DynVar – Diagnostic MIP
Dynamics and Variability of the Stratosphere ‑ Troposphere System

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Goal of the MIP and a brief overview

DynVar focuses on the interactions between atmospheric variability, dynamics and climate change, with a particular emphasis on the two-way coupling between the troposphere and the stratosphere. The key questions addressed by the activity are:

• How do dynamical processes contribute to persistent model biases in the mean state and variability of the atmosphere, including biases in the position, strength, and statistics of blocking events, storm tracks and the stratospheric polar vortex?
• How does the stratosphere affect climate variability at intra-seasonal, inter-annual and decadal time scales?
• What is the role of dynamics in shaping the atmospheric circulation response to anthropogenic forcings (e.g. global warming, ozone depletion) and how do dynamical processes contribute to uncertainty in future climate projections?

An overview of the proposed experiment

Rather then proposing new experiments, we are ***requesting additional output***, critical for understanding the role of atmospheric dynamics in both present and past climate, and future climate projections. ***Without this output, we will not be able to fully assess the dynamics of mass, momentum, and heat transport - essential ingredients in projected circulation changes - nor take advantage of the increasingly accurate representation of the stratosphere in coupled climate models.*** Our rational is that by simply extending the standard output relative to that in CMIP5, there is potential for significantly expanding our research capabilities in atmospheric dynamics.

An overview of the proposed evaluation/analysis of the CMIP DECK and CMIP6 experiments

Understanding circulation changes in the atmosphere, particularly of the mid-latitude storm tracks, has been identified by the World Climate Research Programme (WCRP) as one of the grand challenges in climate research. Changes in the storm tracks are significantly coupled with lower atmosphere processes such as surface temperature gradients and moisture availability (e.g. Booth et al. 2013) as well as with processes in the stratosphere, from natural variability on synoptic to intraseasonal timescales (e.g. Baldwin and Dunkerton 2001) to the response to changes in stratospheric ozone (e.g. Son et al. 2008) and other anthropogenic forcings (e.g. Scaife et al. 2012). The storm tracks depend critically on the transport of momentum, heat and chemical constituents throughout the whole atmosphere. Both resolved (primarily Rossby) and parameterized (gravity) waves play the key roles in these transports, and it is important that the standard output of the DECK experiments, the CMIP6 Historical Simulation and (in principle) any MIP experiment allow proper diagnosis of these wave fluxes.

The lack of output is particularly acute in the stratosphere, where daily means of standard variables (e.g., zonal and meridional winds, geopotential height and temperature) and parameterized gravity wave forcings (a key driver of the circulation) were not well documented in CMIP5, and resolved waves could at best be coarsely assessed, given the importance of the vertical structure to momentum and mass transport. As detailed by Hardiman et al. (2013), the stratospheric community had to rely on direct collaboration to obtain necessary diagnostics to assess the Brewer-Dobson circulation, the first order circulation of mass and momentum in the stratosphere. Daily means of standard variables in both the troposphere and stratosphere would expand our ability to assess the synoptic dynamics of the atmosphere.

Investigation of the impact of solar variability and volcanic eruptions on climate also relies heavily on atmospheric wave forcing diagnostics, as well as radiative heating rates (particularly in the short wave). By extending our request to the energy budget and including diagnostics such as diabatic heating from cloud-precipitation processes, research on the links between moist processes and atmospheric dynamics will be enabled as well. The interplay between moist processes and circulation is central to the WCRP Grand Challenge on Clouds, Circulation and Climate Sensitivity (Bony et al. submitted to Nature Geoscience, 2014).

The CMIP5 saw a significant upward expansion of models with a more fully resolved stratosphere (e.g. Gerber et al. 2012), and several multi-model studies have investigated the role of the stratosphere in present climate and in projections of future climate (e.g., Anstey et al. 2013; Charlton-Perez et al. 2013; Gerber and Son, 2014; Hardiman et al. 2013; Lott et al. 2014; Manzini et al. 2014; Min and Son 2013; Shaw et al. 2014; Wilcox and Charlton-Perez 2013) in addition to many other single model studies. These studies document a growing interest in the role of middle and upper atmosphere in climate, research that would take full advantage of these diagnostics.

Key science questions of CMIP6: DynVar primarily addresses CMIP6 key science questions on the origin and consequences on systematic models biases in the context of atmospheric dynamics and on the storm track theme of the Clouds, Circulation and Climate Sensitivity Grand Challenge, by further enabling and stimulating research on atmospheric dynamics and storm tracks with CMIP models. We envision as well contributions to the questions on how the Earth System responds to forcing, assessments of future climate changes, and on the Grand Challenges on Regional

Climate Information, Climate Extremes and on the Biospheric Forcings and Feedbacks theme.

Synergy with other MIPs: We envision analyses of the atmospheric circulation with the DECK experiments at the highest priority. Availability of dynamically oriented diagnostics within the DECK and for the CMIP6 Historical Simulation will also provide the benchmark for any other MIP. In addition, we envision fruitful potential collaborations with the following proposed MIPS: AerChemMIP, DAMIP, DCPP, ENSOMIP, SolarMIP and VOLMIP.

List of output and process diagnostics for the CMIP DECK/CMIP6 data request

We stress the need of archiving standard variables (e.g. zonal and meridional winds, temperature, and geopotential height) as daily means in the troposphere and stratosphere. We expect that the location and total number of vertical pressure levels for daily mean fields will be discussed during the definition of the standard output.

We request archival of the Transformed Eulerian Mean (TEM) atmospheric circulation, which allows diagnosis of resolved wave driving and transport, and of parameterized atmospheric gravity wave driving. These diagnostics are also widely used in the analysis of chemistry climate models (e.g. CCMVal and CCMI, here AerChemMIP). The TEM diagnostics are particularly sensitive to vertical resolution and model formulation (Hardiman et al. 2010), and so ideally computed following the model's dynamical core assumptions and on the native grid of the model, before coarsened for archival. In addition, we request the archival of heating rates. *Note that the requested diagnostics are 2-D fields (zonal means) on an atmospheric grid defined by latitudes and pressure levels. We are targeting both daily and monthly diagnostics.*

List of proposed variables:

long name	**units**	**comment**
residual northward wind	ms^{-1}	Transformed Eulerian Mean diagnostic calculated from high frequency (6hr or shorter time intervals) atmospheric fields. Reference: Andrews et al (1987): Middle Atmospheric Dynamics. Academic Press.
residual upward wind	ms^{-1}	Transformed Eulerian Mean diagnostic calculated from high frequency (6hr or shorter time intervals) atmospheric fields. Reference: Andrews et al (1987): Middle Atmospheric Dynamics. Academic Press.
residual mean mass stream function	kgs^{-1}	Transformed Eulerian Mean diagnostic calculated from high frequency (6hr or shorter time intervals) atmospheric fields. Reference: Andrews et al (1987): Middle Atmospheric Dynamics. Academic Press.

northward EP-flux	Nm^{-1}	Transformed Eulerian Mean diagnostic calculated from high frequency (6hr or shorter time intervals) atmospheric fields. Reference: Andrews et al (1987): Middle Atmospheric Dynamics. Academic Press.
upward EP-flux	Nm^{-1}	Transformed Eulerian Mean diagnostic calculated from high frequency (6hr or shorter time intervals) atmospheric fields. Reference: Andrews et al (1987): Middle Atmospheric Dynamics. Academic Press.
EP-flux divergence	$ms^{-1}d^{-1}$	Transformed Eulerian Mean diagnostic calculated from high frequency (6hr or shorter time intervals) atmospheric fields. Reference: Andrews et al (1987): Middle Atmospheric Dynamics. Academic Press.
u-tendency by residual northward wind advection	$ms^{-1}d^{-1}$	Transformed Eulerian Mean diagnostic calculated from high frequency (6hr or shorter time intervals) atmospheric fields. Reference: Andrews et al (1987): Middle Atmospheric Dynamics. Academic Press.
u-tendency by residual upward wind advection	$ms^{-1}d^{-1}$	Transformed Eulerian Mean diagnostic calculated from high frequency (6hr or shorter time intervals) atmospheric fields. Reference: Andrews et al (1987): Middle Atmospheric Dynamics. Academic Press.
u-tendency by orographic gravity waves	$ms^{-1}d^{-1}$	Zonal mean of eastward wind tendency by orographic gravity wave parameterization
v-tendency by orographic gravity waves	$ms^{-1}d^{-1}$	Zonal mean of northward wind tendency by orographic gravity wave parameterization
u-tendency by non-orographic gravity waves	$ms^{-1}d^{-1}$	Zonal mean of eastward wind tendency by non-orographic gravity wave parameterization
v-tendency by non-orographic gravity waves	$ms^{-1}d^{-1}$	Zonal mean of northward wind tendency by non-orographic gravity wave parameterization
mean age of air	years	Zonal mean of mean age of air
longwave heating rate	Kd^{-1}	Zonal mean of heating from longwave radiation
shortwave heating rate	Kd^{-1}	Zonal mean of heating from shortwave radiation
latent heating rate	Kd^{-1}	Zonal mean of heating from cloud and precipitation processes

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