An evaluation of tropical waves and wave forcing of the QBO in the QBOi models

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QBOi project :
Towards Improving the Quasi-Biennial Oscillation in Global Climate Models
See :http://users.ox.ac.uk/~astr0092/QBOi.html

To appear on the ongoing QJRMS special section :
QBO MODELLING INTERCOMPARISON

Description of the state of the art models involved in QBOi and their performances in the tropical stratosphere:

Butchart, N., Anstey, J. A., Hamilton, K., Osprey, S., McLandress, C., Bushell, A. C., Kawatani, Y., Kim, Y.-H., Lott, F., Scinocca, J., Stockdale, T. N., Andrews, M., Bellprat, O., Braesicke, P., Cagnazzo, C., Chen, C.-C., Chun, H.-Y., Dobrynin, M., Garcia, R. R., Garcia-Serrano, J., Gray, L. J., Holt, L., Kerzenmacher, T., Naoe, H., Pohlmann, H., Richter, J. H., Scaife, A. A., Schenzinger, V., Serva, F., Versick, S., Watanabe, S., Yoshida, K. and Yukimoto, S., 2018 : Overview of experiment design and comparison of models participating in phase 1 of the SPARC Quasi-Biennial Oscillation initiative (QBOi). Geosci. Model Dev., 11, 1009–1032.

Bushell AC, Anstey JA, Butchart N, Kawatani Y, Osprey SM, Richter JH, Serva F, Braesicke P, Cagnazzo C, Chen C-C, Chun H-Y, Garcia RR, Gray LJ, Hamilton K, Kerzenmacher T, Kim Y-H, Lott F, McLandress C, Naoe H, Scinocca J, Smith AK, Stockdale TN, Versick S, Watanabe S, Yoshida K, Yukimoto S., 2020 : Evaluation of the Quasi-Biennial Oscillation in global climate models for the SPARC QBO-initiative. QJR Meteorol Soc. 2020;1–31. https://doi.org/10.1002/qj.3765

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Models involved in QBOi. All with a QBO in the low equatorial stratosphere

Model	Horiz. resolution	Δz (10-25 km)	References
60LCAM5	100 km	500-800 m	Richter et al. (2014)
AGCM3-CMAM	T47	500 m	Scinocca et al. (2008); Anstey et al. (2016)
CESM1(WACCM5-110L)	$1.25^\circ \times 0.94^\circ$	500 m	Garcia and Richter (2019)
ECHAM5sh	T63	600-700 m	Manzini et al. (2012); Serva et al. (2018)
EMAC	T42	600-700 m	Jöckel et al. (2005, 2010)
HadGEM2-A	$1.875^\circ \times 1.25^\circ$	1-1.2 km	The HadGEM2 Dev. Team (2011)
HadGEM2-AC	$1.875^\circ \times 1.25^\circ$	1-1.2 km	Kim and Chun (2015); The HadGEM2 Dev. Team (2011)
LMDz6	$2.5^\circ \times 1.25^\circ$	0.9-1.1 km	Lott et al. (2005, 2012)
MIROC-AGCM-LL	T106	550 m	Kawatani et al. (2011)
MIROC-ESM	T42	680 m	Watanabe et al. (2011)
MRI-ESM2	T159	500-700 m	Yukimoto et al. (2012); Adachi et al. (2013)
UMGA7	$1.875^\circ \times 1.25^\circ$	600-800 m	Walters et al. (2017)
UMGA7gws	$1.875^\circ \times 1.25^\circ$	600-800 m	Bushell et al. (2015); Walters et al. (2017)

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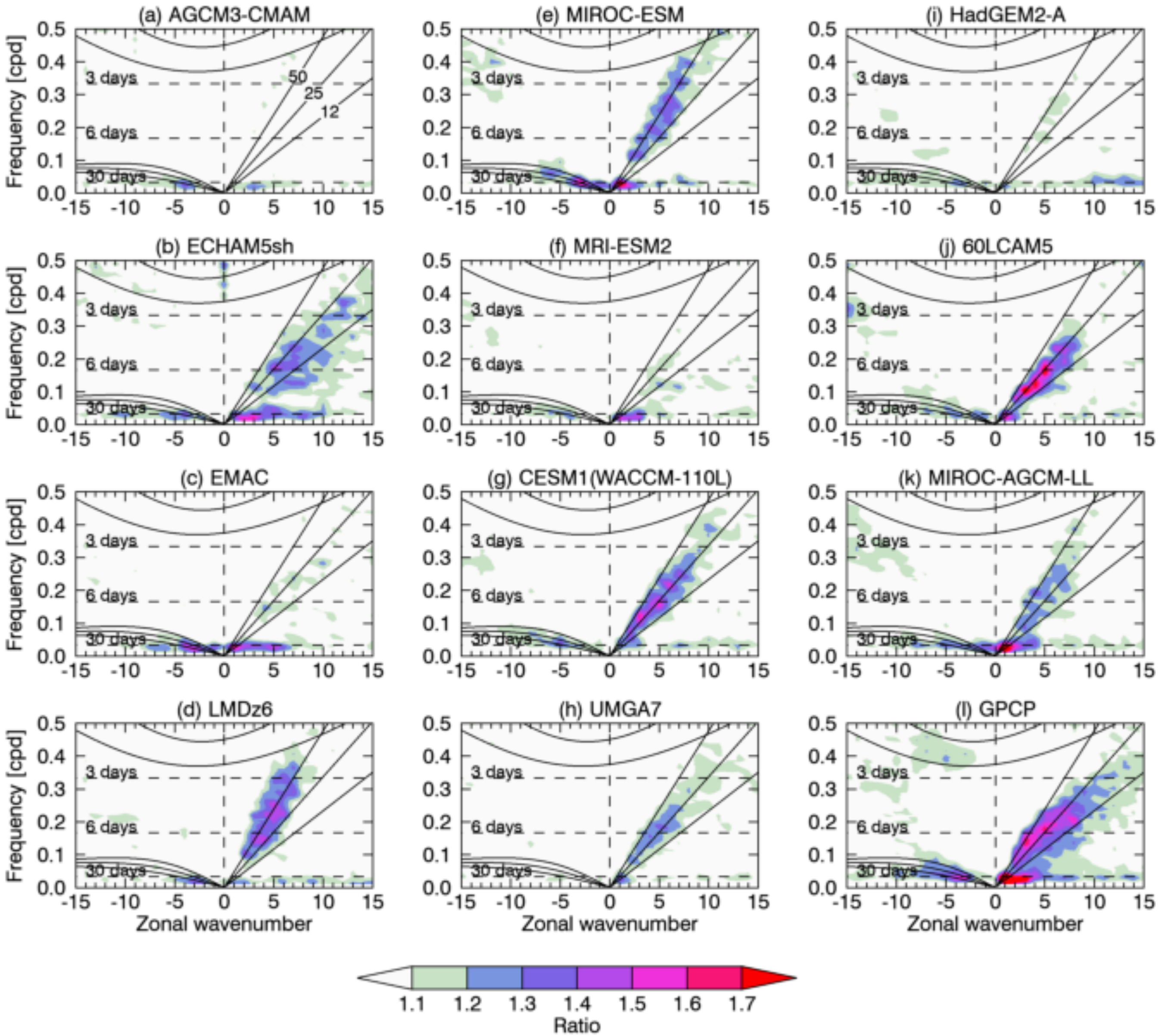

Large spread in models ability to represent the **convectively coupled equatorial waves** (here the Kelvin and Rossby CCEWs, manifestation on the spectra of symmetric precips normalised by model background, see wheeler and Kiladis 1999)

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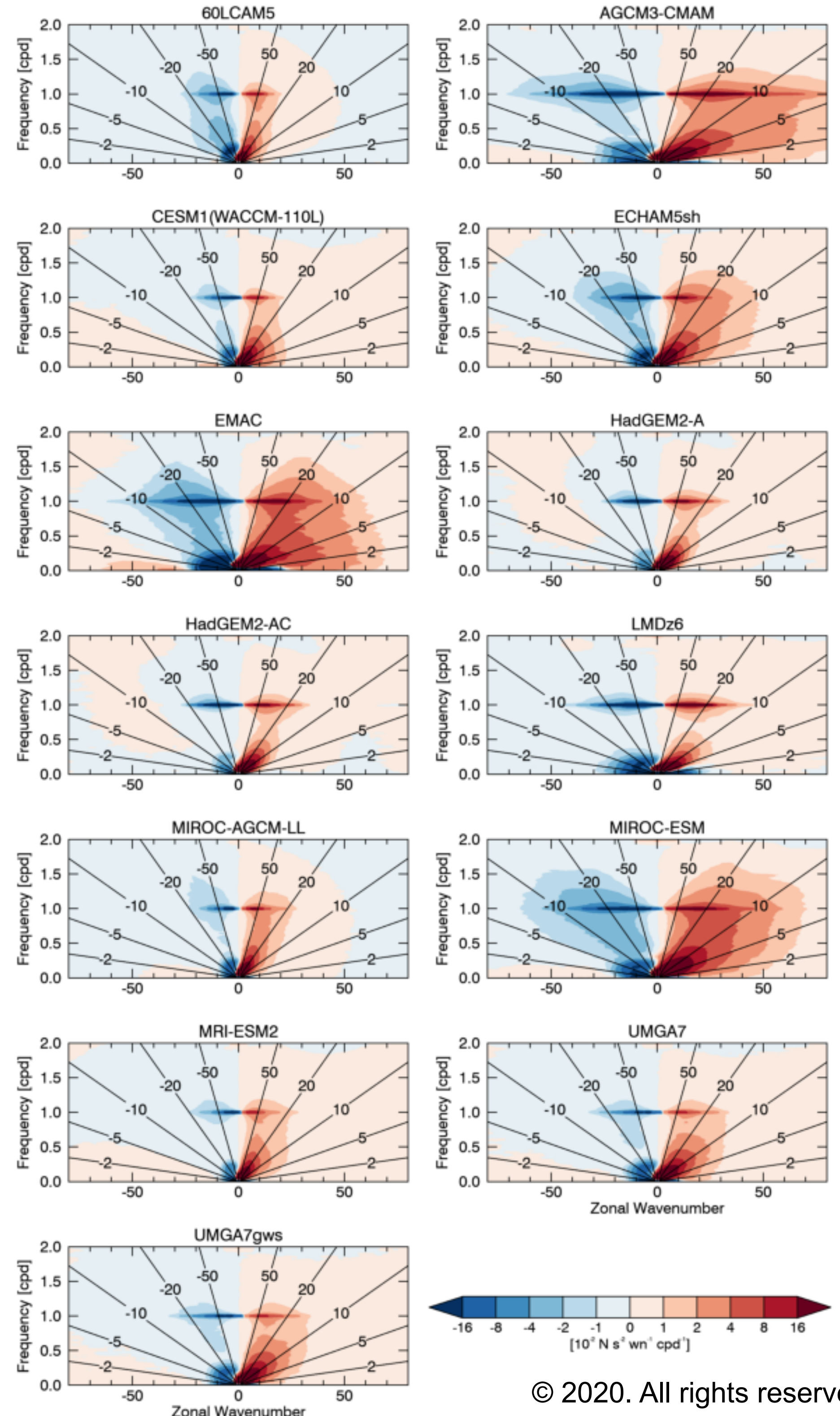
EP flux spectra at 70-80hPa, 10S-10N



The amplitude of the CCEWs is not obviously related to the amplitude of the Eq. Waves entering in the stratosphere.

Examples :
The EPF is quite weak in 60LCAM5 and quite strong in AGCM3-CMAM, this is opposed to the « CCEW» spectra in the previous slide.

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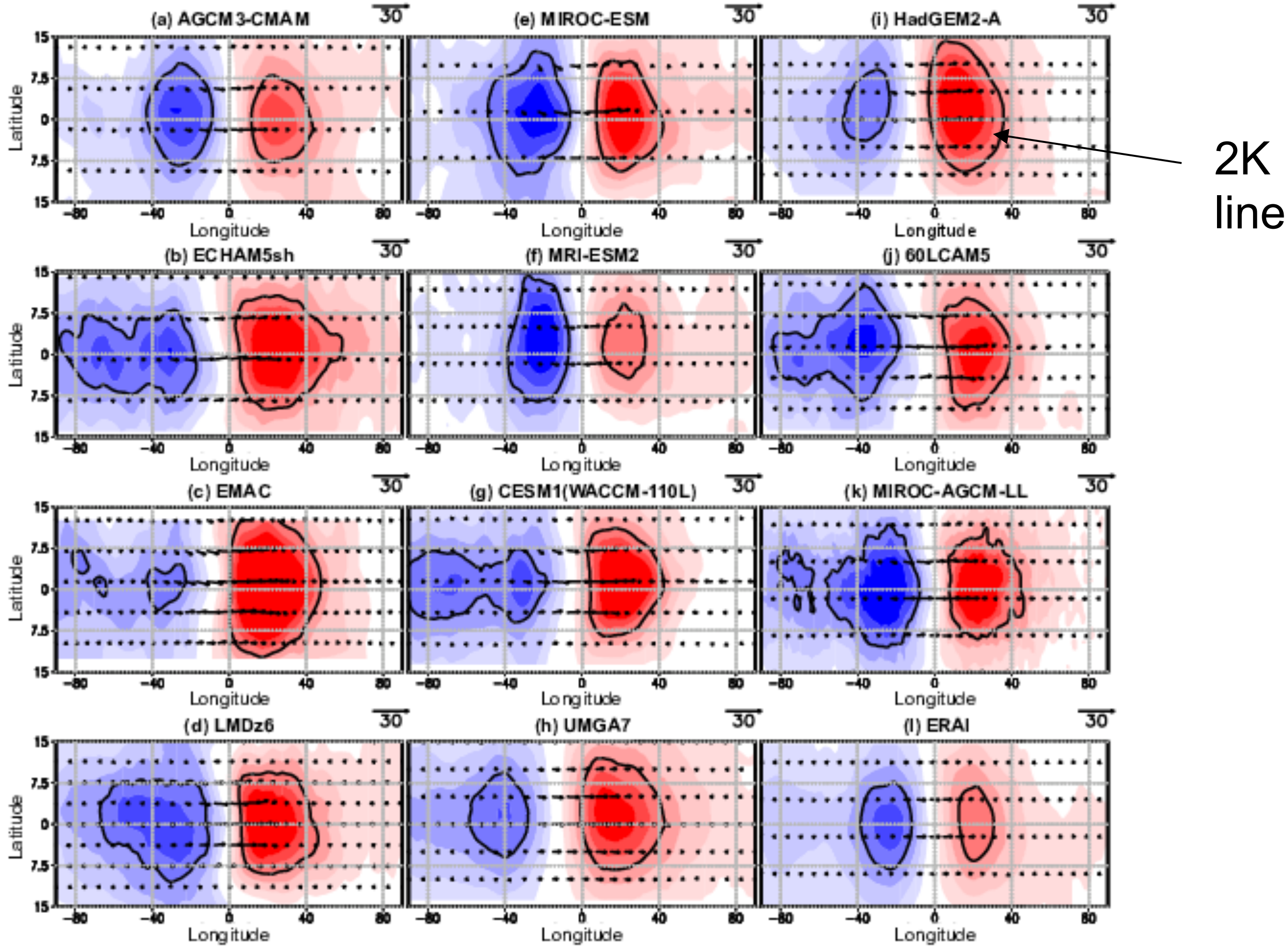
Composite of **Kelvin waves** packets at 50hPa, Horizontal winds and T° (CI=0.5K)

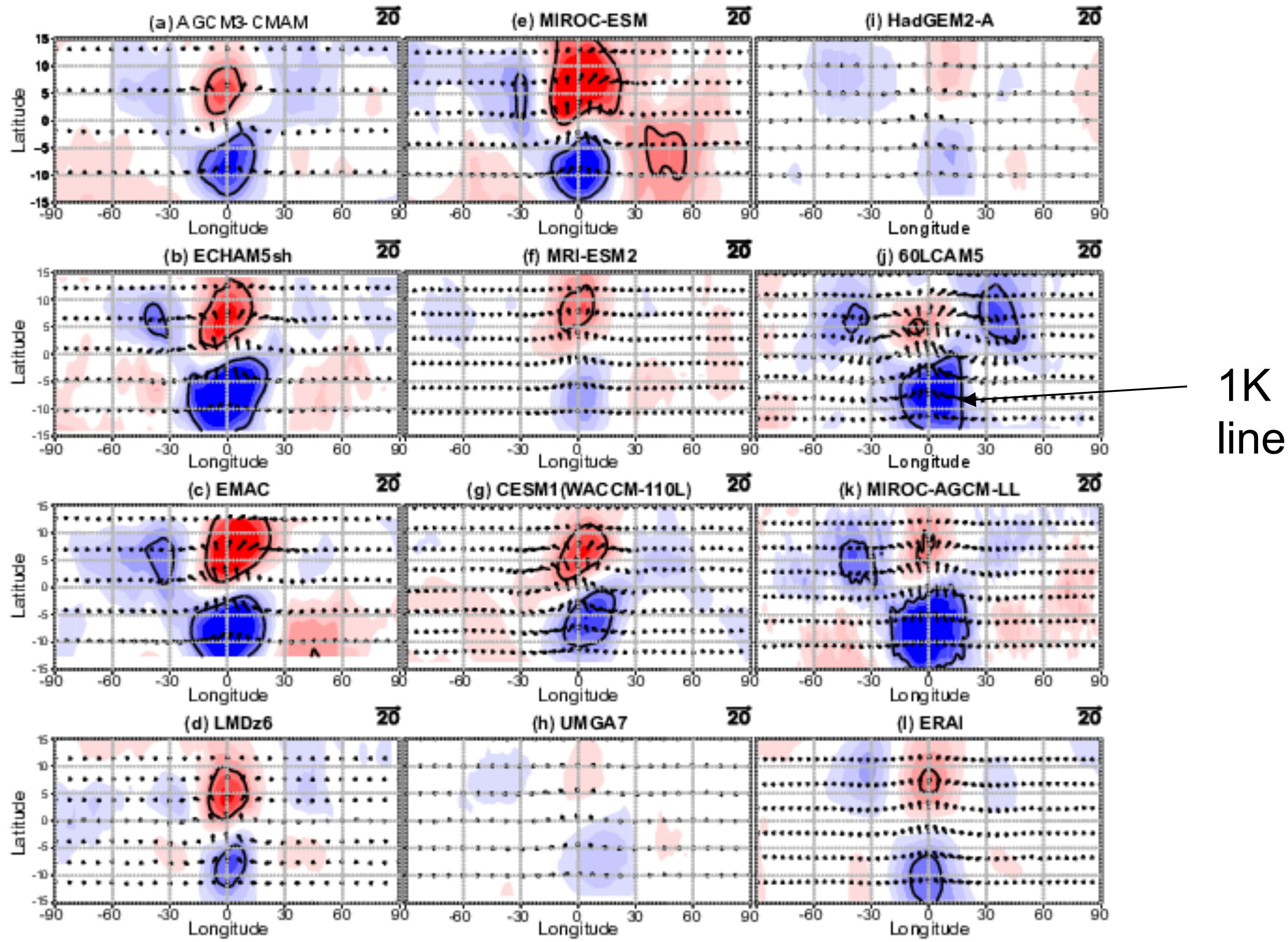


All models have substantial coherent large scale Kelvin waves of substantial amplitude
some spread among models on amplitude and horizontal scale
(for instance a larger s=1 component in ECHAMsh than in the other models)

See method in: Lott, F., J. Kuttippurath, and F. Vial, A Climatology of the Gravest Waves in the Equatorial Lower and Middle Stratosphere: Method and comparison between the ERA-40 re-analysis and the LMDz-GCM, Journal of the Atmospheric Sciences, 66, 1327-1346, 2009.

Tropical waves and wave forcing in the QBOi models. *L. Holt, F. Lott et al.*

Composite of **Rossby gravity wave** packets at 50hPa, Horizontal winds and T° (CI=0.25K)



All models somehow have have substantial coherent large scale RG waves.
Large spreads in amplitude and horizontal extension

See method in: Lott, F., J. Kuttippurath, and F. Vial, A Climatology of the Gravest Waves in the Equatorial Lower and Middle Stratosphere: Method and comparison between the ERA-40 re-analysis and the LMDz-GCM, Journal of the Atmospheric Sciences, 66, 1327-1346, 2009.

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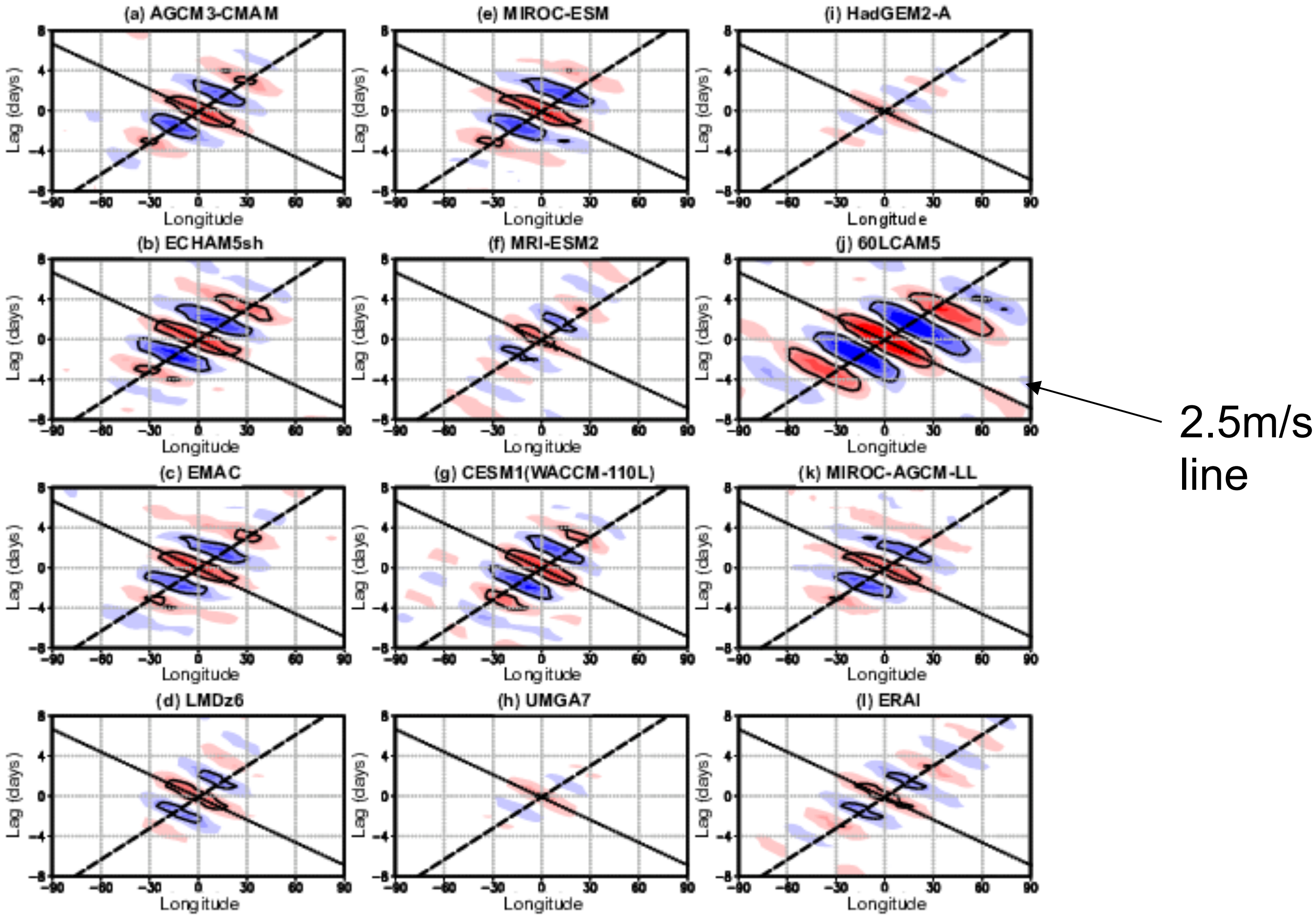
Composite of **Rossby gravity wave** packets at 50hPa, meridional wind at Equator (CI=1m/s)



Large spread in models ability to represent the **Rossby gravity waves.** The phase speed and group speeds are nevertheless more consistent between models than amplitude. A clear benefit of having a QBO when compared to the CMIP5 models in :

Lott, F. and co-authors, 2014 Kelvin and Rossby gravity wave packets in the lower stratosphere of some high-top CMIP5 models, J. Geophys. Res., 119, 5, 2156-2173, DOI: 10.1002/2013JD020797.

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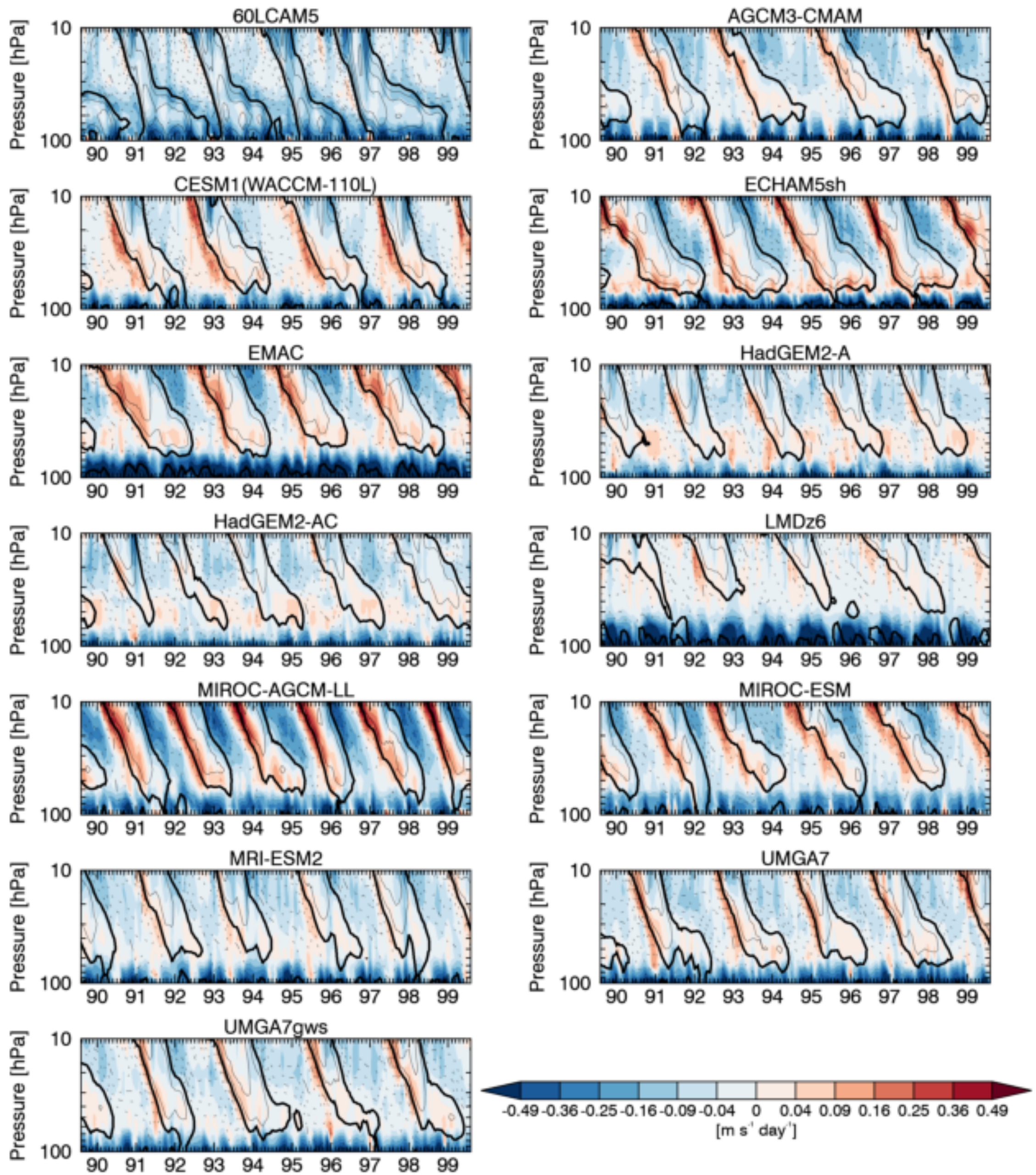
Zonal-mean zonal acceleration due to EP flux divergence from all resolved waves.

A large spread among models. In all of them the parameterized gravity are likely to contribute in compensation (about half Of the dag, in some more).

No GWs param in MIROC-AGCM-LL. Also the one with largest resolved wave forcing



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3 factors that affect the QBO forcing in models :

Vertical resolution, horizontal resolution, and CCKWs strength
case of eastward waves (Kelvin and co)

CCKWs strength is measured as the average of ratios in slide 3
and in the frequency bands of the Kelvin waves.