Generating QBO in WACCM Using Parameterized Inertial Gravity Waves

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2010-02-22

OUTLINE

- Motivation
- Numerical Tests Group 1 (3 cases):
  - symmetric GW spectrum
  - Without consideration of Coriolis Force
- Numerical Tests Group 2 (1 case) :
  - asymmetric GW spectrum
  - With consideration of Coriolis Force
- Conclusion

MOTIVATION: IGW PARAMETERIZATION

- Typical observed GW momentum flux is ~10^{-3} Pa.
  - a=86m/s/d (70km), 11 hours for 40m/s change: parameterized in WACCM/WACCM-X by mesoscale gravity wave.
  - a=8.6×10^{-2} m/s/d (20km), 465 days for 40m/s change: QBO scale, but not resolved or parameterized in WACCM/WACCM-X.

- Wanted: GWs with similar momentum flux break both in the stratosphere and in the mesosphere.

- According to Holton (1982), $z_b \propto 2H \ln(2\pi / \lambda_h A)$, horizontal wavelength and wave amplitude are equivalent in determining wave breaking altitude. An order of magnitude increase in horizontal wavelength/wave amplitude will lead to decrease of breaking level by 4.6H~32km.

- Therefore, to account for stratospheric forcing while keeping the mesospheric forcing, a spectrum of inertial GWs with the same momentum flux should be added to the parameterization.

NUMERICAL TESTS G1 :

WITH SYMMETRIC GW SPECTRUM AND WITHOUT CORIOLIS FORCE

inertial GWs wavelength

$$\lambda_h = 1000km$$

inertial GWs spectral

$$c = [-c0, -c0 + 1m/s, ..., 0, ..., c0 - 1m/s, c0]$$

inertial GWs forcing regions

latitude: $-30^\circ, 30^\circ$

launch altitude:$200mb$

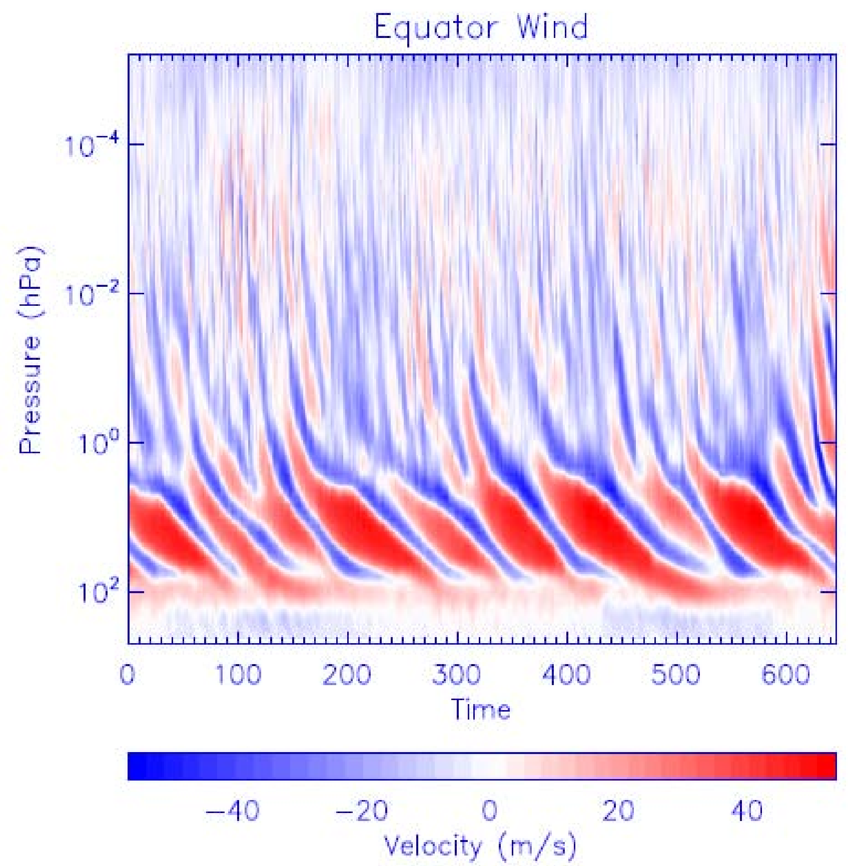
inertial GWs tau at launch altitude

$$\tau = 0.001Pa$$

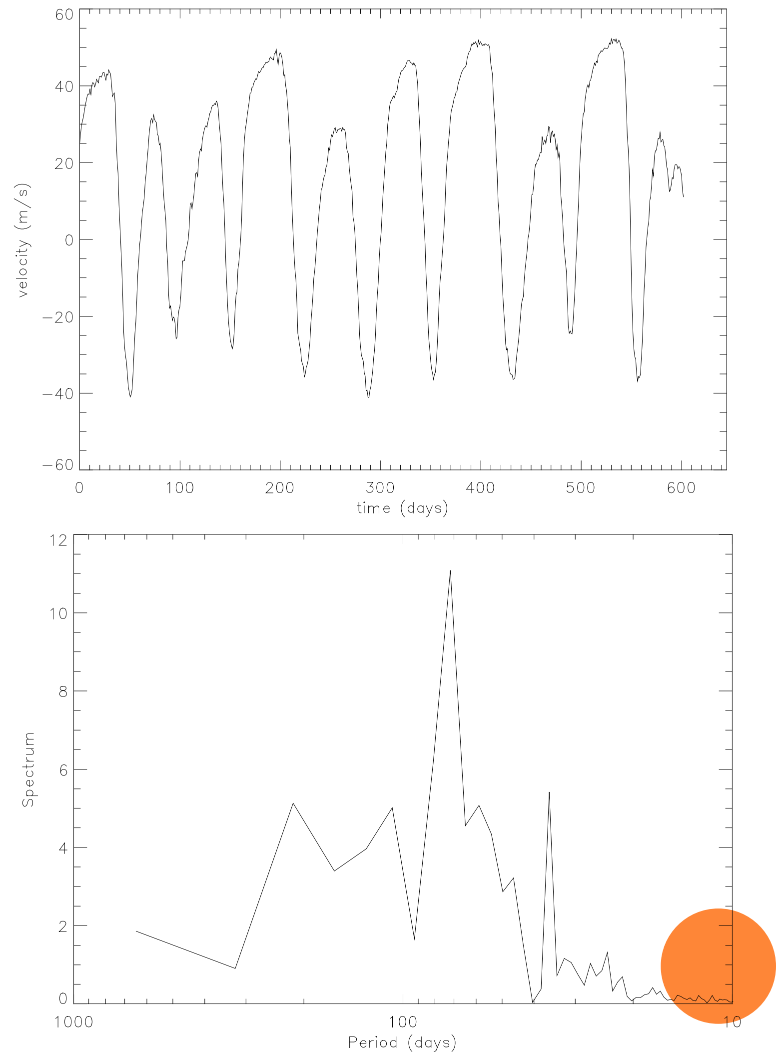
effeciency: *eff_QBO*

NUMERICAL TEST G1:

Case 1: $c0 = 30m/s$, $eff\_QBO = 1.0$



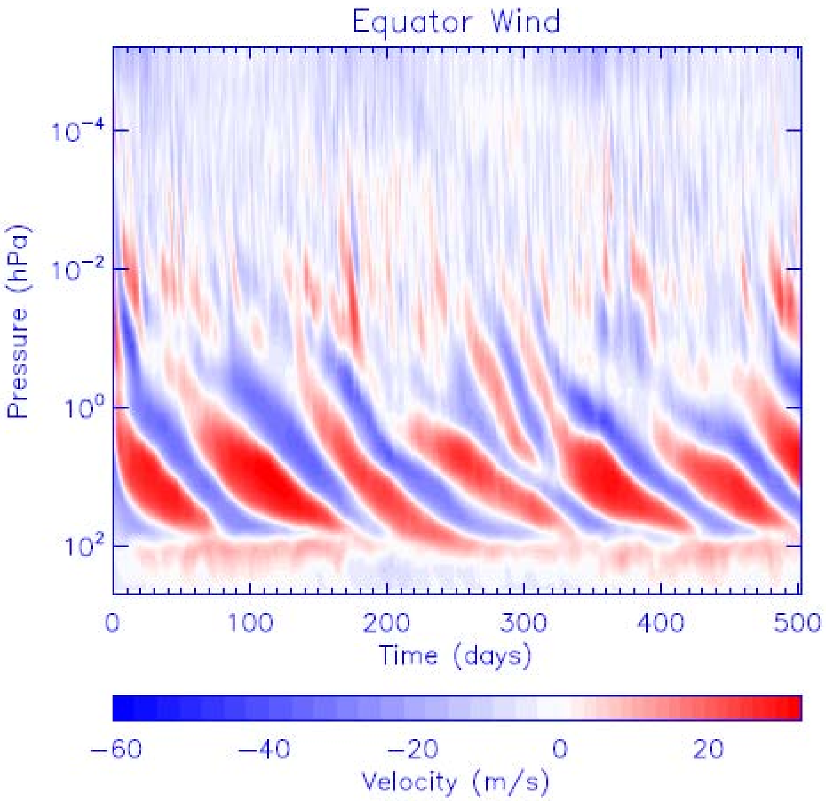
Equatorial zonal mean zonal wind



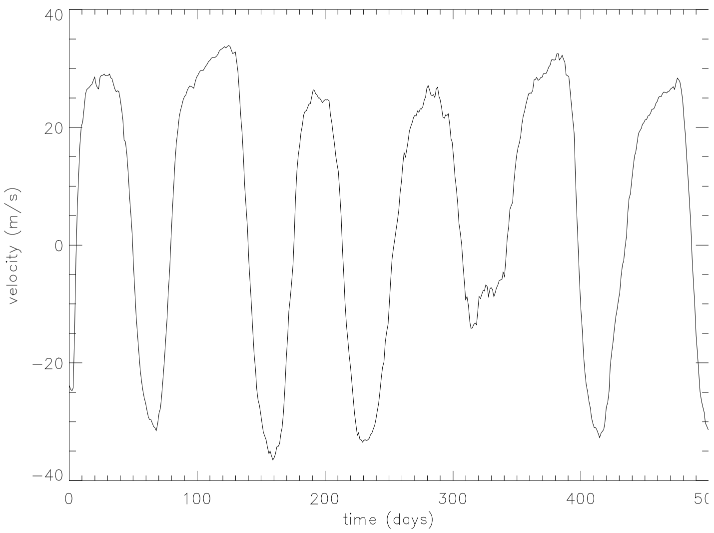
Equatorial zonal mean zonal wind at 10 mb and its FFT spectrum

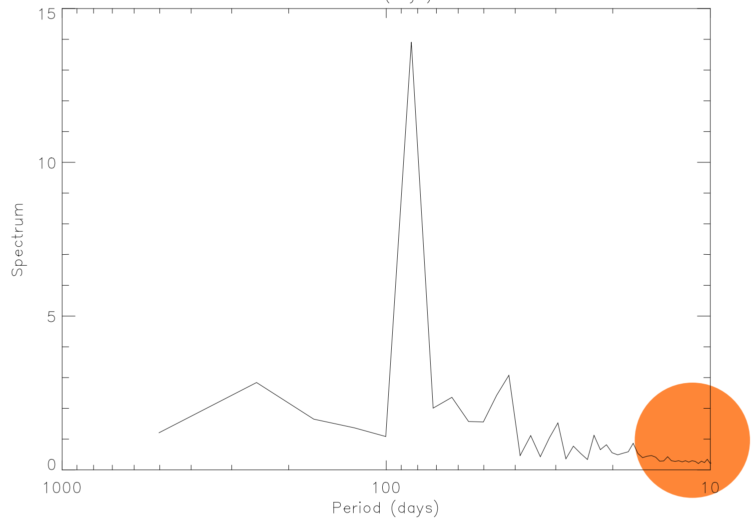
NUMERICAL TEST G1:

Case 2: $c0 = 20m/s$, $eff\_QBO = 1.0$



Equatorial zonal mean zonal wind

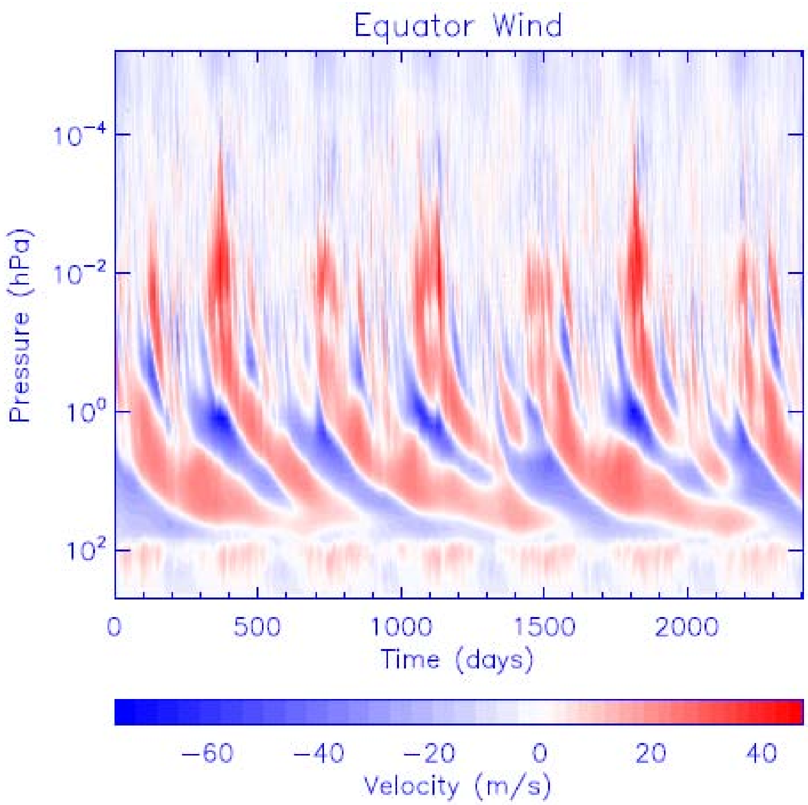




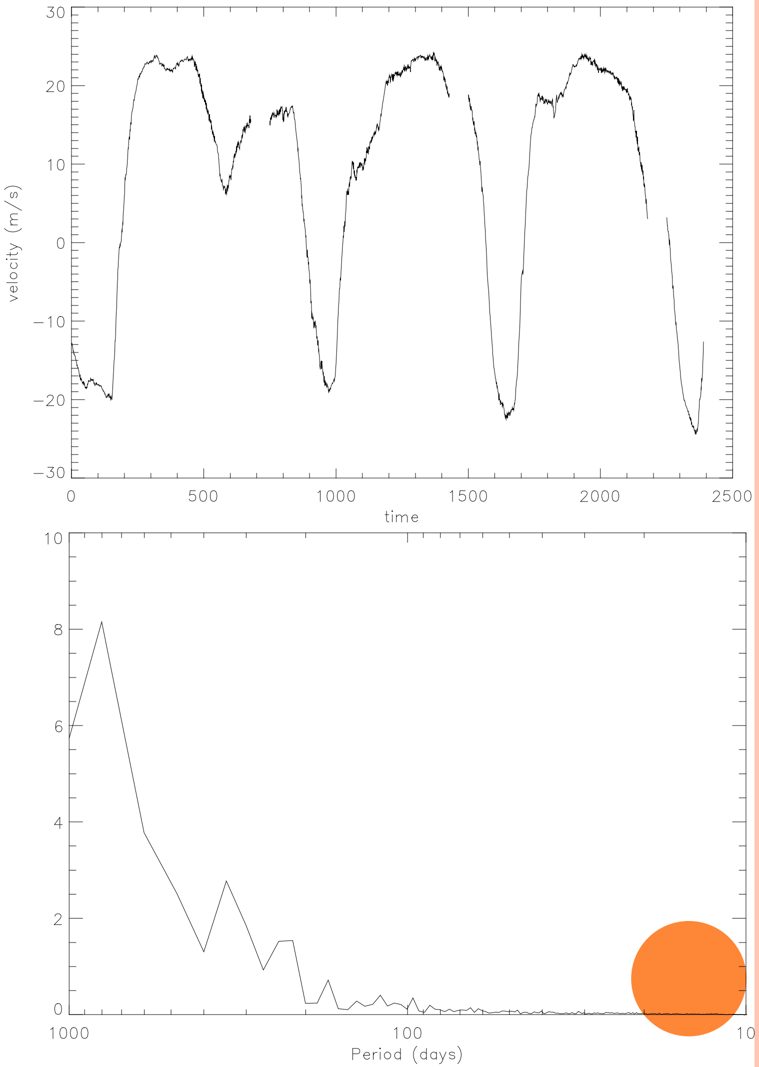
Equatorial zonal mean zonal wind at 10 mb and its FFT spectrum

NUMERICAL TEST G1:

Case 3: $c0 = 20m/s$, $eff\_QBO = 0.1$

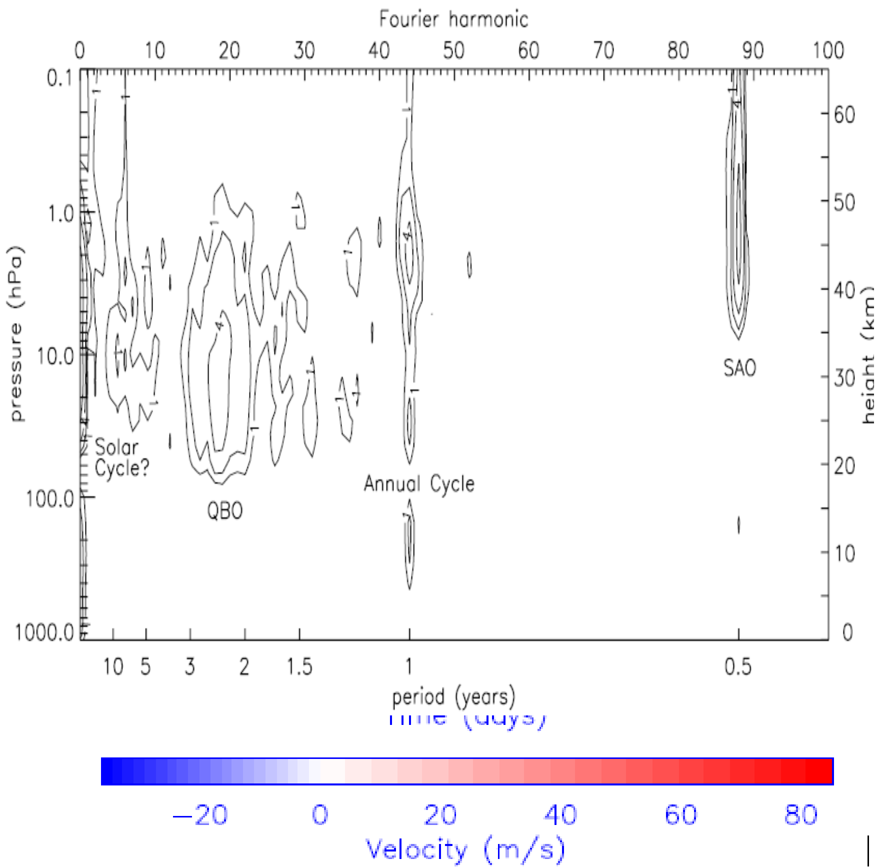


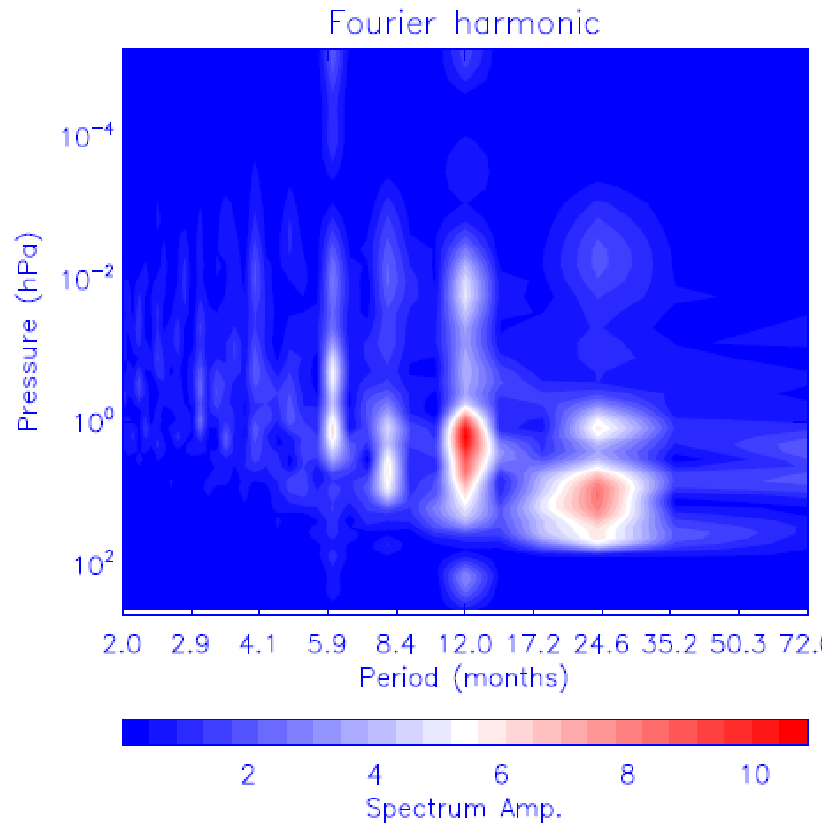
Equatorial zonal mean zonal wind



Equatorial zonal mean zonal wind at 30 mb and its FFT spectrum

Case 3: $c0 = 20m/s$, $eff\_QBO = 0.1$





wind. The Fourier harmonic axis indicates the number of cycles that a given periodic mode experienced during the 44 years of the ERA-40 data set. From Pascoe 2005.

zonal mean wind at 30mb contour

equatorial zonal mean wind FFT spectrum

CONCLUSION - 1

- GW spectral width affects the amplitudes of the oscillation of equatorial zonal wind and also have an small effect on the period of the oscillation.

- Symmetric GW spectrum causes the symmetric oscillation of equatorial zonal mean wind.

- The efficiency/intermittency of IGW has an evident effect on the period of the oscillation of equatorial zonal wind. The proper choice of the efficiency can produce the QBO-like oscillation in stratosphere and mesosphere.

➔ The asymmetric GW spectrum (westward shift) will be considered

NUMERICAL TEST G2:

ASYMMETRIC GW SPECTRUM AND WITH CORIOLIS FORCE

inertial GWs wavelength

$\lambda_h = 1000km$

inertial GWs spectral

symmetric GW spectrum c + westward shift

inertial GWs forcing regions

latitude: $-30^\circ, 30^\circ$

launch altitude:$200mb$

inertial GWs tau at launch altitude

$\tau = 0.001Pa$

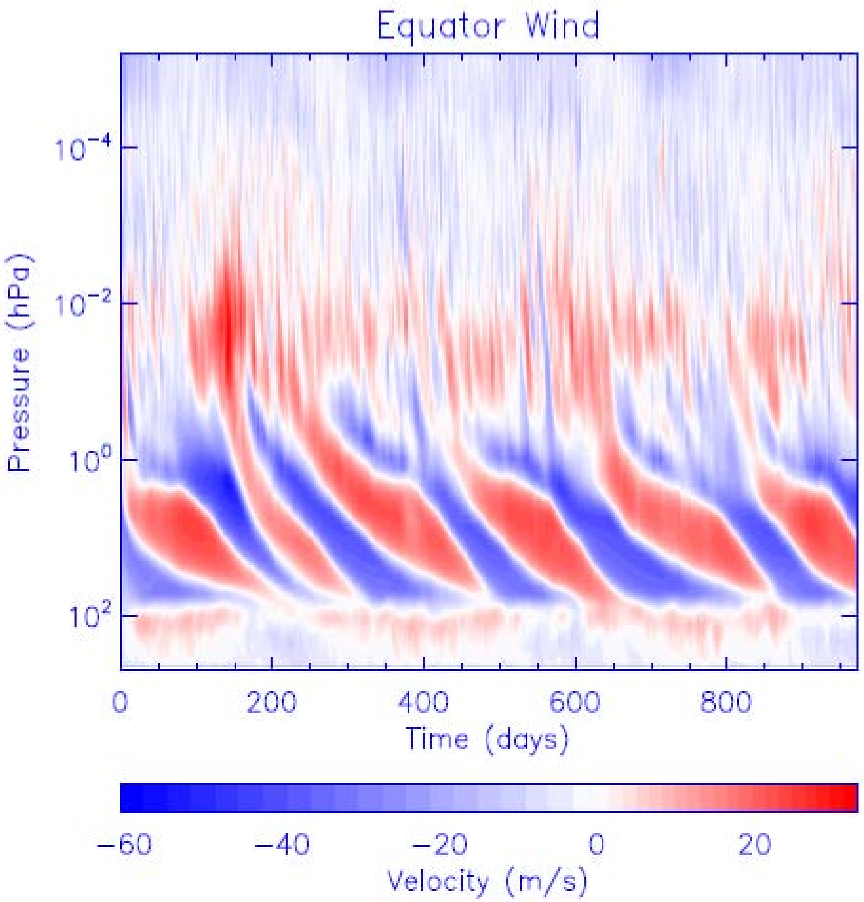
effeciency: eff_QBO

NUMERICAL TEST G2: CORIOLIS FORCE EFFECTS

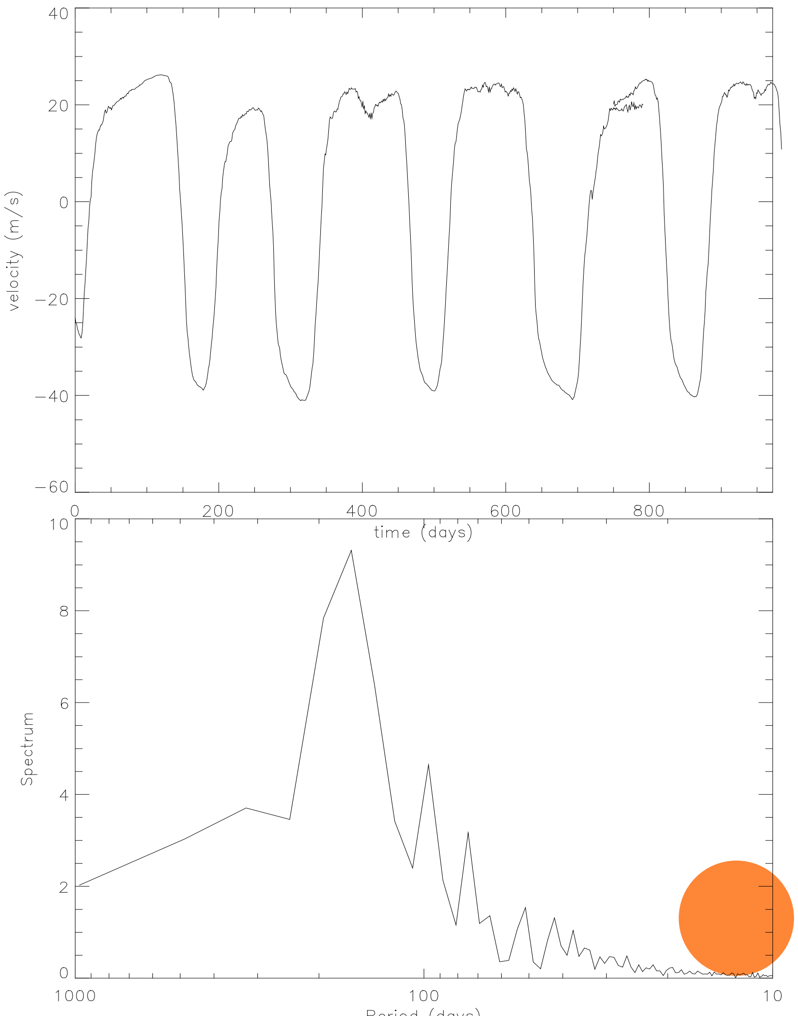
- Dispersion Relation: $$m^2 = \frac{N^2}{(c-u)^2 - f^2/k^2}$$
- Critical level: $$u - |f|/k <= \quad c \quad <= u + |f|/k$$
- Saturation Stress : $$\tau^* = \frac{k\rho_0}{2N}[(c-u)^2 - f^2/k^2]^{1/2}(c-u)^2$$
- Acceleration of zonal wind: $$\frac{\partial u}{\partial t} = -\frac{1}{\rho_0}\frac{\partial \tau^*}{\partial z} = \frac{k[(c-u)^2 - f^2/k^2]^{1/2}(c-u)^2}{2NH}$$

NUMERICAL TEST G2:

Case 1: $c0 = 20m/s$, $\Delta c = 5m/s$ (westward shift), $eff\_QBO = 1.0$



Equatorial zonal mean zonal wind



Equatorial zonal mean zonal wind at 10 mb and its FFT spectrum

CONCULSION -2

- Asymmetric GW spectrum (westward shift) causes the westward shift of the equatorial zonal mean zonal wind.

- The Coriolis effect (f/k) causes the critical level lower than that without the effect of f/k, and the higher atmospheric density in lower critical layer region reduces the acceleration of zonal mean wind and causes the oscillation with a longer period.

NEXT WORK:

- Generate QBO-like oscillation with Coriolis effect and asymmetric GW spectrum

- Combine the parameterization of IGW with the parameterization of the convective system, and try to obtain a near realistic scenario.

Thank you

for your attention!