SPARC DynVar

Modelling the Dynamics and Variability of the Stratosphere-Troposphere System

DynVar web site: http://www.sparcdynvar.org

World Climate Research Programme

SPARC/DynVar

DynVar Committee Members:
Elisa Manzini (Coordinator), Amy Butler, Natalia Calvo, Andrew Charlton-Perez, Edwin Gerber, Marco Giorgetta, Adam Scaife, Tiffany Shaw and Shingo Watanabe

Ex-Officio Members:
Judith Perlwitz, Lorenzo Polvani and Fabrizio Sassi

Goals:

•Promote development of coupled atmosphere, ocean, and seaice global models with tops above the stratopause
•Promote analysis and evaluation of model outputs on:

- stratospheric dynamical variability and processes,
- two-way dynamical couplings between the stratosphere and the troposphere, and
- their impacts on troposph. and surface climate predictability

-> Modelling activity, S-T with emphasis on atm&ocean coupling

Current focus:
HIGH - LOW TOP MODELS INTERCOMPARISON WITHIN CMIP5

Synthesis Papers on the CMIP5 multi-model ensemble:
(1)Mean Climate and Variability of the Stratosphere in the CMIP5 models. Charlton-Perez et al. (submitted JGR 2012)
(2) Role of the stratosphere in Northern winter climate change as simulated by the CMIP5 models. Manzini et al. (submitted JGR 2012)

Background & Progress

DynVar was launched in 2007,
by a funding organizing group lead by Paul Kushner.
-> Core objective defined: Modelling the dynamics and variability of the stratosphere-troposphere system

November 2010 Workshop (second one organized by the activity):
- Focus on the CMIP5 analysis discussed and taken over.
- Status of high top model systems (about 10 groups) in CMIP5 presented.
- Connections to WGSIP's Stratosphere Historical Forecast Project (SHFP).

CLIVAR Exchange Newsletter 56, May 2011:
- Stratosphere-resolving Models in CMIP5. Manzini et al 2011, p29

Position Paper 2012:
- Assessing and Understanding the Impact of Stratospheric Dynamics and Variability on the Earth System. Gerber et al BAMS 2012

Location of model tops in CMIP3 and CMIP5: Number of models

	(a) $P_{top} \geq 10$ hPa	(b) 10 hPa > $P_{top} \geq 1$ hPa	(c) $P_{top} < 1$ hPa	$P_{top} \leq 0.1$ hPa	TOTAL a+b+c
CMIP3 (IPCC 2007)	7	12	4	0	23
CMIP5 (this work)	2	10	14	11	26

LOW TOP MODELS | **HIGH TOP MODELS**

Model	Top	Levels	Subset
CMCC-CESM	0.01 hPa	39	HIGH TOP
CMCC-CMS	0.01 hPa	95	HIGH TOP
EC-EARTH-HIGH			HIGH TOP
GFDL-CM3	0.01 hPa	48	HIGH TOP
GISS-E2-R	0.1 hPa	40	HIGH TOP
HadGEM2-CC	85 km	60	HIGH TOP
IPSL-CM5A-LR	0.04 hPa	39	HIGH TOP
IPSL-CM5A-MR	0.04 hPa	39	HIGH TOP
MIROC-ESM-CHEM	0.0036 hPa	80	HIGH TOP
MIROC-ESM	0.0036 hPa	80	HIGH TOP
MPI-ESM-LR	0.01 hPa	47	HIGH TOP
MPI-ESM-MR	0.01 hPa	95	HIGH TOP
MRI-CGCM3	0.01 hPa	48	HIGH TOP
WACCM4			HIGH TOP
CanESM2	1 hPa	35	-
bcc-csm1-1	2.917 hPa	26	LOW TOP
CCSM4	2.194 hPa	27	LOW TOP
CMCC-CESM-LOW	10 hPa	19	LOW TOP
CNRM-CM5	10 hPa	31	LOW TOP
CSIRO-Mk3-6-0	4.52 hPa	18	LOW TOP
EC-EARTH-LOW			
GFDL-ESM2M	3 hPa	24	LOW TOP
HadGEM2-ES	40 km	38	LOW TOP
inmcm4	10 hPa	21	LOW TOP
MIROC5	3 hPa	56	LOW TOP

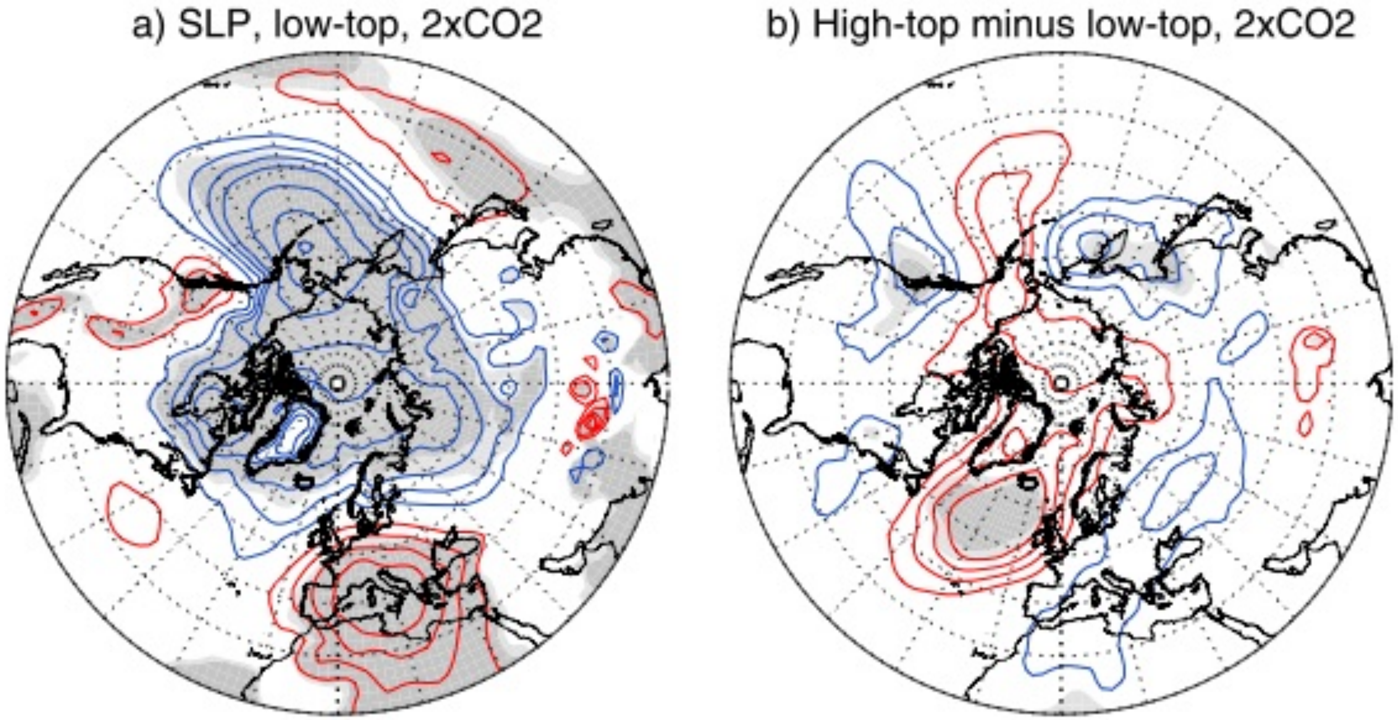
Karpechko and Manzini (JGR 2012) CONTROLLED EXPERIMENTS

Change form 1xCO2 to 2xCO2: one high minus low top model "pair" (MAECHAM5 and ECHAM5). Atmosphere only. SST and SIC anomaly form CMIP3 multi-model means. => CONTROLLED EXPERIMENT

See also Scaife et al. CD 2012

SLP CHANGE JFM

LOW



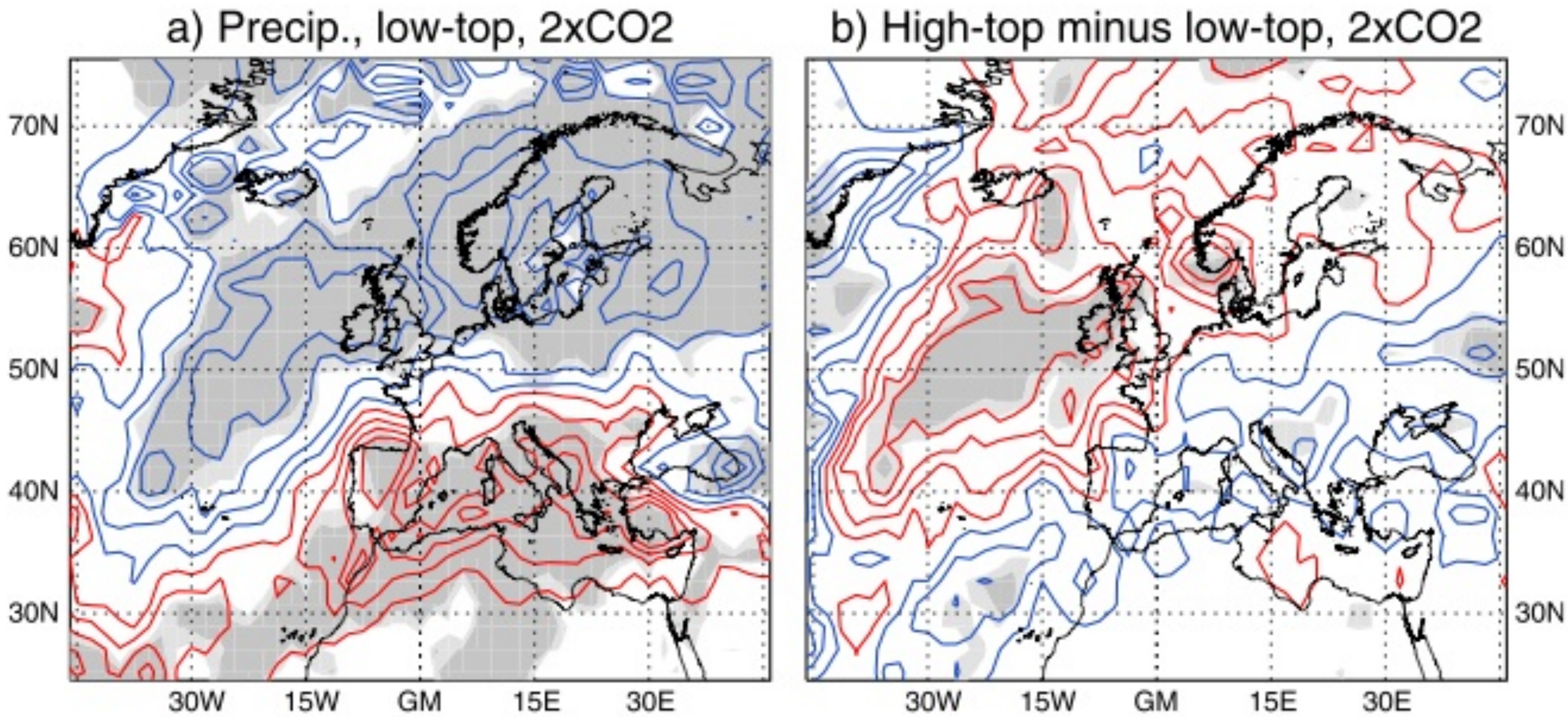
HT-LT

Contours ±0.75, 1.5, 2.25, and 3.0 and then each 1.5 hPa

Consequences on precipitations:

Karpechko and Manzini (JGR 2012)

LOW PRECIPITATION CHANGE JFM HT–LT



Contours ±0.1, 0.3, 0.5, and 0.7 mm d^{-1} (positive=blue)

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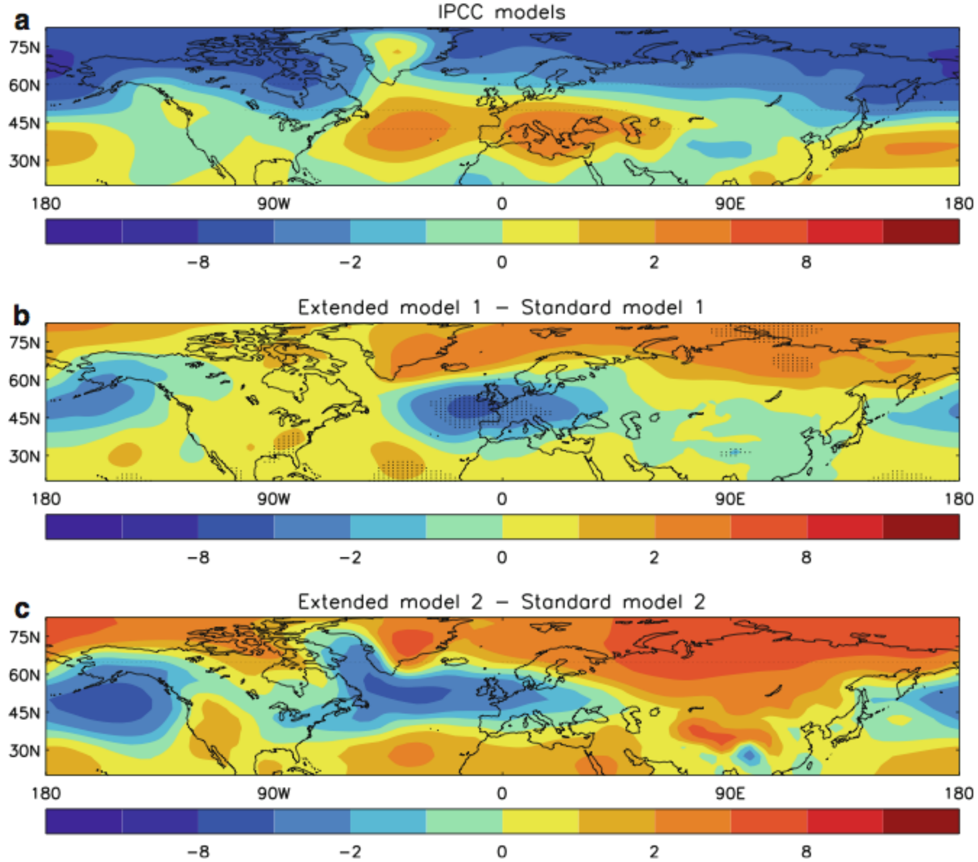
World Climate Research Programme

Assessment of S-T coupling in CMIP5: Motivation

Fig. 2 Climate change in sea level pressure in standard (IPCC) models (**a**) and the difference between the extended and standard versions of model 1 and model 2 (**b**, **c**). All quantities are winter means (December–February) and units are hPa. Statistical significance at the 95% level of confidence is shown by hatching. For **a** this is significance from 0 using a 2 tailed test and the inter-model variability. For individual models 1 and 2 it is calculated using a 2-tailed *t* test for the difference between extended and standard models



Scaife et al CD 2012

Max-Planck-Institut für Meteorologie

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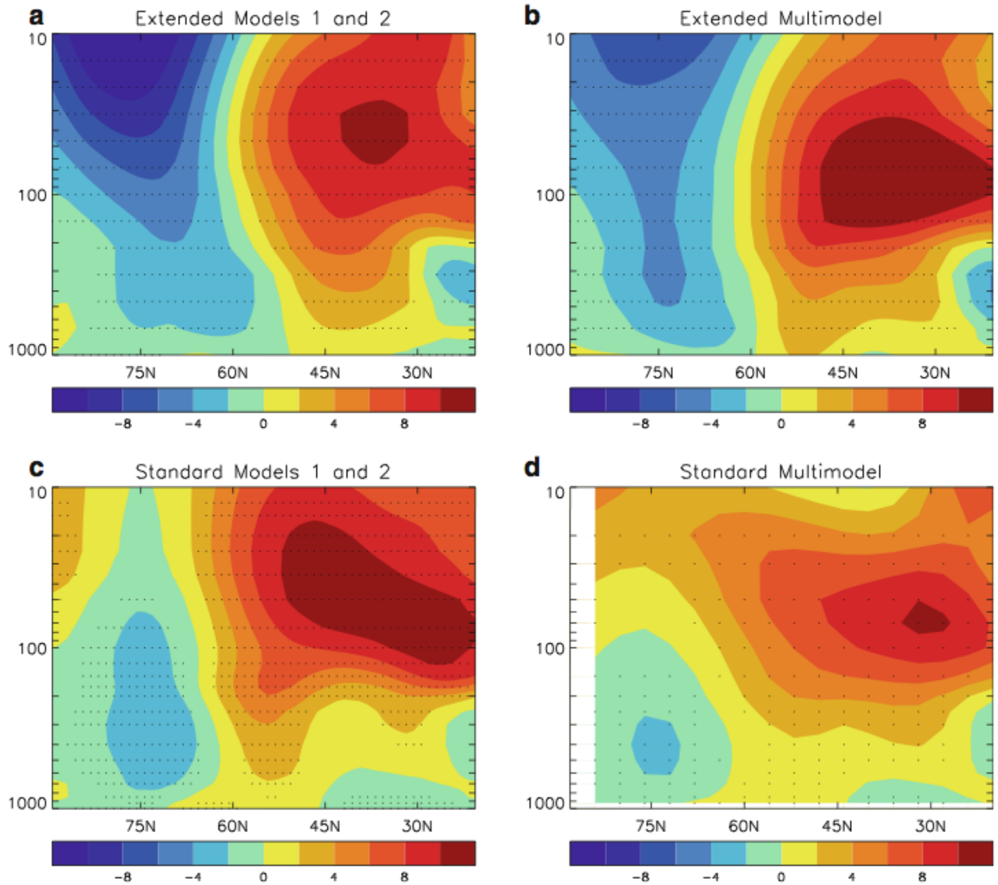
Modelling the Dynamics and Variability of the Stratosphere-Troposphere System

WCRP World Climate Research Programme

Assessment of S-T coupling in CMIP5: Motivation

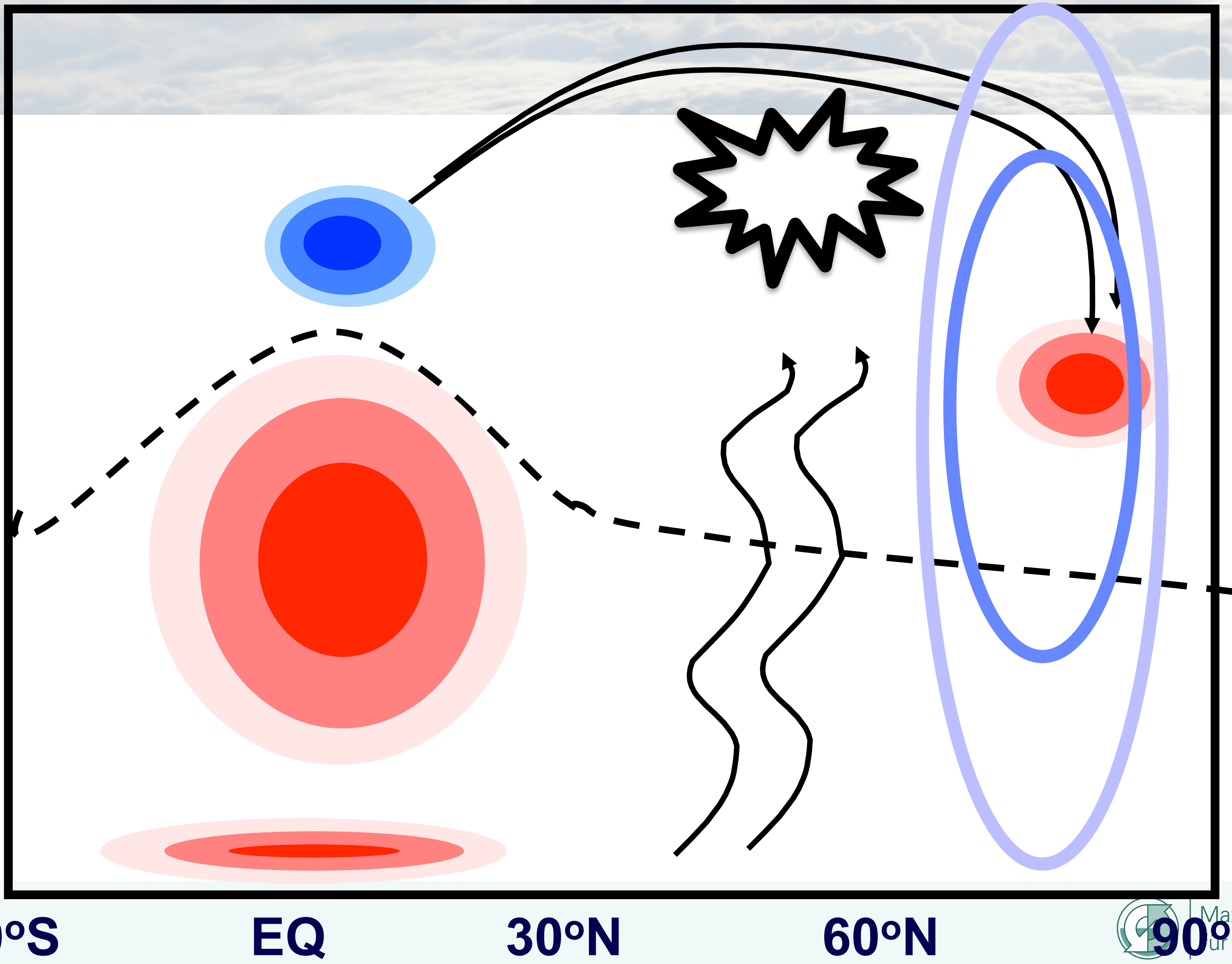
Fig. 3 Climate change in zonal winds from 1 × CO_2 to 4 × CO_2 climate in extended models (**a**, **b**) and standard models (**c**, **d**). **a** shows the average of extended models 1 and 2. **b** shows the average of 9 extended model simulations from the CCMVal project. **c** shows the average of standard models 1 and 2. **d** shows the average of 12 standard model simulations used in the latest IPCC report. Hatching shows statistical significance at the 95% level as in Fig. 1. The winds are a section near the middle of the Atlantic basin anomaly at 10 W (neighbouring longitudes show similar patterns)



Scaife et al CD 2012

Planck-Institut für Meteorologie

3. STRATOSPHERE PATHWAY: INCREASED WAVE DRAG
=> WEAKER POLAR VORTEX
=> HIGHER PRESSURE OVER THE POLE



3.

STRATOSPHERE PATHWAY: INCREASED WAVE DRAG
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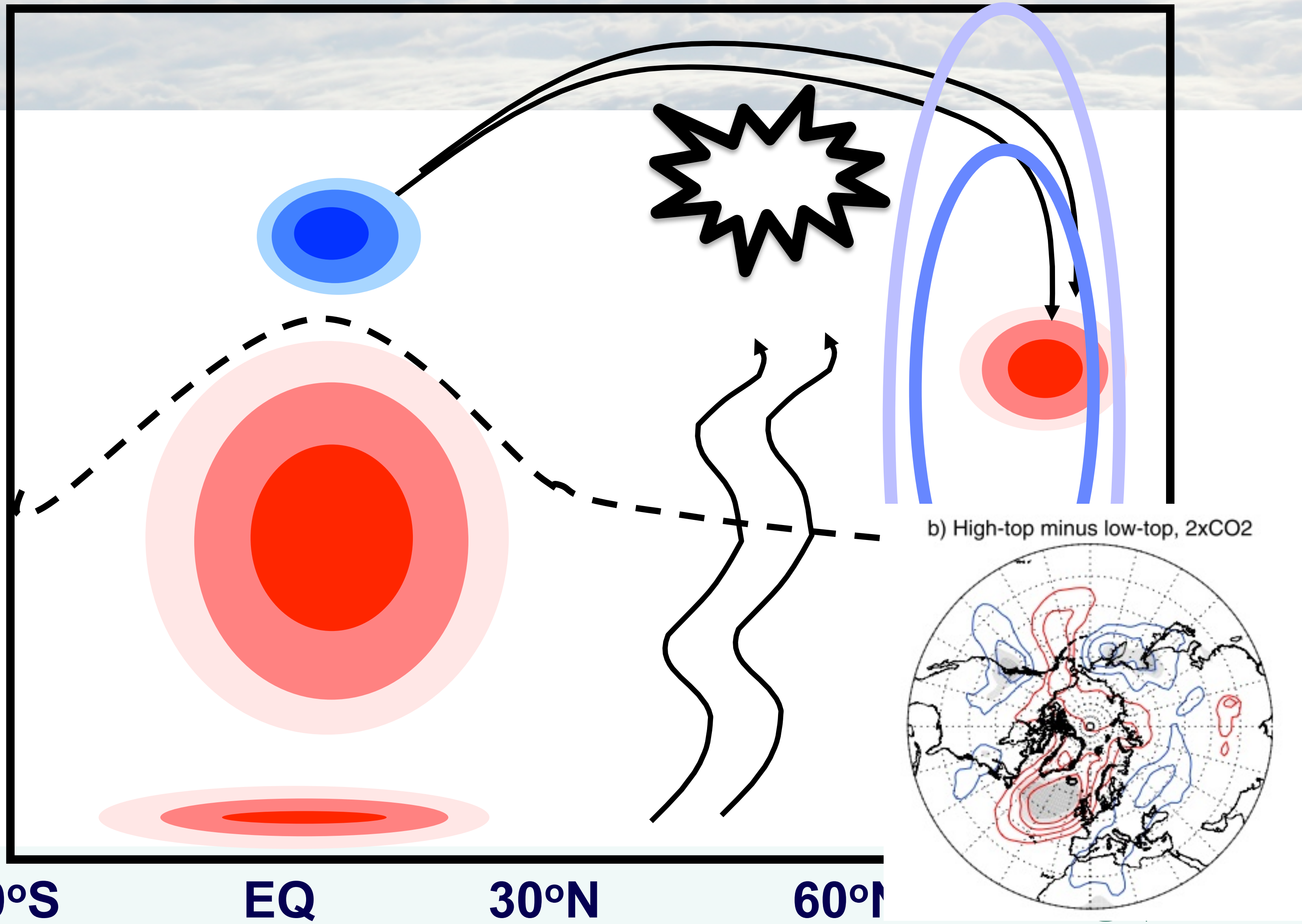
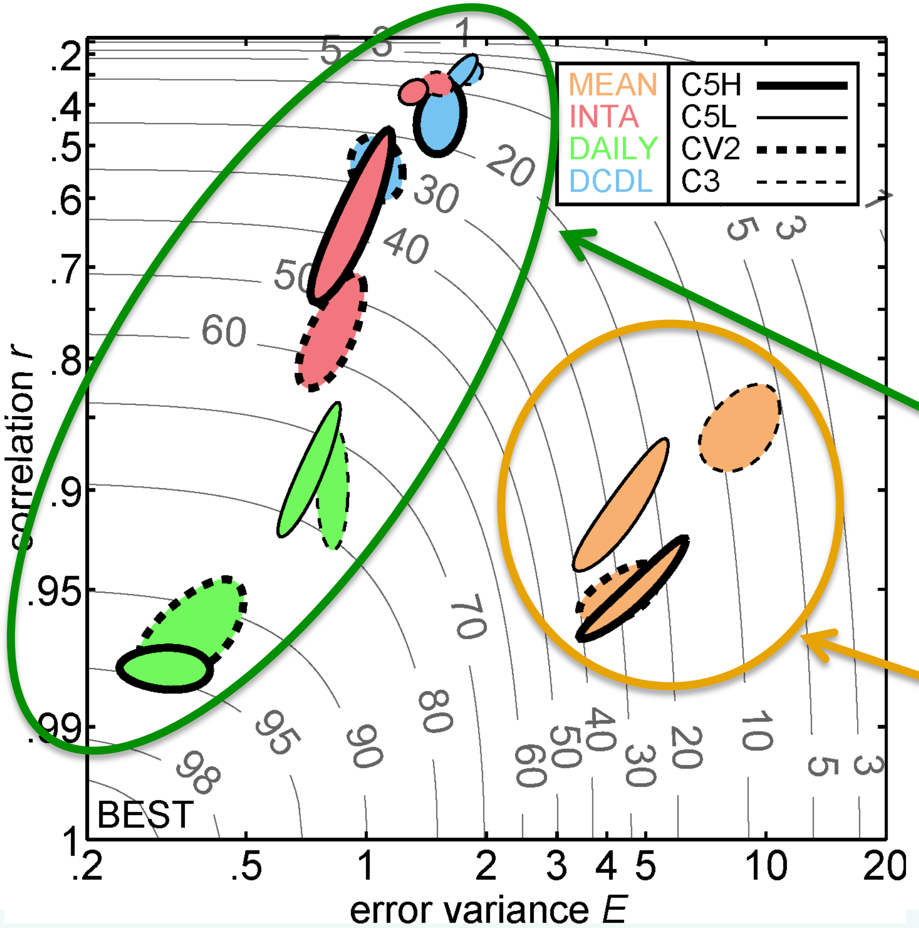


Charlon-Perez et al (2012, JGR submitted)
Mean Climate and Variability of the Stratosphere in 2the CMIP5 models



Assessing performance in the stratosphere (90S-90N, 100-10 hPa)

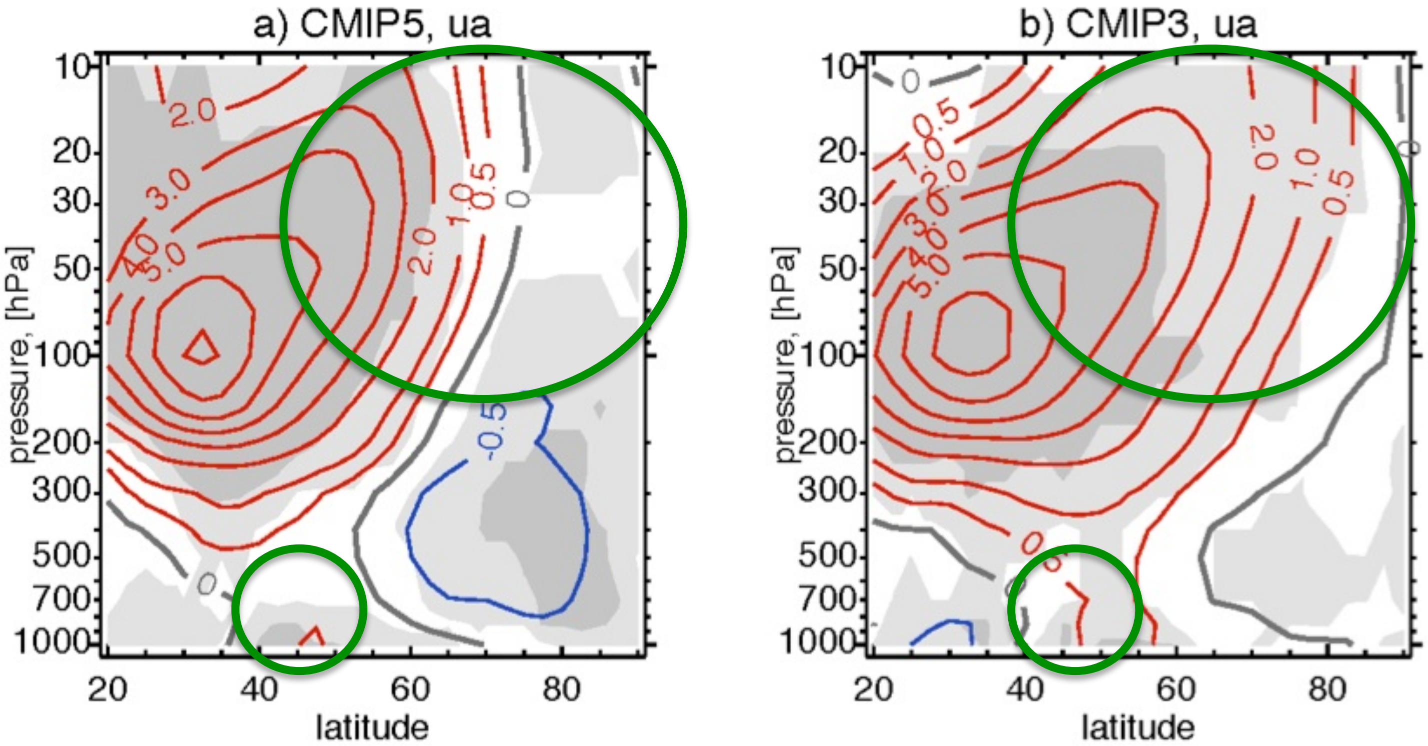
Stratospheric variability at all time scales is better simulated in the CMIP5 models with tops above the stratopause

Mean flow better simulated in the CMIP5 than CMIP3 models

Role of the stratosphere in Northern winter climate change as simulated by the CMIP5 models. Manzini et al. (submitted JGR 2012)

CMIP5 versus CMIP3 (all models) DJF response to 1% CO_2 increase (from 1xCO2 to 3xCO2):

dark (light) shadings mark inter-model sign consistence at the 90% (66%) level

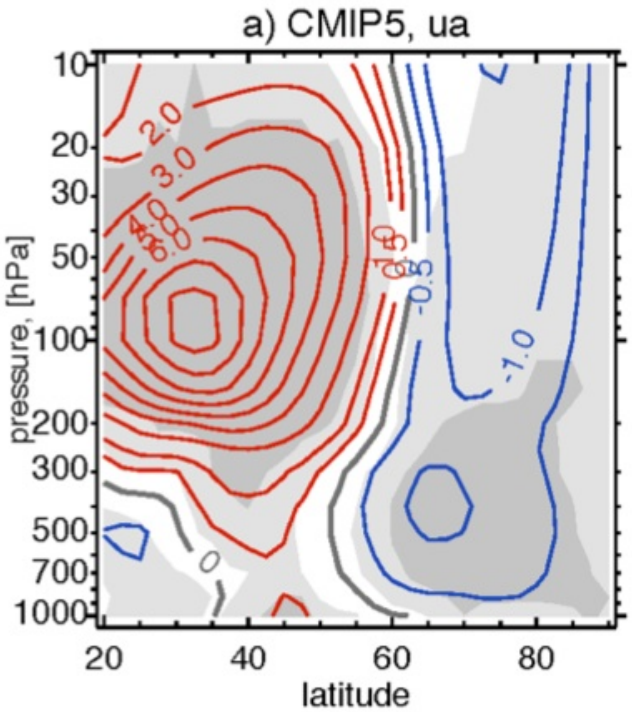


New in CMIP5 wrt CMIP3: negative zonal wind response at high latitudes => The stratospheric polar vortex expands

CMIP5 DJF response to RCP8.5 scenario
Change: 2060-2100 RCP8.5 minus 1960-2000 historical

Change in zonal mean zonal wind (m/s)

CMIP5 (all models)



Two subsets, according to the projected change in the strength of the stratospheric polar vortex:

(1) index = zonal mean zonal wind change (2061-2100 minus 1961- 2000) at 10 hPa & (70-80N), called "SUA"

(2) Ensemble subsets:

•Subset "strong" (labeled CMIP5s) consists of the models with positive SUA index.

•Subset "weak" (labeled CMIP5w) consists of the models with negative SUA index

dark (light) shadings mark inter-model sign consistence at the 90% (66%) level

CMIP5 DJF response to RCP8.5 scenario
Change: 2060-2100 RCP8.5 minus 1960-2000 historical

weak-strong SLP change (hPa)

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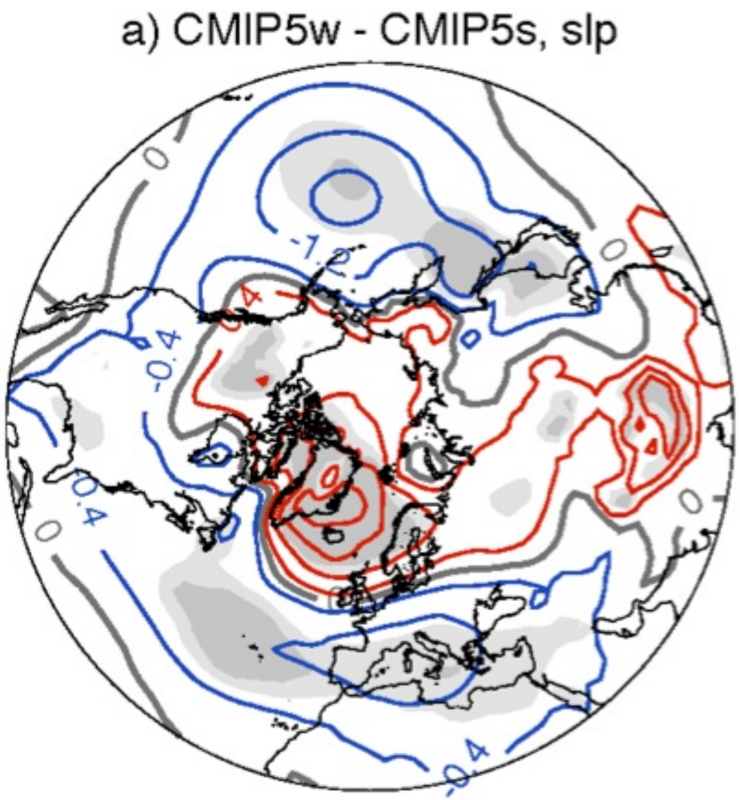

=> Link in the uncertainty of lower stratospheric winds and SLP projections

Summary and conclusions of CMIP5 assessment of stratospheric changes and their potential surface influence, NH winter

• NH stratospheric zonal wind projected changes to the end of the 21st century: likely to be characterized by a dipolar pattern, with stronger winds at low latitudes and weaker winds at high latitudes.

- ○Comparison with CMIP3 for the 1% per year CO2 increase experiment has shown that this dipolar pattern is a novel feature of the CMIP5 ensemble of models relative to the CMIP3 ensemble of models.
- ○Change: 2061-2100 RCP8.5 minus 1861-1900 historical (not shown). Results are reproduced with slightly larger responses (in magnitude) => ozone is not the primarily driver of the stratospheric changes.

• The height of the model top in the CMIP5 model ensembles is not a good predictor of high latitude stratospheric change and its impacts:

- ○The majority of high-top models report a larger tropospheric warming than the low top models.
- ○ BUT stratospheric processes and vertical resolution are not implicated in the high/low-top difference in tropospheric warming.
- ○CMIP5 set of opportunity does not guarantee that uncertainty in model formulations are appropriately considered

Summary and conclusions of CMIP5 assessment of stratospheric changes and their potential surface influence, NH winter

- Covariability of the stratospheric polar winds and downwelling with mean SLP and in intra-seasonal tropospheric processes found. This covariability is consistent with previous results, obtained by means of high/low top controlled experiments. => stratosphere to troposphere coupling is implicated in the CMIP5 results.

- Spread of the modeled stratospheric polar changes:
What is the relative role and interdependence of stratospheric dynamical processes and other factors in leading to the reported mean changes?

- Stratospheric modelling structural uncertainties:
  - Sensitivity to the treatment of gravity wave processes, and their direct and indirect impacts on the mean flow
  - Distortions of wave-mean flow interactions by sponge layers located in the stratosphere: Clearly detrimental for models with tops at 10 hPa. But do they compensate for deficiencies in variability in models with tops between 10 and 1 hPa?

3rd SPARC/DynVar Workshop
22-24 April 2013, Reading, England, UK
&
1st SPARC/SNAP Workshop
24-26 April 2013, Reading, England, UK

A joint DynVar/SNAP session will be held on 24 April

SNAP = Stratospheric Network for the Assessment of Predictability

SPARC DynVar Activity: http://www.sparcdynvar.org/
SPARC SNAP Activity: http://www.sparcsnap.org/

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Research Topics & Groups
[http://www.sparcdynvar.org/research-topics-groups-folder/]

- **Antarctica: From Ozone to Carbon**
  Contact: Judith Perlwitz (judith.perlwitz@noaa.gov)
- **Sudden Stratospheric Warming Events**
  Contact: Andrew Charlton-Perez (a.j.charlton@reading.ac.u
- **Extratropical Wave Coupling**
  Contact: Tiffany Shaw (tas2163@columbia.edu)
- **Annular Modes and Stratospheric Memory**
  Contact: Edwin Gerber (gerber@cims.nyu.edu)
- **QBO and Tropical Waves**
  Contact: Marco Giorgetta (marco.giorgetta@zmaw.de)
- **Water Vapor**
  Contact: Chiara Cagnazzo (chiara.cagnazzo@cmcc.it)
- **Surface Climate, Variability and Change**
  Contact: Elisa Manzini (elisa.manzini@zmaw.de)
- **ENSO and QBO**
  Contact: Natalia Calvo (calvo@ucar.edu)
- **AMOC and PDO**
  Contact: Thomas Reichler (thomas.reichler@utah.edu)
- **Tropopause and the UTLS**
  Contact: Thomas Birner (thomas@atmos.colostate.edu)
- **Volcanic forcing**
  Contact: Matthew Toohey (mtoohey@ifm-geomar.de)

Future …. CMIP6:

- *Diagnostics on stratospheric dynamical processes into the mainstream: Sday and Smon tables now for the unsolicited outputs?*

- *Idealized experiments aimed at demonstrating the role of stratospheric dynamics?*