Assessment of transport in the latest Chemistry Climate Model Initiative (CCMI-2022) simulations

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Abstract: Chemistry climate models (CCMs) are routinely used to study the present-day chemical state of the atmosphere and make projections of how the chemical state may change in the future under different climate change and reactive gas emission scenarios. As part of Phase Two of the Chemistry Climate Model Validation (CCMVal-2) project the distribution of a number of chemical species and diagnostic tracers (e.g. age of air) were compared with available observations to assess the fidelity of stratospheric transport in the participating models. It has been more than 10 years since the CCMVal-2 assessment and chemistry climate models have continued to evolve. Here we revisit and extend the assessment of the distribution of chemical tracers from CCMVal-2 to look at the most recent set of simulations performed for the Chemistry Climate Model Initiative to ask whether the ability of models to accurately simulate stratospheric transport has changed significantly.

The CCMI-2022 Experiments

refD1	A free-running historical hindcast simulation covering 1960 – 2018, using observed SSTs/sea-ice and other forcings (including extended datasets of stratospheric aerosols and solar forcing) designed to reproduce the past.
refD2	The baseline scenario covering 1960 – 2100 to provide updated projections of ozone recovery. This scenario follows the GHGs and reactive gas emissions from SSP2-4.5 of CMIP6 and the WMO(2018) baseline projection for Ozone Depleting Substances. SSTs and sea-ice are calculated by each modelling group, using either prescribed datasets or interactively.
senD2-sai	Based on the refD2, but with modified fields for the specified stratospheric aerosols reflecting increased amounts from 2025 due to Stratospheric Aerosol Intervention. SSTs/sea-ice are to be specified as a repeating annual cycle derived as the 2020 – 2030 average from the baseline refD2 simulation.
senD2-ssp370	Set up largely as the refD2 baseline scenario, only following the low climate mitigation scenario SSP3-7.0 of CMIP6 for GHGs and reactive gas emissions.
senD2-ssp126	Similar to senD2-ssp370, though following the high climate mitigation scenario SSP1-2.6 of CMIP6.

Assigned high priority.

Simulations currently available in the Centre for Environmental Data Analysis (CEDA) data archive

Institute-Model	refD1	refD2	senD2-sai	senD2-ssp126	senD2-ssp370
CSIRO-ACCESS	3				
ECCC-CMAM	5	3	3		
DLR-EMAC	1	3			
GSFC-GEOSCCM	1				
NIES-MIROC32	3	1		1	1
CNRM-MOCAGE	4*	4*	4*		
NIWA-UKCA2	3	3	3	3	3
IPSL-REPROBUS	1				
ETH-SOCOL	1				
NCAS-UKESM1	3				
NCAR-WACCM	3^	3^			

*Multiple realizations using combinations of different model versions and different forcings but the same meteorology.
^Data not currently available in CEDA archive.

Some initial comparisons of CCMI-2022 with CCMVal-2

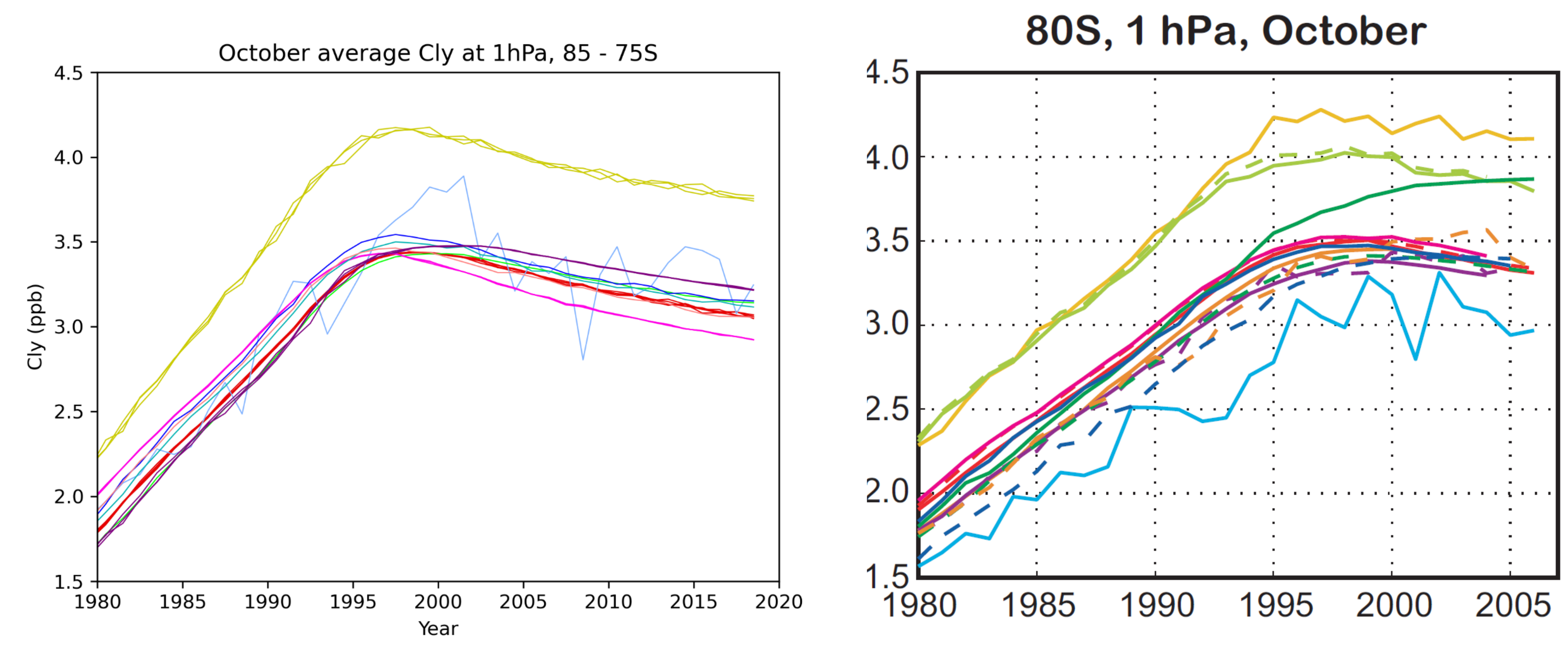

Figure 1. A comparison of total inorganic chlorine (Cly) at 1hPa, 70 - 80°S in October. The left-hand panel shows the results from the CCMI-2022 REF-D1 simulation and the right-hand panel are results from the CCMVal-2 REF-B2 simulation as presented in Neu and Strahan (Chapter 5 of SPARC CCMVal (2010)). At 1hPa in October almost all of the chlorine has been released from the organic species and the total inorganic chlorine should not exceed the maximum specified tropospheric chlorine total of approximately 3.7ppb.
NOTE: The colours used for each model are not consistent between the two panels.

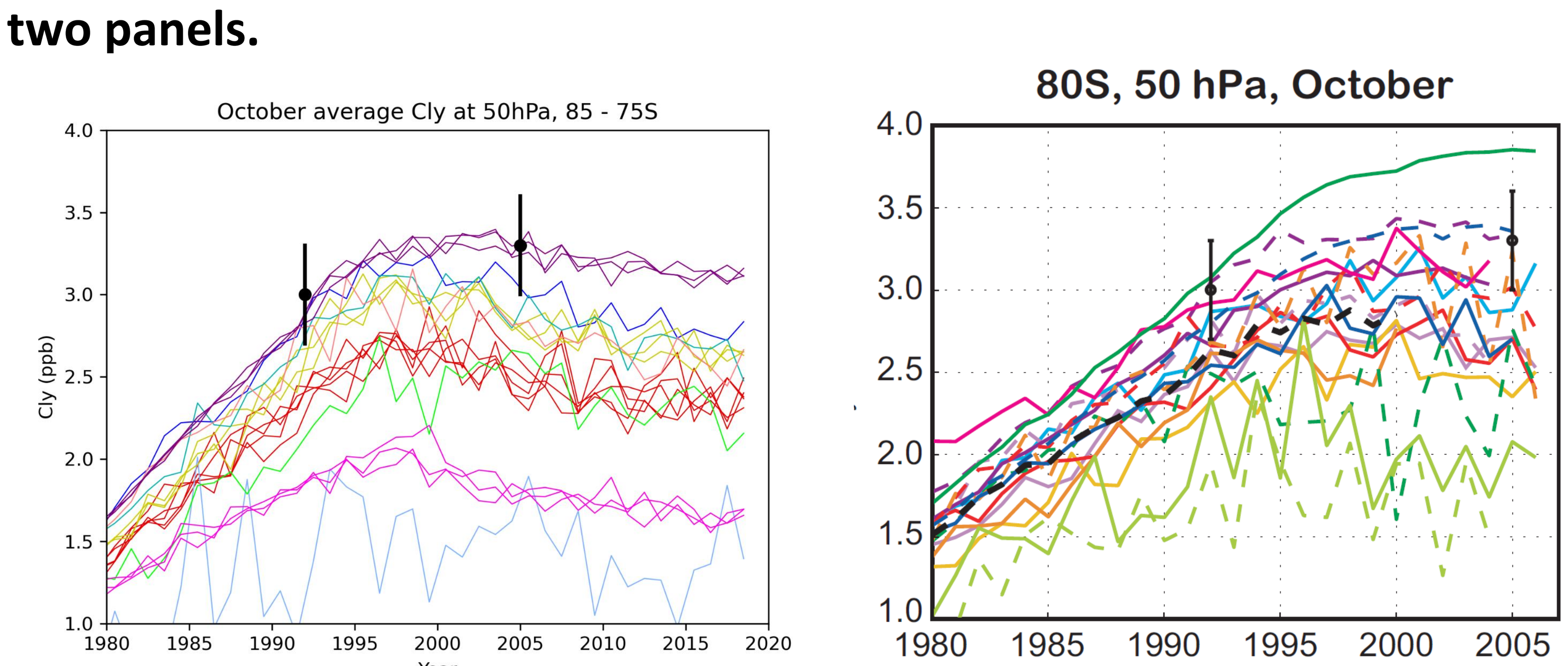

Figure 2. A comparison of total inorganic chlorine (Cly) at 50hPa, 70 - 80°S in October. The left-hand panel shows the results from the CCMI-2022 REF-D1 simulation and the right-hand panel are results from the CCMVal-2 REF-B2 simulation as presented in Neu and Strahan (Chapter 5 of SPARC CCMVal (2010)). Observations of Cly from Lary et al. (2007) are shown as the black circles with uncertainties as derived in Waugh and Eyring (2008).

For CCMI-2022 there are fewer models that appear to have problems conserving total chlorine (Figure 1, Cly at 1 hPa), though the majority of models continue to underestimate reactive chlorine in the Antarctic vortex (Figure 2).

References:
SPARC CCMVal (2010), SPARC Report on the Evaluation of Chemistry-Climate Models, V. Eyring, T. G. Shepherd, D. W. Waugh (Eds.), SPARC Report No. 5, WCRP-132, WMO/TD-No. 1526.
Lary, D. J., Waugh, D. W., Douglass, A. R., Stolarski, R. S., Newman, P. A. and Mussa, H., Variations in stratospheric inorganic chlorine between 1991 and 2006, *Geophys. Res. Lett.*, 34, doi:10.1029/2007GL030053.
Waugh, D. W. and Eyring, V., Quantifying performance metrics for stratospheric-resolving chemistry-climate models, *Atmos. Chem. Phys.*, 8, 5699-5713.