SPARC Report and WGNE role

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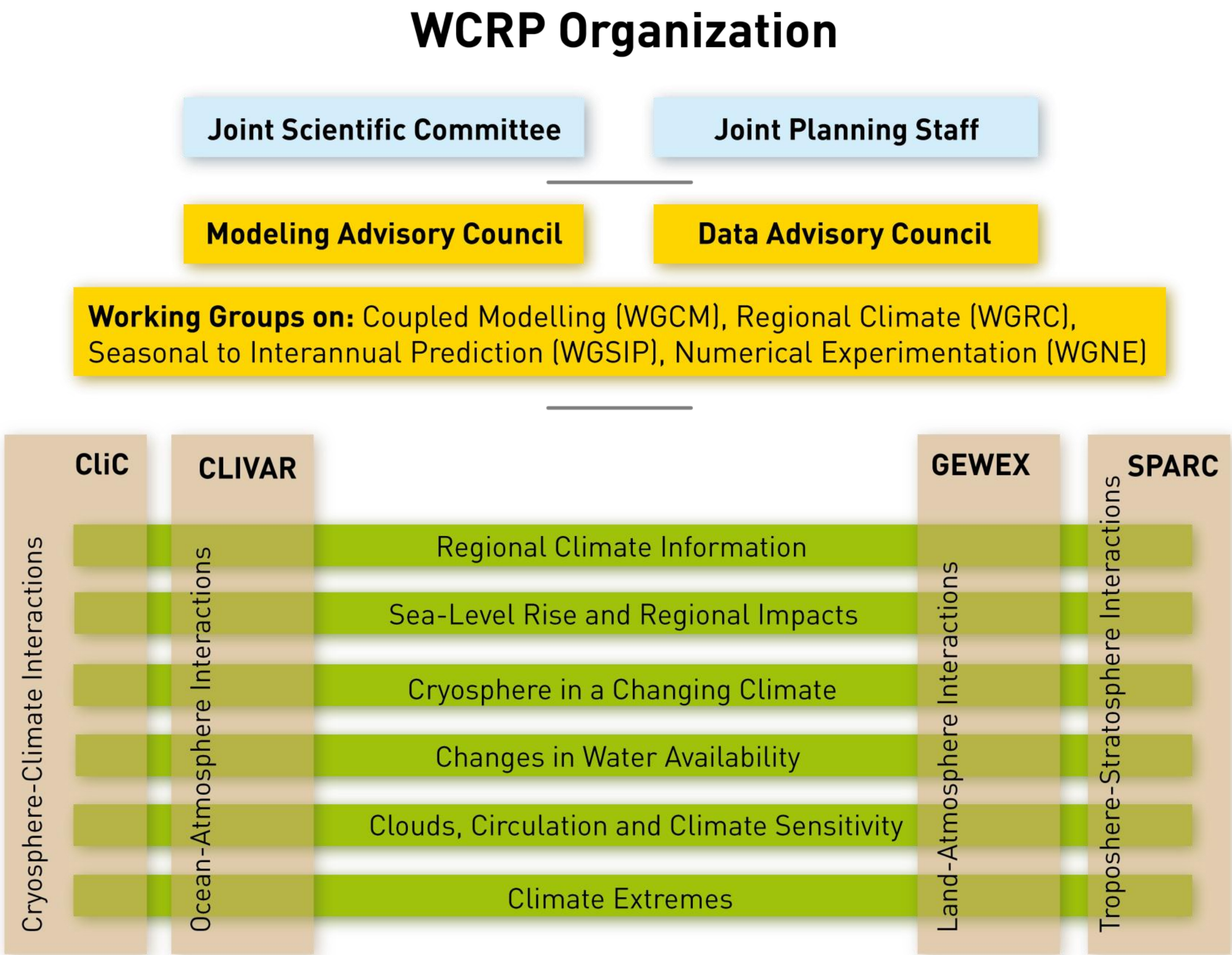
Thanks to Joan Alexander, Andrew Charlton-Perez, Masatomo Fujiwara, Scott Ospray, David Tan and Kaoru Sato

30th WGNE session, March 23-26, 2015

NCWCP, College Park, MA, USA

Stratosphere-troposphere Processes and their Role in Climate (SPARC)



SPARC Themes

Climate-chemistry interactions

- How will stratospheric ozone and other constituents evolve?
- How will changes in stratospheric composition affect climate?
- What are the links between changes in stratospheric ozone, UV radiation and tropospheric chemistry?

Detection, attribution, and prediction of stratospheric change

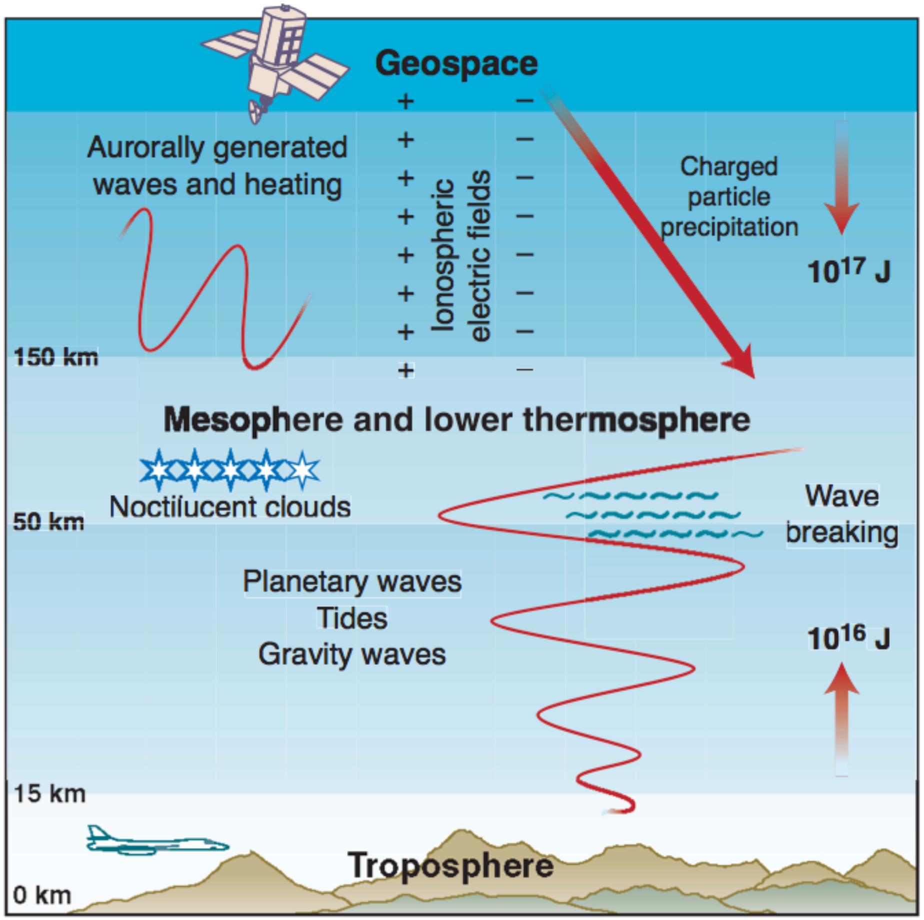
- What are the past changes and variations in the stratosphere?
- How well can we explain past changes in terms of natural and anthropogenic effects?
- How do we expect the stratosphere to evolve in the future, and what confidence do we have in those predictions?

Stratosphere-troposphere dynamical coupling

- What is the role of dynamical and radiative coupling with the stratosphere in extended-range tropospheric weather forecasting and determining long-term trends in tropospheric climate?
- By what mechanisms do the stratosphere and troposphere act as a coupled system?
- What will be the role of the stratosphere as climate changes?

SPARC: a whole atmosphere approach

"**Whole Atmosphere**": *Treating the* ***Stratosphere-Troposphere*** *as one system.*



Chemistry – Dynamics – Radiation – Volcanic Aerosols – Atmospheric Waves – Solar Fluxes – Chemical Transport – Deep Convection – High-altitude Cirrus

SPARC

- SPARC Tasks:
  - Scientific research coordination through SPARC sub-groups (activities)
  - SPARC General Assemblies and WCRP Open Science Conferences
  - SPARC newsletters
  - SPARC Assessment Reports
- SPARC has broadened its scope to include the upper troposphere
- http://www.sparc-climate.org/

SPARC report and WGNE role

- This talk summaried SPARC activities that are relevant to WGNE
- Need for WGNE implication is also highlighted

S-RIP: SPARC-Reanalysis Intercomparison Project

URL: http://s-rip.ees.hokudai.ac.jp/

Activity leaders:

- Masatomo Fujiwara (Univ. of Hokkaido, fuji@ees.hokudai.ac.jp)
- David Tan (ECMWF, David.Tan@ecmwf.int)

S-RIP

- Motivations: Reanalyses are more and more used by the climate community => the is a need for evaluate and intercompared these product w.r.t. "key" climate diagnostics
- Discussed and proposed at the SPARC DA workshop in 2011; the planning meeting at Met Office in 2013
- The goals of S-RIP are to:
  - Create a communication platform between the SPARC community and the reanalysis centres
  - Understand current reanalysis products and contribute to future reanalysis improvements
  - Write up the results of the reanalysis intercomparison in peer reviewed papers and SPARC report (2013-2018)
- S-RIP 2015 Report (May 2015), for basic chapters
- S-RIP 2018 Report (May 2018), for all chapters

S-RIP: Outline Plan for Report

	Chapter Title	Chapter Co-leads
1	Introduction	(Fujiwara & WG members)
2	Description of the Reanalysis Systems	Masatomo Fujiwara, David Tan, Craig Long
3	Climatology and Interannual Variability of Dynamical Variables	Craig Long, Masatomo Fujiwara
4	Climatology and Interannual Variability of Ozone and Water Vapour	Michaela Hegglin, Sean Davis
5	Brewer-Dobson Circulation	Thomas Birner, Beatriz Monge-Sanz
6	Stratosphere-Troposphere Coupling	Edwin Gerber, Patrick Martineau
7	Extratropical UTLS	Cameron Homeyer, Gloria Manney
8	Tropical Tropopause Layer	Susann Tegtmeier, Kirstin Krüger
9	QBO and Tropical Variability	James Anstey, Lesley Gray
10	Polar Processes	Michelle Santee, Alyn Lambert, Gloria Manney
11	Upper Strato. Lower Mesosphere	Diane Pendlebury, Lynn Harvey
12	Synthesis Summary	(Fujiwara & WG members)

Chapters 1-4: Basic chapters due on May 2015

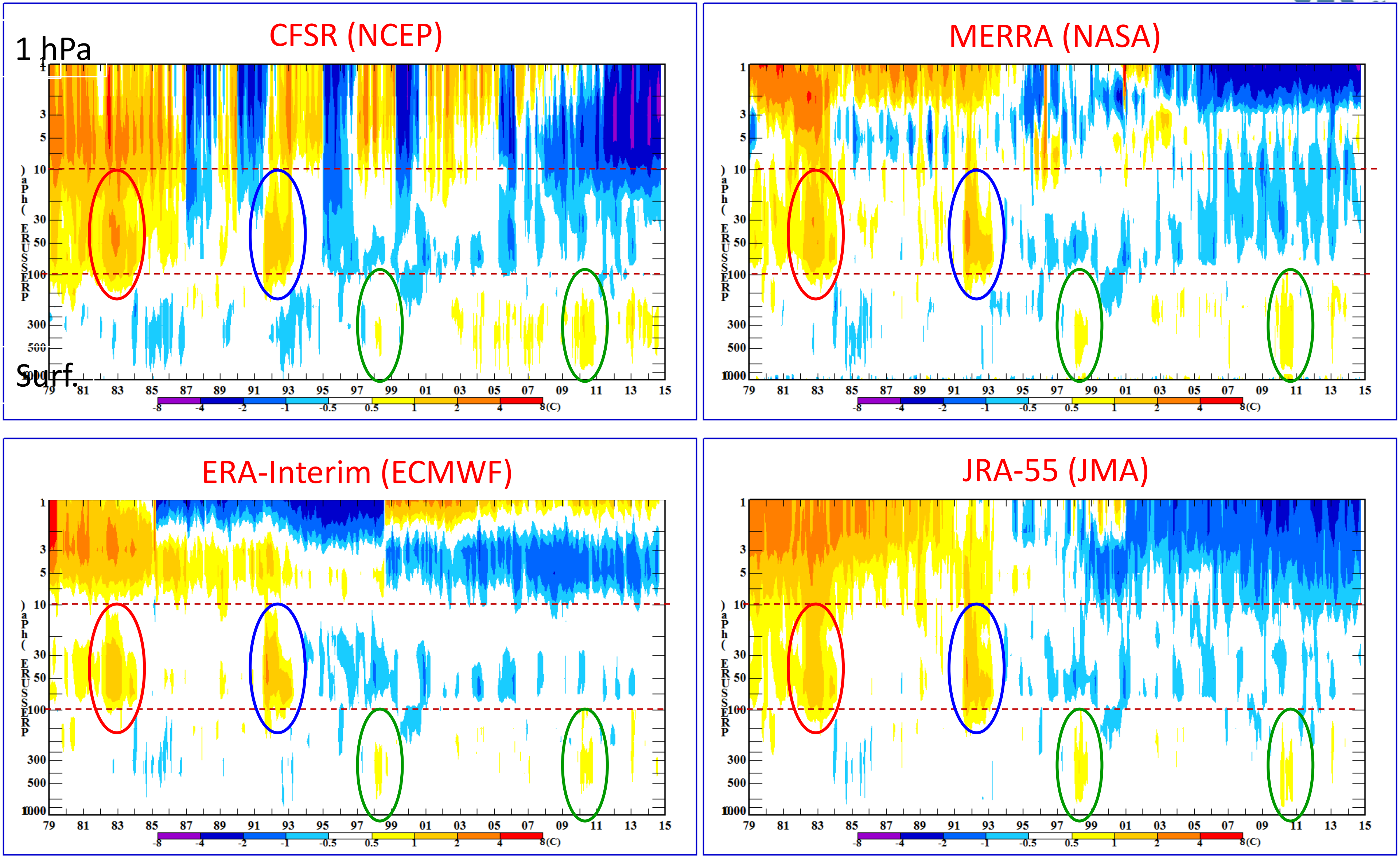
Chapters 5-11: Advanced chapters due on May 2018

S-RIP participants

Product	Centre	Period	Resolution and **Lid Height** of the Forecast Model	Contact for S-RIP
MERRA	NASA	1979 – present	(2/3)x(1/2) deg., L72, **0.01 hPa**	S. Pawson
ERA-Interim	ECMWF	1979 – present	T_L255 & N128 reduced Gaussian (79km), L60, **0.1 hPa**	D. Tan
ERA-40	ECMWF	1957.9 - 2002.8	T_L159 & N80 reduced Gaussian (125km), L60, **0.1 hPa**	D. Tan
NCEP-CFSR	NCEP	1979 – 2009 2010 - present	T382 (T574 for 2010 -), L64, **0.266 hPa**	C. Long
JRA-55	JMA	1958 - present	TL319, L60, **0.1 hPa**	K. Onogi
JRA-25/JCDAS	JMA and CRIEPI	1979.1 – 2014.1	T106, L40, **0.4 hPa**	K. Onogi
NCEP-2 (R-2)	NCEP and DOE AMIP-II	1979 – present	T62, L28, **3 hPa**	W. Ebisuzaki
NCEP-1 (R-1)	NCEP and NCAR	1948 – present	T62, L28, **3 hPa**	W. Ebisuzaki
NOAA-CIRES 20th Century Reanalysis (20CR_v2)(*)	NOAA/ESRL PSD	1871 – 2010	T62, L28, **2.511hPa**	G. Compo & J. S. Whitaker

- New reanalysis data sets, within a few years:
    - MERRA-2 <mid 2015>, ERA-20C (and ERA5), etc.

Global Mean Temperature Anomaly (1979-2014) from Four Reanalysis



Real signals: El Chichon (1982), Pinatubo (1991); El Nino 1998 and 2010; Cooling in strato & Warming in tropo
Artificial signals: Stream changes (e.g., CFSR); TOVS-ATOVS transition (1998, e.g., ERA-I); Other sat. transitions

S-RIP summary and WGNE role

- S-RIP is one of the *community-level* activities to understand reanalysis quality and uncertainty
- Good progress already on the 3 goals (communication between science and reanalysis communities, understanding, publications)
- S-RIP's approach to implementation is a good template for similar (current/future) reanalysis intercomparison/validation/improvement activities
- **WGNE could help** SPARC/S-RIP by getting its various members to participate in S-RIP and/or to make available their internal knowledge/reports (grey literature) about reanalysis products
- For the future: Extending this kind of community-level activity to the troposphere, surface, ocean, land and to chemistry, biosphere, etc., i.e., targeting the "Earth system reanalysis"?

SNAP: Stratospheric Network for the Assessment of Predictability

URL: http://www.sparcsnap.org/

Twitter: #sparcsnap

Activity leaders

- Andrew Charlton-Perrez (Met Office, a.j.charlton@reading.ac.uk)
- Gregory Roff (Australian Bureau of Meteorology, G.Roff@bom.gov.au)

SNAP

- Network of researchers in universities and operational centres with focus on **predictability of** and **from** stratospheric dynamical variability
- Key questions:
  - Which stratospheric dynamical events influence tropospheric predictability?
  - How far in advance can stratospheric dynamical events be predicted and usefully add skill to tropospheric forecasts?
  - Which stratospheric processes need to be captured by models to gain optimal stratospheric predictability?

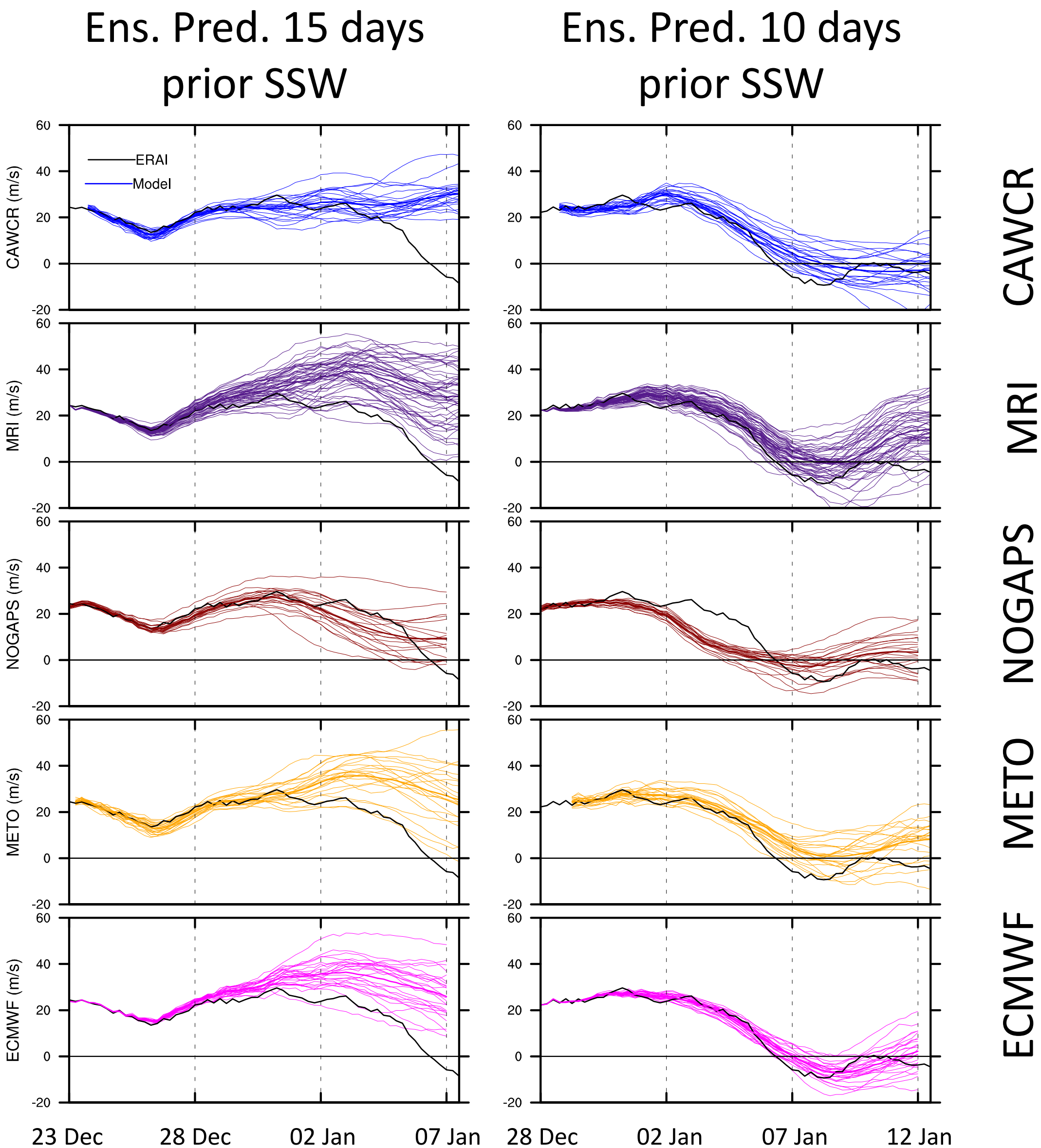
SNAP Operational Partners

Modeling Center	Country	Abbreviation
MetOffice	UK	METO
Meteorological Research Institute	Japan	MRI
Naval Research Laboratory	USA	NOGAPS
Bureau of Meteorology	Australia	CAWCR
Korea Polar Research Institute	Korea	KOPRI
European Center for Medium Range Weather Forecasts	International	ECMWF
Korean Meteorological Administration	Korea	KMA
Environment Canada	Canada	EC

- Phase 0: Collecting 1 year of forecasts from three centres
- Phase 1: Assessment of predictability of Jan 2013 SSW and Oct 2012 SH Final Warming

Results from SNAP experiment (1/2)

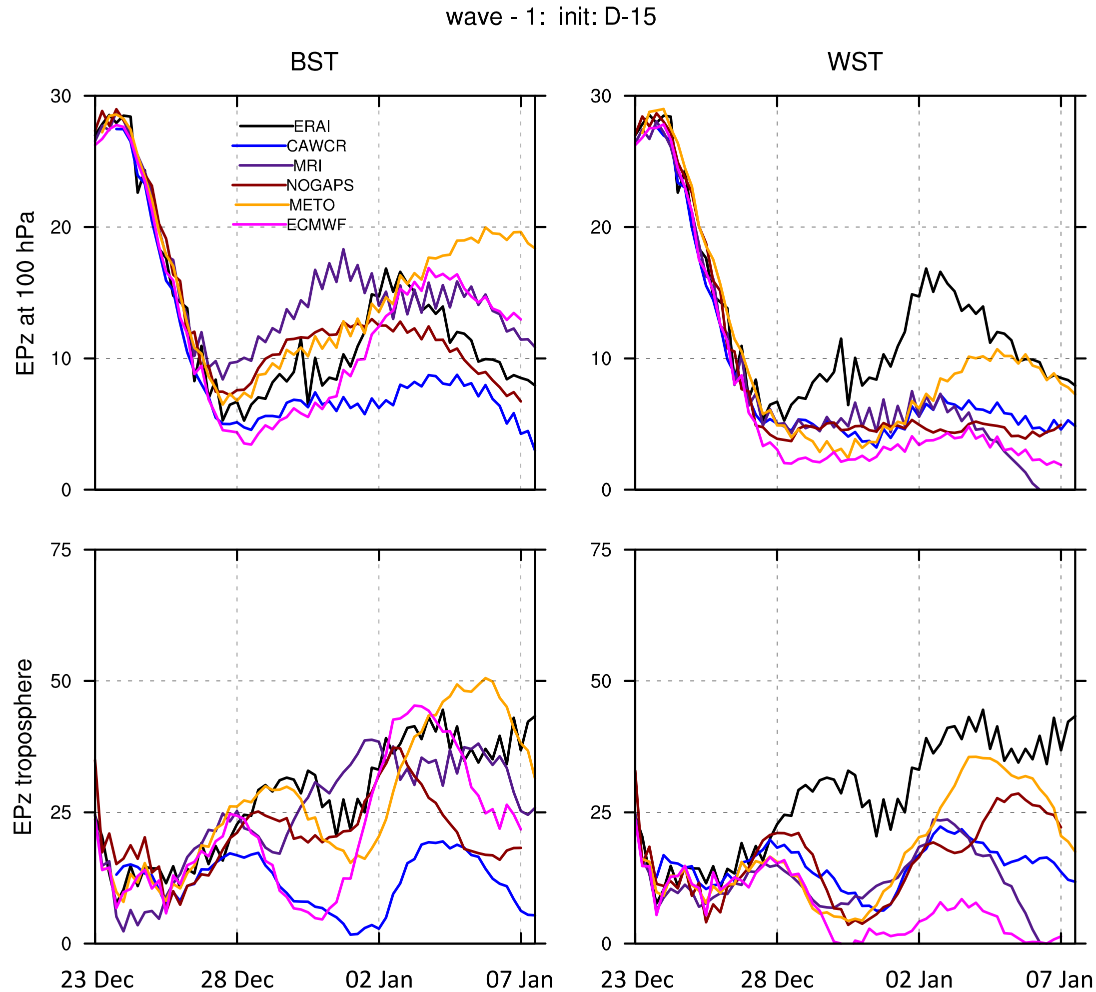
- Series of operational forecasts for 2013 SSW with lots of stratospheric diagnostics
- Exploit range of behaviour across each forecast ensemble
- Joint analysis of Jan 2013 SSW case recently submitted to Mon. Wea. Rev.



U zonal mean at 10 hPa 60˚N (m/s). Black line is ERA-I

Results from SNAP experiment (2/2)

- Splitting ensemble into Best and Worst forecasts can trace dynamical behaviour and compare models
- For 15 days forecast, worst members of all models fail to capture amplification of wave-1 EP flux in troposphere



EP_z at 100 hPa (top) and in the troposphere (bottom) from Best (right) and Worst (left) members, from different model forecast initialized 15 days before the SSW. Black line is ERA-I

SNAP Summary

- Building a community of researchers interested in stratospheric predictability and its impact on tropospheric forecasts particularly in the higher latitudes
- Developing collaborations with Subseasonal-to-Seasonal (S2S) and Polar Prediction Program (PPP) – key for the future
- Opportunities for WGNE community to get involved, please get in touch

Data is accessible at
http://badc.nerc.ac.uk/help/jasmin_workspaces.html

GW: Gravity Waves

URL: http://www.sparc-climate.org/activities/gravity-waves/

Activity leaders:

- Joan Alexander (North West Research Associate, alexand@cora.nwra.com)
- Kaoru Sato (Univ. of Tokyo, kaoru@eps.s.u-tokyo.ac.jp)

Gravity Waves (GW)

- GW is involved in HiResMIP (High resolution model inter-comparison project)
- GW activity has in recent years focused on gravity wave effects on the atmospheric momentum budget
- The group described a method for comparing gravity wave momentum fluxes between observations, high resolution GCM and low resolution GCM with parameterization (Geller et al., 2013 *J. Climate*)
- The method uses variances of wind and temperatures in high-resolution models to evaluate high-resolution model effectiveness at resolving the gravity wave spectrum
- The group has contributed to the HiResMIP proposal and diagnostic list for the purpose of evaluating the models' capabilities in resolving the mesoscale wave spectrum

GW: High-Resolution GW Resolving Models

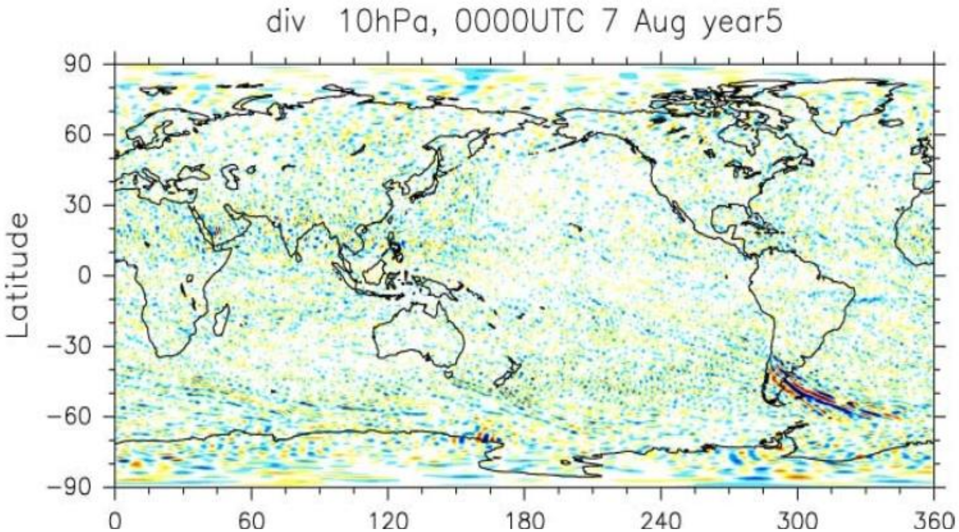
BIRA-IASB

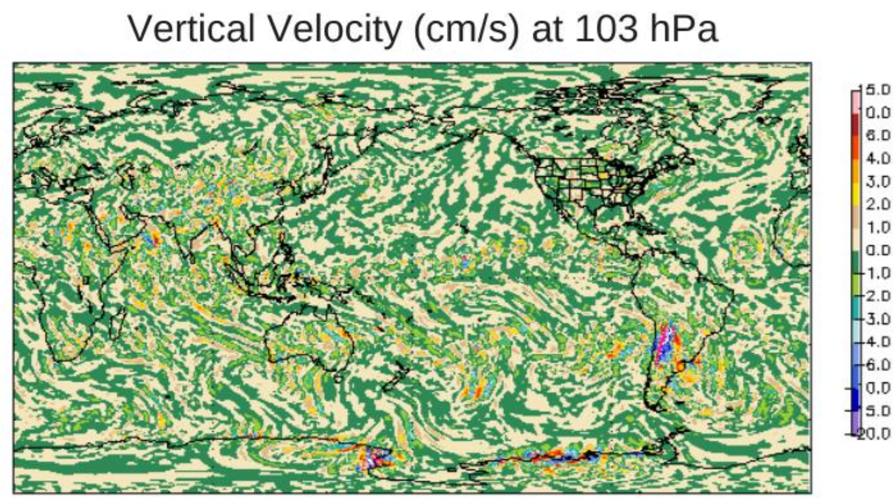
Kanto Model

Spectral model numerics
T213 Minimum wavelength ~180km
L256 vertical resolution ~300m to 85km
No parameterized gravity wave drag

CAM5 Model

Finite Volume numerics
0.25° horizontal resolution ~25km
L30 vertical resolution ~2km to 40km)
Parameterized orographic wave drag





=> High Res. GCM can resolve at least a part of gravity waves

GW: Geller et al., 2013

Intercomparison of Observations & Models

- Since satellite observations don't have directional information, we compare total absolute value of the momentum fluxes:

  1. Parameterized waves in climate models:
     Total |flux| = |eastward|+|westward|+|northward|+|southward|
     ... and integrated over the wave spectrum

  2. High-resolution models compute:
     Total |flux| ~ $|w'|^2(|u'|^2+|v'|^2)$ ... then binned in lat/lon and averaged

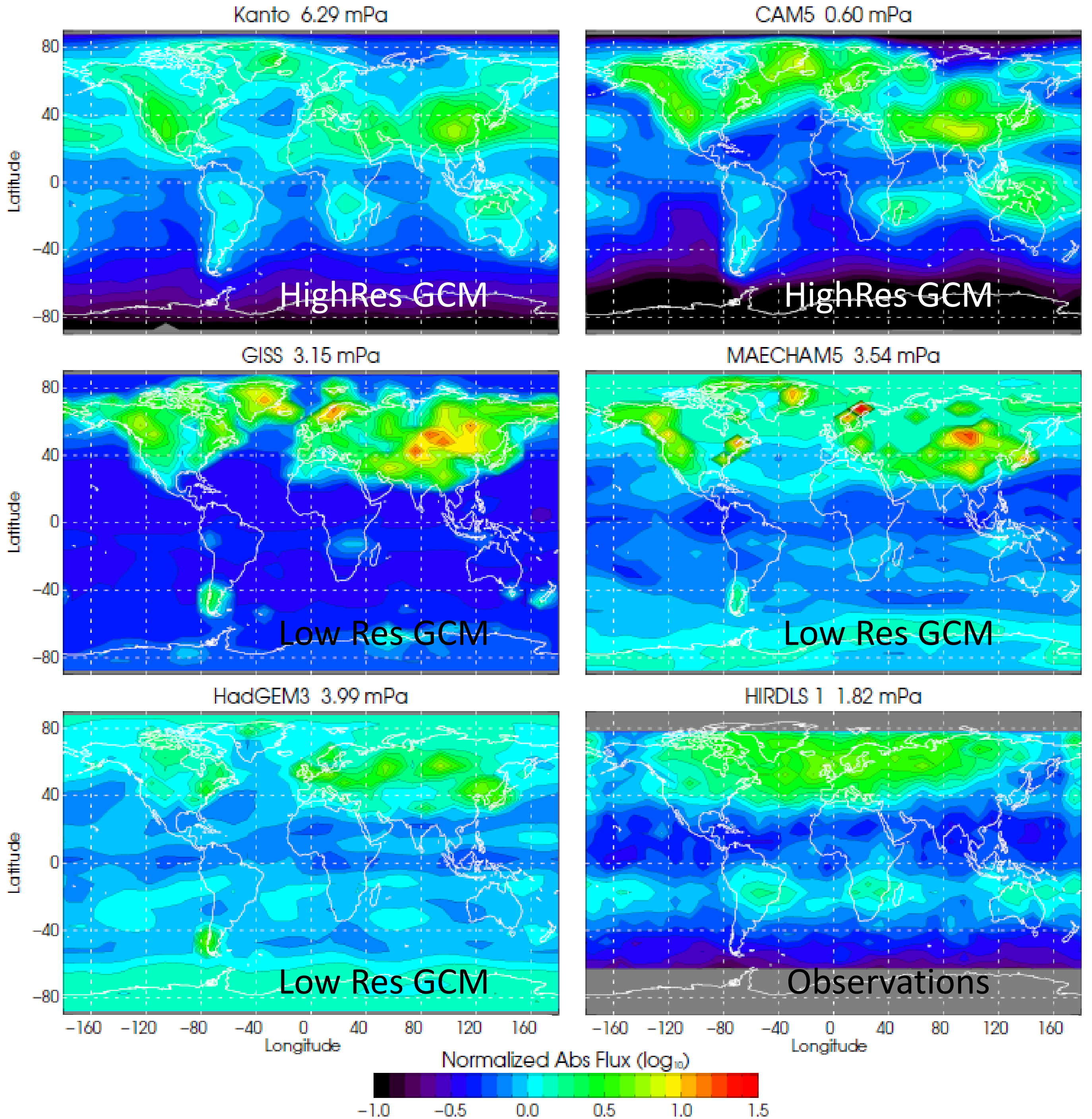
  3. Balloons compute local (u'w', v'w') or ($u'T'_{90}$,$v'T_{90}'$) and
     Total |flux| ~ |u'w'| + |v'w'| ... then binned in lat/lon and averaged

- Monthly-means for January and July in three years: 2005-2008
- Latitude/Longitude binning 5° x 10°

Global map of **Absolute GW momentum flux** for High and Low Res. model, and observations: January ratio to global mean at 20 km

- Similar patterns
- Differences:

1. Summer subtropical max. that is weak of absent in parameterizations (low res. model)
2. Decay flux at the poles not present in parameterization (low res. model)



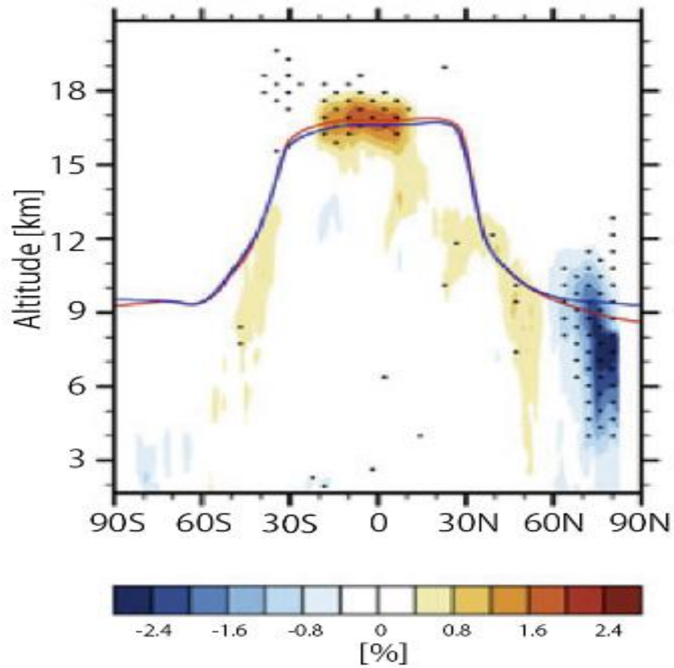
GW: Summary of Geller et al.

- Despite using different parameterization methods, **all the models with a middle atmosphere have similar gravity wave momentum fluxes**, presumably because the settings were chosen to obtain a reasonable middle atmospheric circulation and temperature structure.

- **Observations and high-resolution models remain resolution limited**:
  a. Satellite observations are greatly hindered by horizontal resolution
  b. Long-duration balloon measurements are limited geographically and to campaign periods.
  c. Kanto at 0.6^o had sufficient flux to generate a realistic MA circulation but mountain waves are very clearly still under-resolved.
  d. CAM at 0.25^o suffers from lack of vertical resolution, exaggerating wave dissipation with altitude.

GW: Wave-driven circulation modifies cloud incidence (CI) in the upper troposphere

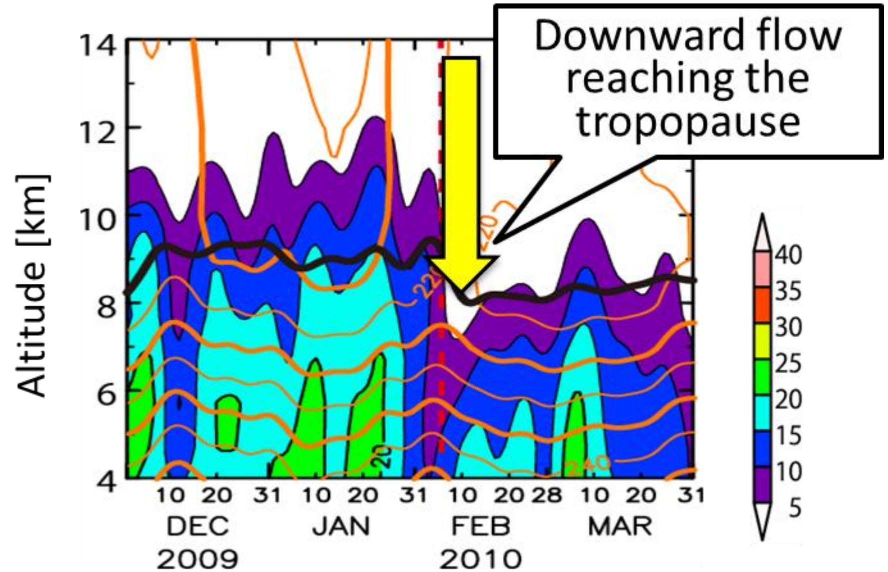
CI regressed to BDC index

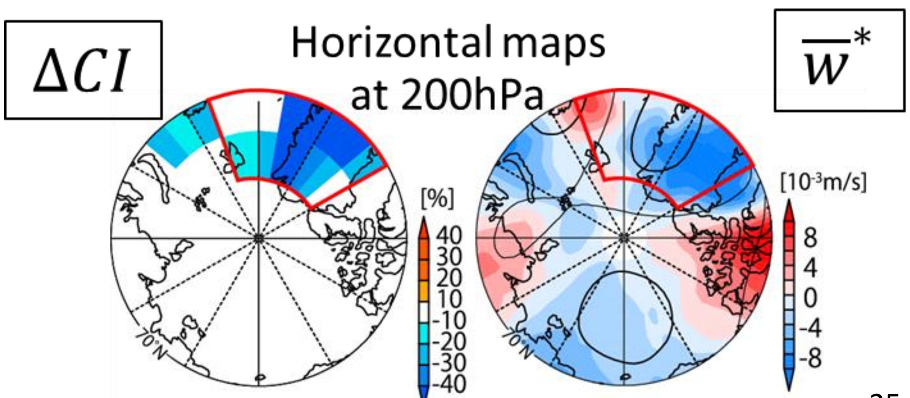


Increase in circulation=>incr. of CI in TTL and decr. at Pole (Li and Thompson, JGR, 2013)

CI in the upper troposphere soon after an SSW (Kohma and Sato, JGR, 2014)

CI before & after SSW





GW: Summary and WGNE Role

- Promote WGNE's extension of forecast model surface drags to climate models among SPARC community
- Possible synergies with momentum terms in free atmosphere above the surface layer?
- Wave-driven circulation – cloud connections?
- Work with WGNE to evaluate gravity waves for momentum budget studies with HiResMIP?

QBOi: a SPARC Emerging activity

URL: http://users.ox.ac.uk/~astr0092/QBOi.html

Activity leader:

- Scott Ospray (Oxford Univ., sosprey@atm.ox.ac.uk)
- Neal Butchart (UK Met Office, neal.butchart@metoffice.gov.uk)
- Kevin Hamilton (International Pacific Research Center, USA, kph@hawaii.edu)

QBOi: Better Representing Tropical Stratosphere Variability in GCMs

Motivations

- QBO is the longest predictable atmospheric phenomenon (~3 years) which when coupled with robust extratropical teleconnections, provides clear scope for significantly improved seasonal/interannual ***predictability***.
- Important in TTL transport and processes (stratospheric water vapour), position of subtropical transport barriers and their seasonality. Important in ***Projections*** of future stratospheric composition

QBOi: Science Questions (1/2)

- Many QBO parameters are sensitive to 'everything':
  - Latitudinal extent
    - Horizontal propagation of Rossby waves into tropics
    - Why is the width too narrow?
  - Vertical extent, especially low levels, tropospheric effects
    - Why do modelled QBOs not descend enough?
  - Variability of QBO cycles, predictability
    - Why do models exhibit a wide range of annual synchronisation?
    - Why are modelled QBO cycles too regular?
    - Stalling of QBO shear zones
  - Real QBO is very robust, yet modelled ones are sensitive to everything
    - Are high-resolution (horizontal and vertical) models a useful benchmark?
    - Can we test convergence?
- Understand this parameter space, which is non-linear.
  - Range of numerics combos that "work"
  - Range of parameterisations combos that "work"
- Wave absorption: What are the relative roles of PWs vs. resolved small-scale waves vs. parameterised waves, as a function of height?
  - Can we evaluate this. (See observations, below.)
  - Does it matter?
- What details of parameterized waves matter? E.g. stochasticity

QBOi: Science Questions (2/2)

- Wave generation
  - What is the relationship between tropical convection, precip and waves.
  - Relate space-time distribution of convection to distribution of wave fluxes at the tropopause.
  - Walker circulation, ENSO: effect on space-time distribution of waves
- Top-down influence: is SAO important for QBO?
- Observations: Use existing observations (balloons etc.) to compare momentum fluxes to simulations.
  - No one knows the truth about GWs. [needs better obs]
- Understand the zonal-mean momentum budget in models near the equator.
- Is there a robust response to climate change? There appears to be one at 70 hPa, but needs to be verified. Doubled CO_2 runs are not consistent. Why?

QBOi: Experiments

Types of experiments (in order of priority)

1. Climate runs (interannual to decadal timescales) 1xCO2
    1. AMIP SSTs
    2. climatological AMIP SSTs 2xCO_2
    3. AMIP + SST anomaly derived from coupled run → or just +2K 4xCO_2, but 2xCO_2 is priority
2. Initialization experiments (seasonal timescale)
    1. Common initial state for all models (perhaps initialize by nudging).
    2. 4 QBO states, 2-4(?) annual cycle states.
3. Nudging to specify dynamics
    1. Zonal-mean in stratosphere is nudged
    2. See what nudging has to put in (as with analysis increments)
    3. Resolved waves in troposphere are nudged

Types of models

1. Use model version with "best" QBO for the above experiments
2. Use other model versions as well, if desired, for the above experiments. Model should have an oscillation recognizable as QBO-like.
3. If dynamical core experiments: Held-Suarez
4. Other types of models, e.g. WRF

QBOi: Timeline and Deliverables

1. Defining experiments, decide diagnostics: end of May 2015
2. Model experiments & data upload
   i. Control vs 2x (and/or 4x) CO2: May 2016
   ii. Initialization: May 2016
   iii. Nudging: up to groups what they do
3. Deliverables
   i. SPARC newsletter article
   ii. White paper
   iii. Scheninger et al. (in prep., CMIP5 & CCMVal models, defining metrics)
   iv. Paper comparing model results of experiment 1
   v. Paper comparing 1 & 2 experiments
   vi. Data archive (BADC)
4. Next workshop:
   1. Oxford, Autumn 2016 4-5 days, ~2 of which are open(?)
   2. Small writing meeting after Second Workshop

QBOi: WGNE role

- WGNE could help to improve convection and/or gravity waves parameterisation which are essential to facilitate wave driving of the QBO
- WGNE support could also help to improve GCM dynamical cores in order to improve the representation of the QBO (e.g. advection and diffusion)

DAWG: Data Assimilation Working Group

URL: http://www.sparc-climate.org/activities/data-assimilation/

Activity leader:

- Quentin Errera (Belgian Institute for Space Aeronomy, quentin@oma.be)

DAWG: Aims and scopes

- Discussion forum for data assimilators, data providers, modellers and users of data assimilation products that focus on the SPARC themes
- This is done throughout (almost) annual workshops with suggested themes and invited speakers
- Next meeting will be in Paris, Oct. 14-16, 2015, joint with S-RIP

DAWG: Next meeting and themes

- Themes:

1. Harmonization of data sets and bias corrections with a focus on limb sounder instruments
2. Added value of Chemistry DA
3. S-RIP
4. Representation of the upper stratosphere lower stratosphere in model and analysis with a focus on QBO, SAO and temperature
5. Future observational capabilities in the situation of lack of future plan for limb sounding

- Any comments/suggestions from WGNE?

Conclusions

- SPARC has several need from WGNE
  - S-RIP, GW, QBOi
- Oppertunities for WGNE community
  - DAWG, SNAP, QBOi, S-RIP, GW