SPARC DynVar:
Dynamics and Variability Initiative
Status and Plans

Paul Kushner (University of Toronto, Canada)

and

Elisa Manzini (INGV-CMCC, Bologna, Italy)

Outline

- Background
- Current status
- Proposal for 2010-2012

Background

<u>DynVar broad aim and focus:</u>

- Demonstrate the dynamical influence of the stratosphere on tropospheric mean climate and climate variability, using AGCMs as the principal tools.
- The focus is on dynamical processes.

The initiative is described in Kushner et al (2007, SPARC Newsletter 29, 9-14; 2009, SPARC Newsletter 32, 13-15).

The initiative attracted 55+ participants.

AGCM = Atmospheric General Circulation Model

…at the core of more complex models not excluded.

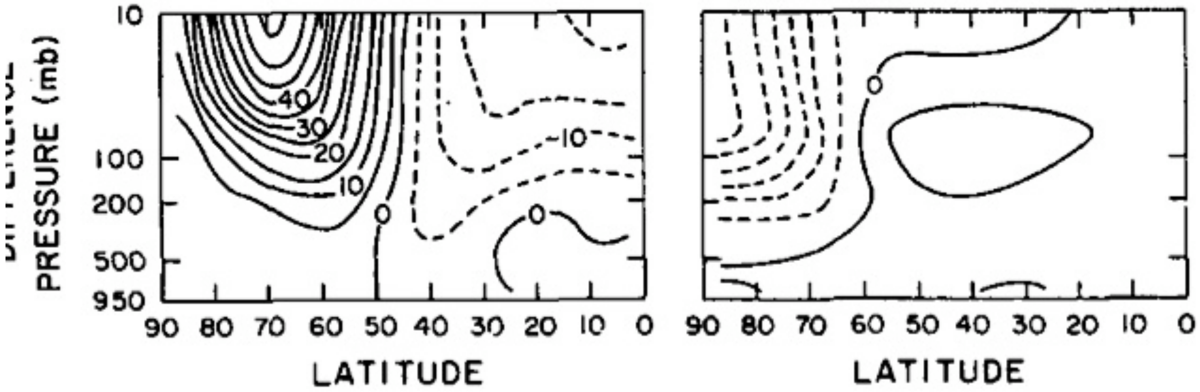
SPARC DynVar within WCRP Strategic Plan

DynVar addresses:

- Stratospheric change as part of the attribution and detection of climate change
- Changes in the stratosphere affecting meteorological (dynamical) variability in the troposphere
- Impact of stratospheric representation on seasonal prediction.
- Improvement of stratospheric representation in GCMs.

Motivation: Role of a well resolved stratosphere

NH winter Zonal Mean Zonal Wind   and Temperature

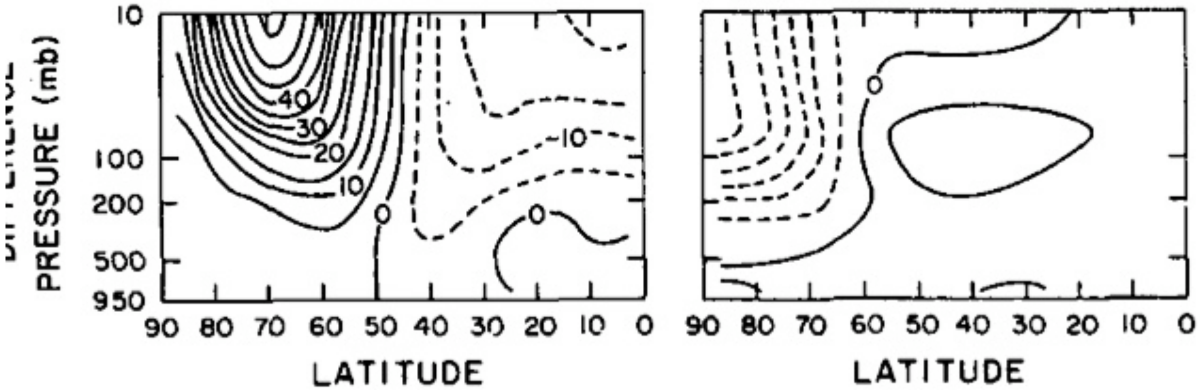


Boville (1984)

U changes: 50 m/s at 10 hPa and 20 m/s at 100 hPa
T changes: from 25 to 30 K at 10-100 hPa at the Pole

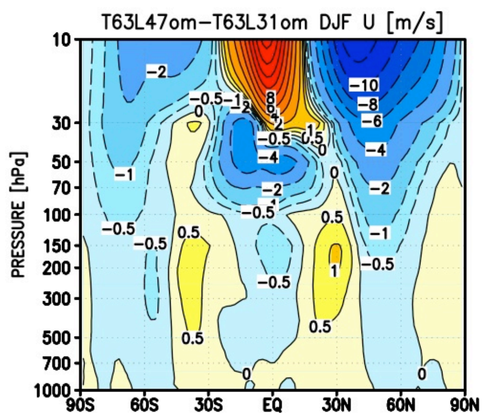
Motivation: Role of a well resolved stratosphere

NH winter Zonal Mean Zonal Wind and Temperature



Boville (1984)

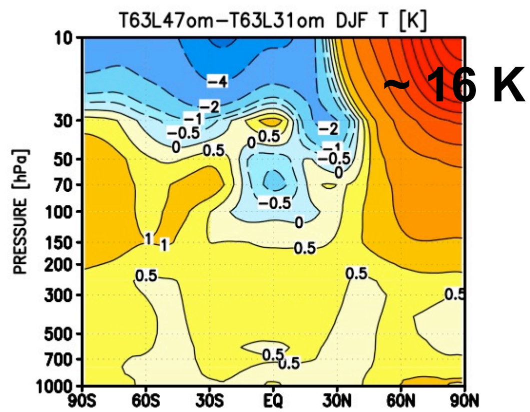
U changes: 50 m/s at 10 hPa and 20 m/s at 100 hPa
T changes: from 25 to 30 K at 10-100 hPa at the Pole



ECHAM5/MPIOM:

IPCC class model

Difference in mean climate: Difference between 100 year means



=> Today, we might be looking at the modeling effects of substantially smaller mean differences existing in the lower and middle stratosphere, between high and low top models

DynVar Specific Aims

- How AGCMs' stratospheric representation affects tropospheric climate variability, on all time scales, and climate responses (high-top vs. low-top)?
- Focus on circulation & dynamical processes (complementing CCMVal and SOLARIS)
- Comprehensive AGCMs, but include a component on theory and simplified models.
- Analyze stratospheric issues and influences in coupled of Atmosphere Ocean GCMs
- Document the costs and benefits of including a well resolved stratosphere in an Earth Systems Model.

DynVar Analysis Areas

A. *DynVar Top (Giorgetta, Sassi)*: **Effect of model stratospheric representation on the circulation and variability of the climate system.**

B. *DynVar Intraseasonal (Perlwitz)*: **Intraseasonal strat-trop coupling, with a view to seasonal prediction.**

C. *DynVar Climate Change (Manzini)*: **Stratospheric control of response to climate forcings.**

D. *DynVar Ideal (Polvani)*: **Cross-cutting theme, analysis of stratospheric influence using theoretical and simple-modelling approaches.**

DynVar Activities 2008-2009

1. Planning Workshop, held in March 2008, Toronto, Canada.
2. Setup of DynVar server: DynVar server at the U of Toronto currently hosting daily output from CMAM.
3. Publication of plan and 2008 workshop report: Kushner et al (2009, SPARC Newsletter 32,13-6).
4. AGU Newsletter highlight.
5. Starting coordinated runs: Not done . . . for reasons to be described next.
6. Convene workshop in spring 2009: postponed . . . for reasons to be described next.

At the same time, a large portion of our membership was very busy with CCMVal and WMO Assessment activities as coauthors or lead authors. Let's explore this further.

A Dose of Reality

- We had originally planned DynVar as a full scale model intercomparison project.
- But CCMVal is a mandated assessment driven activity that overlaps with DynVar in terms of goals, people, and simulations.
- Calling for additional coordinated runs would have been a huge effort and it was unclear who would have done it, given the CCMVal effort in 2008-2009.
- Similarly, there seemed to be no point in pushing a DynVar workshop last year when we were so busy with CCMVal workshops, meetings, reports.

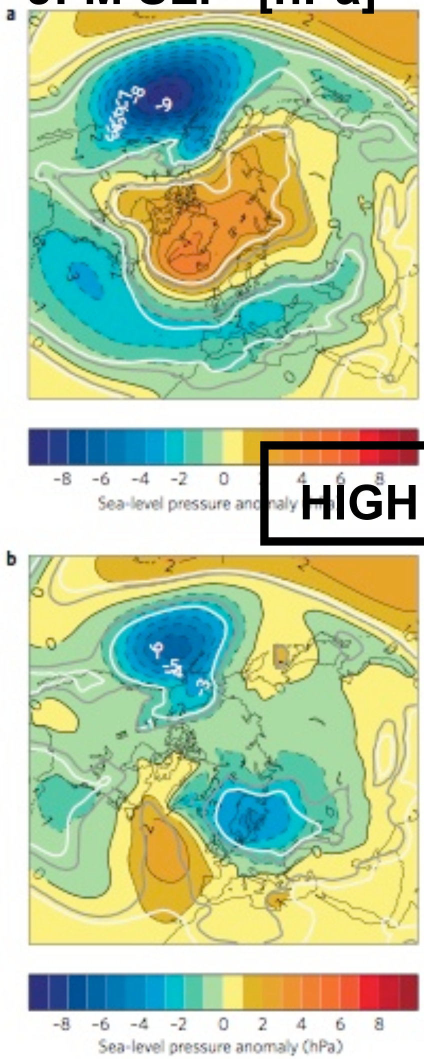
Analysis of Past Efforts

- ***The efforts of DynVar (communication + workshop + newsletters) have helped spur research:*** **The applied and theoretical research that we proposed should be carried out has actually been done very well by different groups in the past couple of years.**
- **From the research in the past couple of years, we have learned a lot about fundamental ways in which stratospheric representation works in climate models.**
- **Some examples follows ….**

Ineson and Scaife, NG, 2009

Cagnazzo and Manzini, JC, 2009

JFM SLP [hPa]



ENSO

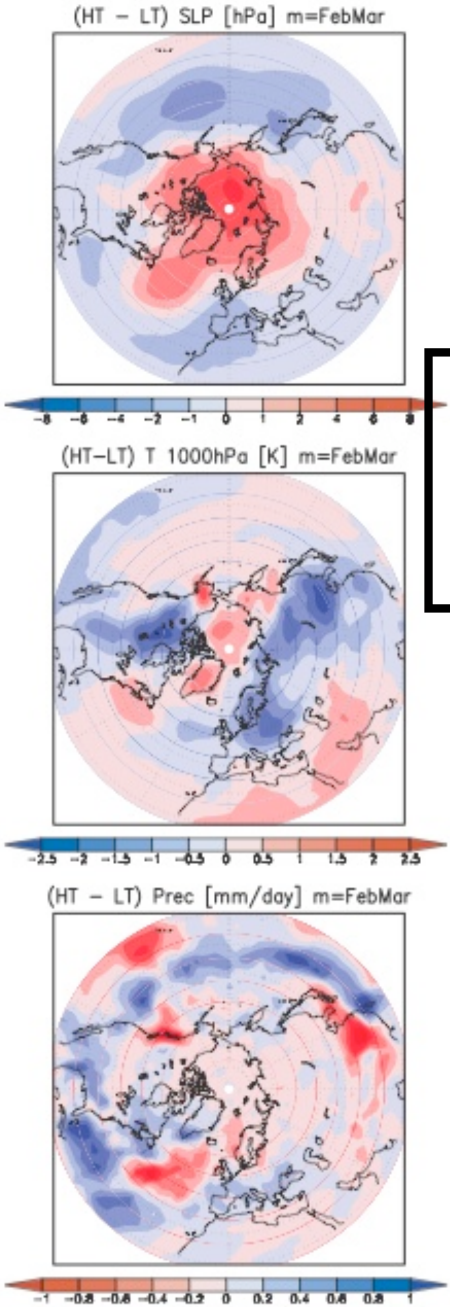
with SSW

HIGH TOP MODEL

ENSO

without SSW

Figure 5 | Modelled surface climate response to El Niño associated with a weak and strong polar vortex. a,b, Composite sea-level pressure anomaly (hPa) for El Niño years with sudden stratospheric warmings (**a**) and El Niño years with no sudden stratospheric warmings (**b**). Anomalies are for January–March as in Fig. 1. Grey and white contours indicate significance at the 95% and 99% confidence levels.



FM SLP [hPa]

ENSO for

HIGH - LOW TOP

MODELS

FM T@1000 hPa [K]

FM PRECIP [mm/day]

FIG. 10. High-top minus low-top model difference in the FM ENSO anomaly for (top) SLP (hPa), (middle) 1000-hPa temperature (K), and (bottom) precipitation (mm day^{-1}).

Cagnazzo and Manzini, JC, 2009

HIGH TOP MODEL

LOW TOP MODEL

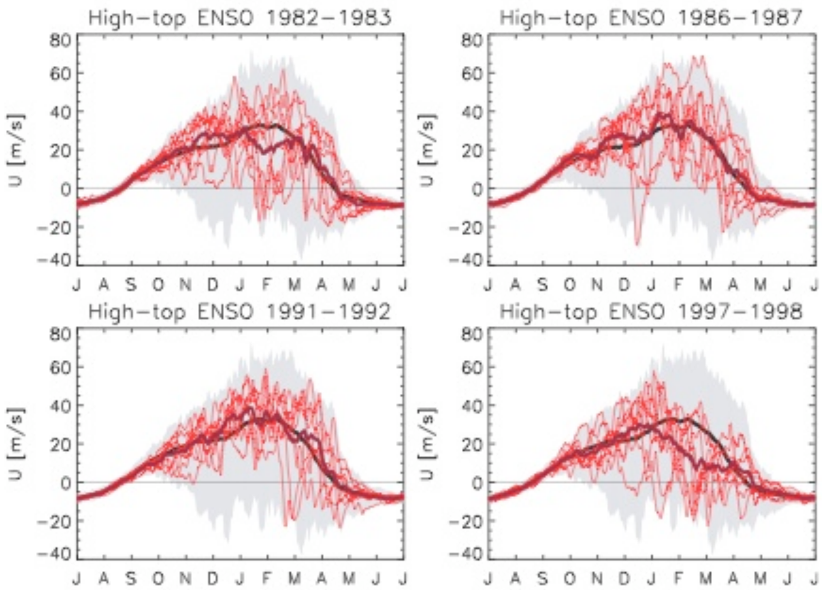


FIG. 6. July–June daily zonal mean zonal wind (m s^{-1}) at 60°N and 10 hPa for the high-top model. Dark red curves: ensemble average (9-member set) stratified by ENSO event for (top left) 1982/83, (top right) 1986/87, (bottom left) 1991/92, and (bottom right) 1997/98. Light red curves: individual members stratified by ENSO event. Black and light gray curves from Fig. 4 (top, left).

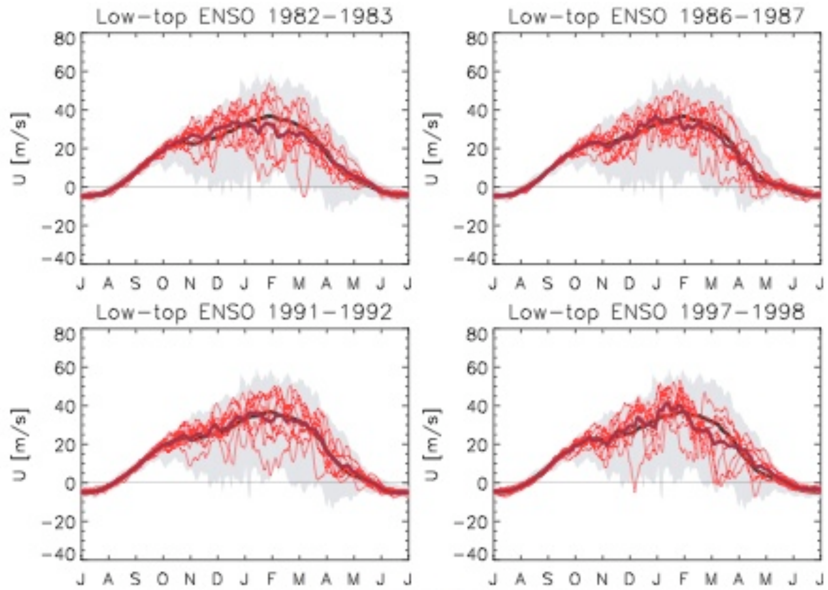


FIG. 7. Same as Fig. 6 but for the low-top model.

Variability: Sudden Stratospheric Warming Events (Weak Vortex)

Zonal Mean U @ 60N Daily evolution (July - June) for the 4 ENSO events

Minimum and Maximum all simulations (9x20 years)

Circulation Response to Global Warming

- The Hi-Top Canadian GCM (CMAM) has a tropospheric NAM response to 2XCO2.
- The Low-Top Canadian GCM (Standard) does not.
- But a Low-Top version of CMAM also has the NAM response.
- *Orographic GWD* (OGWD) settings turn out to control the response via its control of lower stratospheric winds; stratospheric *resolution* is secondary here.

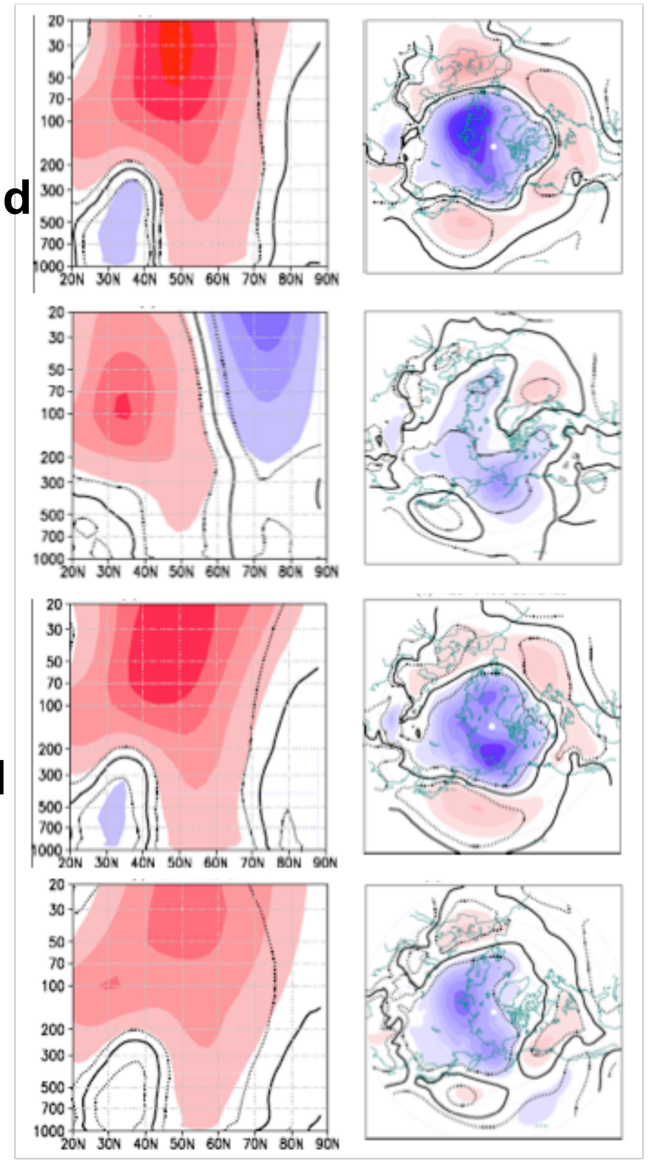
ΔU ΔSLP

CMAM Hi-Top 10^{-3} hPa Lid

Standard Low-Top 3 hPa Lid

CMAM Low-Top 10 hPa Lid

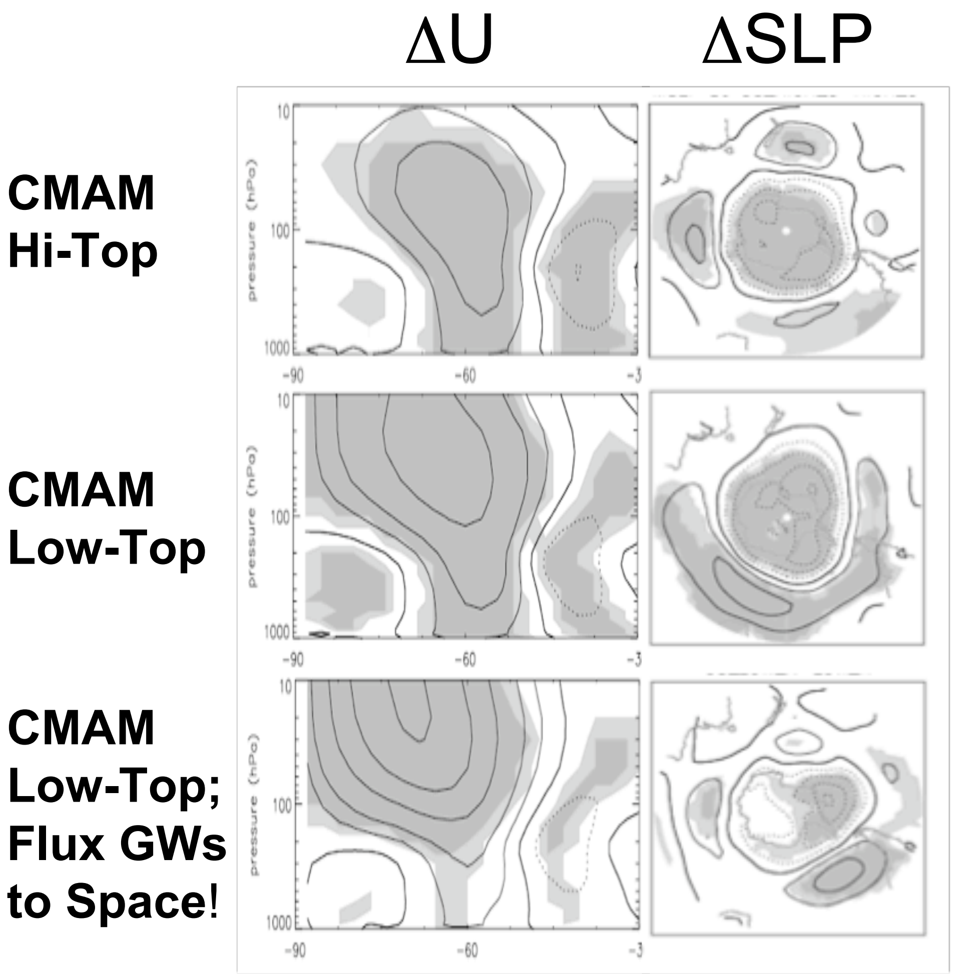
Standard Low-Top, CMAM OGWD



Sigmond et al. 2008

Control of Tropospheric Response to Stratospheric Cooling

- Hi-Top and Low-Top CMAM have a tropospheric SAM+ response to Antarctic stratospheric cooling.
- But non-orographic GWD can control the response.
- The bottom row shows the impact of using a non-conservative boundary condition on the GWD.
- Low-top models might represent SAM sensitivity accurately, but you have to be careful with implementation details.



Shaw, Sigmond, Shepherd & Scinocca 2008

Outside the DynVar and/or CCMval communities, appreciation of the role of stratospheric processes is clearly getting established:

1. **Seasonal Forecasting (Adams Scaife talk)**
2. **Carbon Cycle Modelling:**

Lenton et al, GRL, 2009

IPSL Carbon cycle model (“low top”)

pCO2 air-sea

Air to sea CO2 flux

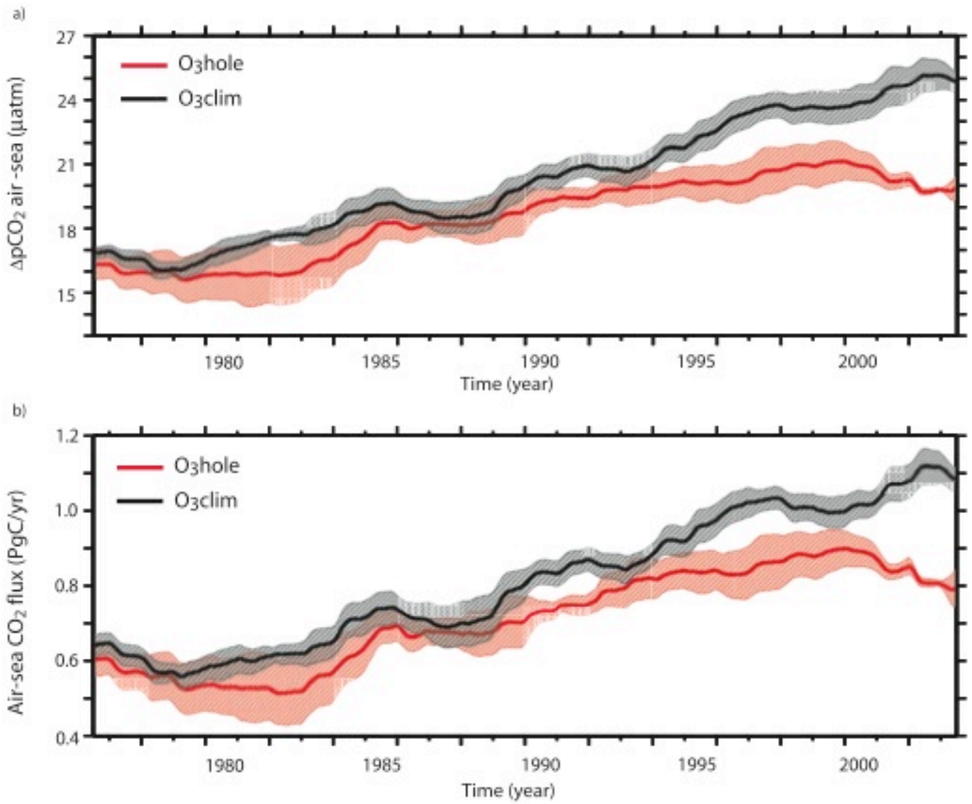


Figure 2. (a) Spatially averaged ΔpCO_2 (south of 40°S), showing that accounting for stratospheric ozone depletion (O_3hole) reduces ΔpCO_2 (relative to O_3clim), in response to increased upper ocean carbon concentration (Figure 1b). (b) Integrated air to sea CO_2 flux (south of 40°S) showing stratospheric ozone depletion (O_3hole) significantly reduces CO_2 uptake (relative to O_3clim), and is strongly correlated with changes in ΔpCO_2. The values of ΔpCO_2 and CO_2 fluxes represent the ensemble mean, while the shaded area represents the standard error of the mean. CO_2 fluxes and ΔpCO_2 are smoothed with 36-month running mean filters.

Impact of ozone depletion on ocean carbon uptake

Atmospheric model used in Lenton et al 2009:

A "low top" model from our perspective.

Ozone trend: specified.

But representation of stratospheric dynamical processes and feedback involving chemistry can affect the magnitude of the signal.

Son et al, S, 2008

CCMVal Models

AR4 Models

AR4 Models with O3 Recovery

AR4 Models without O3 Recovery

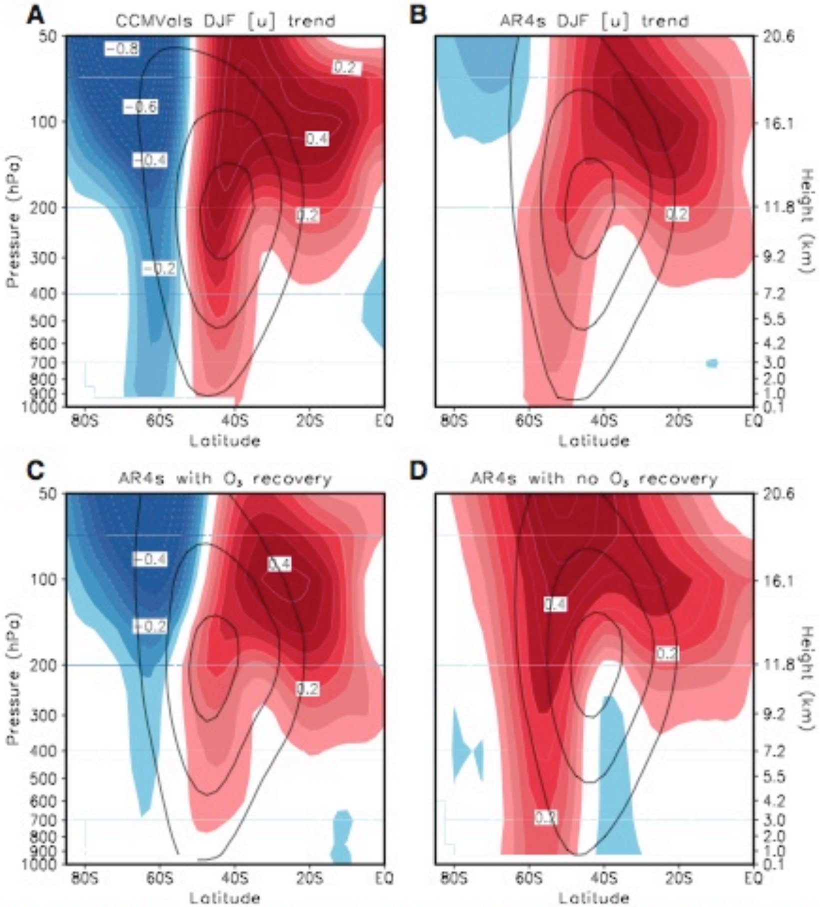


Fig. 2. Trends in December-to-February (DJF) zonal-mean zonal wind. The multimodel mean trends between 2001 and 2050 are shown for the CCMVal models (**A**), the AR4 models (**B**), the AR4 models with prescribed ozone recovery (**C**), and the AR4 models with no ozone recovery (**D**). Shading and contour intervals are 0.05 ms^{-1} $decade^{-1}$. Deceleration and acceleration are indicated with blue and red colors, respectively, and trends weaker than 0.05 ms^{-1} $decade^{-1}$ are omitted. Superimposed black solid lines are DJF zonal-mean zonal wind averaged from 2001 to 2010, with a contour interval of 10 ms^{-1}, starting at 10 ms^{-1}. EQ, equator.

Impact of ozone recovery on SH DJF zonal mean U trend

Analysis of Past Efforts

- *The efforts of DynVar (communication + workshop + newsletters) have helped funding and encouraged labs to include high top model configurations:*
  - Selected CMIP5 runs will include several climate models with high top AGCMs.
  - Mark Baldwin's recent funded NSF proposal that referred in a substantial manner to DynVar.
  - The European COMBINE modelling project includes a prominent DynVar related component.

- DynVar of course can't claim all the credit, but we can argue that it helped encourage these outcomes.

Analysis of Past Efforts

- The scientific portion of the March 2008 DynVar workshop in Toronto was a success that served the initiative well.
- The organizational portion included an effort to generate a project list and a detailed plan of runs. This was not too successful --- a lot of overlapping ideas were presented, and we did not feel comfortable organizing research.
- Setting up the runs involved more of a time commitment than the international modeling community is prepared to undertake.

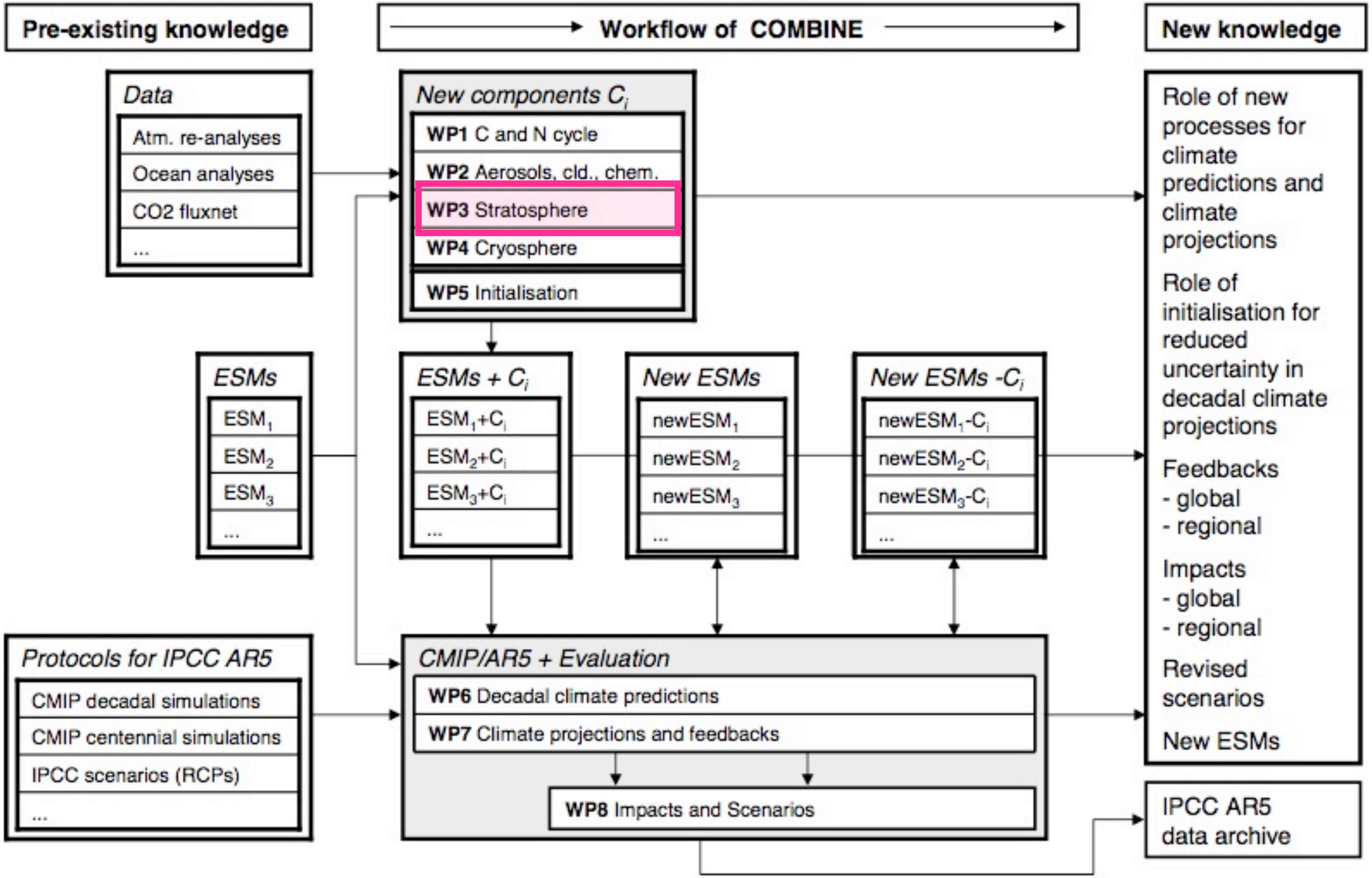
A More Thoughtful Approach

- Make use of the assessment driven coordinated sets of simulation experiments (CCMVal, CMIP5, and WGSIP).
- Continue with the more successful portion, and convene a second science workshop.
- Focus on emerging selected topics, such seasonal forecast, decadal predictability and ocean-atmosphere coupling.
- Tackle the QBO simulation issue.
- Sustain the link with the gravity wave activity.

Proposed 2010 Workshop

- Three day workshop on DynVar themes, with SPARC support.
- We are proposing October or November 2010 in Boulder CO.
- Paul is planning to be in Boulder at that time, and will organize it with Judith Perlwitz.
- At this time (post ozone assessment and SPARC report), there will be an opportunity to look in a more careful and detailed way at the CCMVal database.
- In addition, the CMIP5 archive will include several runs with good stratospheric representation (at the least for the historical 1850-2005 simulation).
- Also, there are several ongoing projects in which effects of stratospheric representation are being tested by met centres.

COMBINE - European Integrating Project: 2009-2013. Coordinator: MPG-HAMBURG



WP3 STRATOSPHERE: State and Aims (E Manzini & N Butchart)

- The starting point is given by the availability of atmosphere general circulation models with the capability to resolve stratospheric dynamical processes and including physically based parameterization of the momentum flux deposition from sub-grid scale (gravity) waves.

- WP3 will contribute to the COMBINE objective of advancing climate models by focusing on improving the modeling of the processes associated with increased vertical resolution and on the inclusion of a dynamical stratosphere (while long term changes in ozone are specified).

=> Most climate modes focused so far only on having a reasonably realistic stratospheric mean state. Here the focus is on intra-seasonal to decadal variability.

=> Benefit for stratospheric research per se with a climate model: Investigate stratospheric variability in an energetically consistent climate system, i.e., without the artificial constrain of specified SST and SIC.
[but with the consequences of the ramifications of systematic biases]

Simulations:

- **WP3:** historical 1850-2005 run
- **Phase 1:** runs of WP6 (predictability) and/or WP7 (ESMs: CMCC, COSMOS, and EC-EARTH)
- **Phase 2:** runs of WP6 and/or WP7 (ESMs: EC-EARTH, CMCC, COSMOS, METO and IPSL-ESM)

Simulations:

- **WP3:** historical 1850-2005 run
- **Phase 1:** runs of WP6 (predictability) and/or WP7 (ESMs: CMCC, COSMOS, and EC-EARTH)
- **Phase 2:** runs of WP6 and/or WP7 (ESMs: EC-EARTH, CMCC, COSMOS, METO and IPSL-ESM)

International Framework:

Modeling groups around the world are getting organized for possibly performing a selected set of CMIP5 runs with stratospheric resolving models.

CMIP5 high top models

Institute	Model	Res'n	Scenario	Contact
Hadley / NCAS	**HadGEM2**	**192x145xL60 top=85km**	**RCP4.5 to 2100**	**neal.butchart@metoffice.gov.uk**
MPI	**ECHAM6/MPIOM**	**?**	**RCP4.5,2.6,8.5**	**marco.giorgetta@zmaw.de**
GFDL	**CM2**	**?**	**?**	**john.austin@noaa.gov**
NCAR	**CCSM: WACCM + POP2**	**95x144xL66 top=6x10^{-6}hPa~135km**	**RCP4.5 to 2050**	**rgarcia@ucar.edu marsh@ucar.edu**
CMCC	**ECHAM5+OPA**	**T63L95, top=0.01hPa**	**RCP4.5 to 2030**	**manzini@bo.ingv.it chiara.cagnazzo@cmcc.it**
GISS	**GISS-E**	**90x144xL40 top=0.1hPa**	**All 4 RCPs**	**dshindell@giss.nasa.gov**
DMI	**EC_Earth**	**T159xL91 top=0.01hPa**	**RCP4.5 to 2100**	**shuting@dmi.dk boc@dmi.dk**
IPSL	**IPSL-CM5**	**L35, top=65km**	**RCP4.5**	**francois.lott@lmd.jussieu.fr**

Adam Scaife