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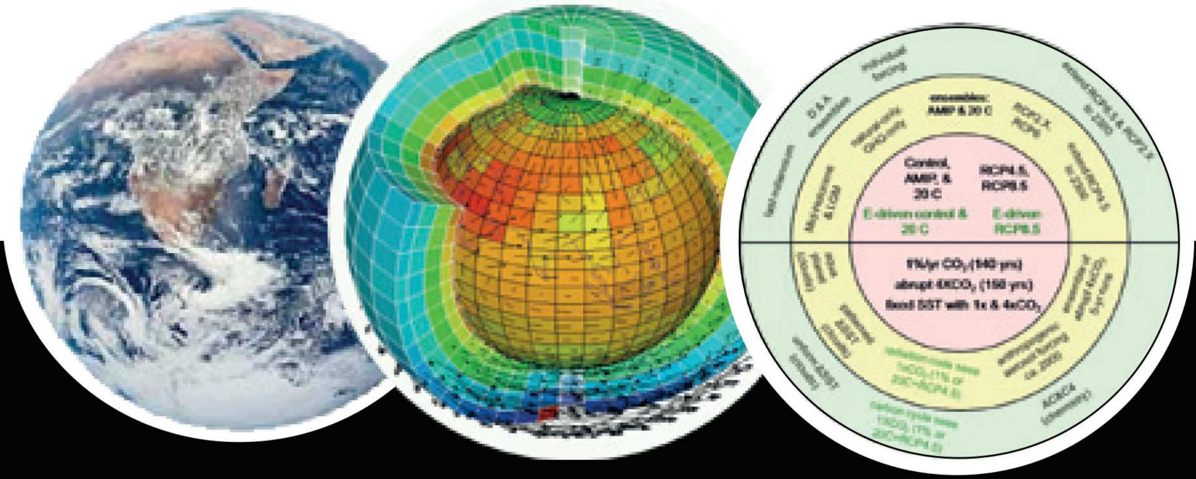
WCRP Coupled Model Intercomparison Project - Phase 5 - CMIP5 -



CLIVAR is an international research programme dealing with climate variability and predictability on time-sales from months to centuries. CLIVAR is a component of the World Climate Research Programme (WCRP). WCRP is sponsored by the World Meteorological Organization,the International Council for Science and the Intergovernmental Oceanographic Commission of UNESCO.

WCRP World Climate Research Programme

CMIP5 presents a unique opportunity to update the first C4MIP analysis of carbon cycle feedbacks in coupled climate-carbon cycle models using a greater number of state-of-the-art ESMs from a wider modelling community, and encompassing improved experimental design and model processes.

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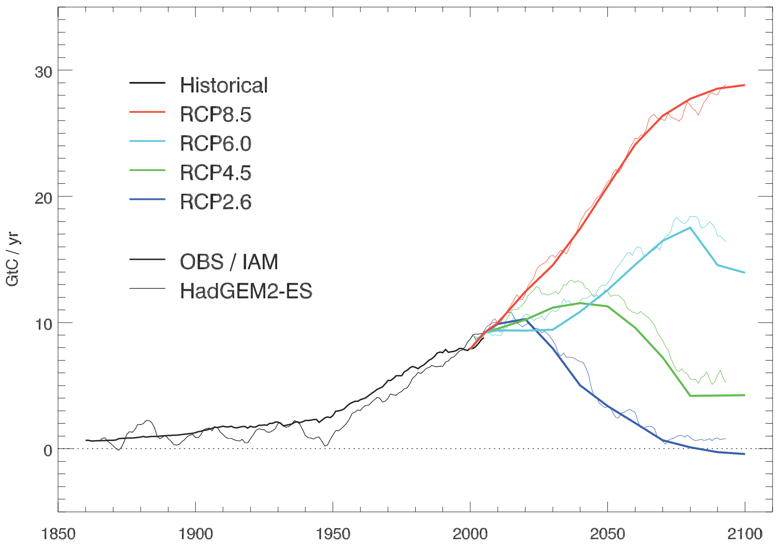

Figure 1. Permissible emissions as simulated by HadGEM2-ES (thin lines) compared with observed CO_2 emissions for the historical period and those projected for the RCP scenarios by the integrated assessment models (IAMs) which created the RCPs (thick lines)

Stratosphere-resolving Models in CMIP5

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There is growing evidence that variability in the stratosphere has a significant impact on surface climate (Baldwin and Dunkerton, 2001, Thompson et al., 2002, Charlton et al., 2004, Scaife et al., 2005, Manzini et al., 2006, Ineson and Scaife, 2009, Cagnazzo and Manzini, 2009, among others). During boreal winter, there is the potential that models with a well resolved stratosphere will lead to an improved representation of blocking and cold air outbreaks over Europe, due to the simulation of realistic stratospheric sudden warming events in the stratosphere resolving models. In addition, stratospheric changes induced by anthropogenic climate change may contribute substantially to changes in storm tracks, sea level pressure and precipitation.

Stratospheric dynamics may also be implicated in linking remote changes in the Earth system, such as ozone depletion/recovery and ocean carbon fluxes (Lenton et al., 2009). A suggested mechanism for this is that ozone depletion leads to a stronger southern hemisphere polar night jet in October which in turn leads to increased zonal wind over the southern ocean decreasing the uptake of CO_2 by the southern ocean (Le Quéré et al., 2007). Figure 1 shows this trend in zonal wind in ERA40, a coupled stratosphere-resolving model, known as a high top model, run at the UK Met Office (Martin et al., 2011) for CMIP5, and and equivalent standard, low top climate model (differing only in vertical resolution). In this particular case, the high/low top model comparison indicates sensitivity of the zonal wind trend to the representation of stratospheric dynamics.

Recently, the Stratospheric Processes and their Role in Climate (SPARC) Chemistry-Climate Model Validation phase 2 (CCMVal-2) multi-model intercomparison has demonstrated that the CCMval-2 models, generally with a better-resolved stratosphere, perform better than AMIP CMIP-3 models in the stratosphere and perform equally well if not better in the troposphere (Chapter 10, Baldwin et al., 2010).
These advancements in the knowledge of how stratospheric representation operates in climate models have lead a number of climate modeling groups to undertake the Coupled Model Intercomparison Project Phase 5 (CMIP5) experiments with models that include a well-resolved stratosphere, the so-called "high-top models".

"High-top models" currently refer to coupled atmospheric-ocean-sea ice general circulation models (AOGCMs), or their extension to Earth System Models (ESMs), whose atmospheric model extends above the stratopause. More specifically, to properly simulate stratospheric processes, the development of high-top models needs to include also revised implementations of radiation, gravity wave effects, and how radiative active trace fields are represented. Paying particular attention to the evolution of ozone has already been demonstrated as important (Son et al., 2008).

The high-top models therefore distinguish themselves from the large majority of climate/Earth system models, such as those that participated to CMIP3 and used for the Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC AR4) (Chapter 8, Randall et al., 2007). Consequently, the label "low-top" is now applied to any AOGCMs/ESMs, which atmospheric model component does not reach the stratopause. Most of the low-top models do extend to the middle stratosphere; however, high-top models typically extend to the middle/upper mesosphere. A few models extend to the lower thermosphere.

From the point of view of stratospheric dynamics, the major limitation of the low top models is that in this class of models, the explicit simulation of stratospheric variability is hampered in the upper layers of the model domain and in the lower stratosphere. This technique may provide reasonable results for the modelled mean climate, but it reduces the modelled stratospheric variability and therefore its downward influence. Its quantitative implications for tropospheric and surface variability for seasonal to decadal and longer time scale are just starting to become apparent.

The status of development of high-top models and their potential participation in CMIP5 have been recently reviewed in a workshop lead by the SPARC DynVar Activity on Modelling the Dynamics and Variability of the Stratosphere-Troposphere System (Manzini et al., 2011). Topics addressed in the workshop included: Influence of the stratosphere on the tropospheric circulation, on the ocean circulation via air-sea interactions, and on snow and sea ice fields; role of the stratosphere in the tropospheric circulation response to climate change; and mechanisms for two-way stratosphere-troposphere coupling. Presentation sections were complemented by discussions on how to best analyze, make full use, and exchange knowledge from the ensembles of CMIP5 runs, with the role of the stratosphere in focus.

A major outcome of the DynVar workshop is that about 10 modeling groups are carrying out analysis of the CMIP5 simulations with high top models and comparing this with the low top model simulations. The modeling groups represented at the DynVar workshop are listed in Table 1, together with information of the model names, atmospheric resolution, scenario, and contacts. Of the 10 high top models represented at the DynVar workshop, three models include interactive atmospheric chemistry and at least three modeling systems will additionally be run with CO_2 emissions, requiring modules for the land and ocean carbon cycle.

Following the workshop, Research Groups have been established within the SPARC DynVar Activity, to foster analysis of the CMIP5 archive, with the role of the stratosphere in focus.

A SPARC/DynVar workshop will be held jointly with CLIVAR's Stratosphere Historical Forecast Project (SHFP), which is carrying out a similar activity for high top and low top seasonal forecasts. The workshop will take place in spring/summer 2012. For more and updated information see the SPARC DynVar web site (http://www.sparcdynvar.org/).

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Table 1: High top models participating to CMIP5 so far.

Institute / Group	Model	Atmospheric Resolution	Scenario	Contact
CMCC	CMCC-CMS	T63xL95 top=0.01hPa	RCP4.5	chiara.cagnazzo@cmcc.it piergiuseppe.fogli@cmcc.it silvio.gualdi@bo.ingv.it
	CMCC-CESM	T31xL39 top=0.01hPa	RCP8.5	
DMI	EC-EARTH	T159xL91 top=0.01hPa T159xL61 top=5hPa	RCP4.5	shuting@dmi.dk boc@dmi.dk
GEOS	GEOS-5	1°x1.25°xL72 top=0.01hPa	Decadal prediction runs	Steven.Pawson-1@nasa.gov
GFDL	CM3	~200kmxL48 top=0.017hPa	All 4 RCPs	john.austin@noaa.gov leo.j.donner@noaa.gov larry.horowitz@noaa.gov
GISS	GISS-E	90x144xL40 top=0.1hPa	All 4 RCPs	dshindell@giss.nasa.gov
IPSL	IPSL-CM5	144x143xL39 top=65km	RCP4.5	Francois.lott@lmd.jussieu.fr
Met Office Hadley Center / NCAS	HadGEM2	192x145xL60 top=84km	RCP4.5, RCP8.5	neal.butchart@metoffice.gov.uk steven.hardiman@metoffice.gov.uk s.osprey@physics.ox.ac.uk gray@atm.ox.ac.uk
MPI-M	MPI-ESM	~360x180xL95 top=0.01hPa	All 4 RCPs	marco.giorgetta@zmaw.de
MIROC	MIROC-ESM MIROC-ESM-CHEM	T42xL80 Top=85km	All 4 RCPs	wnabe@jamstec.go.jp kawamiya@jamstec.go.jp nozawa@nies.go.jp
MRI	MRI-ESM1	TL95xL48 (320x160) top=0.01hPa	RCP4.5, RCP8.5 RCP8.5	kshibata@mri-jma.go.jp
NCAR	WACCM4	144x96xL66 top=6x10⁻⁶hPa~135km	RCP4.5 (RCP8.5, RCP2.6)	aksmith@ucar.edu rgarcia@ucar.edu marsh@ucar.edu

Figure 1: December-January-February (DJF) trend ($ms^{-1}decade^{-1}$) in zonal wind in ERA40 (left), a coupled high top model, run at the UK Met Office for CMIP5 (middle), and equivalent low top model (right). The trends are computed over the 1980-1989 period.