QBOi

Quasi-Biennial Oscillation Initiative

James Anstey, Neal Butchart, Kevin Hamilton & Scott Osprey

+ QBOi Collaborators

Achievements 2017

- SPARC Workshop Report #48 (**Anstey et al., 2017**)
- Metrics paper, published (**Schenzinger et al., *Geosci. Model Dev*., 2017**)
- QBOi Experiment & Data Protocol submitted (Paper 0), (**Butchart et al., *Geosci. Model Dev*.**)
- Descent Rate Model Paper submitted (**Rajendran et al., *J. Atmos. Sci*.**)
- Dynamics and chemistry of the upper troposphere and stratosphere: observations and models, The confounding recent behaviour of the Quasi-Biennial Oscillation, EGU, Vienna, 24 April 2017
- The QBOi Initiative, 19th Conference on Middle Atmosphere, Portland, 26 June 2017
- QBO-Disruption, Special Session AOGS, Singapore (organiser Jack Kaye, NASA), August 10 2017
- GOTHAM “Summer” School, Investigating Teleconnections of Weather Extremes, Potsdam Institute for Climate Impacts Research, 18-22 September 2017
- Joint Dynamics & Observations Workshop held in Kyoto, Japan, 9-14 October 2017 (QBOi, FISAPS & SATIO-TCS)

Joint SPARC Dynamics & Observations Workshop 9-14 October 2017, Kyoto

- QBOi, FISAPS & SATIO-TCS
- 70 Participants
- 5 early career scientists (Funding gratefully received from WCRP)
- Workshop Themes
  - Dynamics & Radiation with Tropical convection
  - S-T Coupling & Tropical Convection
  - Vertical Coupling in the Extratropics
  - QBO, MJO & Intraseasonal Variations
  - Vertical Propagation of Waves
  - QBO Modelling
  - QBO Disruption
  - Fine-Scale Processes & Structures
  - Teleconnections
- **Breakout Sessions**
- QBOi Synthesis – Richard Scott

QBOi Session

- **Purpose of QBOi: Improve our understanding of and ability to model the QBO and its impacts.**
- Coordinated experiments and coordinated analyses.
- **Multi-model ensemble of QBO-resolving AGCMs**
- **Available diagnostics:** similar to those requested by DynVar MIP for CMIP6
- **Five experiments** to examine inter-model differences in QBOs, QBO predictability, response of QBO to climate forcing, and QBO impacts:
  - **Exp1: AMIP**
  - **Exp2: Present-day timeslice (climatological SSTs)**
  - **Exp3: Idealized future no. 1: 2 x CO2 and +2 K SST**
  - **Exp4: Idealized future no. 2: 4 x CO2 and +4 K SST**
  - **Exp5: Hindcasts (prescribed SST or coupled model)**

Same model is used to perform all experiments (very important!)

QBOi Phase One Models & Experiments

Butchart et al., *Geosci. Model. Dev.*

Table 5. Participating models and contact information.

Model names	Expts.	Institutes	Investigators	Email address	References
60LCAM5	1-4	NCAR	J. Chen	cchen@ucar.edu	Richter et al. (2014)
			J. Richter	jrichter@ucar.edu	
AGCM3-CMAM	1-3, 5	CCCMa	J. Anstey	james.anstey@canada.ca	Scinocca et al. (2008)
			J. Scinocca	john.scinocca@canada.ca	Anstey et al. (2016)
		U. Toronto	C. McLandress	charles@atmosp.physics.utoronto.ca	
CESM1-	1-4	NCAR	R. Garcia	rgarcia@ucar.edu	
(WACCM-L110)			J. Richter	jrichter@ucar.edu	Garcia and Richter (2017)
EC-EARTH3.1	5	BSC	J. Garcia-Serrano	javier.garcia@bsc.es	Christiansen et al. (2016)
ECHAM5sh	1-4	ISAC-CNR	F. Serva	federico.serva@artov.isac.cnr.it	Serva et al. (2017)
			C. Cagnazzo	c.cagnazzo@isac.cnr.it	Manzini et al. (2012)
EMAC	1-4	KIT	P. Braesicke	peter.braesicke@kit.edu	Jöckel et al. (2005)
			T. Kerzenmacher	tobias.kerzenmacher@kit.edu	Jöckel et al. (2010)
			S. Versick	stefan.versick@kit.edu	
HadGEM2-A	1	Ewha W. U.	Y.-H. Kim	young-ha.kim@ewha.ac.kr	Martin et al. (2011)
		Yonsei U.	H.-Y. Chun	chunhy@yonsei.ac.kr	
HadGEM2-AC	1	Ewha W. U.	Y.-H. Kim	young-ha.kim@ewha.ac.kr	Martin et al. (2011)
		Yonsei U.	H.-Y. Chun	chunhy@yonsei.ac.kr	Kim and Chun (2015b)
IFS43r1	1-5	ECMWF	T. Stockdale	tim.stockdale@ecmwf.int	ECMWF (2016); Orr et al. (2010)
LMDz6	1-4	ISPL-LMD	F. Lott	flott@lmd.ens.fr	Lott et al. (2005, 2012)
MIROC-AGCM-LL	1-5	MIROC	Y. Kawatani	yoskawatani@jamstec.go.jp	Kawatani et al. (2011)
MIROC-ESM	1-5	MIROC	S. Watanabe	wnabe@jamstec.go.jp	Watanabe et al. (2011)
MPI-ESM-MR	5A	MPI	H. Pohlmann	holger.pohlmann@mpimet.mpg.de	Pohlmann et al. (2013)
		U. Hamburg	M. Dobrynin	mikhail.dobrynin@uni-hamburg.de	Dobrynin et al. (2016)
MRI-ESM2	1-5	MRI-JMA	K. Yoshida	kyoshida@mri-jma.go.jp	Adachi et al. (2013)
			H. Naoe	hnaoe@mri-jma.go.jp	Yukimoto et al. (2012)
			S. Yukimoto	yukimoto@mri-jma.go.jp	
UMGA7	1-4	Met Office	A. Bushell	andrew.bushell@metoffice.gov.uk	Walters et al. (2016)
		MOHC	N. Butchart	neal.butchart@metoffice.gov.uk	
		U. Oxford	S. Osprey	scott.osprey@physics.ox.ac.uk	
UMGA7gws	1-4	Met Office	A. Bushell	andrew.bushell@metoffice.gov.uk	Bushell et al. (2015)
		MOHC	N. Butchart	neal.butchart@metoffice.gov.uk	Walters et al. (2016)
		U. Oxford	S. Osprey	scott.osprey@physics.ox.ac.uk	
UMGC2	5A	MOHC	A. Scaife	adam.scaife@metoffice.gov.uk	Dunstone et al. (2016)

QBOi Core Papers

Paper 0: Overview of experiment design, models, and diagnostics
Butchart et al., submitted to GMD, July 2017

Paper 1: Intercomparison and evaluation for present climate.
Experiments: 1,2 (AMIP, present-day timeslice)
Co-leads: Andrew Bushell, Scott Osprey, Neal Butchart

Paper 2: Robustness of QBO's response to climate forcing.
Experiments: 2 (present-day), 3 (2xCO2 and +2K SST), 4 (4xCO2 and +4K SST)
Co-leads: Yaga Richter, Neal Butchart, Scott Osprey

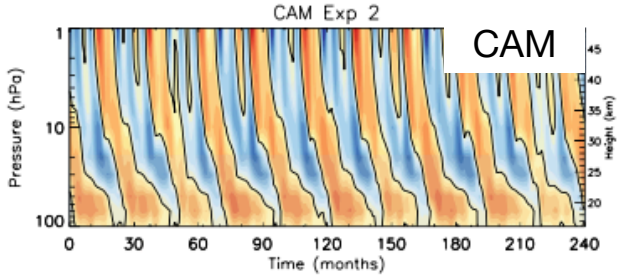
Paper 3: QBO predictability and mean-flow forcing in hindcasts
Experiments: 5 / 5A (AGCM/coupled hindcasts)
Co-leads: James Anstey, Young-Ha Kim, Tim Stockdale, Adam Scaife

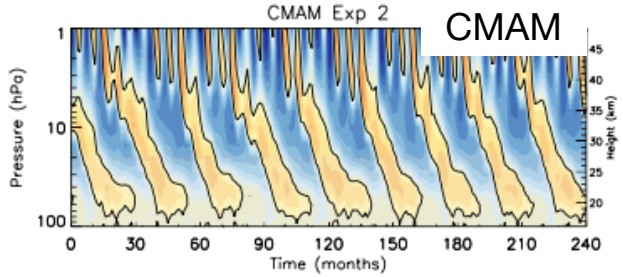
Paper 4: Tropical waves.
Experiments: 1, 5 (hindcasts), 1 (AMIP, hindcasts)
Co-leads: Laura Holt, Francois Lott, Rolando Garcia, Young-Ha Kim, Yoshio Kawatani

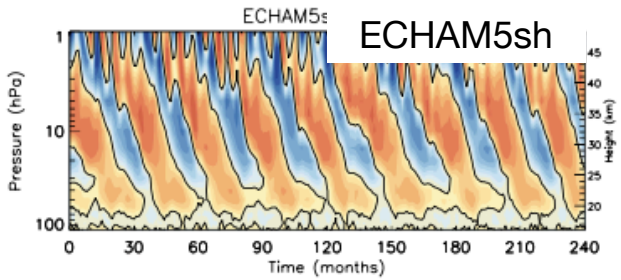
Paper 5: Teleconnections
Experiments: 1, 2 (AMIP, present-day timeslice)
Co-leads: Yaga Richter, James Anstey, Isla Simpson

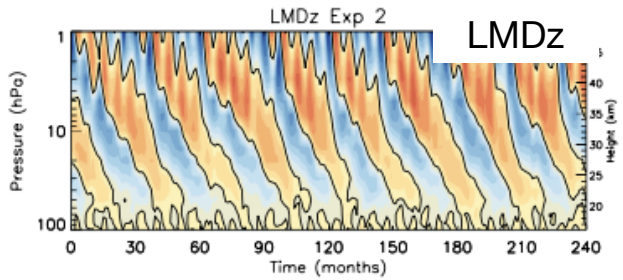
Present-day QBO

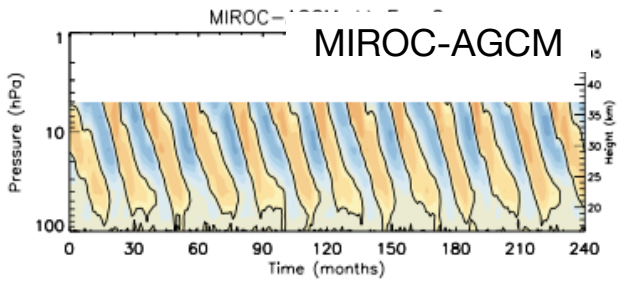
Present Day QBOs

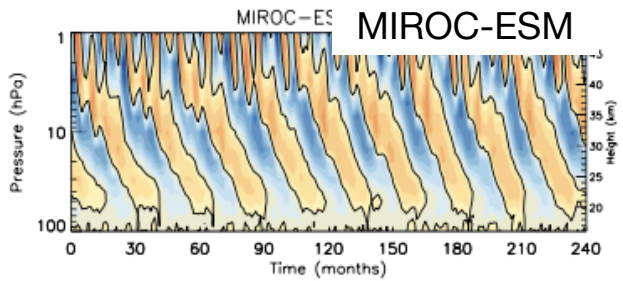


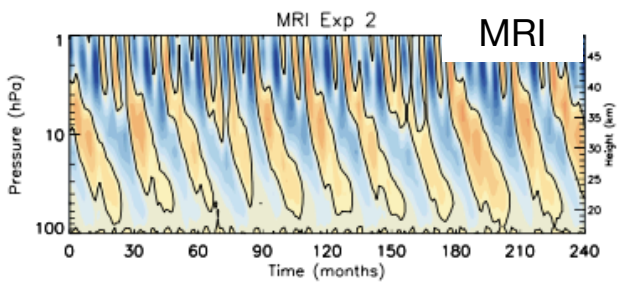


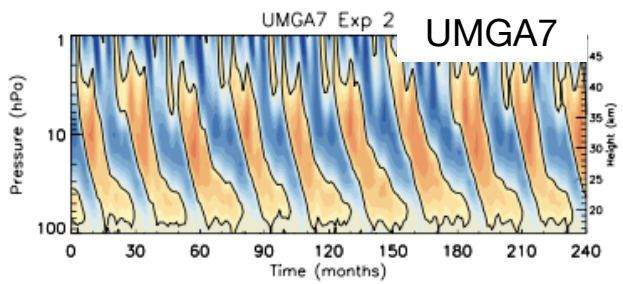


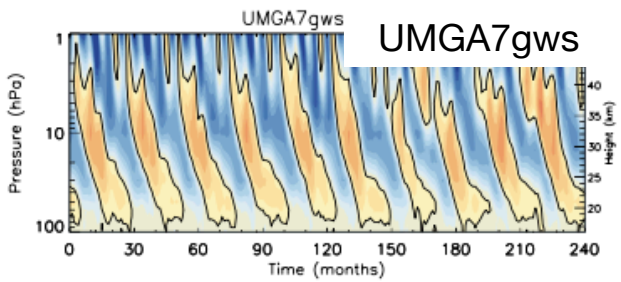


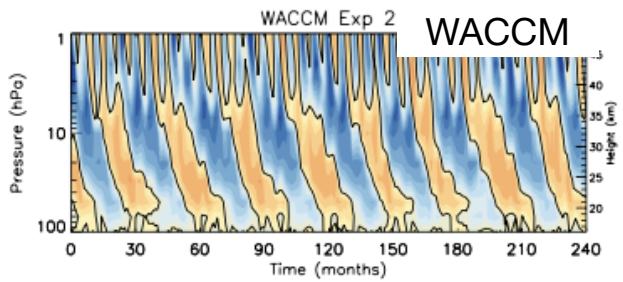




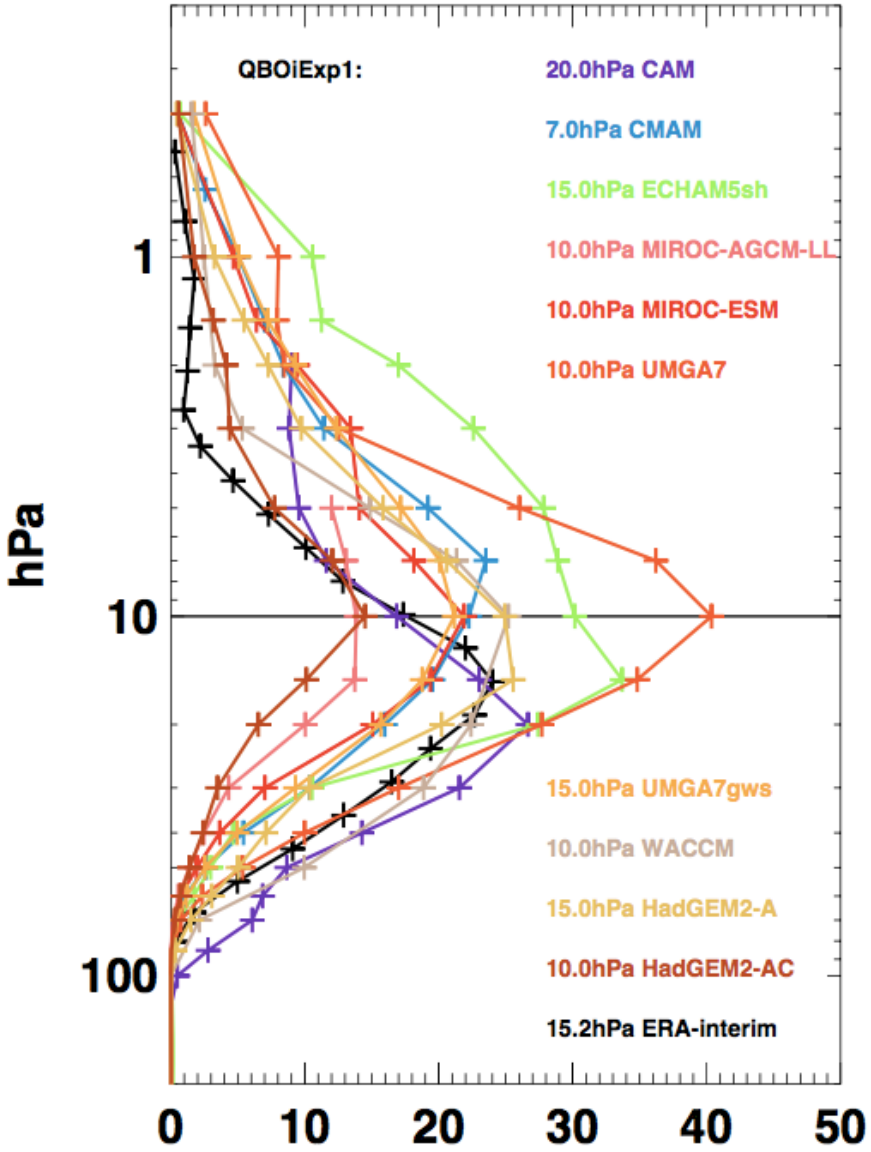








QBO in Exp 1 Models



Level of max QBO Amplitude:

- **7 hPa**: CMAM
- **10 hPa**: HadGEM2-AC, MIROC-ESM, MIROC-AGCM-LL, MIROC-ESM, UMGA7, WACCM
- **15 hPa**: **ERAi**, ECHAM5sh, HadGEM2-A, UMGA7gws
- **20 hPa:** CAM

QBO Amplitude:

- **Lower than ERAi:** MIROC-AGCM-LL, HadGEM2-AC
- **Higher than ERAi:** ECHAM5sh, UMGA7

QBO in warmer climate

Previous Studies:

Predictions of QBO in future:

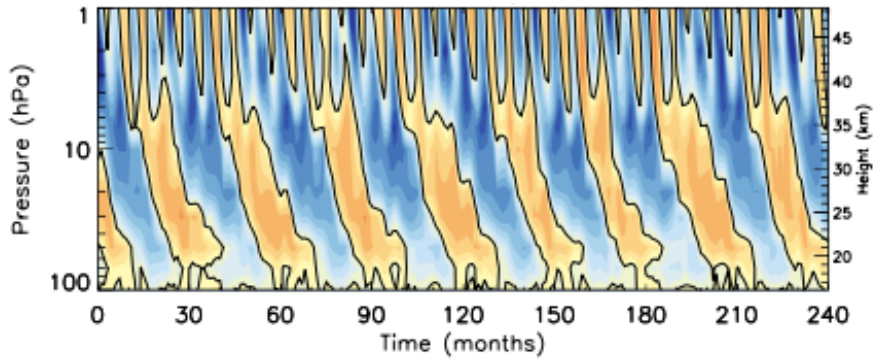
- Giorgetta & Doege (2005): shortened QBO period from 26 to 17 months ($2xCO_2$)
- Kawatani et al (2011): lengthened period ~ 3 months ($2xCO_2$)
- Watanabe & Kawatani (2012): lengthening ~ 3 months
- Schirber et al. (2015): Inconclusive

Increased Wave Momentum Flux -> Shorter QBO period

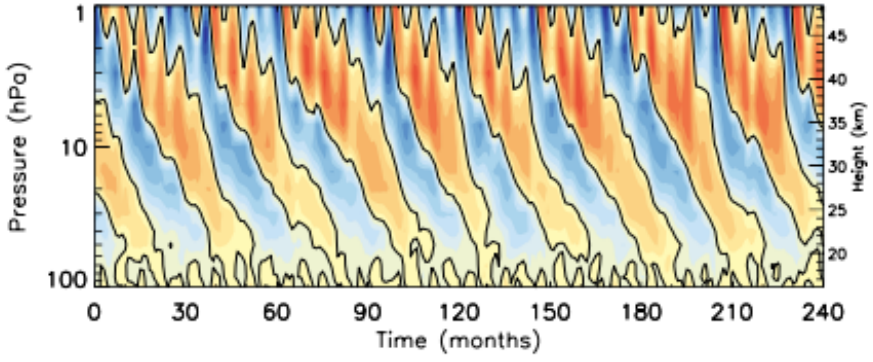
Increased w* -> Longer QBO period

WACCM vs LMDz

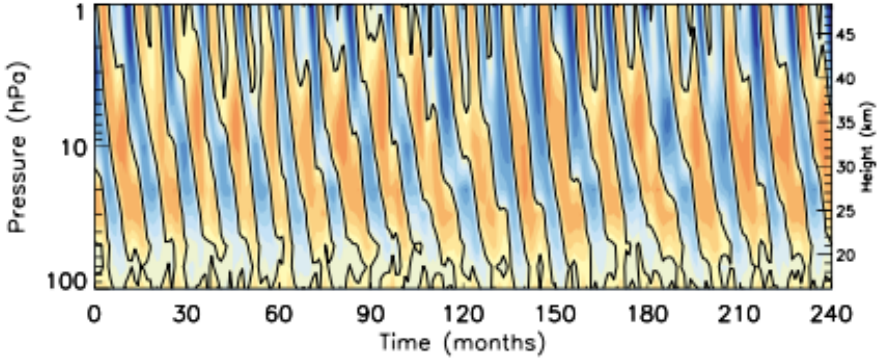
WACCM EXP2



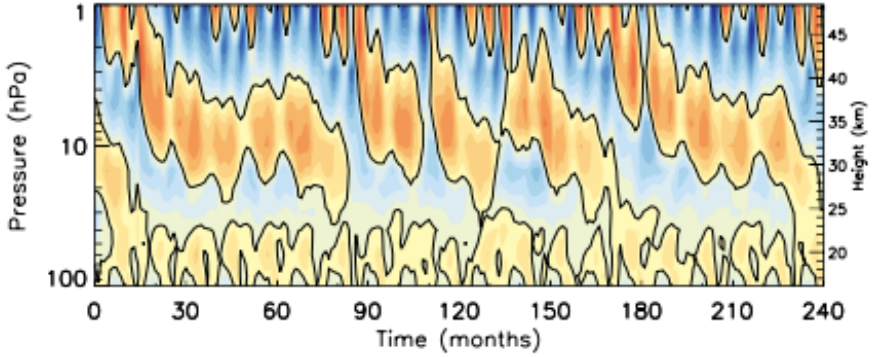
LMDz EXP2



WACCM EXP4

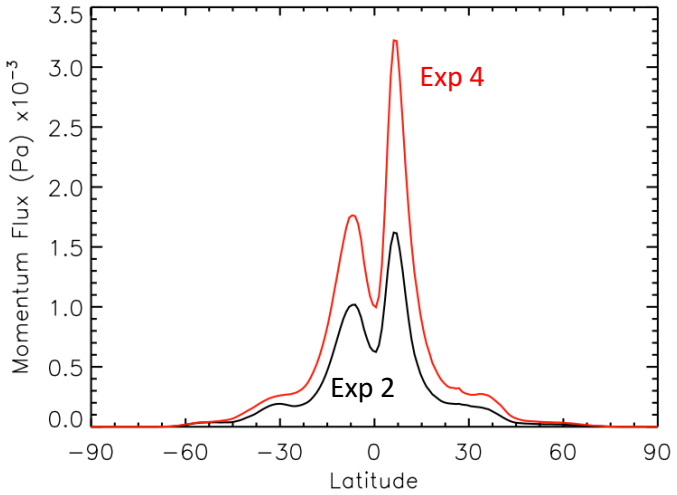


LMDz EXP4



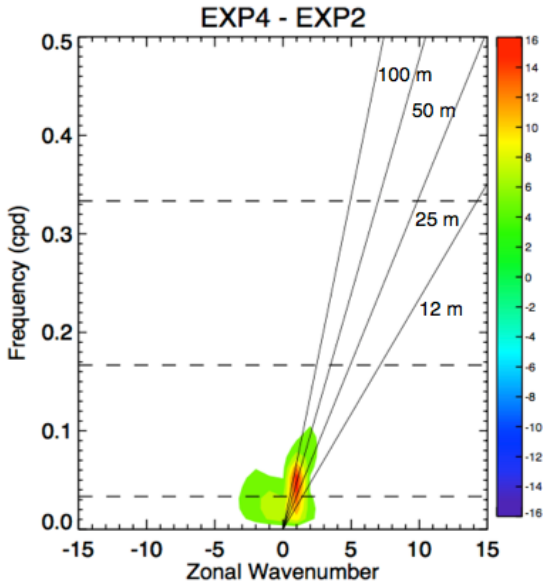
Much shorter QBO period in WACCM

Westward GW Flux Exp 4



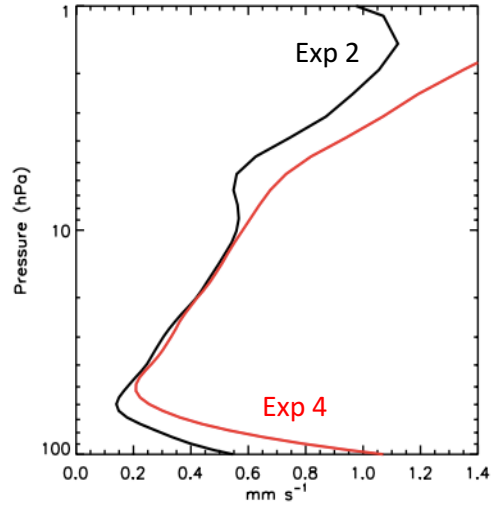
Increased GW Flux->
Shorter QBO period

Resolved waves



Increased Kelvin waves->
Shorter QBO period

Residual w*

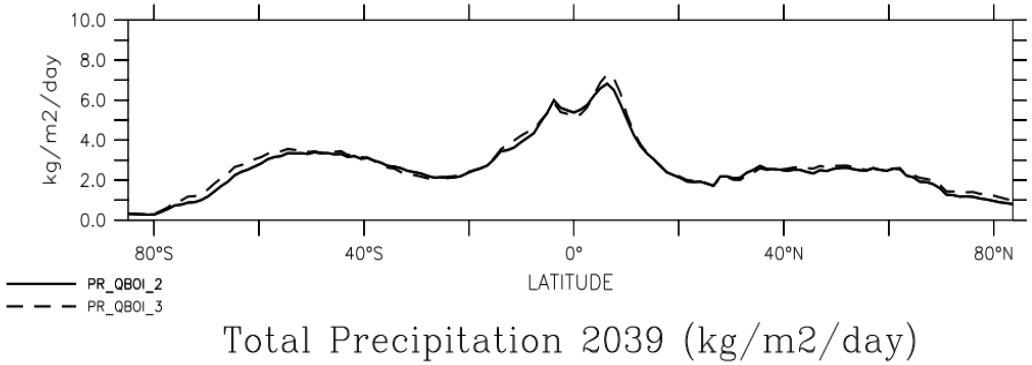


Increased w* ->
Longer QBO period

Decrease of QBO period in EXP4 due to increased GW source momentum flux & increased Kelvin wave activity

LMDz Convective GW flux:

- **Stochastic parameterization:** frequency & wave numbers chosen randomly
- Wave amplitude is related to **precipitation**, which is converted into heating rate
- Normally distributed latent heating similarly to Beres et al. 2004 (chose ‘dz’)



Total Precipitation 2039 (kg/m2/day)

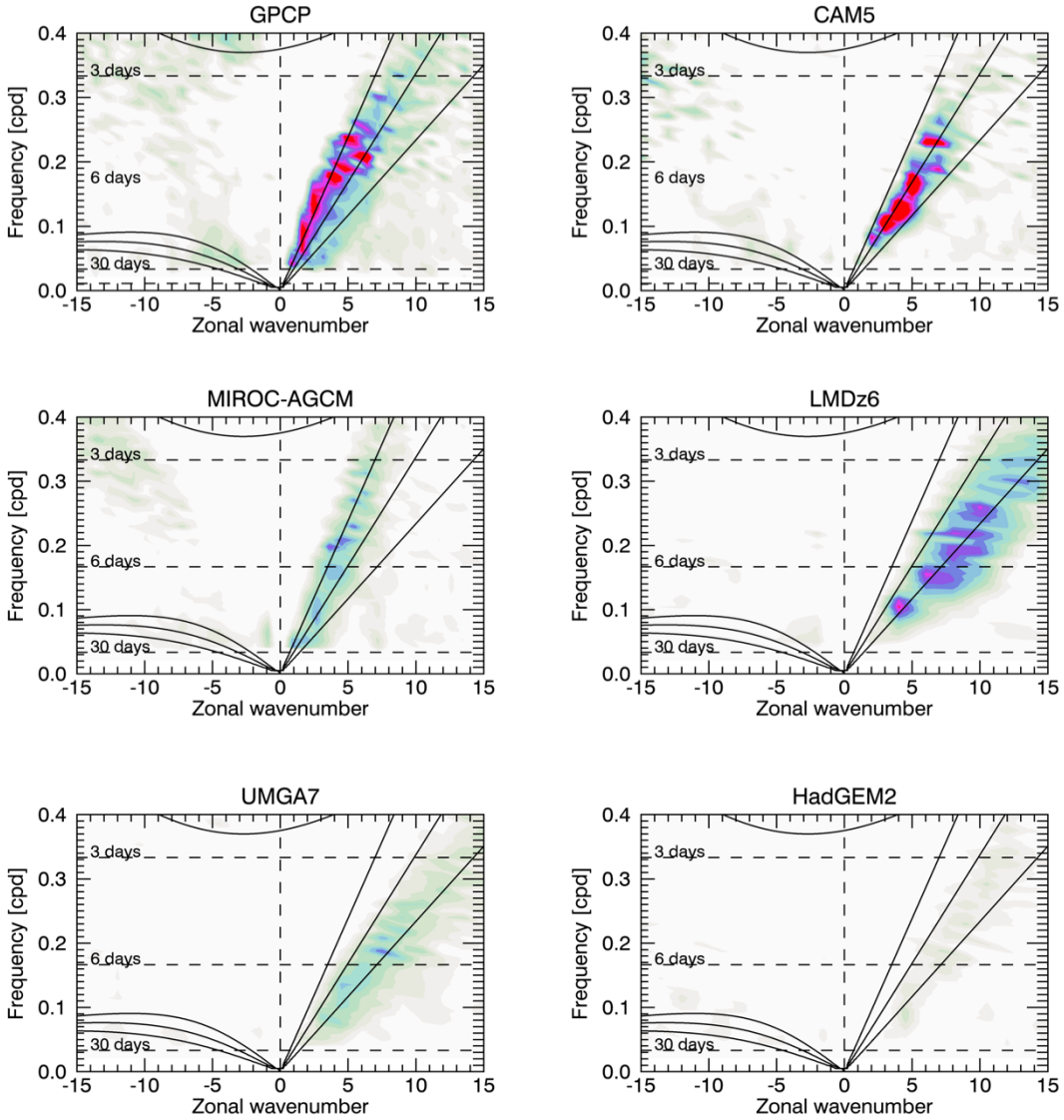
Precip Exp2 = Precip Exp 4

GW Flux Exp 2 = GW Flux Exp4

No changes in Precip - >No changes in GW source momentum flux

Tropical Waves

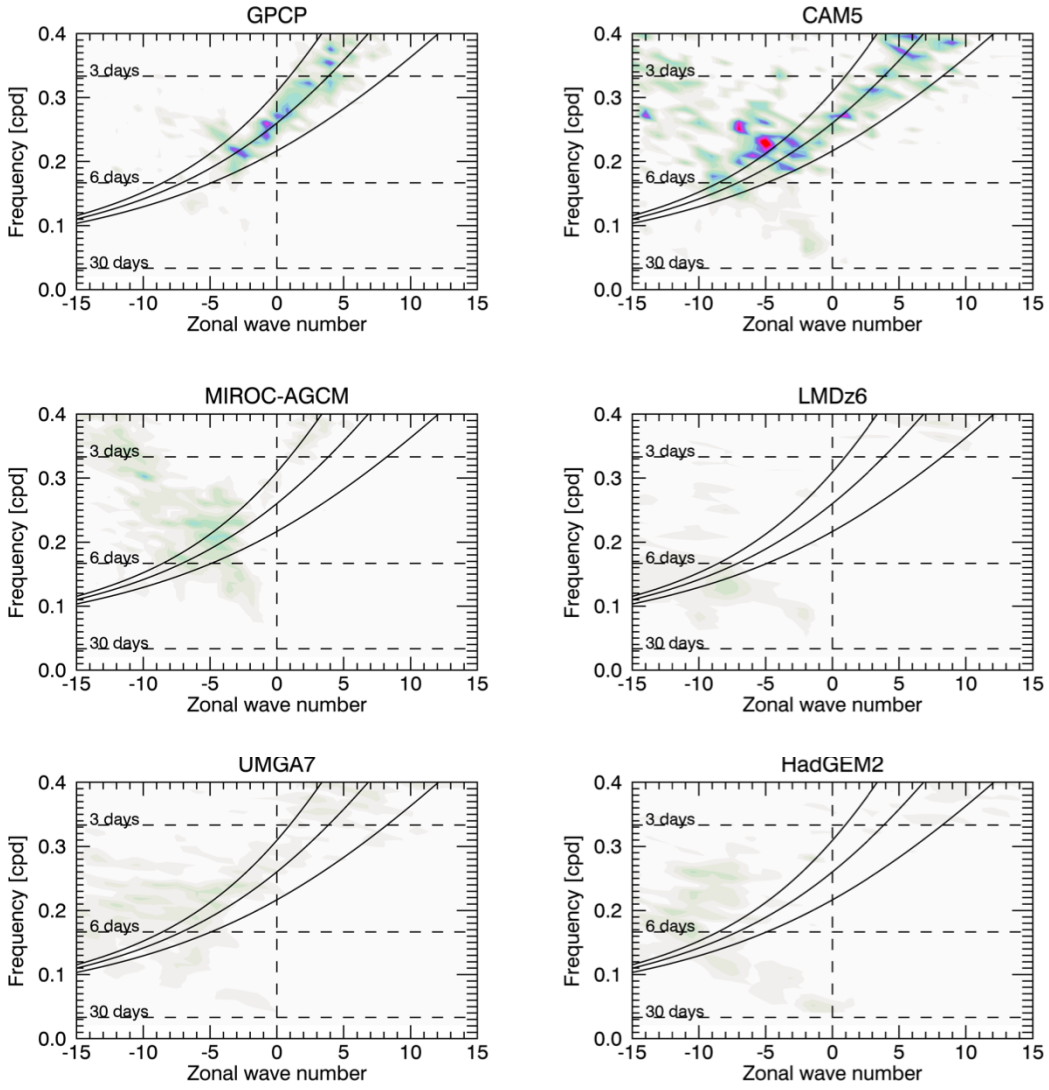
Symmetric Precipitation Spectra: Exp1



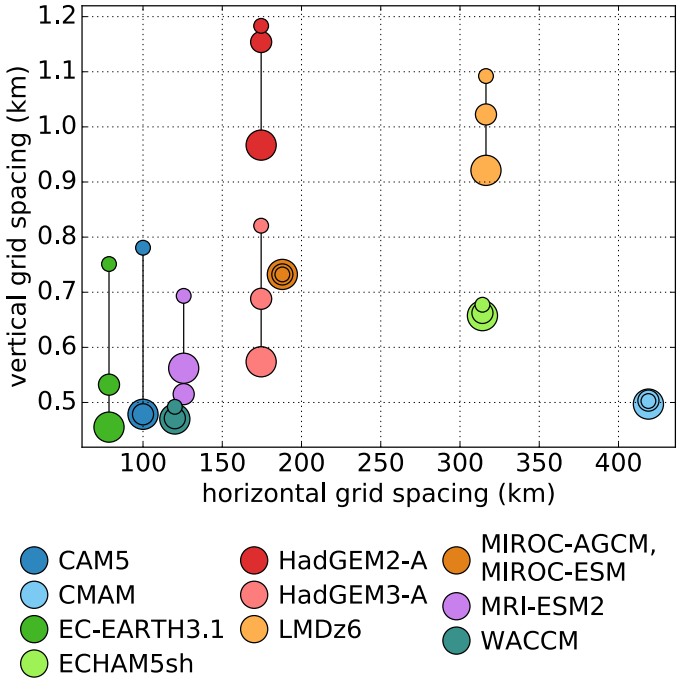
Background removed. Dispersion curves with equivalent depths of 12, 25, and 50 are overplotted.

Most QBOi models capture the Kelvin wave mode in GPCP, some better than others.

Asymmetric Precipitation Spectra: Exp1



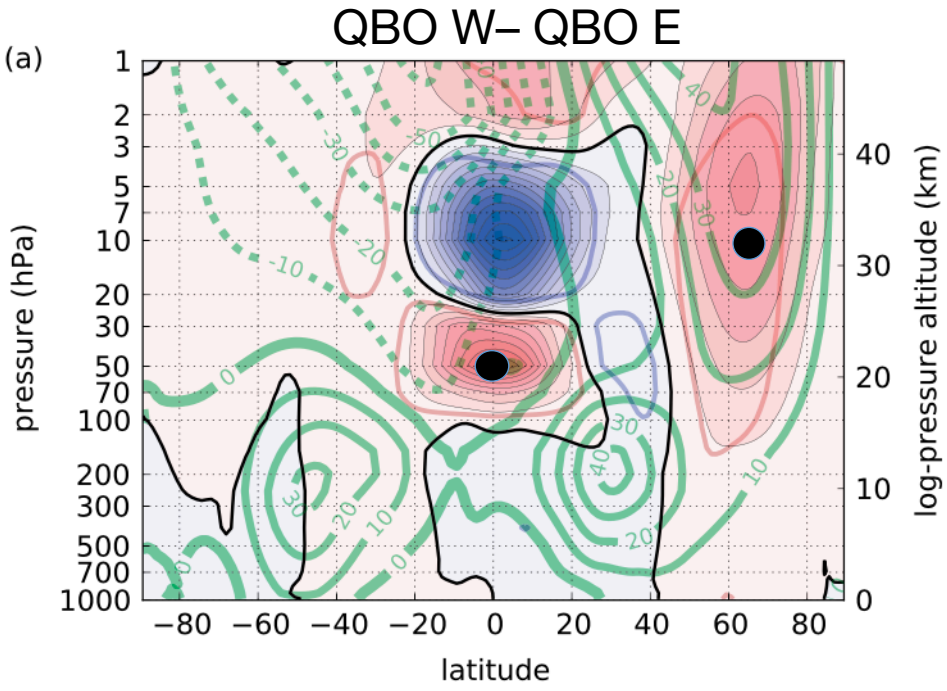
Mixed-Rossby GWs are underestimated by several QBOi models



Teleconnections

Teleconnections

Observations show a robust relationship between phase of QBO and strength of polar vortex:



Anstey & Shepherd (2014)

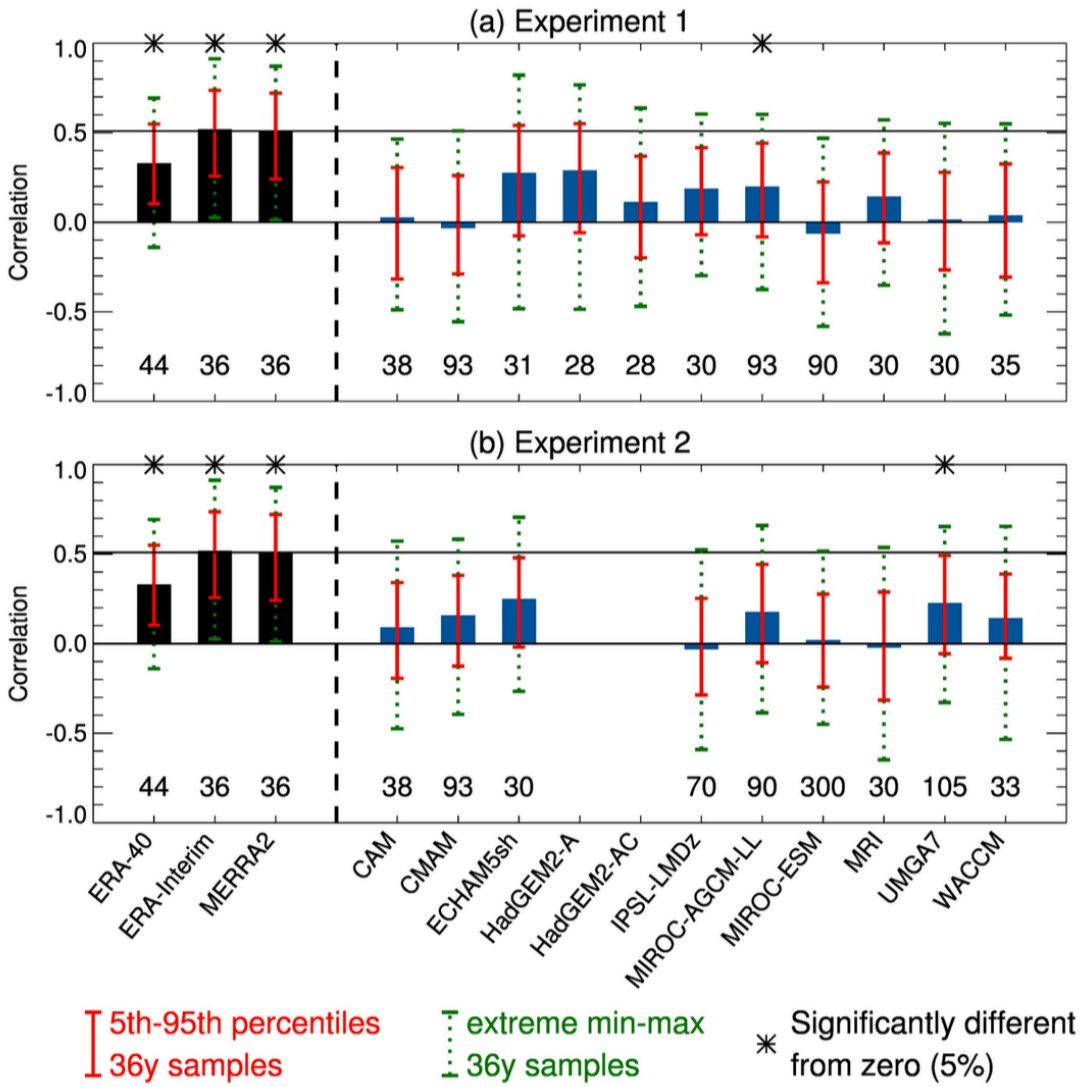
- QBO index: U at 50 hPa Equator
- Polar vortex index: U at 10 hPa, 65N

Correlation in OBS:

ERA-40 (44 yrs): 0.32
1958 – 2001

ERA-Interim (36): 0.5
MERRA-2 (36): 0.5
1979 - 2016

QBO vs Polar Vortex Correlation



← Number of Years

- **Only 2 models exhibit a significant positive correlation:**
  MIROC-AGCM-LL (EXP1)
  UMGA7 (EXP 2)

Going Forward in 2018

Data

- QBOi data archive: open access when core papers published?
- Any restrictions for individual modelling groups?

Actions

- Define additional set of output diagnostics (for any new runs)
- Define ENSO experiments (and/or any other new experiments)

Next meeting

- Side meeting at SPARC GA? (1st week of Oct 2018)
- Virtual meetings

Core papers

- Finish over next year, preferably full drafts within 6 months.

Interested in Core Paper analysis? Contact scott.osprey@physics.ox.ac.uk or one of the other QBOi Coordinators