SPARC Dynamics and Variability Project (DynVar) Plans and Status

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Introduction

In SPARC Newsletter No. 29, we introduced the SPARC Dynamics and Variability Project (SPARC DynVar), a model intercomparison project focussed on the question of stratospheric influence on tropospheric climate. We here summarize the DynVar project plans for the next few years based on input from a workshop held at the University of Toronto, 27-28 March 2008 and from surveys of the DynVar participants. Further details and updates will be posted on the SPARC DynVar website, www.sparcdynvar.org.

Review and Update on DynVar Goals

The SPARC DynVar project aims to study the dynamical influence of the stratosphere on the troposphere using "high-top" atmospheric general circulation models (AGCMs) with good stratospheric representation. The project's long-term goal is to determine the dependence of the mean climate, climate variability, and climate sensitivity on the stratospheric general circulation as represented in AGCMs. It aims to answer the thematic questions posed in our article in SPARC Newsletter No. 29:

1. *How does the stratosphere (more specifically, the stratospheric general circulation as represented in climate models) affect the tropospheric general circulation?*
2. *How does the stratosphere influence climate variability on all time scales?*

3. How does the stratosphere influence climate change?

Within its scope, the project includes ocean models coupled to high-top AGCMs to investigate in a more realistic setting the two-way troposphere-stratosphere dynamical coupling. It also includes a theoretical component intended to improve our physical understanding of stratosphere-troposphere coupling. The project is complementary to and coordinated with other SPARC Initiatives, in particular SPARC CCMVal, SPARC SOLARIS and the SPARC Gravity Wave Drag Parameterization Initiative. A strategic aim will be to provide a clear assessment on how important it is to simulate the stratosphere in climate-change simulations for future international climate assessments.

The project's main activity will be to analyze a database of AGCM simulations developed for the project. The features and requirements of the AGCMs, the simulations, and the analysis have been developed through the March 2008 planning workshop and through participant surveys. The main focus will be on "high-top" AGCMs with a good representation of the stratosphere and with prescribed radiatively active gases. These will be compared to "low-top" AGCMs with poor stratospheric representation that most modelling groups have until now used for climate assessment. The project will not require participating models to include interactive chemistry modules or realistic simulation of solar influences. The minimum requirements for models in the project are outlined in the section entitled "AGCM Requirements" below.

DynVar will initially focus on "free-running" GCM simulations. This means that realistic observations (other than standard boundary and radiative forcings) will not be incorporated within the standard simulations. This thus excludes from the current core DynVar effort 1) data assimilation based analysis and 2) initialization from realistic atmospheric and oceanic initial states.

DynVar has several connections to other SPARC projects. First, DynVar has coordinated some of its planning efforts with the SPARC Gravity Wave Drag initiative that is being lead by Joan Alexander (SPARC Newsletter No. 31). As a result of this effort to coordinate plans, the GWD initiative's first workshop was held in Toronto at the same time as the DynVar workshop and included a joint afternoon session for the two projects. Second, the SPARC CCMVal project developed plans for new simulations and data protocols in 2007; DynVar will coordinate its data and simulations sets with the new CCMVal plans and diagnostic efforts.

SPARC DynVar's organizing group consists of the co-authors of the article describing the project in SPARC Newsletter No. 29. Kushner is the project coordinator and the project is divided into four analysis areas with their own coordinators. The four analysis areas are: (A) "DynVar Top" (Coordinators: *F. Sassi and* M. Giorgetta), which addresses the influence of the stratosphere on the tropospheric circulation, on the ocean circulation *via* air-sea interactions, and on the cryosphere (in particular the sea ice field), apart from anthropogenic climate change; (B) "DynVar Intraseasonal (Coordinator: J. Perlwitz), which addresses issues of stratosphere-troposphere coupling on intra-seasonal time scales; (C) "DynVar Climate Change" (Coordinator: E. Manzini), which addresses the role of the stratosphere in controlling the tropospheric circulation response to climate change; and (D) DynVar Ideal (Coordinator: L. Polvani), which is a cross-cutting theme that uses simplified models and more theoretical approaches to improve the dynamical understanding of stratospheric influences.

Anyone may join the DynVar project; to access DynVar data researchers will need to become participants in the project. This is simply a matter of contacting Paul Kushner and filling out a survey to identify data and analysis needs and contributions. All project participants will need to agree to a data use policy that is based on the CCMVal data policy that will be described below. The current project participant list is on the DynVar website.

Requirements on AGCM Resolution and Configuration

The project will first focus on models that are of sufficient resolution to capture large-scale extratropical stratosphere-troposphere circulation features: baroclinic eddies in the troposphere, Rossby-wave breaking in the stratospheric surf zone, the vertical structure of extra-tropical planetary-scale waves propagating from the troposphere to the stratosphere, and stratospheric sudden warming events. We will not aim for models that realistically simulate solar variability or the QBO. At a minimum, participating high-top AGCMs should solve the primitive equations or the non-hydrostatic equations on the sphere, with a horizontal resolution that corresponds to at least T42 horizontal spectral resolution (3 to 4 degree resolution), and a vertical resolution of at least 35 levels, with the model lid and the model sponge layer located above the stratopause, which is located at approximately 1 hPa. The high-top models should also include parameterizations of the gravity wave influence on the large scale atmospheric circulation. The low-top models used for low-top/high-top comparisons should satisfy the same horizontal resolution requirements but no additional requirements will be placed on their vertical resolution.

The project will require multiple realizations of multi-decadal simulations to ensure good sampling of stratosphere-troposphere signals. Each of the simulation sets described next will have prescribed boundary and radiative forcings that should be implemented in as consistent a manner as possible. Several of the simulations use CCMVal prescriptions as their starting point.

Proposed Simulation Sets

We plan to run and analyze a sequence of three simulation sets:

- *Simulation Set A* examines stratosphere-troposphere dynamics in the absence of coupling to the ocean (AGCM + prescribed SSTs)
- *Simulation Set B* examines stratosphere-troposphere dynamics in the presence of thermal coupling to the ocean (AGCM + slab mixed-layer ocean), examining standard 2XCO2 as well as the less well studied Gillett-Thompson (2003) type ozone forcing.
- *Simulation Set C* examines stratosphere-troposphere dynamics in the presence of full dynamical coupling to the ocean circulation (AGCM coupled to ocean general circulation model).

We initially proposed that Simulation Set A be based on the CLIVAR Climate of the 20th Century (C20C) prescriptions of forcings for SSTs, sea ice, and volcanoes (see SPARC Newsletter 29). We now modify this proposal in light of SPARC CCMVal's new integrations in support of the next SPARC report and the UNEP ozone assessment. The URL describing these integrations is at the CCMVal website: http://www.pa.op.dlr.de/CCMVal/Forcings/CCMVal_Forcings_WMO2010.html. We highlight CCMVal REF1 for the 1960-2006 period. REF1 integrations include detailed prescriptions for various GHGs, a surface area density prescription for volcanic aerosols, solar irradiance inputs, and prescriptions for ozone depleting substances (ODS). CCMVal REF1 overlaps significantly with the C20C prescription. The CCMVal group is committed to carrying out the REF1 simulations in support of the CCMVal report and the WMO ozone assessment.

A key issue to be resolved prior to beginning these integrations regards the prescription of stratospheric ozone concentrations in REF1 type runs, since ozone will not be a predicted field in typical DynVar models. This has also been the case for all the models in the CMIP3 project that contributed to the IPCC assessment reports, which used various prescriptions for ozone forcing. The lack of consistent stratospheric ozone forcing is an important source of spread of the IPCC models Southern Hemisphere tropospheric circulation response to climate change (see Miller et al. 2006, Perlwitz et al. 2008, Son et al. 2008). A SPARC working group, led by G. Bodeker, has been established to address the issue of deriving an authoritative observational ozone database for the period up to 2006. The results of this working group's activites are reported separately in this Newsletter.

The mixed layer Simulation Set B and the coupled ocean atmosphere Simulation Set C are not being carried out by any other SPARC project. The discussion on these two sets of simulations was started during the March 2008. However, given the computational demand of some of these simulations, we did not finish setting out the details of these simulation sets. We will briefly discuss coupled ocean atmosphere modelling in the Conclusion.

The DynVar Database and Data Distribution Policy

The principal activity of DynVar will be to analyze data from the DynVar model database. We aim to make it easy for modelling groups to provide data and for all participants to use that data collaboratively. The DynVar database will be developed and situated at the University of Toronto. DynVar participants will sign (electronically) a data use policy and afterwards be granted password protected access to this database.

The database consists of a file server (“`dynvar`”) with moderate data processing capabilities. This server has been purchased with the support of the Natural Sciences and Engineering Research Council of Canada. The server is a linux Network Attached Storage (NAS) RAID device that project participants will have accounts on. Roughly 3TB of backed up space will be available for the project, along with 1TB of scratch space; more will be added as needed and as financially feasible. Standard netcdf data processing tools (e.g. CDO, NCO) will be available so that participants can do some preliminary processing prior to downloading the data. Usage will be monitored to ensure that everyone has fair access to the machine.

Easy accessibility to the data needs to be balanced against other considerations. The DynVar model database will serve model output from various international modelling groups and University groups, each with their own data sharing policies. Thus we will need to be careful to conform to the needs of those groups, and to recognize the effort it takes to produce quality-controlled model output and to correctly interpret that model output. Fortunately, the CCMVal project has developed a two-phase data distribution policy that apparently satisfies the needs of the centres participating in that project. Thus we propose to match our data policy to CCMVal’s policy:

- A 1.5 year Phase 1 period during which participants are obliged to offer co-authorship on DynVar model-based research to model PIs and
- A subsequent Phase 2 period during which the co-authorship obligation is lifted but during which DynVar participants are expected to communicate their results to model PIs to allow model PIs the possibility to comment on results. The latter is a best-practice policy that recognizes the inherent difficulty in interpreting and intercomparing GCM results.

Model output will be provided from the DynVar database in the “CF compliant” netcdf format. This format conforms with that of several projects including CCMVal and CMIP3 (IPCC AR4).

Because CF compliant netcdf format has become more common, many modelling centres will have routines to convert their native data into this format. However, the group at Toronto will be willing to convert surface and pressure-level data provided by the centres into the CF compliant format if required. The intention is to prevent data conversion from being a bottleneck in getting the data out to participants. Nevertheless, we will need all the modelling groups to be involved in quality control of the data.

We hope that the database will "stay live" and be updated on a regular basis and that diagnostics developed by participants will be sufficiently straightforward that they can be repeated quickly as new data becomes available. Thus if a modelling centre wishes to provide updated model data (e.g. extra realizations of a run or an updated model version) we will aim for a quick turnaround.

Several groups made informal commitments to provide data for the project. For more information, see the "survey synthesis" document on the project website.

Proposed Diagnostic Projects

A wealth of exciting research projects were outlined at the planning meeting in March, and these will be updated, summarized and put on the project website. It became clear that dynamical analyses of interest to DynVar participants require high-frequency — typically daily — sampling of meteorological fields, and serving this data will be a key goal for the project. In addition, we discussed the need for very high frequency output over relatively short periods to assist in the evaluation of GWD parameterization schemes against observations.

Table 1 lists the projects submitted to the DynVar project to date. Many of the research projects within the CCMVal project will also be able to take advantage of the DynVar database. For more details, see the survey synthesis document on the project website.

Table 1. List of project titles and participants submitted to the DynVar Project.

Participant	Title
C. Bell, A. Scaife, S. Ineson, L. Gray	• The possible role of the stratosphere in mitigating the effects of ENSO on climate.
P. Canziani	• Southern Hemisphere UT/LS dynamic climatology.

A. Charlton-Perez, L. Polvani, L. Gray	• Basic characteristics and climatology of major mid-winter stratospheric sudden warmings. • Determining the behaviour of the polar vortex using potential vorticity diagnostics.
J. Cohen, C. Fletcher, S. Hardiman, P. Kushner	• Stratosphere-Troposphere Coupling Index (STCI) in GCMs. • Surface boundary perturbation experiments. • Stratospheric control on the tropospheric circulation response to surface forcing. • Effect of Eurasian snow variability on winter climate in GCMs.
E. Cordero	• Temperature trends in stratosphere and upper troposphere. • Longitudinal variations in ozone and the influence on wave propagation and wave reflection.
E. Gerber, L. Polvani, M. Baldwin	• The time scales of stratospheric-tropospheric interactions. • Dynamical core - Full GCM intercomparison: The role of dynamics.
N. Gillett	• Sensitivity of Southern Annular Mode response to ozone to vertical resolution. • Sensitivity of tropospheric climate and stratospheric climate to zonal asymmetries in ozone.
L. Gray and S. Osprey	• Tropical variability of the stratosphere and its impact on the extratropics. • Annular Mode variability and its interpretation for Stratosphere-Troposphere studies.
K. Hamilton, M. Kadota, P. Liu	• Stratospheric influence in NOAA historical reforecasts. • QBO influence on tropospheric seasonal circulation.
D. Kirk-Davidoff	• Stratospheric influence on the 20^{th} century expansion of the tropics. • Stratospheric influence on tropical tropopause height and saturation vapor pressure.
E. Manzini	• Stratospheric variability and climate change.
J. Perlwitz and N. Harnik	• Impact of planetary wave reflection on troposphere in climate models.
A. Pogoreltsev	• Climatic and interannual variability of the dynamical regime of the middle atmosphere during the seasonal changes of the general circulation and effects in the upper atmosphere caused by these changes.
T. Reichler	• Stratospheric influences on tropospheric circulation. • Climate model performance metric.
F. Sassi	• Influence of stratospheric circulation on the climate of the troposphere.
M. Sigmond and J. Scinocca	• Influence of the stratosphere on tropospheric climate change.
S.W. Son	• Stratospheric impact on the midlatitude jet and Hadley cell. • Stratospheric impact on the tropospheric teleconnection pattern
D. Straus and C Stan	• Origin of stratospheric intra-seasonal variability.
T. Woolings and A. Charlton-Perez	• Stratospheric involvement in blocking.
D. Vyushin and P. Kushner	• Temporal power-law characteristics of the stratosphere-troposphere circulation.
S. Yoden	• Reproducibility of stratospheric sudden warming (SSW) events in the historical runs.

Conclusion: Project Status & Looking Forward

After an exciting planning workshop in March, the project was significantly delayed by technical problems with Kushner's computer and storage hardware at the University of Toronto. These have been for the most part resolved and the `dynvar` server should be available by the end of 2008. Some preliminary integrations for the project have already been carried out and the output for these integrations will be made available once the server is ready. These will serve as a starting point for more coordinated simulations in future.

At the recent SPARC Scientific Steering Group meeting (discussed in this newsletter), Kushner gave a progress report on the DynVar project. Some of the main points from that report and subsequent discussions follow:

- We proposed that the DynVar project would be one of the first users of the new ozone forcing database through Simulation Set A (REF1) and B (Mixed Layer) integrations.
- We recognized that the DynVar project will probably need to wait for the CCMVal runs to be completed before expecting major commitments from participating modelling groups to run simulations for and provide data to the project.
- We discussed coupled ocean atmosphere modelling with high-top models, a theme that is not the focus of any other SPARC project. This is an important aspect of the DynVar project, because it will enable the stratospheric modeling community to test its models within the experimental design of the core simulations of the CMIP3 project and the new CMIP5 project that provide the pools of the simulations for the assessment of climate change. We are therefore strongly encouraging several groups to carry out such simulations to examine stratospheric impacts on climate variability and sensitivity in the presence of realistic ocean coupling.
- We envisioned a future focus on tropical troposphere-stratosphere variability, with a view to an intercomparison of models that are capable of spontaneously simulation of the main features of the QBO. Outcomes from this expanded project would shed light on the meaning of “a good representation of the stratosphere”.
- Finally, we proposed to hold a second DynVar workshop in Hamburg on April 27-28, 2009, during which these topics and early results will be discussed.

Details of future plans and the workshop will be posted on the DynVar project website.

References

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