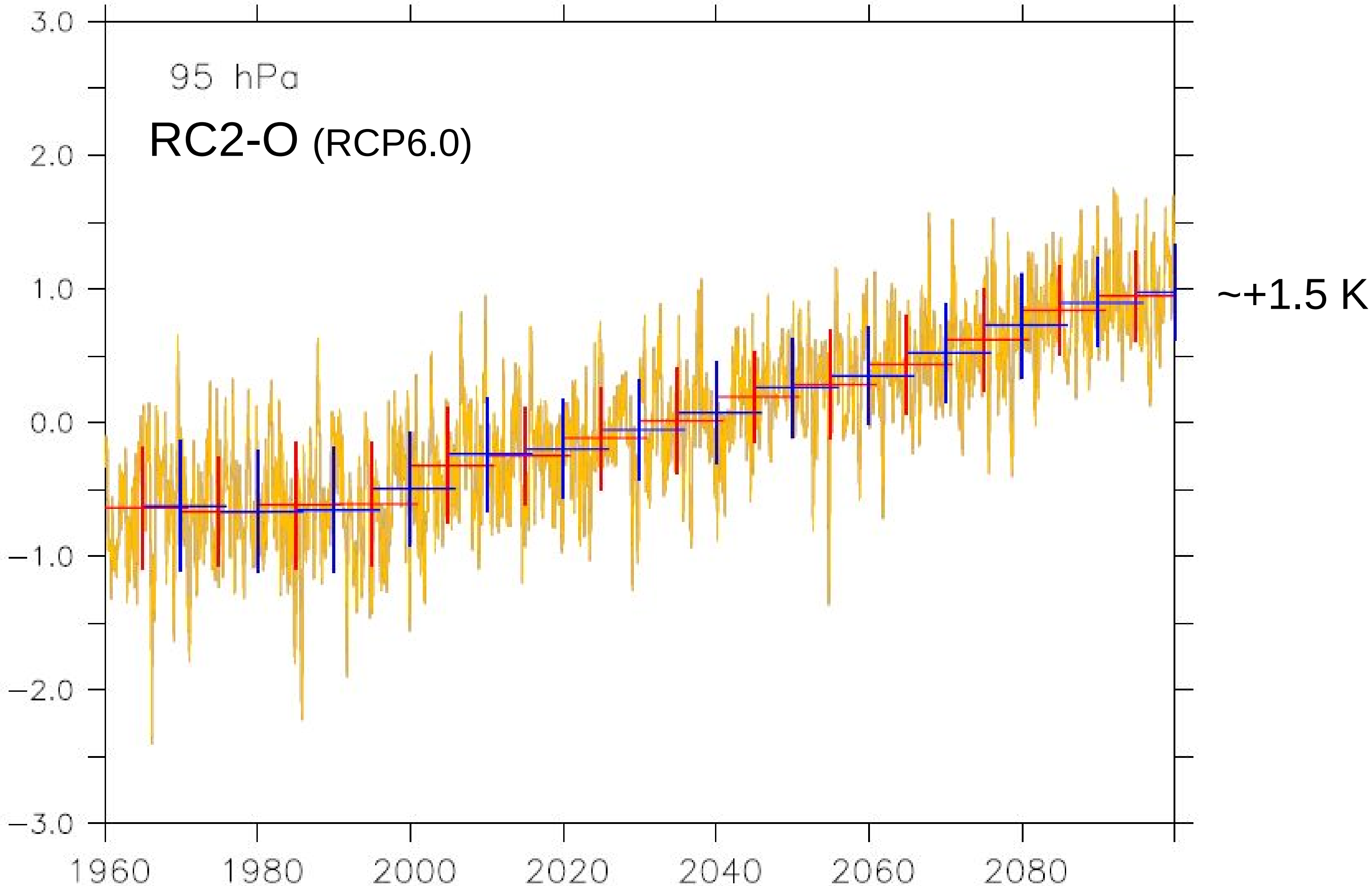

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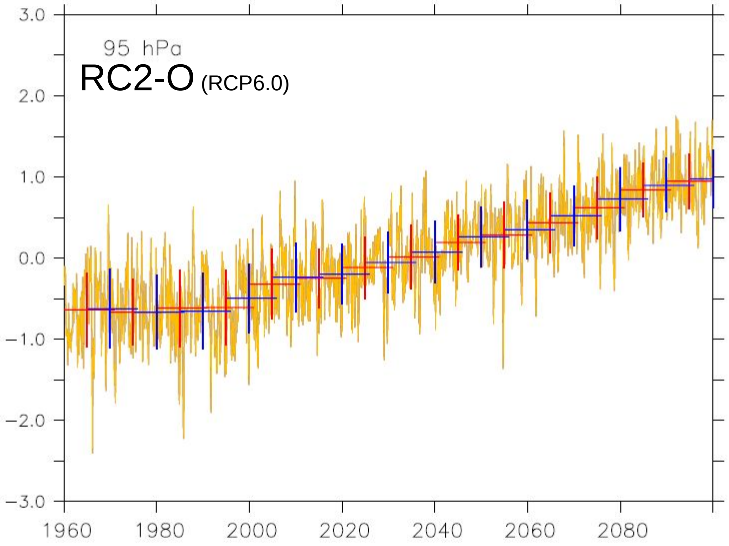
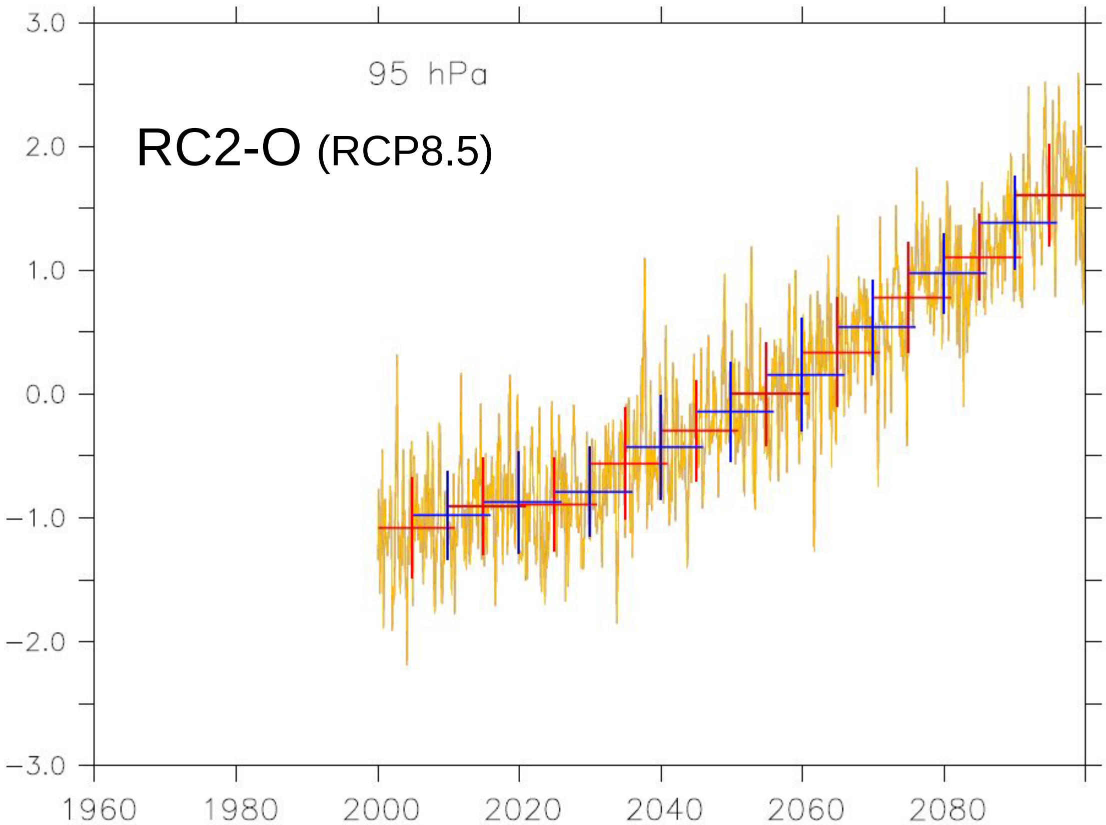



~+1.5 K

~+2.7 K

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# Concluding remarks

**Stratospheric ozone**

- Regional differences with respect to the timing of full recovery
- Strong impact of climate change
- Important changes are expected in the tropics (surface UV)

**Stratospheric water vapour**

- Fluctuations are driven by the QBO, SST variability and in particular El Nino/La Nina events
- No significant (global) trend is found in the last 50 years
- Future increase due to climate change is expected