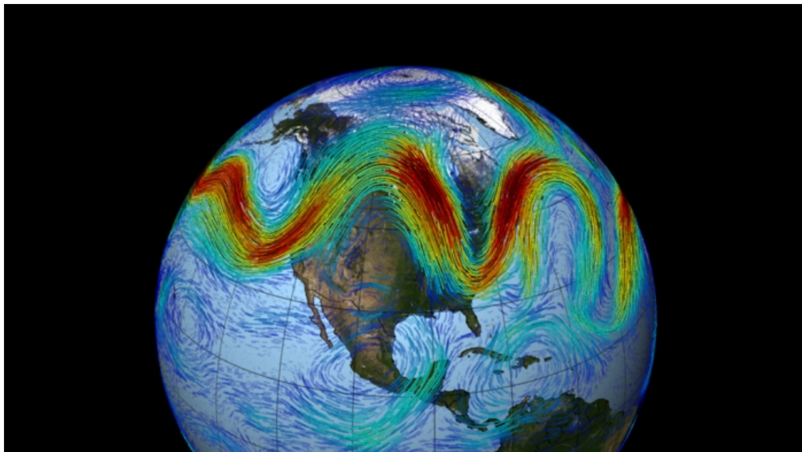
The QBO in Models and Reanalyses

Scott Osprey, James Anstey, Neal Butchart &
Kevin Hamilton

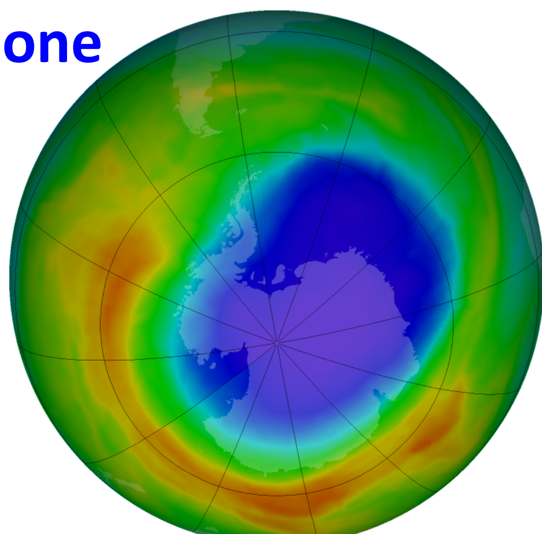
Contributions: Verena Schenzinger

QBO Sensitivity & Impacts



High latitude weather

ozone



Precipitation & Convection

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Motivation

- 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

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*Of **45** models submitting results to CMIP5 **14** were classified as High-top…*

…compared to just 1 for CMIP3

Finally people realise how important the stratosphere is!

Job done!

QBO Phenomenology Questionnaire

- Mean period
- Mean amplitude
- Range of periods
- Depth
- Amplitude asymmetry (east vs west)
- Asymmetry in descent rates
- Stalling of easterlies
- Latitudinal extent
- Level of maximum (E/W)
- Temperature amplitude
- w^* at 70hPa
- Total momentum flux at 100hPa

87% OF THE 56% WHO COMPLETED MORE THAN 23% OF THE SURVEY THOUGHT IT WAS A WASTE OF TIME

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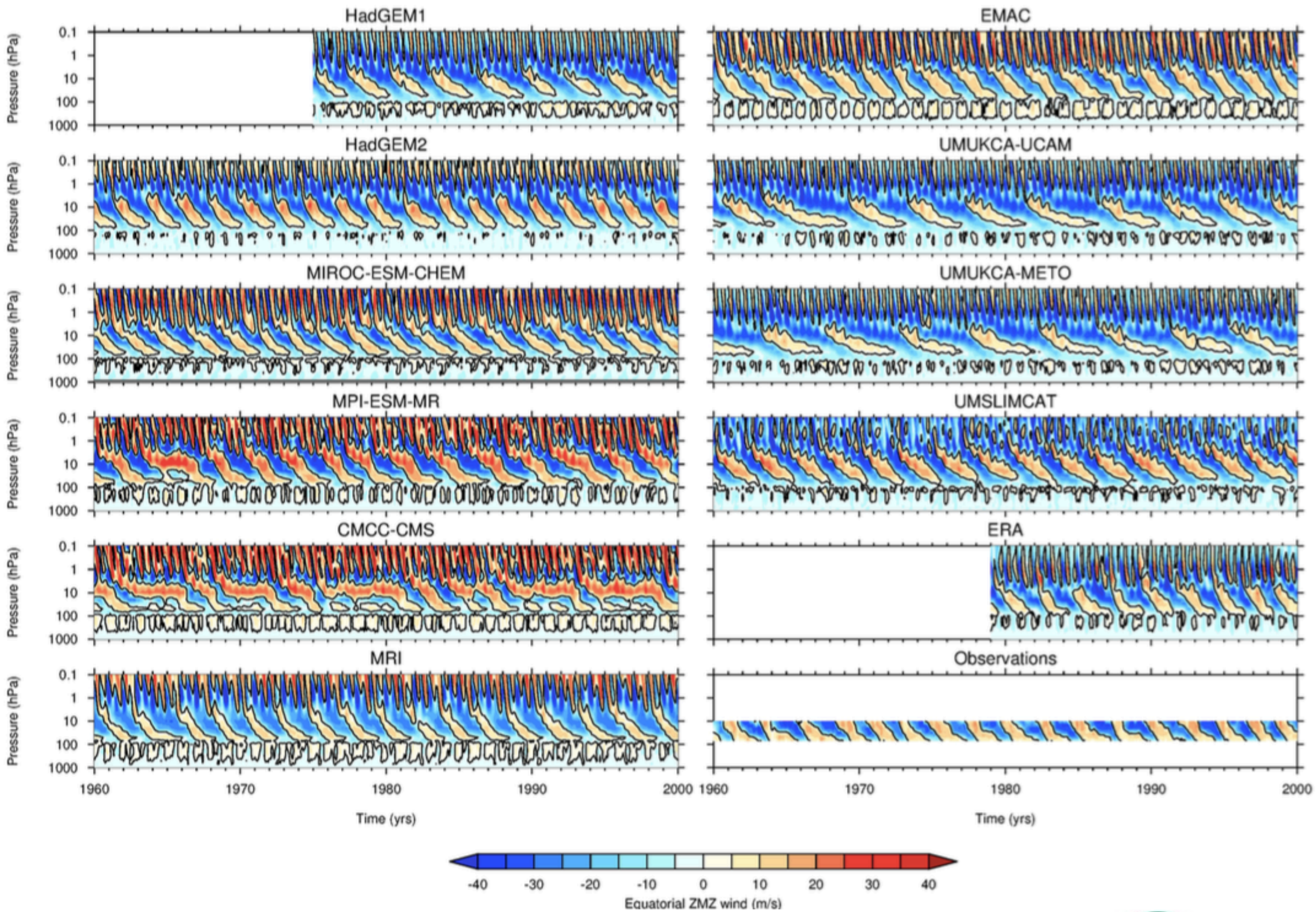
Model Overview

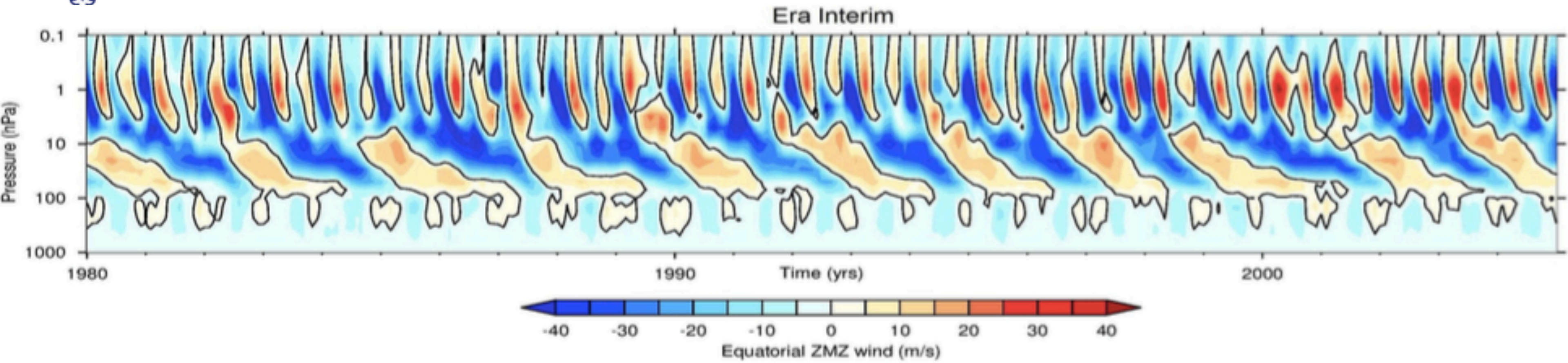
Model	Time Range	Model Resolution	GW Parameterisation
UMSLIMCAT	1961-2005	2.50° x 3.75° L64	Warner & McIntyre
UMUKCA-METO	1960-2006	2.50° x 3.75° L60	Warner & McIntyre
UMUKCA-UCAM	1951-2005	2.50° x 3.75° L60	Warner & McIntyre
HadGEM 1	1975-2000	2.5° x 3.75° L60	Warner & McIntyre
HadGEM 2-CC	1860-2005	1.25° x 1.875°L60	Warner & McIntyre
MIROC-ESM-CHEM	1850-2005	2.8° x 2.8° L68	Hines
MPI-ESM-MR	1960-2005	1.875° x 1.875° L95	Hines
CMCC-CMS	1960-2005	1.875° x 1.875° L95	Hines
EMAC	1960-2000	2.8° x 2.8° L90	Hines
MRI	1960-2006	2.8° x 2.8° L68	Hines

CCMVal-2 & CMIP5

Profile u Timeseries



QBO Characteristics



Period (months)	Shortest	26.9 ± 9.1	22.9 ± 0.3
	Longest	48.9 ± 17.1	35.9 ± 0.8
	Mean	35.9 ± 10.7	27.9 ± 0.1
ZMZ wind maximum	Fourier Amplitude (m/s)	15.3 ± 3.0	14.7 ± 0.7
	Height (hPa)	12.0 ± 3.5	20.0 ± 0.0
Mean Amplitude (m/s)	East	-32.9 ± 3.6	-34.9 ± 0.5
	West	18.8 ± 5.2	15.8 ± 0.8 1
Descent rate (km/yr)	Easterly shear zone	7.8 ± 2.9	5.9 ± 3.0
	Westerly shear zone	11.1 ± 5.1	25.9 ± 0.4
Extent	Latitude (o)	19.2 ± 1.1	21.1 ± 0.4
	Height (hPa)	78.3 ± 4.7	87.5 ± 2.9

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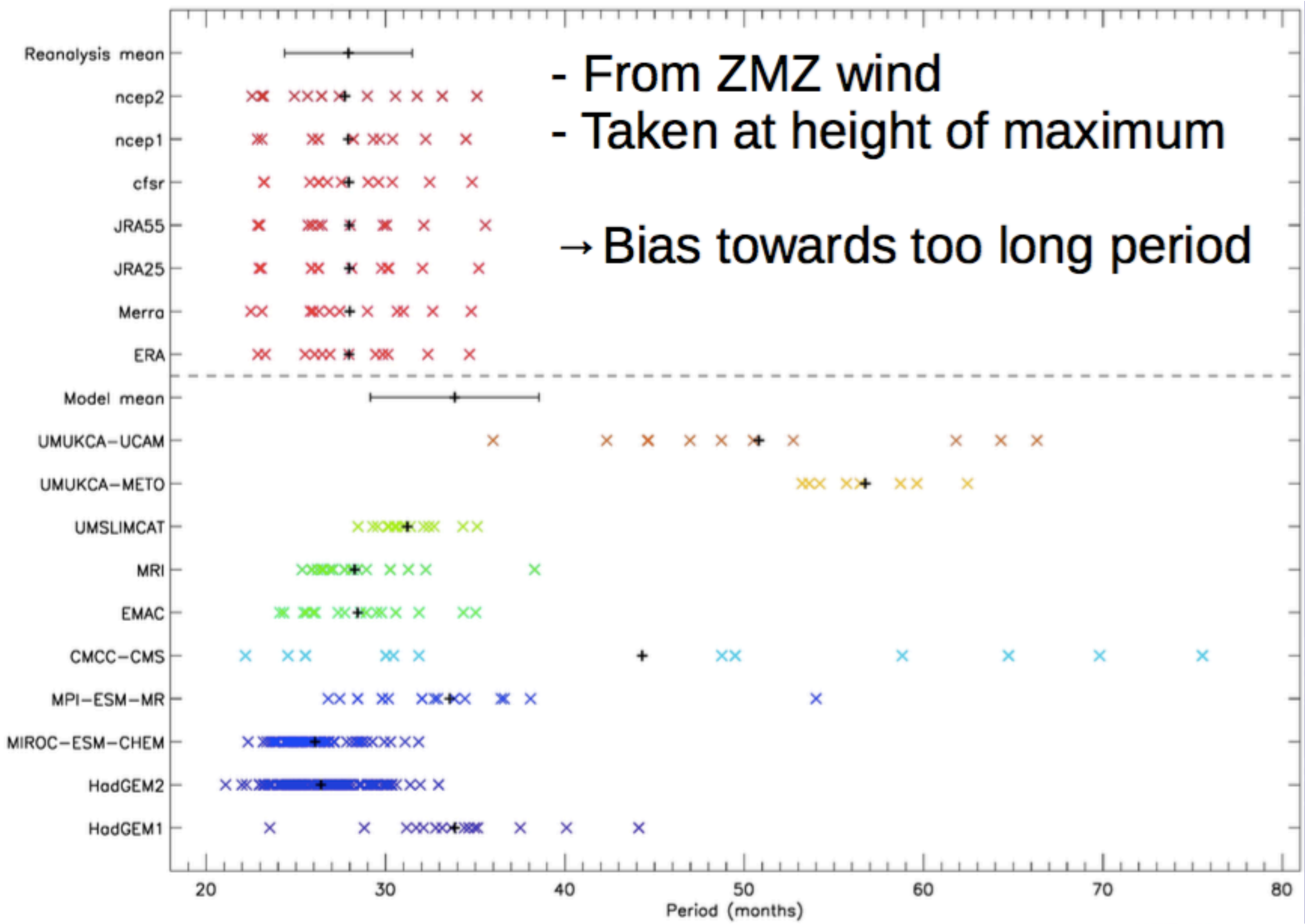
QBO Period – Models & Reanalyses



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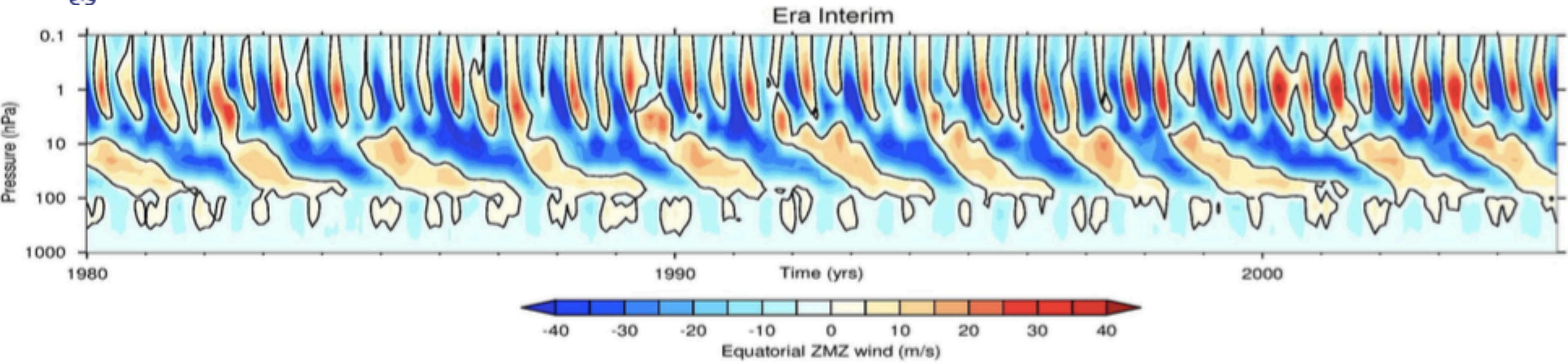
QBO Characteristics



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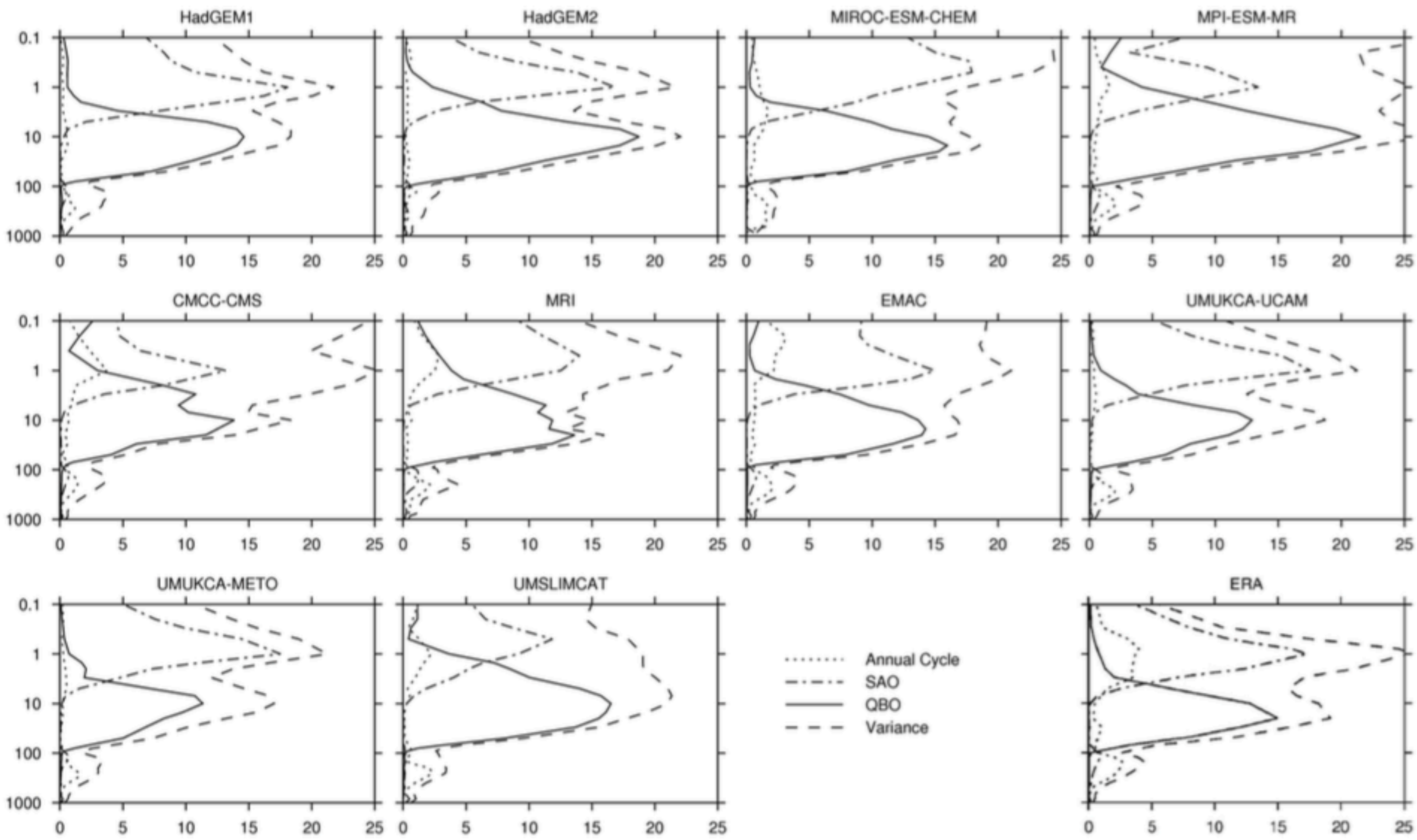
Amplitude-Height Structure



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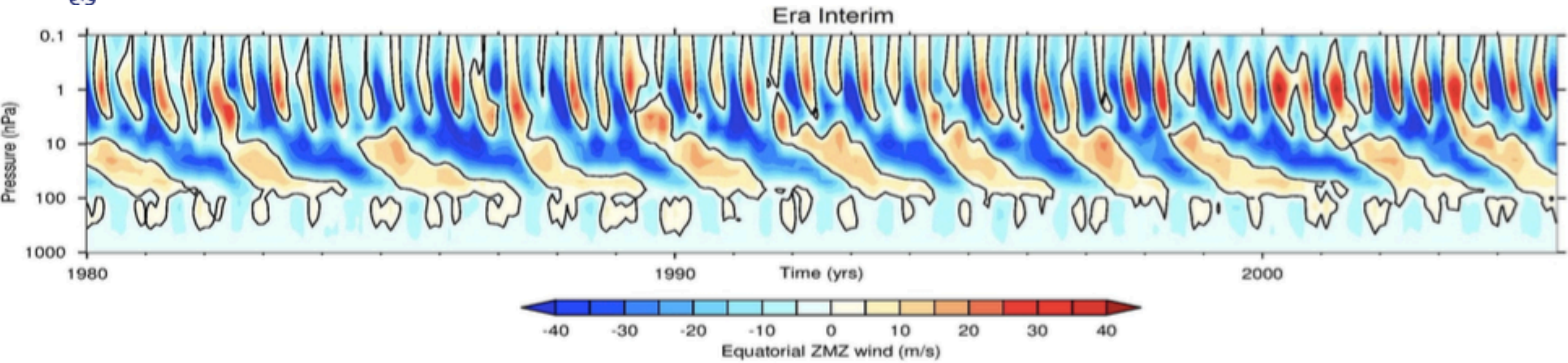

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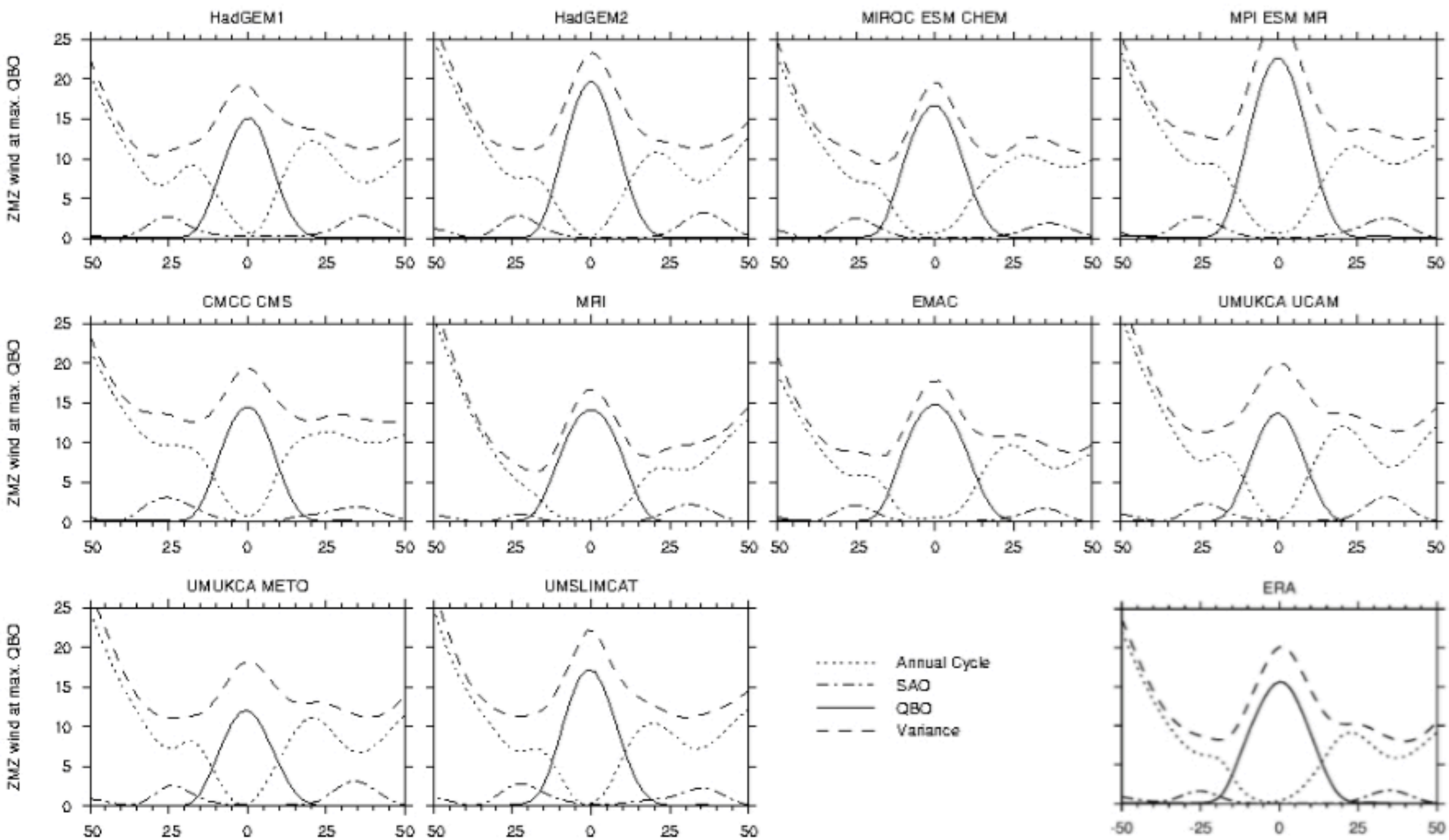
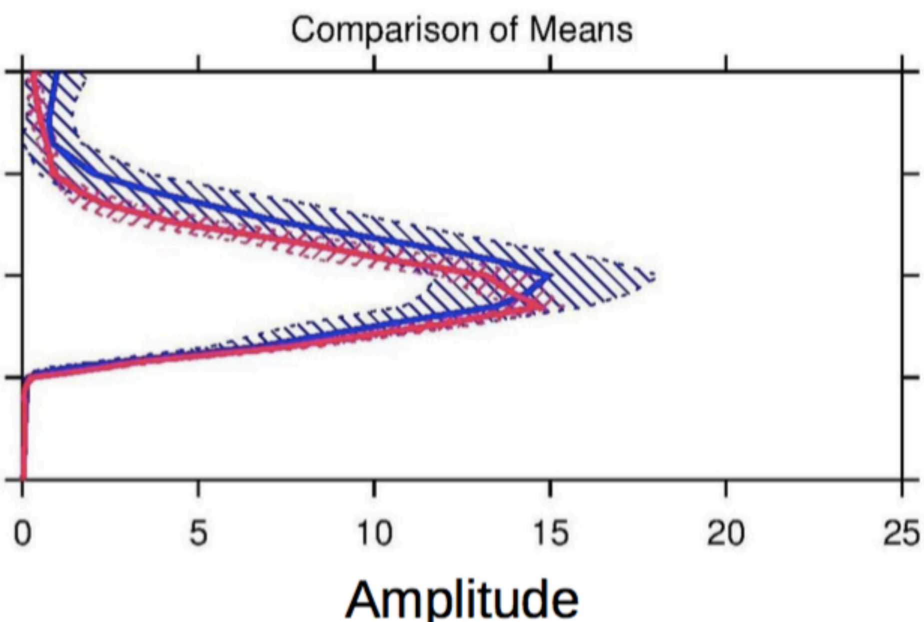
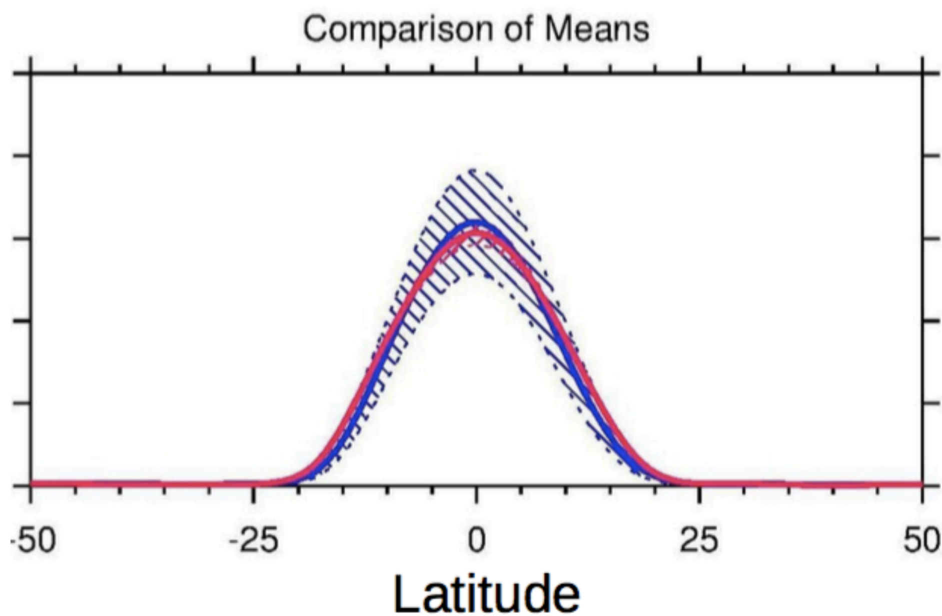
Amplitude-Latitude Structure



Structure Comparison

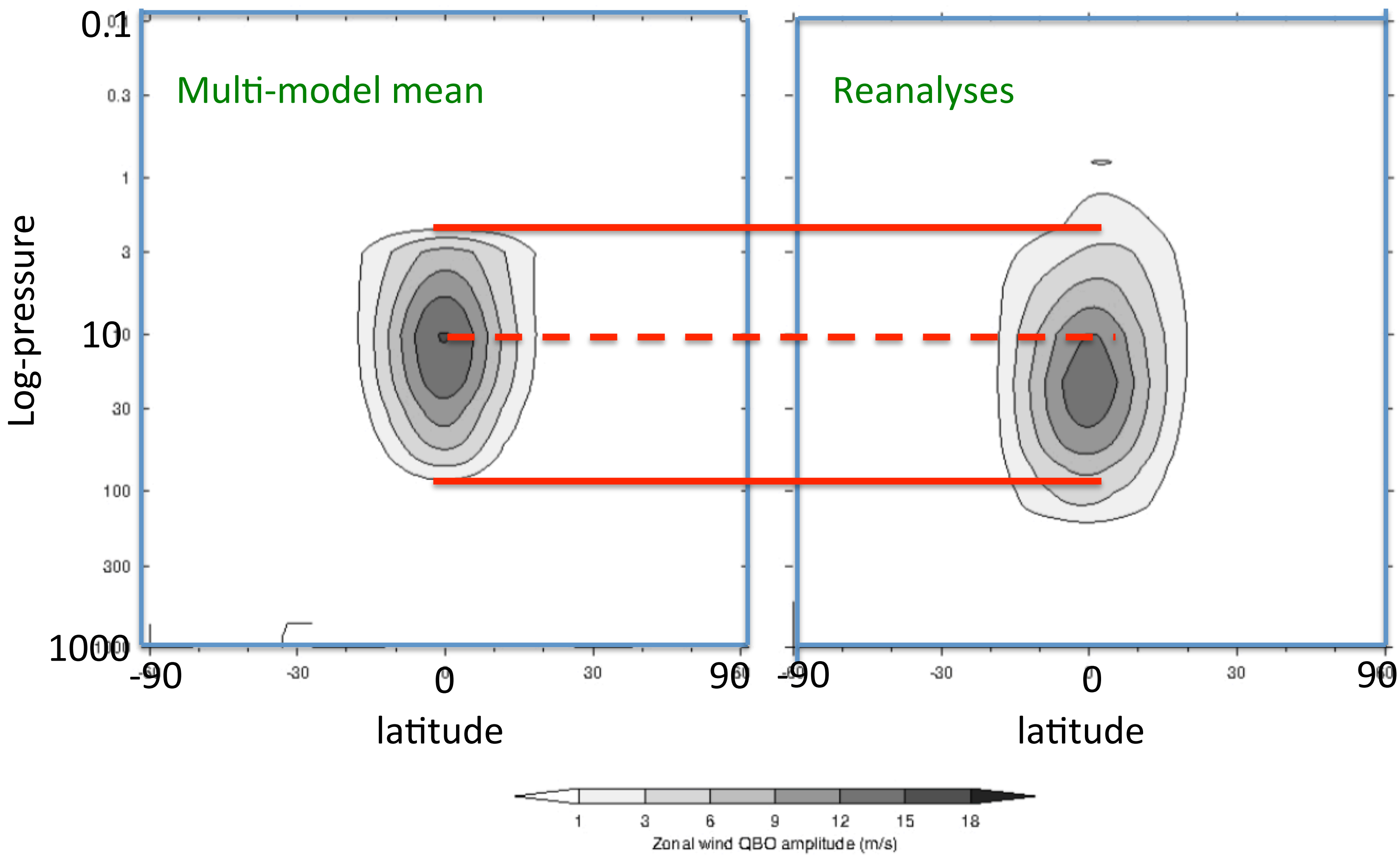




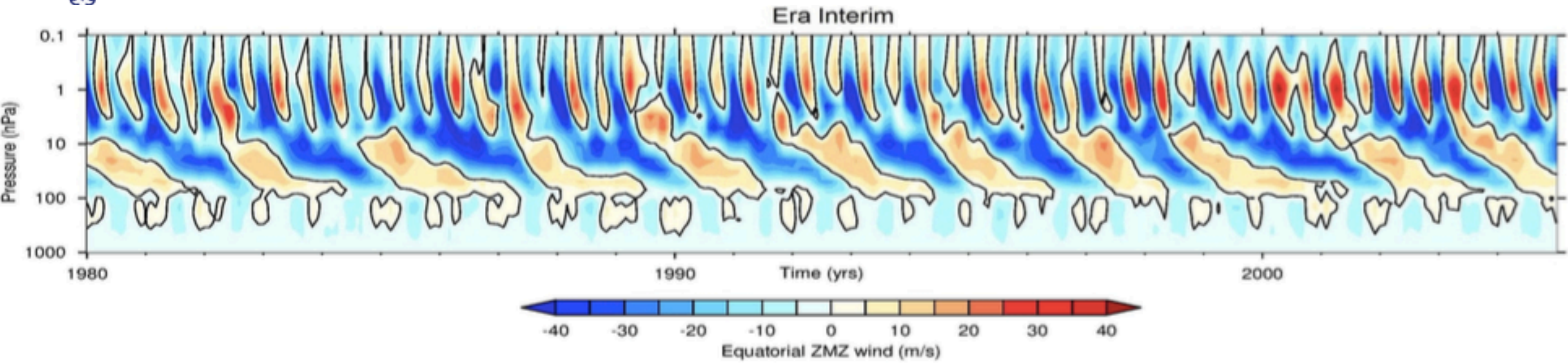
Model mean

Reanalyses mean

QBO Structure Comparison



QBO Characteristics



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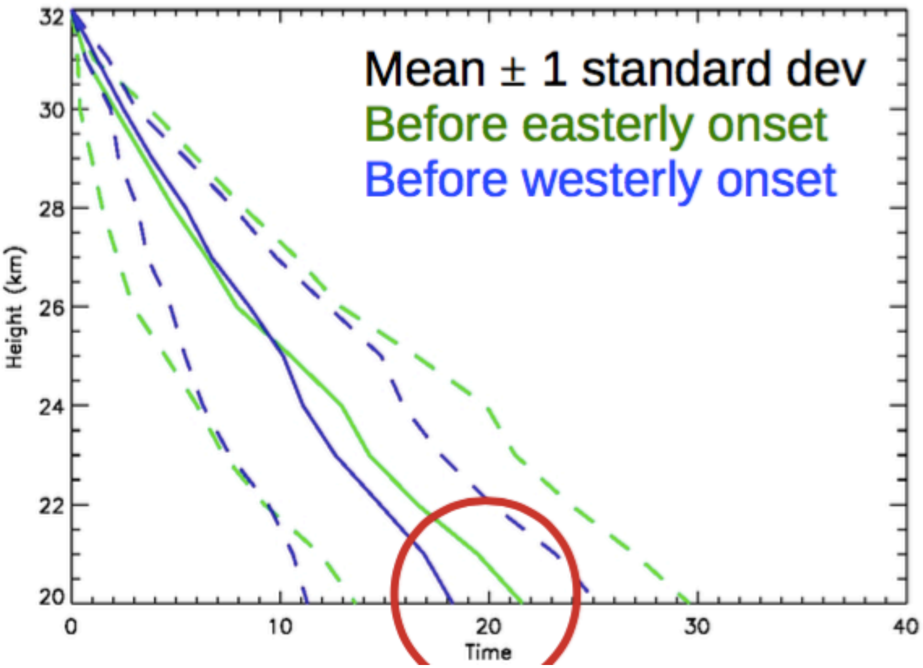
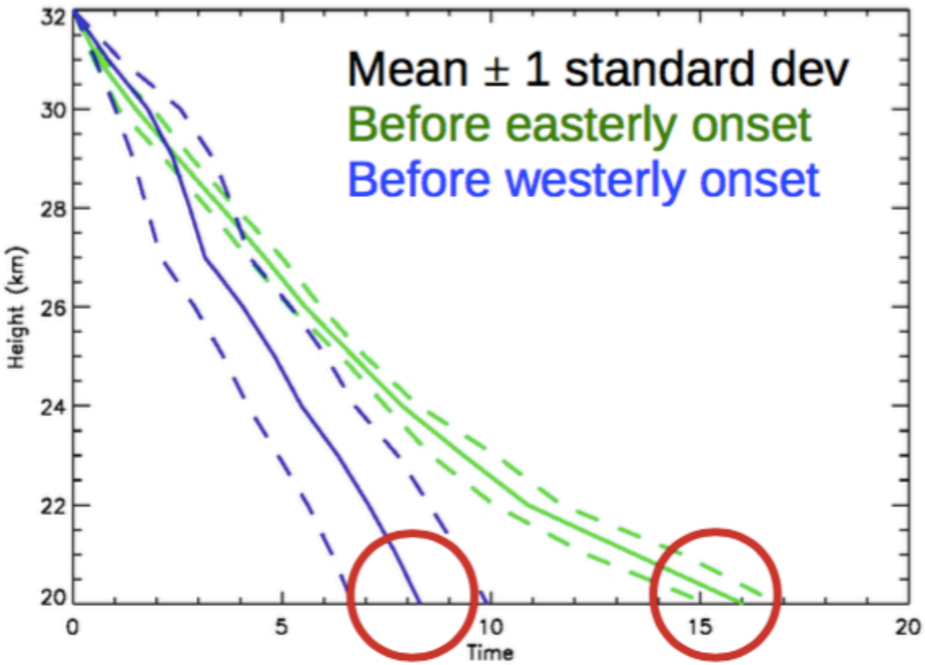
Stalling of Shear Zones



Multi-model mean



Reanalyses

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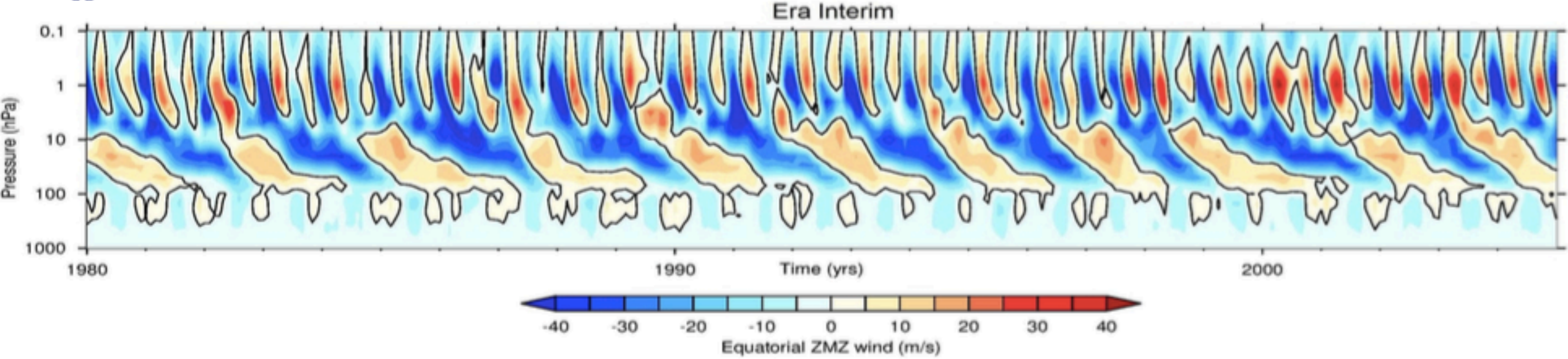
Stalling of Shear Zones



- Slower descent of the easterly shear zone
- Occasional delay (up to 1 year) of the easterly shear zone between 30 and 50 hPa
- Results in greater range of easterly descent rates
- Representation differs across models

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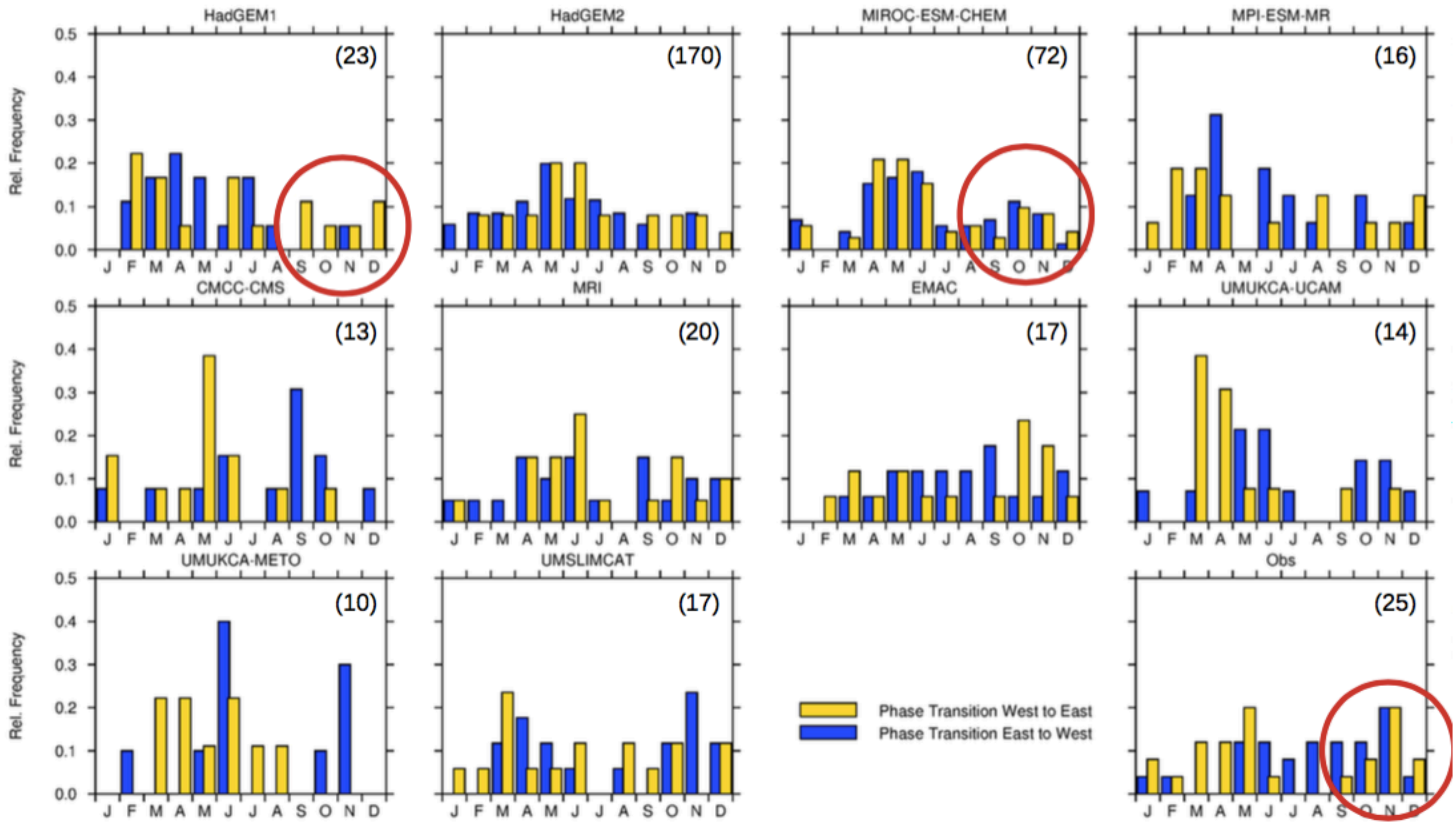
Annual Synchronisation



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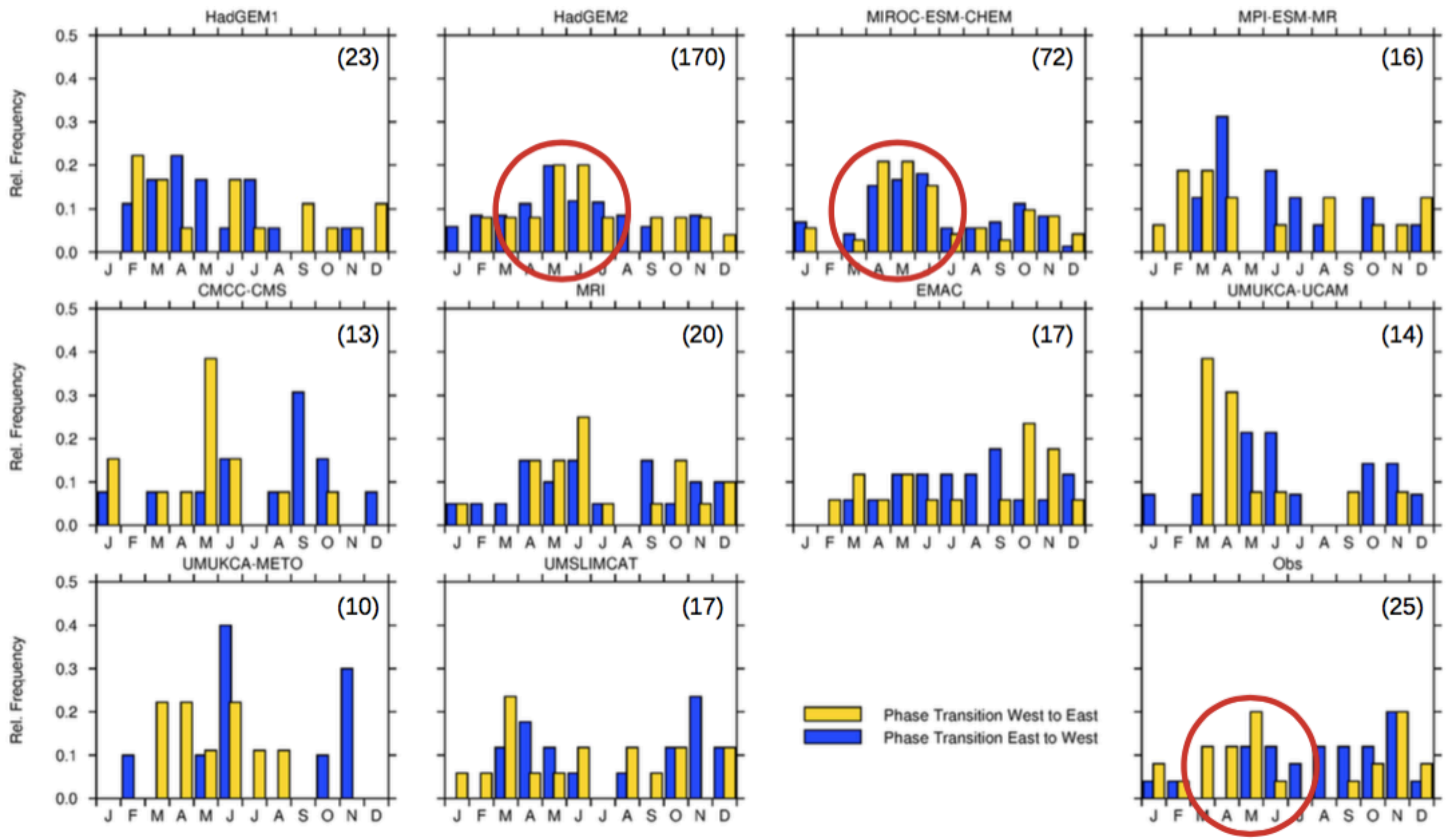

Preliminary Conclusions

Common biases

✗ Long periods

✗ Slow descents

✗ Little asymmetry in descent rates

✗ Peak too high in altitude, not deep enough

✗ Slightly too narrow

Disagreements

✗ Representation of stalling

Good representation

✔ Latitudinal structure

✔ Asymmetry of easterly/westerly amplitudes

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Remaining Challenges

Where do the differences originate from ?
How can simulations be improved ?
What is necessary to simulate a realistic QBO in a global climate model ?
Are these diagnostics sufficient ?

Some Relevant Issues

- Do all models show sensitivity to the same range of vertical grid spacings?
- Is it trivial to get a QBO as long as dz < 1 km and resolved/parameterized nonorographic gravity waves are strong enough? Will this just work in any model?
- What determines the vertical and latitudinal structure of a simulated QBO?
- Does it matter which gravity wave parameterization is chosen?
- Does the chosen launch level of the parameterized gravity waves matter?
- Does interactive ozone strongly affect the QBO?

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QBOi Models

Group	Model Name	Spatial Resolution	Timestep	GW Parameterisation	Convection	References
IPSL-LMD	LMDz	96x95xL80	30(3)min	**orographic:** Lott and Miller (1997), Lott (1999); **non-orographic:** Hines (1997); **stochastic:** Lott, F., L. Guez, and P. Maury, (2012)	Tiedke (1989) or Emanuel (1991)	Lott, F., L. Guez, and P. Maury, 2012; Lott, F.,L. Fairhead, F. Hourdin and P. Levan, 2005
MOHC	HadGEM2-CCS	192x145xL60	30min	**non-orographic:** Warner and McIntyre (1999); Scaife et al. (2002); **orographic:** Webster et al. (2003)	Maidens and Derbyshire, 2006; Martin et al. (2010); Gregory, D. and Rowntree, P. R (1990)	Hardiman et al. (2012); Osprey et al. (2013)
DMI/ECMWF	EC-EARTH	T159xL91	1hr	**non-orographic:** Hines, 1997	Bechtold et al. 2008	Hazeleger et al. (2012)
NASA-GISS	GISS Model-E	2x2.5x79L	30min	**orographic:** McFarlane (1987); **non-orographic:** Alexander and Dunkerton (1999)	Del Genio et al. 1996	Geller et al. (2011)
NASA-GSFC	GEOS-5	1x1.25xL72	30min	**orographic:** McFarlane (1987); **non-orographic:** Garcia and Boville (1994)	Moorthi, S., and M.J. Suarez, 1992	Rienecker et al., 2008
CMCC	CMCC-CMS	T63L95	15min	**non-orographic:** Hines, 1997; Charron and Manzini (2002); **orographic:** Lott and Miller (1997)	Tiedtke 1989; Nordeng (1994)	Manzini et al. (2006); Giorgetta et al. (2006); Roeckner et al. (2006)
CCCma	AGCM3-CMAM	T63L98	(6)min	**orographic:** Scinocca and McFarlane, 2000; **non-oro:** Scinocca (2003)	Zhang and McFarlane (1995)	Beagley et al. (1997); Scinocca et al. (2008)
MIROC	MIROC-ESM	2.8x2.8xL80	30min	**orographic:** McFarlane (1987); **non-orographic:** Hines (1997)	Emori et al., 2001	Watanabe et al. (2011)
NCAR	CAM5	~100km x L60	30min	Richter et al (2010) **Orographic:** McFarlane (1987); **Non-orographic:** Lindzen (1981); Beres et al. (2004)	Zhang and McFarlane (1995)	Richter et al. (2013)*
NCAR	WACCM	1.9x2.5xL66	30min	Xue et al. (2012); **orographic:** McFarlane (1987), **non-orographic:** Richter et al. (2010); Garcia et al. (2007)	Zhang and McFarlane (1995)	Collins et al. (2006)

QBOi Core Experiments

- **Present-Day Climate**: Identify and distinguish the properties of and mechanisms underlying the different model simulations of the QBO in present-day conditions.
- **Climate Projections**: Subject each modelled QBO contribution to an external forcing that is similar to that typically applied for climate projections
- **QBO Hindcast and Process Study**: Evaluate and compare the predictive skill of modelled QBOs in a seasonal prediction hindcast context, and study the model processes driving the evolution of the QBO.

QBOi timeline

- Experiments outlined and Participating groups implementing experiments
- Spring-summer 2016 completion of experiments and upload data to project workspace at BADC
- First discussion and dissemination of QBOi results at second QBO Modelling and Reanalyses Meeting, Sept 26-30 2016, Oxford
- Meeting open to everyone, including impacts discussion, planning & studies.