The dynamical composition of the Madden-Julian Oscillation

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Problem

- What are the modes more excited by the convection associated with the MJO, and in which modes is the energy generated?
The energy balance equation

The balance of the total energy (the kinetic plus the available potential energy), $E_{nlk}$, of the atmospheric circulation is given by

$$\frac{d}{dt} E_{nlk} = C_{nlk} + S_{nlk},$$

(1)

$n$, $l$, $k$ stand for zonal wavenumber, meridional and vertical mode indexes, respectively. Terms $C_{nlk}$ and $S_{nlk}$ represent the nonlinear energy interactions and the energy source/sink due to diabatic heating and dissipation. (See, Marques et al, 2020, https://doi.org/10.5194/gmd-2019-340, for more details).
Data & Method

- Horizontal wind field and geopotential from ERA-Interim reanalysis (1979-2016), and the outgoing longwave radiation (OLR)-based MJO index (OMI – https://www.esrl.noaa.gov/psd/mjo/mjoindex/).

- Energy spectra for the composite differences between strong and weak convection were calculated.

- The composite were calculated finding the days when the MJO index strength falls in the first quartil or forth quartil of each phase.
In the next figures the following convention for the meridional index, $l$, was followed. Negative indexes denote Rossby waves with $l = -1$ representing the first equatorial Rossby mode. The index $l = 0$ denotes the mixed Rossby-gravity mode.

Positive indexes denote gravity mode with $l = 1$ denoting the Kelvin waves.
composite difference (strong - weak convection)
Nonlinear Interaction

composite difference (strong - weak convection)
Total Energy

OMI interquartile range

$\Delta E_{nl}$ (kJ.m$^{-2}$)

wavenumber

meridional index

composite difference (strong - weak convection)
strong - weak convection: shading represents the OLR anomalies; the thick blue vector in lower right corner of which panel represents a wind speed difference of $5 \text{ m} \cdot \text{s}^{-1}$. 
Conclusions

The MJO is characterised by:

1. Strong generation of energy in the equatorial Rossby waves of wavenumbers 1, 2 and 3;

2. Energy transfer from the Rossby waves to the Kelvin waves of wavenumber 1;

3. Strong dissipation of energy in the Kelvin waves of wavenumber 1;

4. Compared to the case of weak convection, during strong convection the energy in the equatorial Rossby waves and in the Kelvin waves of wavenumber 1 is 1.5 and 1.9 times higher, respectively.