Support of satellite-based data analyses with CCM simulations

Martin Dameris

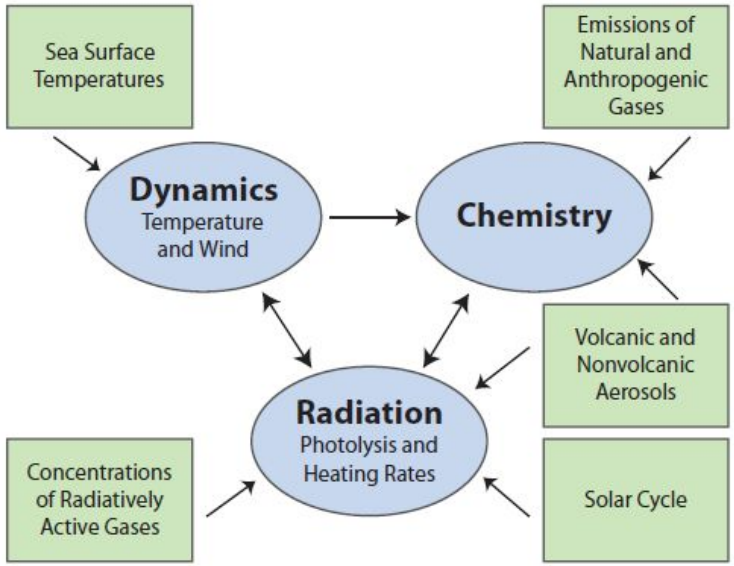
in cooperation with Sabine Brinkop and Melanie Coldewey-Egbers

Deutsches Zentrum für Luft- und Raumfahrt (DLR)
Institut für Physik der Atmosphäre, Oberpfaffenhofen
Email: martin.dameris@dlr.de

Chemistry-Climate Model: Definition and context

- A Chemistry-Climate Model (CCM) is an atmospheric general circulation model (AGCM) that is interactively coupled to a detailed chemistry module.
- The simulated concentrations of the radiatively active gases are used in the calculations of net heating rates.
- Changes in the abundance of these gases due to chemistry and advection influence heating rates and, consequently, variables describing atmospheric dynamics such as temperature and wind.

Schematic of a Chemistry-Climate Model (CCM)



Possibilities of CCM simulations

- ☹ Today I am not presenting a detailed analysis of CCM results with final conclusions!
- ☺ I will try to motivate the usage of CCM simulation results based on total ozone column and strato-spheric water vapor, the possibilities we have, and how CCM studies can support the analysis of observations (and vice versa).

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Chemistry-Climate Model: Purposes

- First, observations are needed for verification and evaluation CCM results (e.g. SPARC CCMVal report, 2010).
- Then, CCM simulations in combination with respective observations are usually used for process-oriented investigations, in particular analyzing the feedback of physical and chemical processes.
- Such a detailed evaluation and analysis of CCM results is the foundation for future projections (e.g. for WMO ozone assessments).
- In addition to this, CCM simulation results can contribute and support investigations of individual observations by providing consistent data sets allowing a more comprehensive, three-dimensional view of the atmospheric system, in particular for longer time periods (up to several decades).

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Strategy for CCM simulations

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

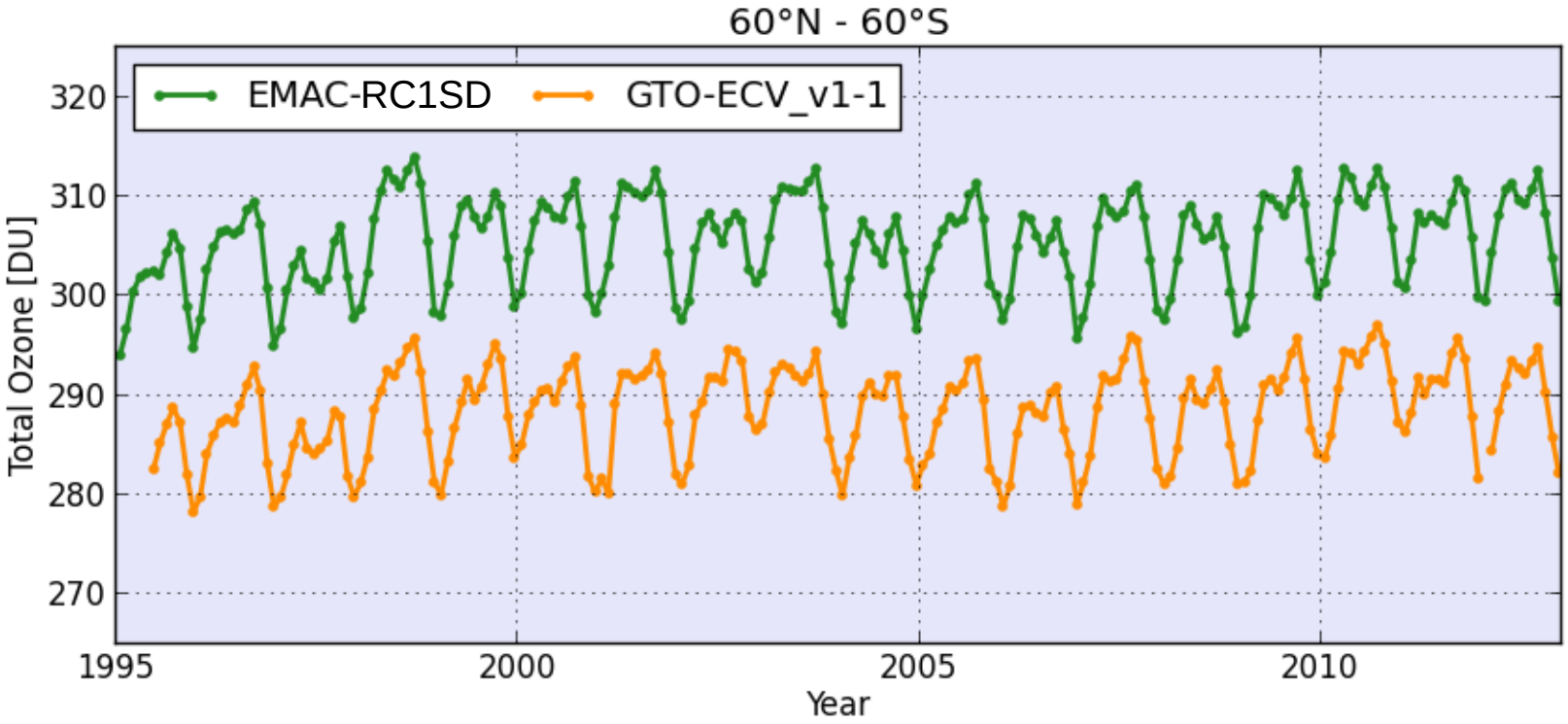
(1) a free-running hindcast simulation representing the past (from 1950 to 2011; referred to RC1),

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

In the following CCM simulation results are shown which have been performed recently with the EMAC model.

Example: Evaluation of the total ozone column



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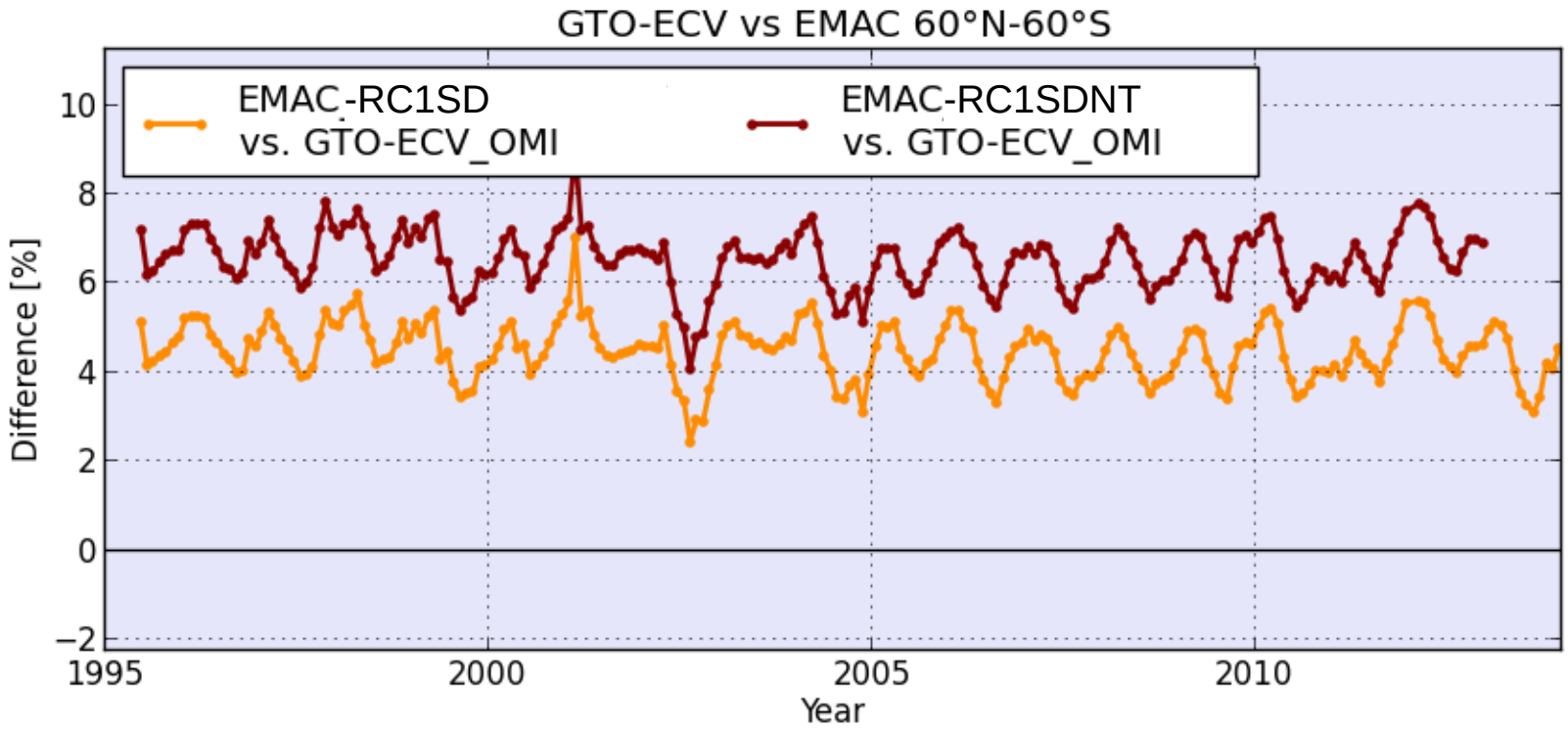
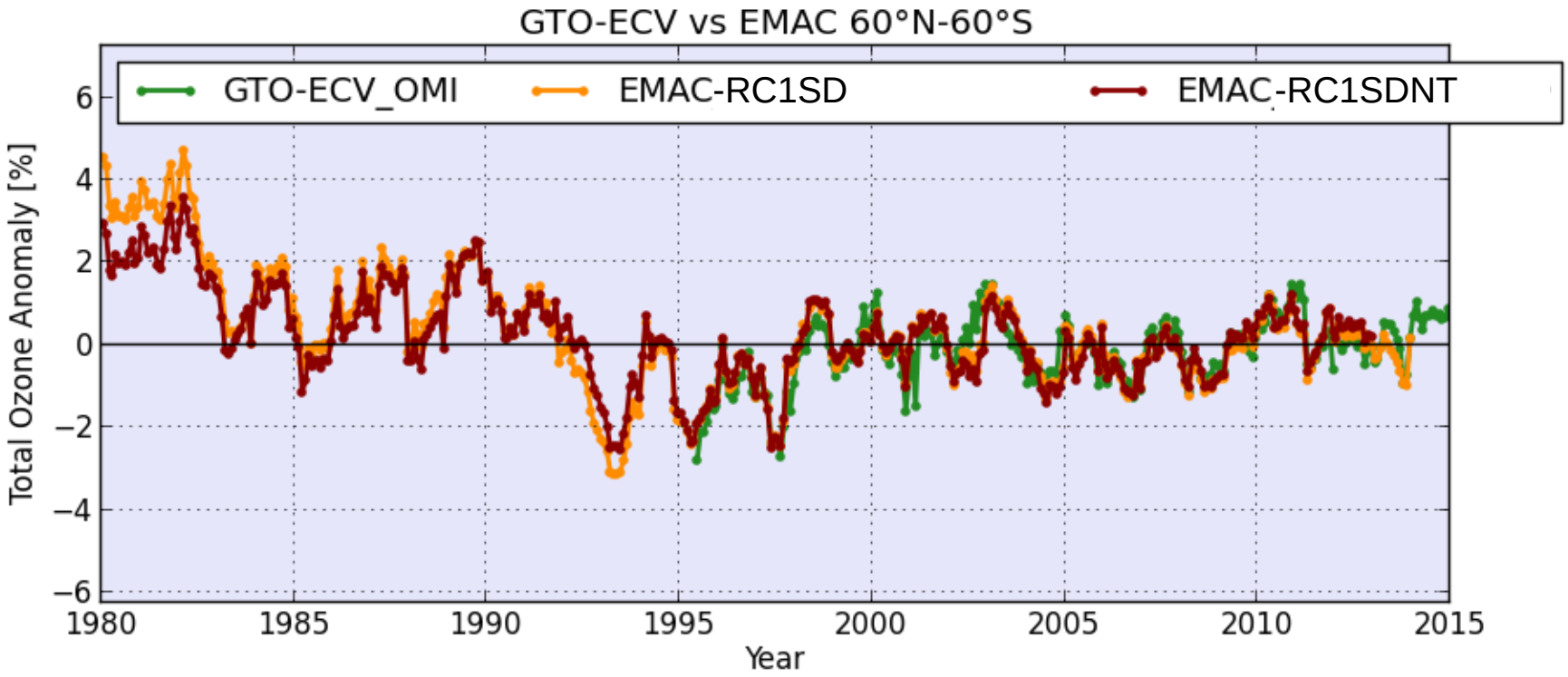
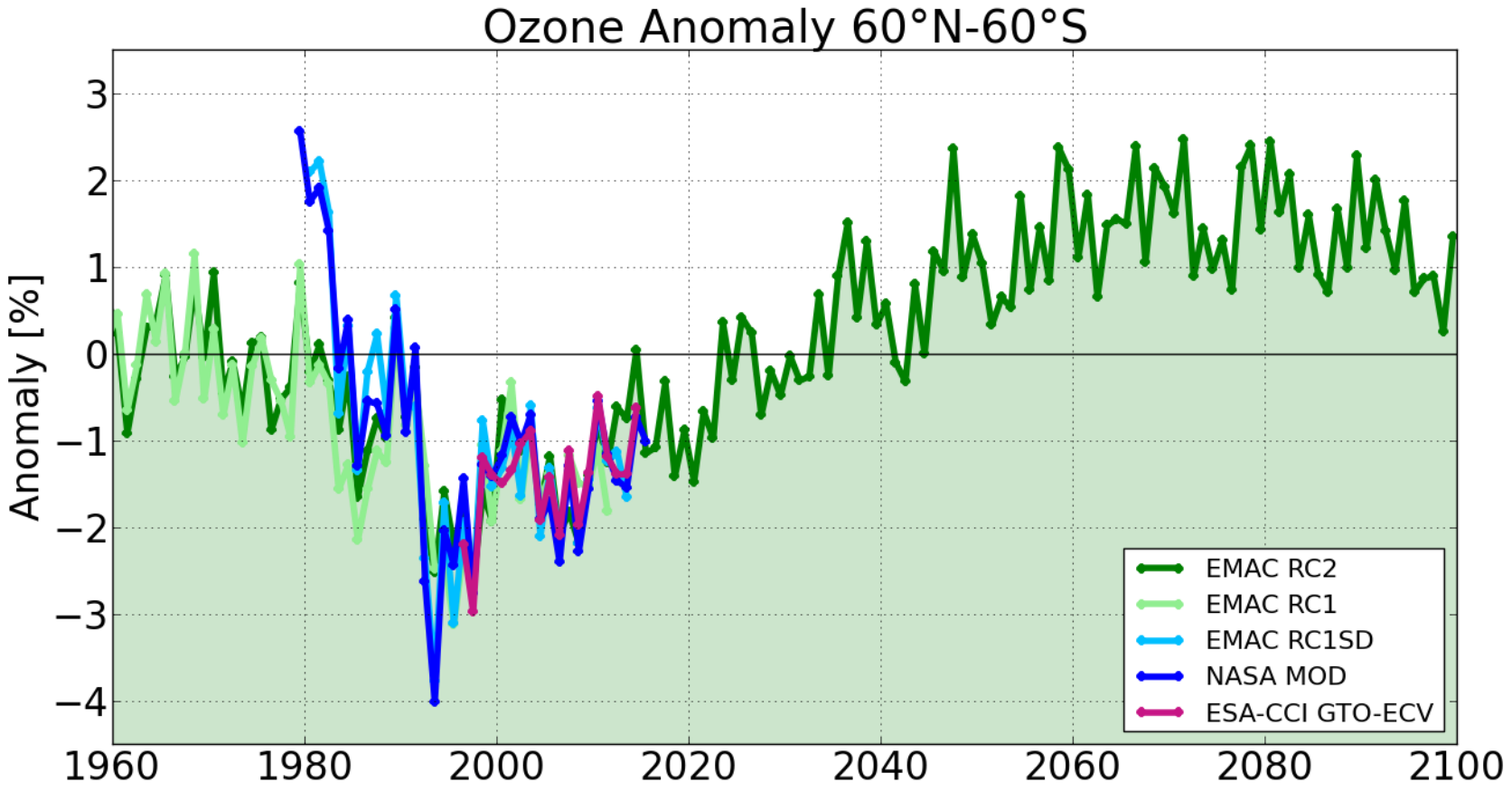
Example: Differences of the total ozone column



Example: Anomalies of the total ozone column



Example: Future projection



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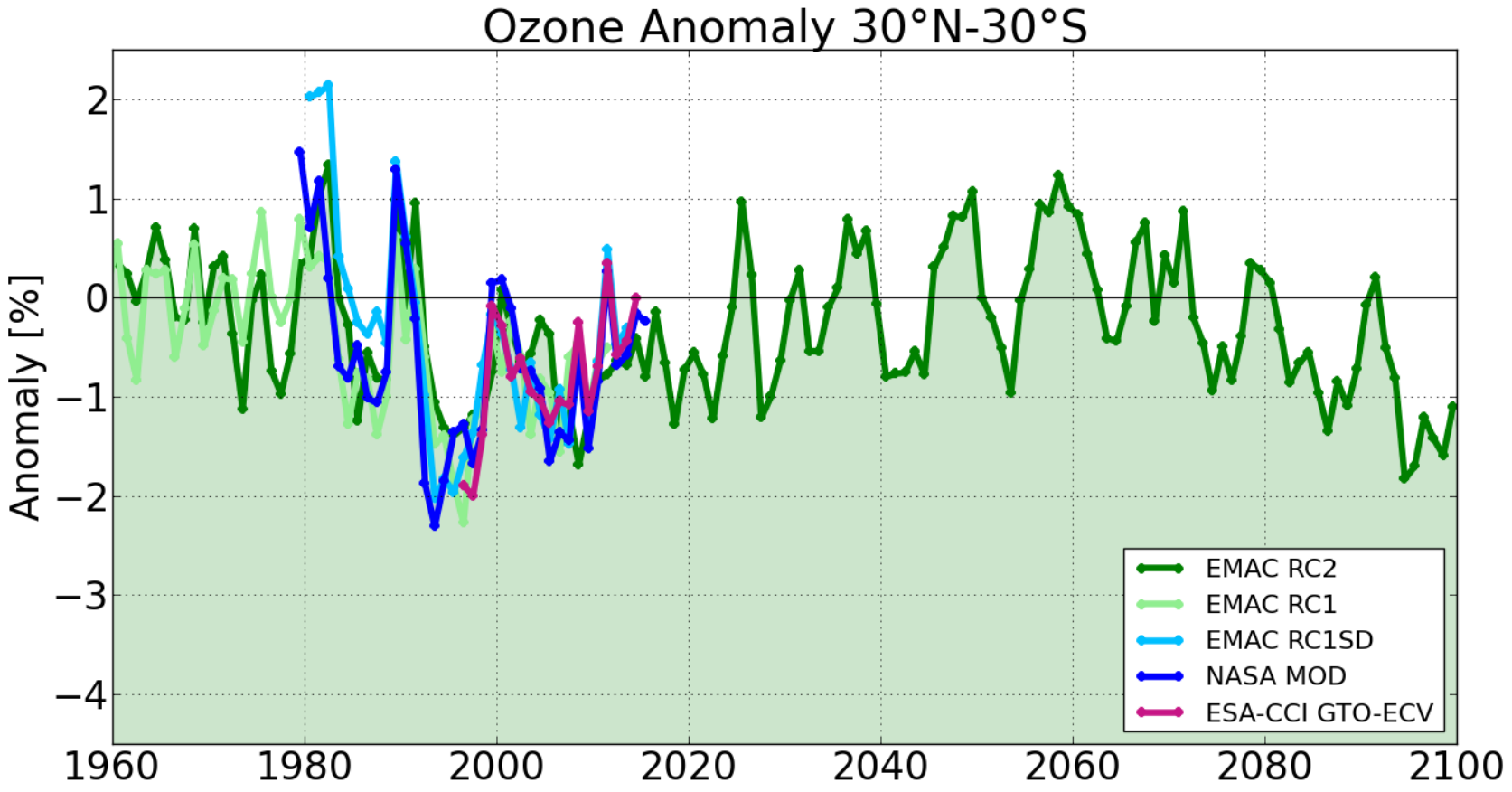
Example: Future projection



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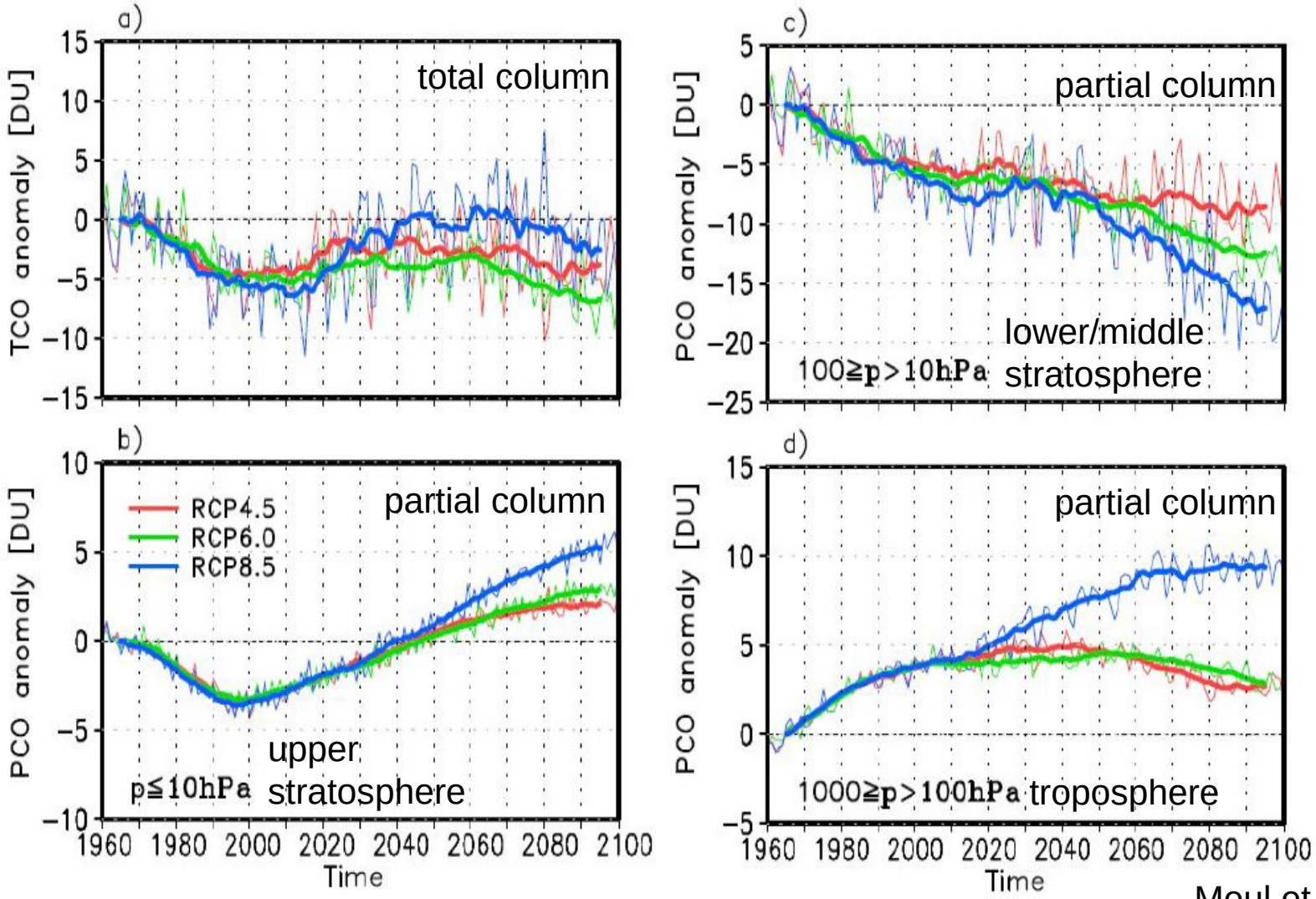
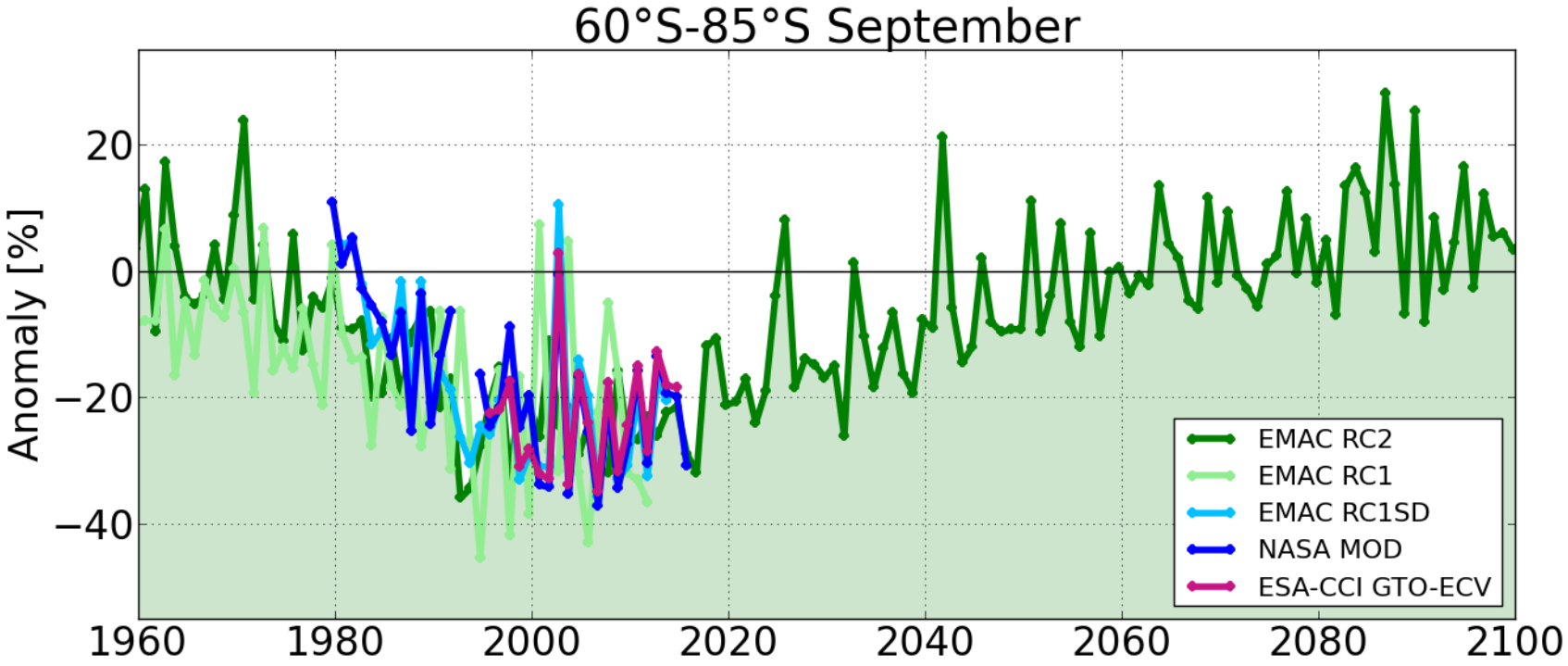
Example: Ozone changes in the tropics



Meul et al., 2016

Example: Recovery of the ozone hole



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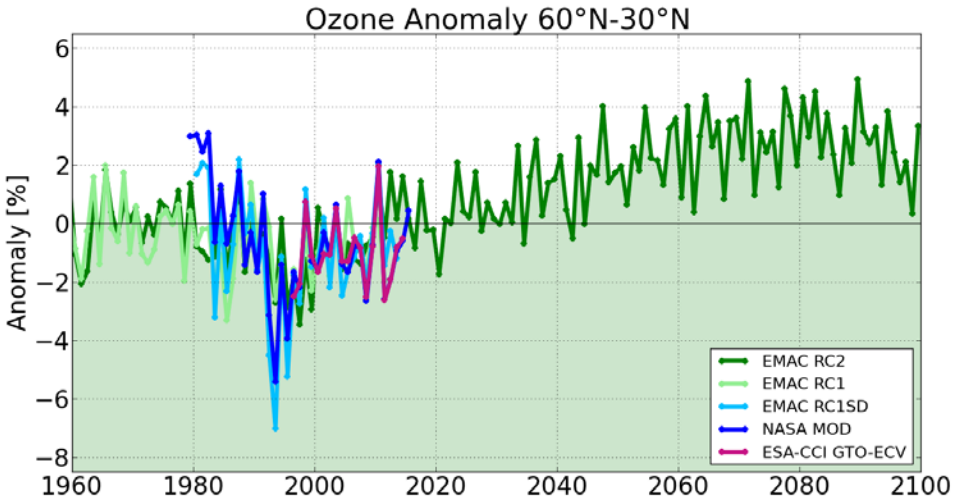
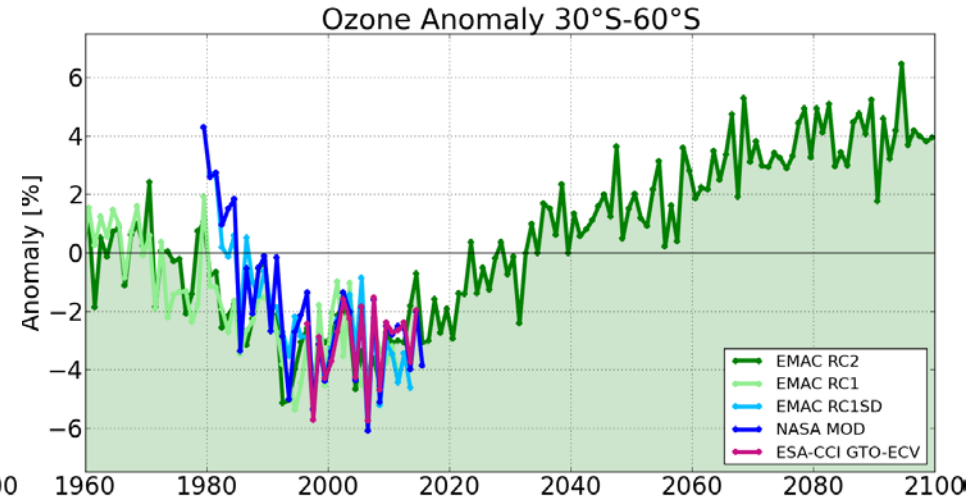
Example: Interhemispheric differences of ozone evolution





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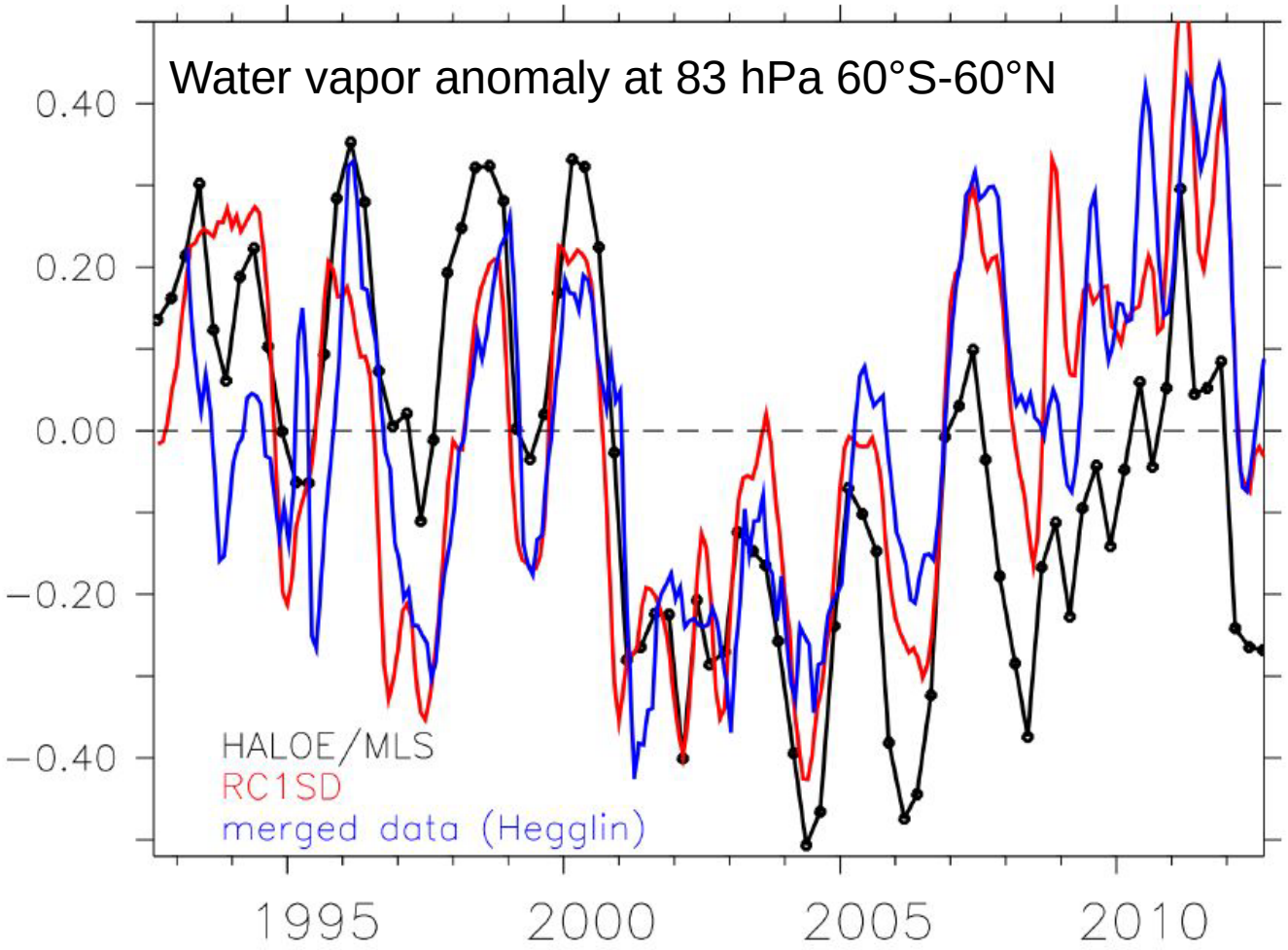
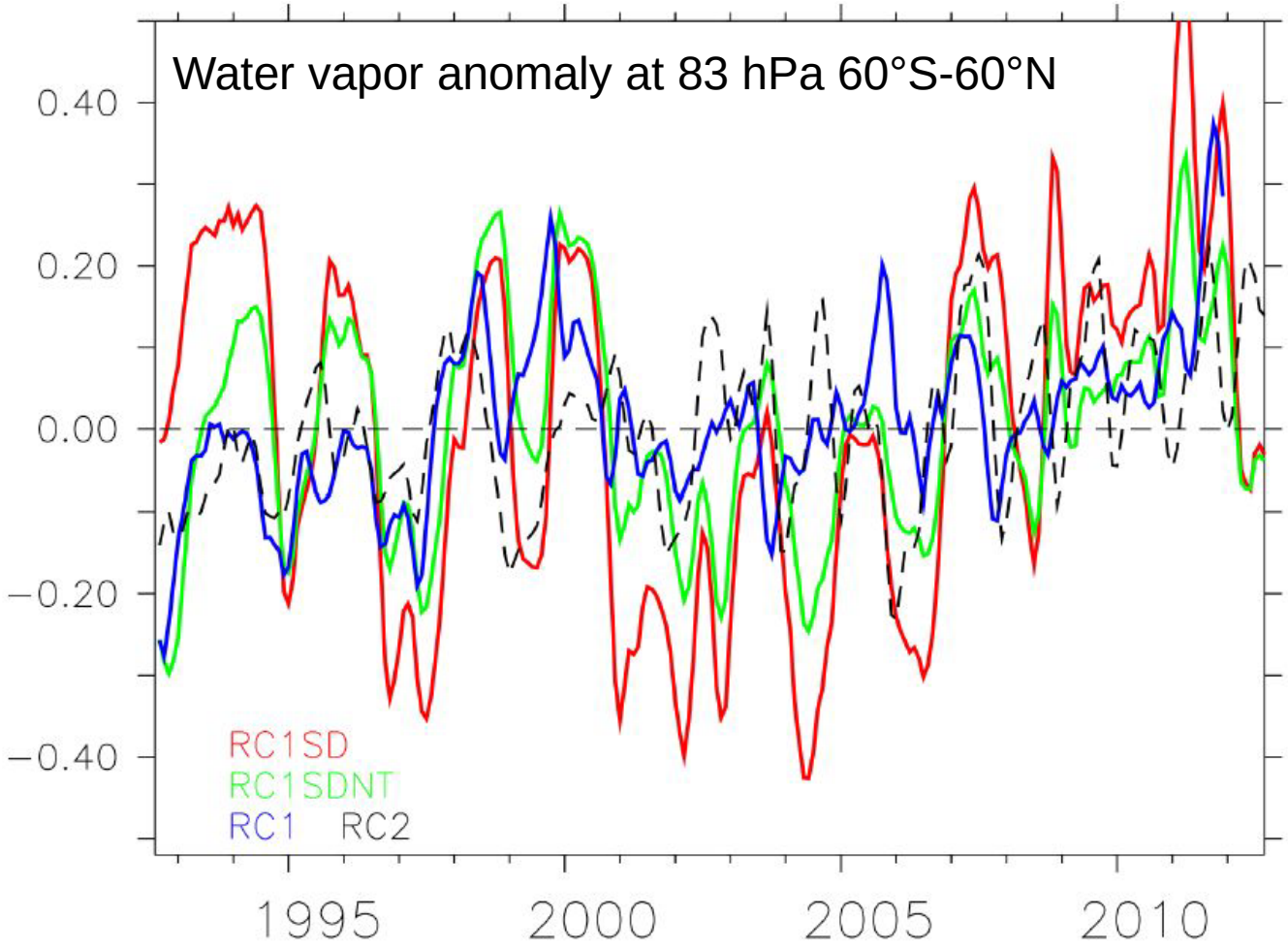
Example: Explanation of the millennium water drop



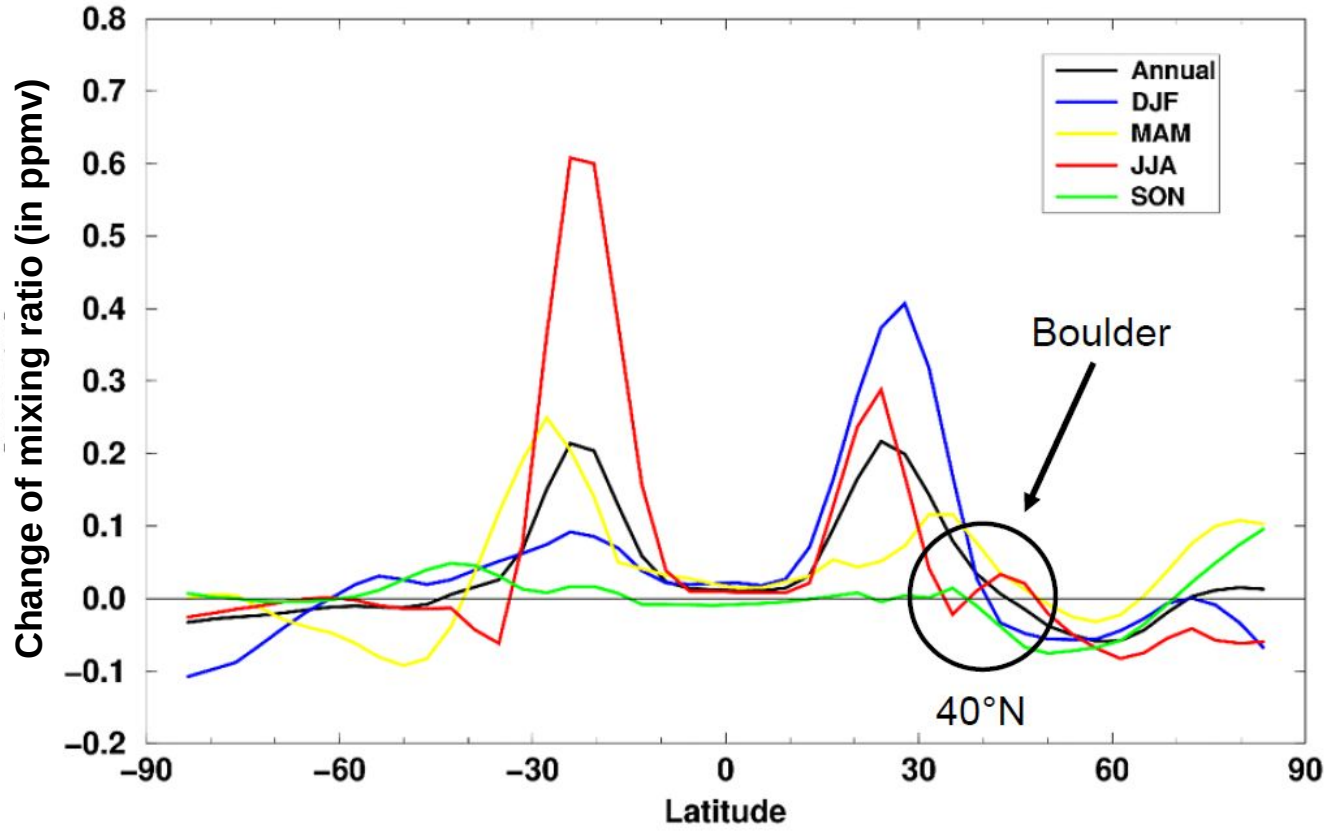
Brinkop et al., 2016

Example: Explanation of the millennium water drop



Brinkop et al., 2016

Example: Stratospheric water vapor trends at the thermal tropopause (1980-2000)



Old CCM results (nearly 15 years old) indicate

- significant trends only in the subtropics, and show
- a seasonal dependence.

Is this model assessment robust?

Discussions of difference between Boulder measurements and satellite observations are still going on since the beginning of the early 2000s (e.g. Randel et al., 2004; Hegglin et al., 2014).

Is the Boulder location (FPH measurements) representative for the detection of global water vapor trends in the LS?

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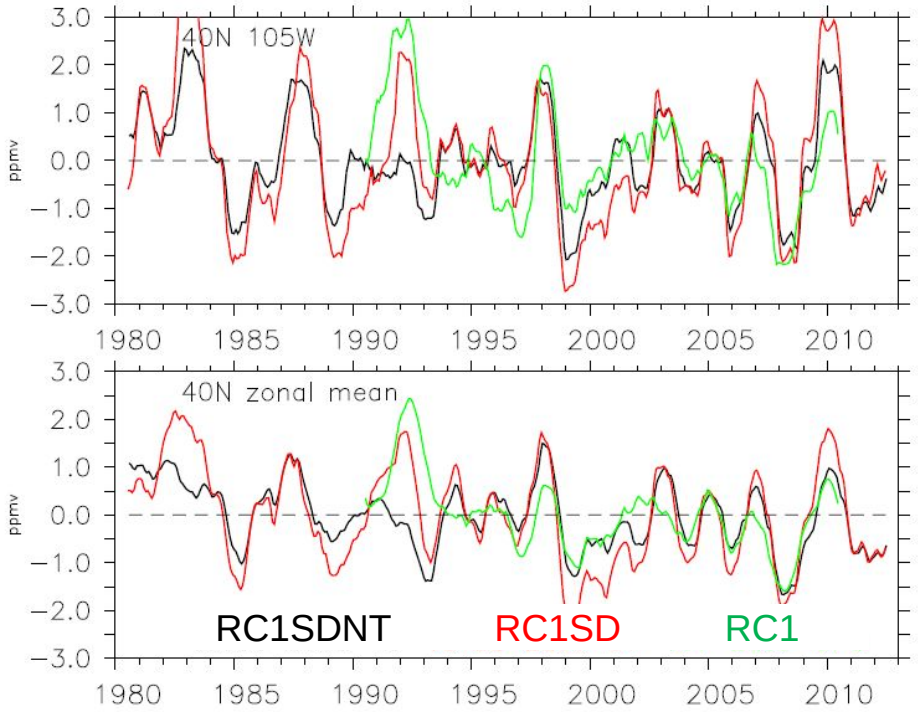
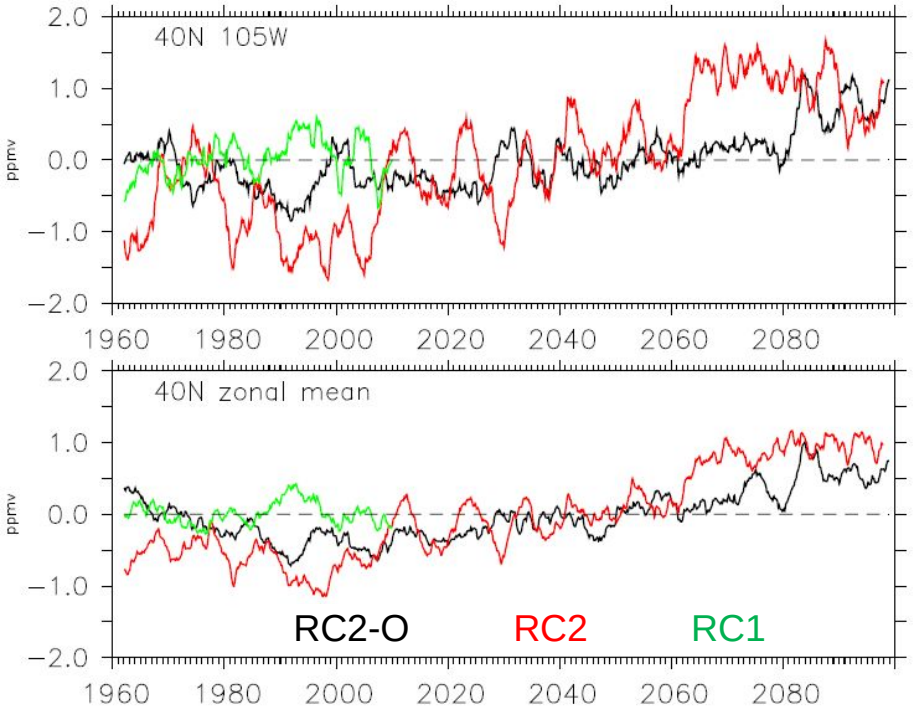
New results: Evolution of stratospheric water vapor

Boulder

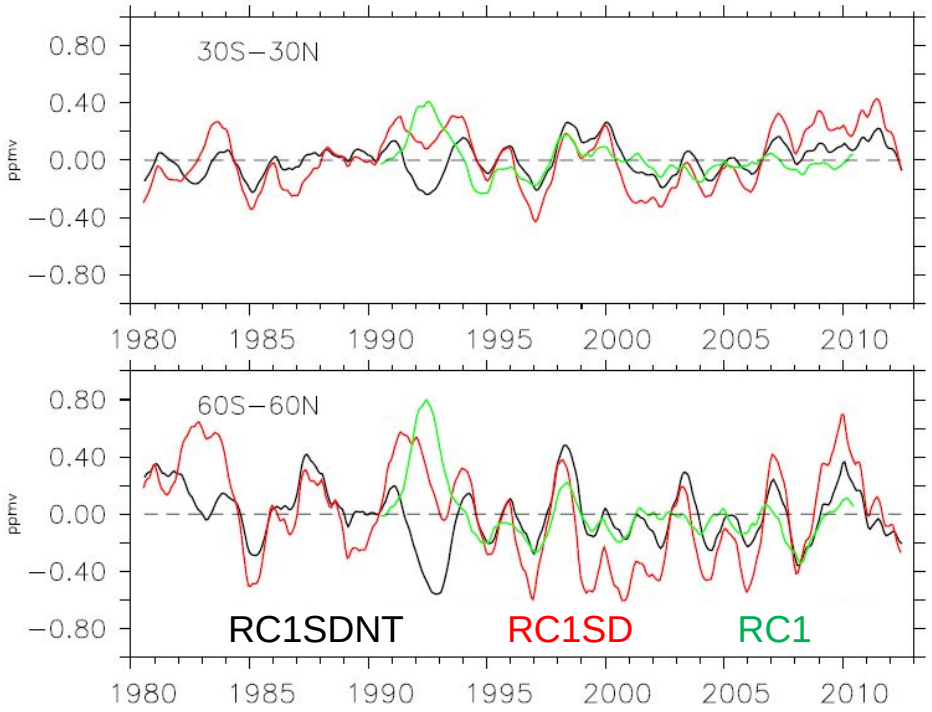


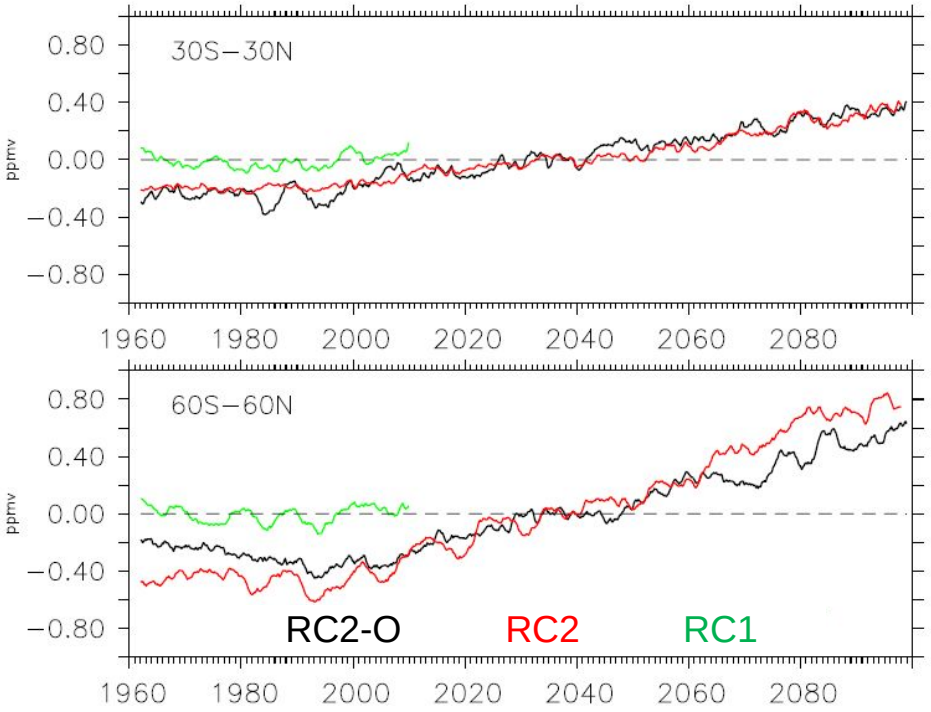


Water vapor anomalies at the CPT !

New results: Evolution of stratospheric water vapor

Tropics and near global mean

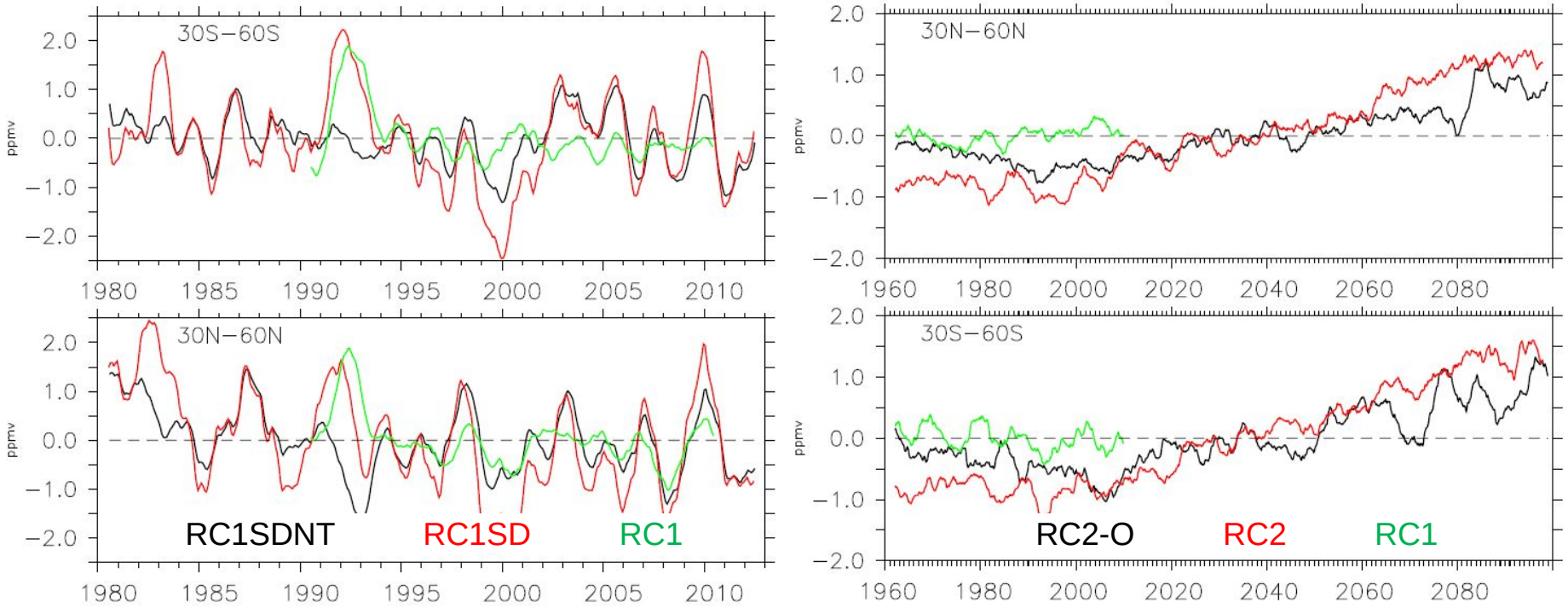




Water vapor anomalies at the CPT !

New results: Evolution of stratospheric water vapor

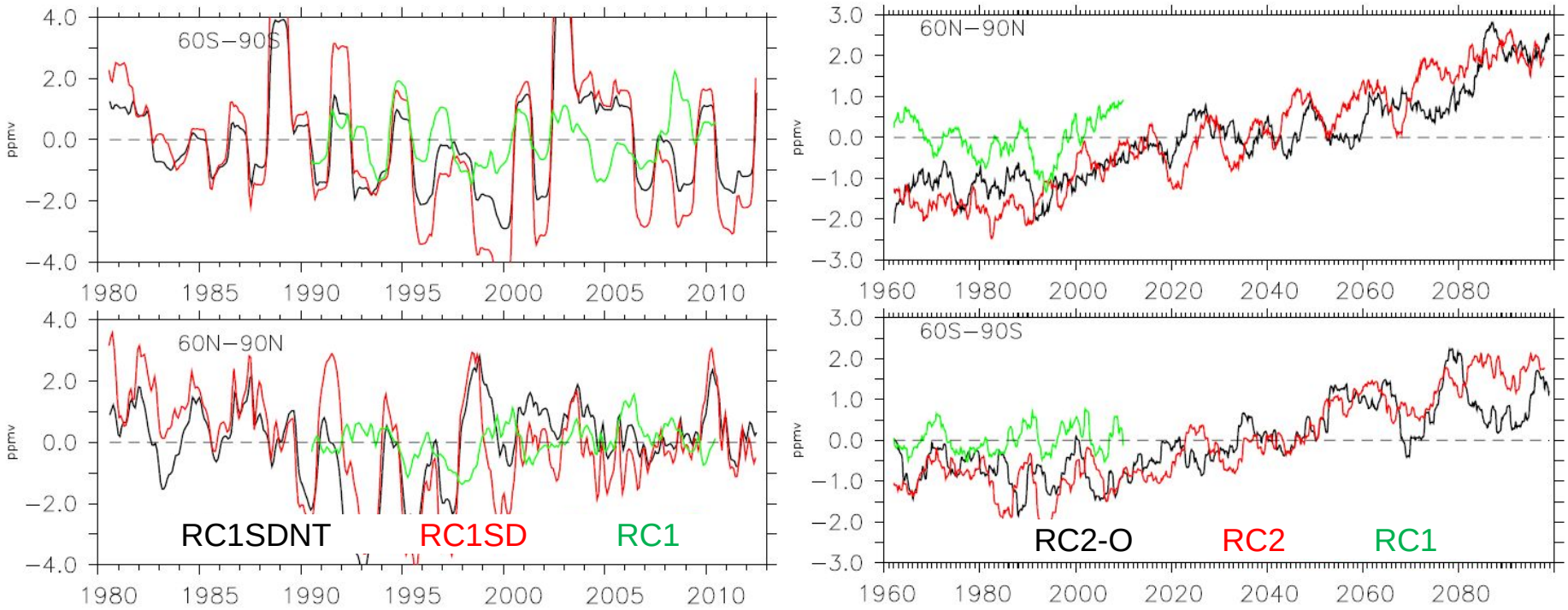
Middle latitudes



Water vapor anomalies at the CPT !

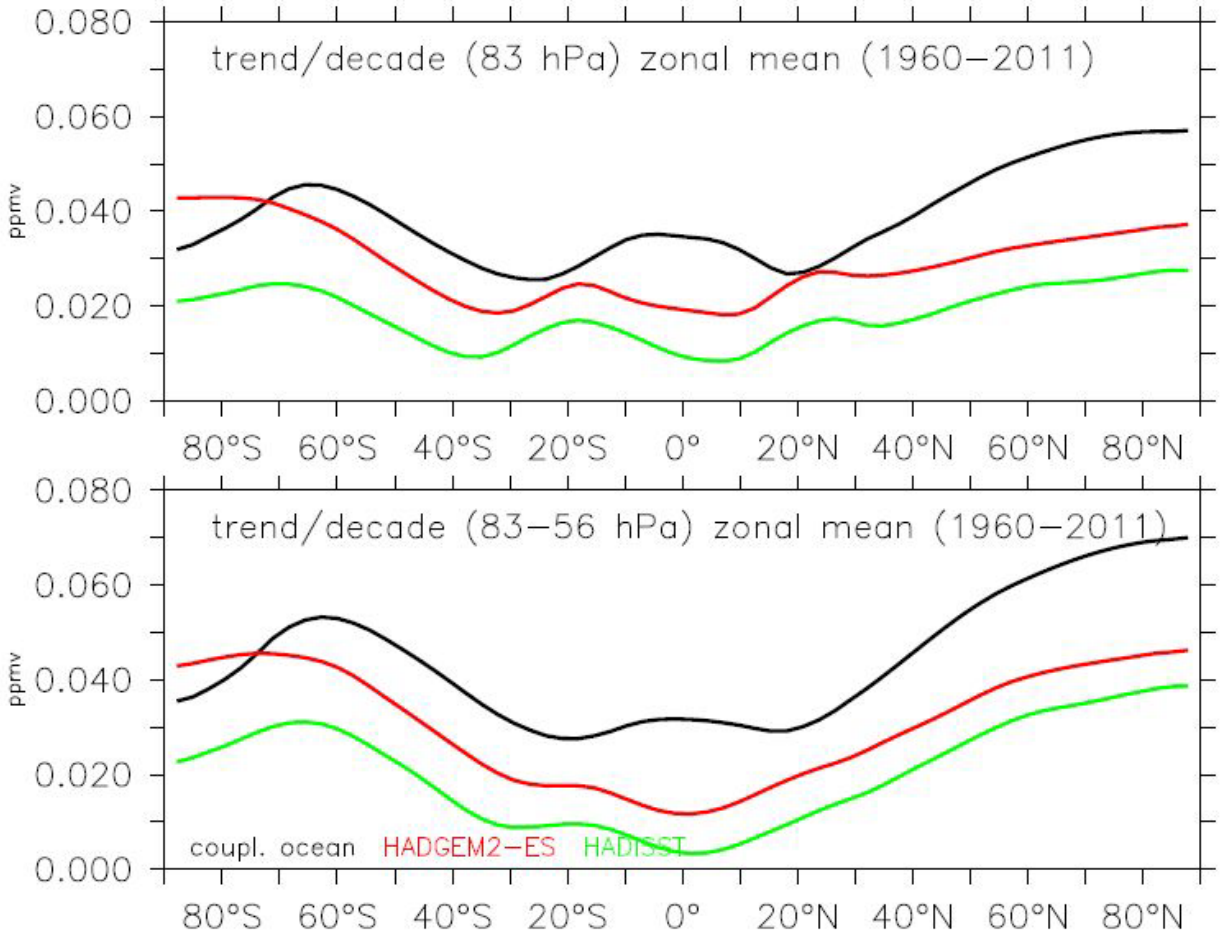
New results: Evolution of stratospheric water vapor

Polar regions



Water vapor anomalies at the CPT !

New results: Trends of stratospheric water vapor



RC1

RC2

RC2-O

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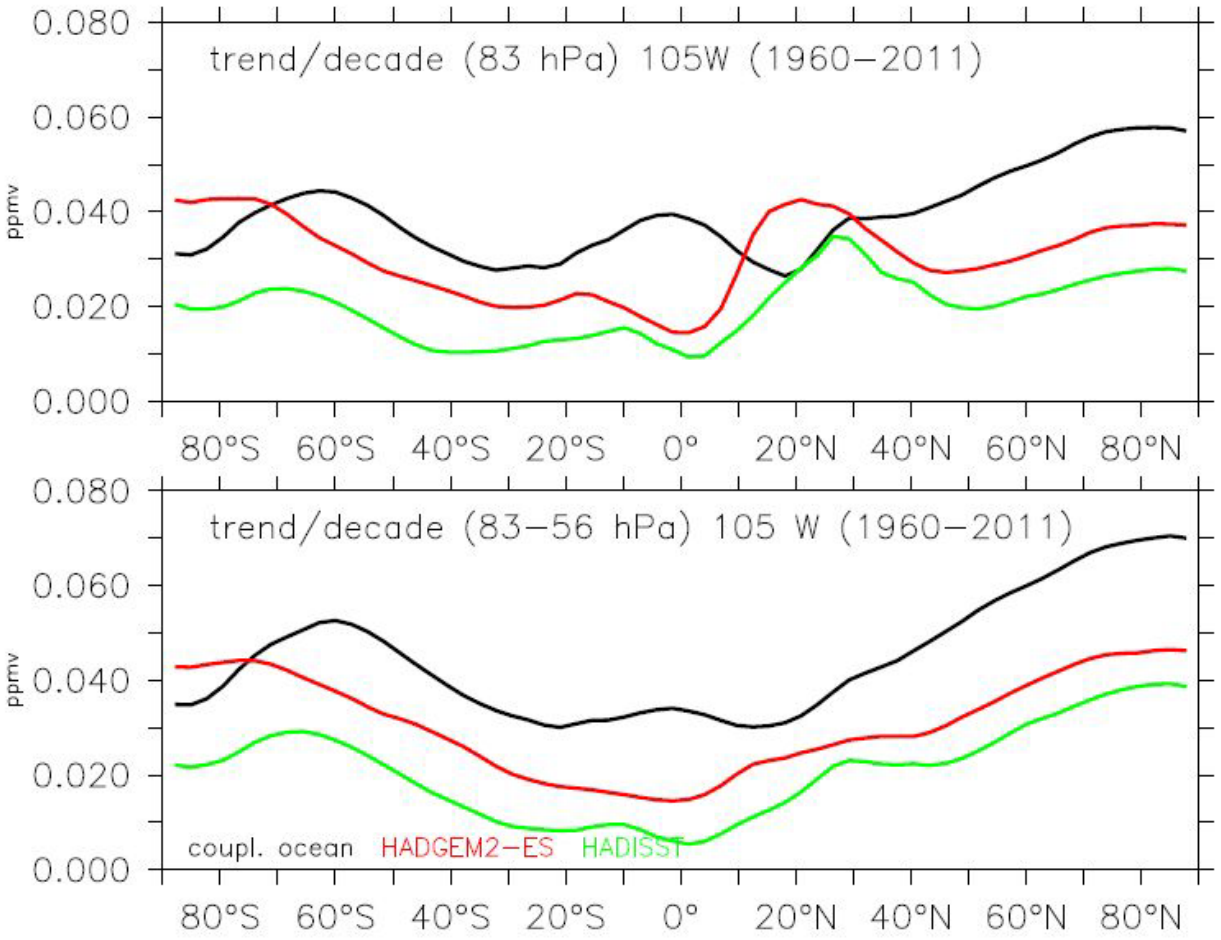
New results: Trends of stratospheric water vapor

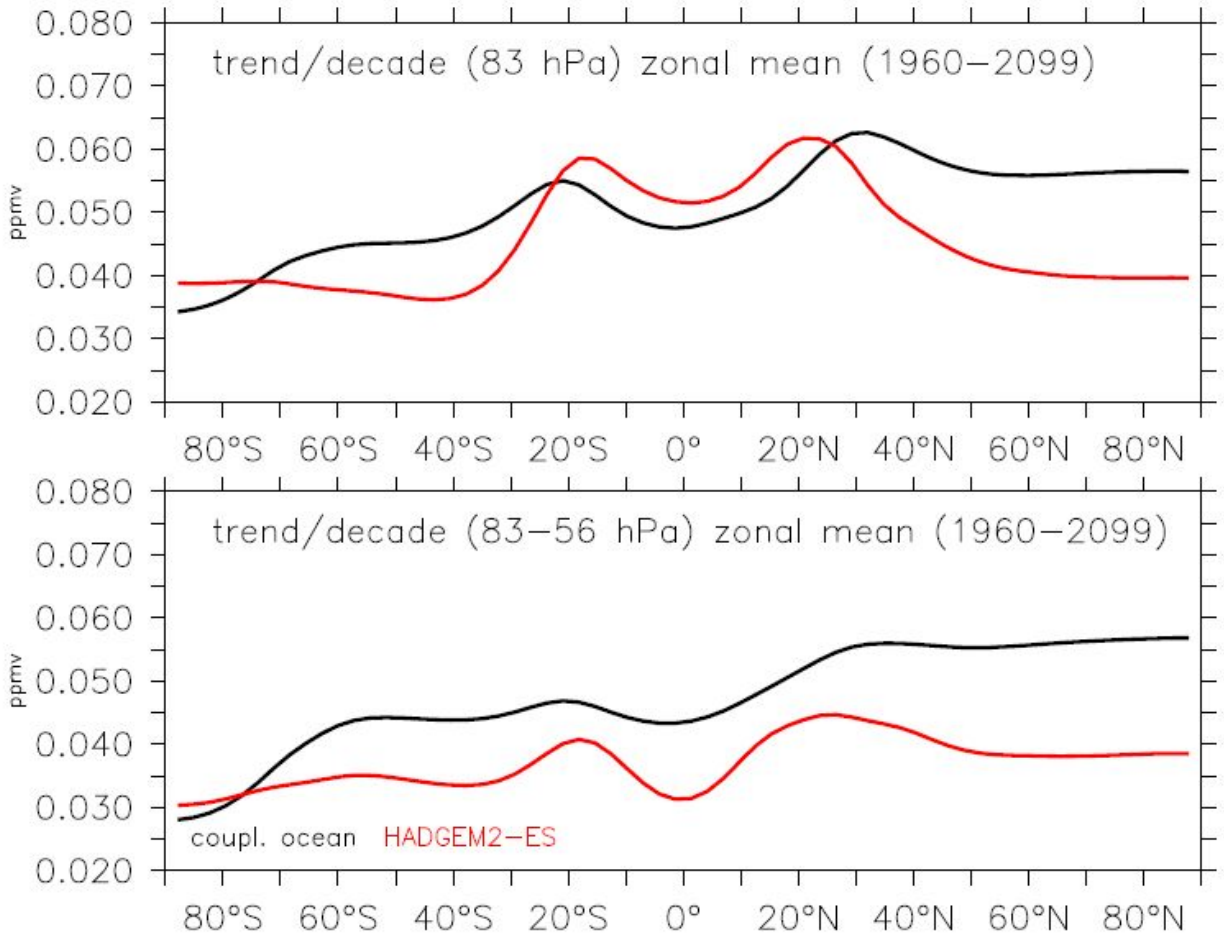


RC1

RC2

RC2-O

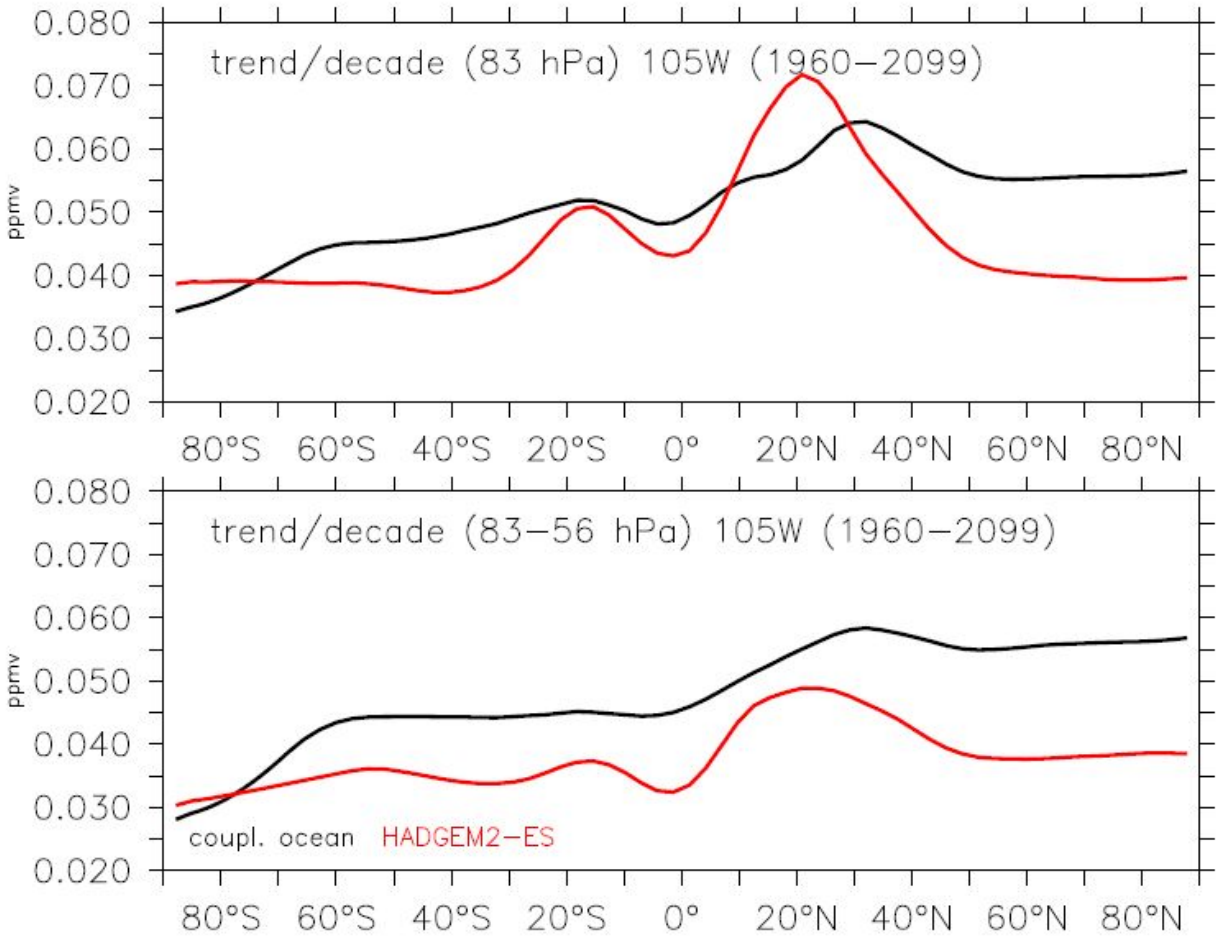
New results: Trends of stratospheric water vapor



RC2

RC2-O

New results: Trends of stratospheric water vapor



RC2

RC2-O

Summary

- A hierarchy of new CCM simulations have recently been conducted and the output of many CCMs is now available (CCMI archive).
- A detailed comparison of CCM data with observations is required.
- Sensitivity studies with CCMs can verify the importance of specific processes and feedback mechanisms and therefore can help to understand the variability of the atmospheric system.
- Long-term CCM simulations (several decades) can support merging individual measurements (e.g. shorter satellite records) into a consistent long-term record and therefore providing additional information which cannot be received from the observations alone.
- More robust investigations can be carried out on the long term (e.g. identification of significant trends, their causes and effects).
- Cooperation between “observers” and “modellers” is essential!

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