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Contributions of equatorial planetary and gravity waves to the QBO evolution in a GCM with a parameterization of convective gravity waves

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Introduction

- ❖ The quasi-biennial oscillation (QBO) is the prominent oscillation of the zonal wind in the whole tropical stratosphere. The QBO plays important roles in modulating dynamical circulations and tracer distributions not only in the tropical stratosphere but in the extratropics as well as the troposphere.
- ❖ Although it has been known that the QBO is driven by the equatorial waves with various scales (Kelvin and mixed Rossby-gravity waves and inertio- and internal gravity waves), quantitative contributions of each of these waves to the QBO are not fully understood and the relevant studies are on-going (e.g., Ern et al., 2014, JGR; Richter et al., 2014, JGR; Krismer and Giorgetta, 2014, JAS).
- ❖ Provided that the gravity waves generated by tropical convections are one of the crucial forcing to the QBO driving, adequate parameterization of the gravity waves linked to their convective sources is important to the realistic representation of the QBO in models (Kim et al., 2013, GRL; Schirber et al., 2014, JAMES).
- ❖ **In this study**, the contributions of the equatorial planetary waves and gravity waves to the QBO evolution are investigated using a climate model in which the QBO is simulated realistically with the parameterization of convective gravity waves.

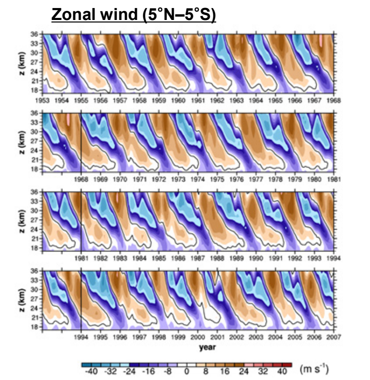
Experiment

Model	HadGEM2 – atmosphere
Configuration	AMIP-type climate run (w/ observed historical forcing, following CMIP5)
Resolution	N96 L60 (1.25° x 1.875°, z_{top} ~ 84 km)
Period	1953–2006 (54 yrs)
Convective GW parameterization	Choi and Chun (2011)[1]
Background GW parameterization	Warner and McIntyre

✓ [1] Choi and Chun (2011) : parameterization of convective gravity waves (CGW) updated from Song and Chun (2005) in which the cloud-top CGW momentum flux spectrum is calculated using the information from convection parameterization.

1. Simulated QBO

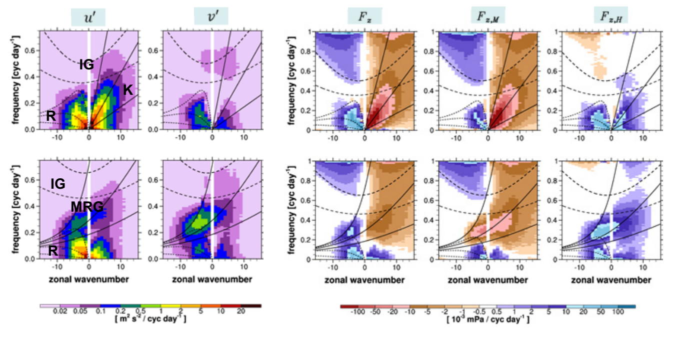
Zonal wind (5°N–5°S)



	Period (mean)	20-hPa E/W duration	50-hPa E/W duration	20-hPa Amplitude	20-hPa E/W Magnitude
Model (1979–)	19–29 (24.9)	13–18 / 7–13	9–14 / 9–18	27.9	33.1 / 19.3
MERRA	23–35 (28.0)	11–23 / 6–13	10–18 / 12–21	27.0	36.4 / 16.7

[month] [m/s]

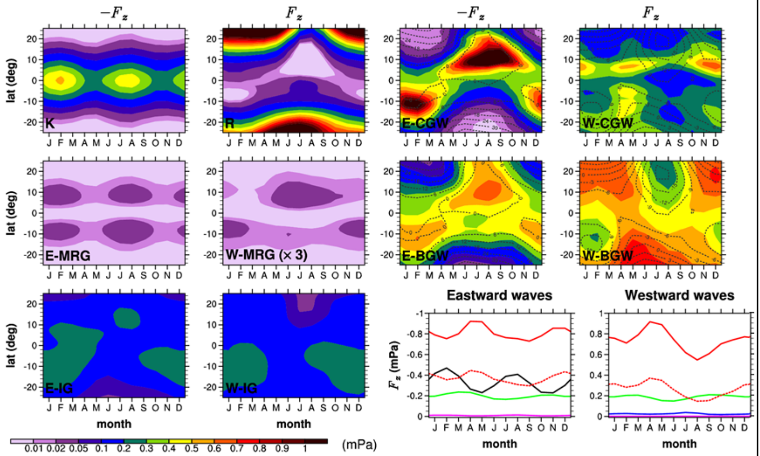
2. Spectra of resolved equatorial waves



$$F_z \equiv \underbrace{-\cos\phi\overline{(\rho w)'u'}}_{F_{z,M}} + \underbrace{\psi\left[f - \frac{1}{a\cos\phi}\frac{\partial(\overline{u}\cos\phi)}{\partial\phi}\right]}_{F_{z,H}}$$

$$\psi \equiv \frac{\cos\phi}{\left|\nabla\overline{\theta}\right|^2}\left[\overline{(\rho v)'\theta'}\frac{\partial\overline{\theta}}{\partial z} - \overline{(\rho w)'\theta'}\frac{1}{a}\frac{\partial\overline{\theta}}{\partial\phi}\right]$$

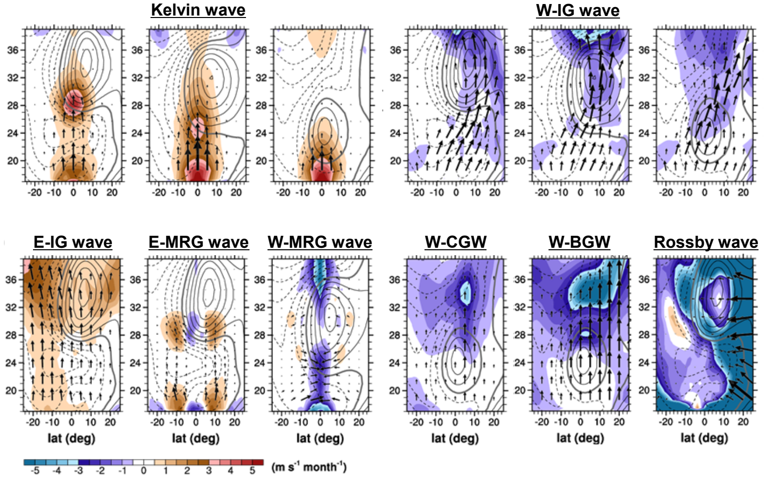
3. Wave activity flux into the stratosphere



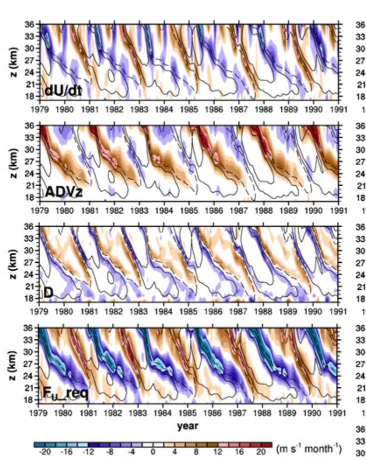
Vertical component of E–P flux for each wave

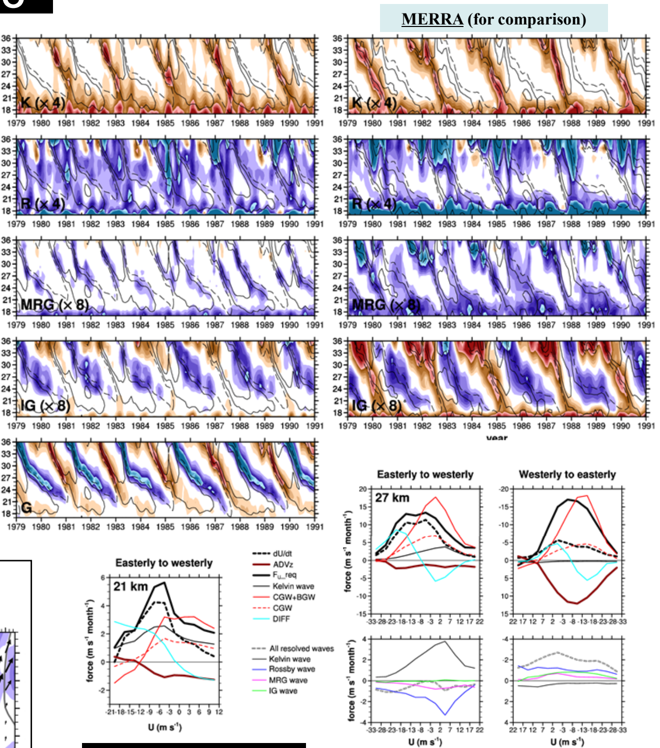
5°N–5°S avg.

4. Wave propagation pattern



5. Forcing to the QBO





$$\frac{\partial\overline{u}}{\partial t} = \overline{v}^*\left[f - \frac{1}{a\cos\phi}\frac{\partial(\overline{u}\cos\phi)}{\partial\phi}\right] - \overline{w}^*\frac{\partial\overline{u}}{\partial z} + \underbrace{\frac{\nabla\cdot\mathbf{F}}{\overline{\rho}\cos\phi} + \overline{G}_\lambda + D_{\overline{u}}}_{F_{U\_req}}$$

Summary

- ❖ The contributions of the equatorial planetary waves and gravity waves to the QBO evolution are investigated using a climate model in which the QBO is simulated realistically with the parameterization of convective gravity waves.

✓ Propagation patterns and magnitude of the upward flux of the equatorial planetary and gravity waves are investigated.
- Near the tropopause, the parameterized GW and Kelvin wave carry significant eastward momentum (0.4–1 mPa), and the westward momentum is transported mostly by the parameterized GWs.
- The model-resolved IG waves show a significant meridional propagation, which cannot be considered in the current GW parameterization.

✓ In the stratosphere the parameterized GW is the predominant forcing for driving the QBO in this model. The Kelvin wave also contributes to the easterly-to-westerly transition of the QBO in the lower stratosphere.
- Compared to the MERRA reanalysis, the simulated Kelvin and Rossby waves has a realistic magnitude in the stratosphere, although the other equatorial waves are underestimated.

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