Equatorial Wave Packets in the LMDz Stratospheric Model and in the ERA40 Reanalysis

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Summary:

A climatology of the gravest Equatorial waves **packets** (Kelvin, Rossby and Rossby Gravity) in the lower stratosphere is extracted from the ERA40 re-analysis. The method is based on the fact that for these waves, at least one atmospheric flow field at a given pressure level and at a given longitude is almost uniform in latitude and in the Equatorial band (here -10°S-10°N): The Kelvin and the Rossby waves have a strong signature on u, T, and Z averaged in latitude over the Equatorial band, the Rossby-gravity have a strong signature on the fields of V averaged in latitude over the Equatorial band.

A spectral analysis of those averaged quantities is done to detect the spectral windows where those waves affect the flow dynamics in the stratosphere. The spatial structure of the waves is then extracted **(i)** by filtering the data with broad band pass filters and **(ii)** by building composites using indexes measuring when the waves enter in the lower stratosphere.

The also method permits to diagnose that the LMDz-model produces slow Kelvin waves packets of about the right amplitude but of two large horizontal extension, and almost fails in producing Rossby gravity waves. We attribute these to a too weak tropospheric forcing at horizontal wavenumbers s>3 and to an insufficient vertical resolution in the lower statosphere.

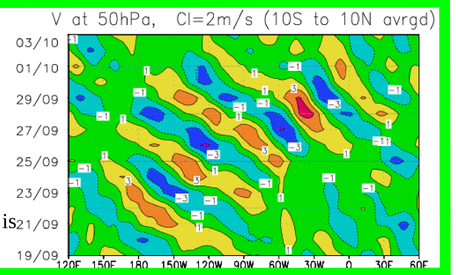
The LMDz model has a correct equatorial signature of the s=1 free planetary waves (periods around 5d and 16d), consistent with the fact that it has a realistic midlatitude variability (not much shown in this poster).

1) Motivation

Because they are near aloft their tropospheric source, equatorial waves in the lower stratosphere are still grouped in **packets.**

Here an example for a Rossby-gravity packet wave in Sept-Oct 1995

A climatology need to extract these packets (rather individual harmonics) because it is in these packets that irreversible processes occur (breaking, ice condensation...).



2) Spectra (ERA40, 1978-2003):

The T and U spectra show enhanced power in the eastward direction for s=1-8 and periods ω^{-1}=10-25 days.

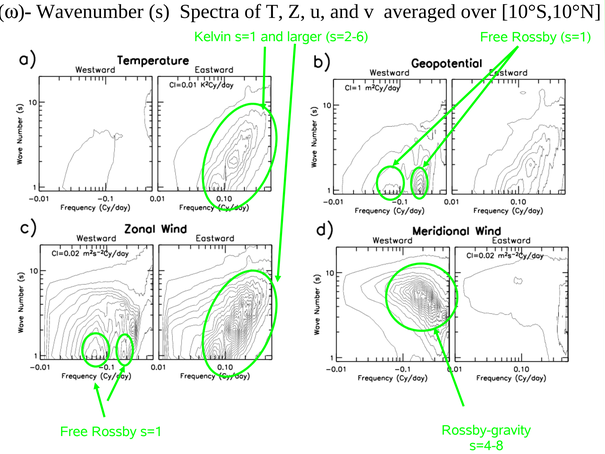
These maxima are Presumably due to **Kelvin waves** with s=1, and/or Kelvin waves packets with larger s (see composite in panel 4).

The V spectrum shows enhanced power in the westward direction for s=2-9 and periods ω^{-1}=3-15 days

This maximum is presumably due to Rossby gravity waves like the one seen in the Panels 1) and 5)!

There are also equatorial signatures of free Rossby (planetary) waves (at least the 5days s=1 and the 16day s=1) in the spectra for Z and U.

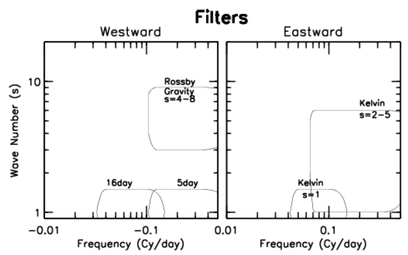
Freq. (ω)- Wavenumber (s) Spectra of T, Z, u, and v averaged over [10°S,10°N]



3) Composite method:

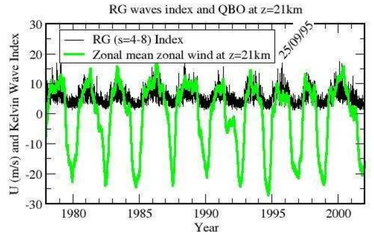
Step 1

filter all dataset by broad band pass filters wich largely « dub » the maxima seen in the Spectra of panel 2)



Step 2

Build and index measuring when the corresponding waves enter in the low stratosphere.



For the $(s \approx 4-8)$ Rossby Gravity Wave, the strongest signals being on v, the index is

$$RG(\lambda, d, y) = \overline{v}(\lambda, \phi, z = 21\text{km}, d, y).$$

We then identify the dates where RG exceeds a given threshold (such that 25 Cases are selected over the entire dataset).

$\overline{v}$: Average over the Equatorial band of the filtered v.

Step 3

Sum the maps corresponding to extrema in this index.

4) Kelvin waves with s>1

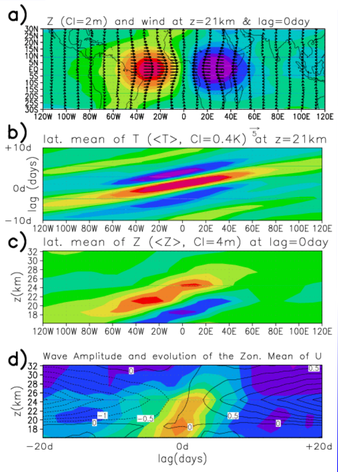
a) Spatial patterns characteristic of Kelvin waves: substantial amplitude for all the dynamical fields

b) Eastward phase and group velocities

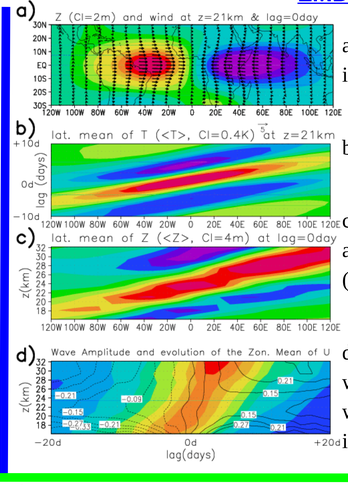
c) Vertical structure tilted eastward (upward energy propagation), attenuated by the presence of the QBO

d) During the life cycle of the waves, the zonal mean zonal wind (black) increases (QBO driving)

ERA40



LMDz



a) Larger zonal extension than in ERA40

b) Significantly longer duration

c) Vertical structure not attenuated in the vertical (absence of QBO)

d) During the life cycle of the waves, the zonal mean zonal wind (black) increases a little, indicative of some attenuation

5) Rossby gravity waves

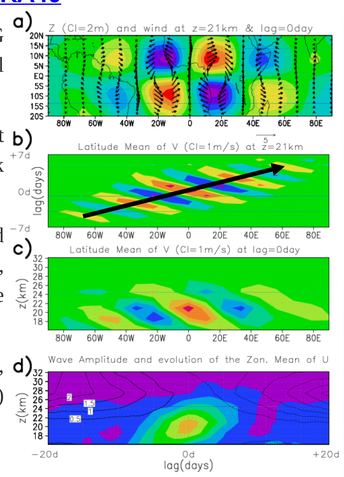
a) Characteristic structure of RG waves: substantial amplitude for all the dynamical fields

b) Westward phase propagation but eastward group velocity (black arrow)

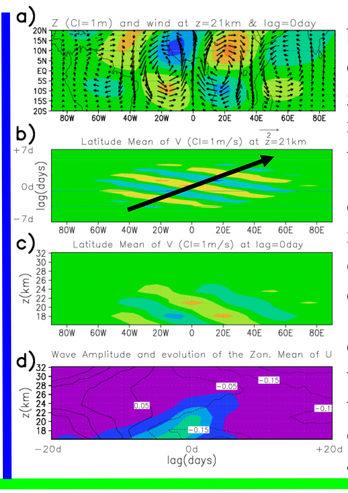
c) Vertical structure tilted westward (upward energy propagation), attenuated by the presence of the QBO

d) During the life cycle of the waves, the zonal mean zonal wind (black) increases

ERA40



LMDz



a) Note very clear RG signal

b) Significantly shorter duration, slower eastward group velocity (balanced by the negative zonal wind present in the model?)

c) Vertical structure attenuated in the vertical (in the absence of QBO this mean numerical dissipation)

d) During the life cycle of the waves, the zonal mean zonal wind (black) decrease a little, consistent with these waves attenuation

References:

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