Ozone and stratospheric water vapour concentration databases for CMIP6

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Background:

CMIP is organizing its next phase (i.e., CMIP6) and a new set of coordinate climate model simulations, which aim at improving our understanding of the past and current climate, providing estimates of future climate change, and identifying Earth system feedbacks. While ESMs and AOGCMs move towards ever higher spatial resolution and complexity, with coupling to more Earth system components, there will still be models participating that lack interactive chemistry due to its high computational costs. Stratospheric and tropospheric constituent changes have however important impacts on climate and the Earth system (e.g. the effect of the Antarctic ozone hole on summer surface climate)(Son et al. [2008]). In addition, climate change feed backs on constituent distributions through changes in temperatures and transport (Hegglin and Shepherd [2009], Plummer et al. [2011], Dietmüller et al. [2014]). In order to avoid inconsistencies between a chosen emission scenario and constituent distributions and to allow for a more realistic representation of the significant local and surface radiative forcing effects that past and future ozone and stratospheric water vapour changes have on climate (Dietmüller et al. [2014], Nowack et al. [2015]), there is a need to provide continuous time series of radiatively active gases and aerosol from the past into the future as forcings to the CMIP6 models. The ozone database developed for CMIP5 (Cionni et al., 2011) for the first time allowed that time-varying ozone was included also in those CMIP simulations that did not have interactive chemistry. However, the Cionni et al. (2011) has several weaknesses, including the underestimation of the Antarctic ozone hole in the past and the restriction to a single greenhouse gas scenario for stratospheric ozone in the future. There is hence a need to provide an updated version of this climatology.

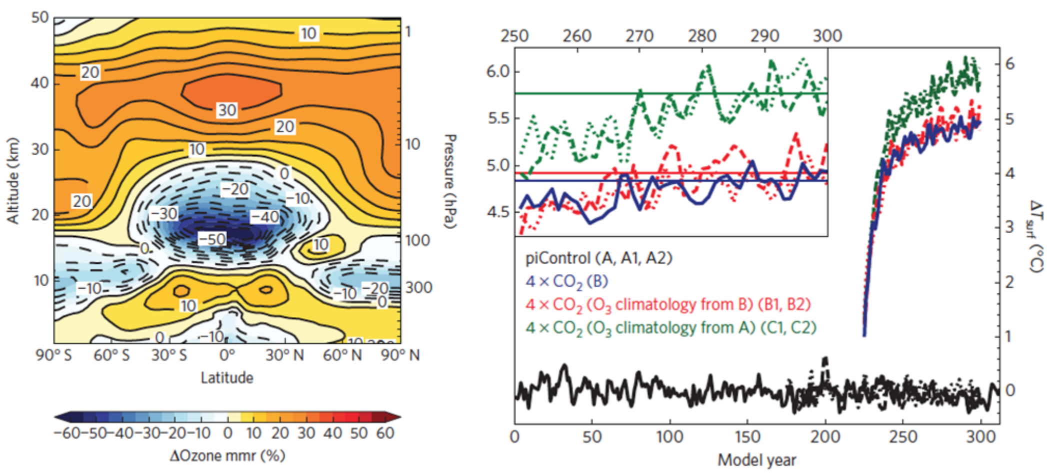

Figure: Annual zonal mean ozone changes after 50 years of simulation with an abrupt forcing of 4xCO_2 (left panel). Temporal evolution of the global annual mean surface temperature anomaly for different simulations: Green indicating simulations with climatological pre-industrial ozone fields prescribed, blue and red simulations with freely evolving ozone (right panel). An increase of surface warming of around 1 degree Celsius (approx. 20%) after 75 years is found in response to an instantaneous climate forcing of 4xCO2 when ozone is prescribed at pre-industrial levels rather than being allowed to evolve self-consistently with the forcing. (from Nowack et al. [2015])

Design of forcing data basis:

Within the IGAC/SPARC Chemistry-Climate-Model Initiative (CCMI, see http://www.met.reading.ac.uk/ccmi/), an update to the *Cionni et al.* [2011] ozone concentration database encompassing both the stratosphere and the troposphere will be generated and provided to CMIP6 modelling groups. In addition, a stratospheric water vapour concentration database will be produced, since many ESMs and AOGCMs lack realistic stratospheric water vapour fields, despite its importance for surface climate (see Nowack et al. [2015]).

General approach:

The constituent forcing data-bases will be generated based on new and improved comprehensive model simulations (including models with combined stratosphere-troposphere chemistry only) that are currently run as part of CCMI Phase-1 (Eyring et al., 2013) and using refined methodologies that are expected to lead to a physically consistent and in time homogeneous evolution of the constituents from the past into the future (1850-2100). It is for the reason of homogeneity that we will refrain from merging the model simulations with observations for the period between 1980 and 2010, when observations are available. However, observations will be used to evaluate each model's performance and extract mean and variability, which then will be reflected in the weighting scheme applied to the different models' outputs. The methodology to generate the constituent timeseries will account for solar, QBO, ENSO, and EESC signals and weight the models based on their performance with respect of each to those (if the signal is included in the model simulation). The final concentration database will however only include the EESC and solar signals. In addition, a pattern recognition methodology will be developed that separates the effects of CO_2, N_2O, and CH_4 emission changes on the distributions of ozone and water vapour. The goal is that the quantification of these patterns can be used to create future ozone and water vapour distributions based on other emission scenarios that are likely used within CMIP6 through simple scaling, replacing the need of running expensive chemistry-climate model simulations.

Currently the following *characteristics* of the different forcing fields are envisaged (these are open for discussion in the community):

Stratosphere/troposphere ozone concentration fields

- Time period covered: 1850-2100
- Multi-model mean ozone concentrations from chemistry-climate model simulations with interactive tropospheric and stratospheric chemistry
- Full 3D-fields
- 5-day means and/or monthly means [users are asked to send us their preference]
- for REF-C2 scenario, plus RCP4.5, RCP6.0 and RCP8.5 scenarios
- A methodology to scale to other scenarios

Rationale: We consider exploring a methodology (e.g. based on potential vorticity or dynamical information such as wave numbers) that could be used to generate consistent 3D fields within each model. 5-day mean fields will be provided so to capture the evolution (and in particular depth) of the Antarctic ozone hole more accurately, which is important for the dynamical response in the models. The different simulations will be run to cover a range of emission scenarios that then can be used to develop the scaling methodology.

Stratospheric water vapour fields

- Time period covered: 1850-2100
- Multi-model mean stratospheric water vapour concentrations from chemistry-climate model simulations with interactive tropospheric and stratospheric chemistry
- zonal means (2D) (tropopause and above, with the tropopause being defined as the thermal tropopause)
- monthly means
- for REF-C2 scenario, plus RCP4.5, RCP6.0 and RCP8.5 scenarios

Rationale: Water vapour in the stratosphere is a relatively long-lived tracer and hence only little longitudinal variations are expected, hence only 2D monthly mean fields will be provided.

Documentation: A research paper will be published on the ozone and water vapour fields used for CMIP6 with submission soon after the data are made available (end of 2016/early 2017).

Users of the ozone and water vapour fields: Modelling groups wishing to use the ozone and/or water vapour fields are asked to register and provide feedback on the outlined plan as soon as possible to m.i.hegglin@reading.ac.uk. Feedback should include preferences on methodological approach, preferred temporal and spatial resolution of data fields, output format, and other specific requests.

References

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