Influence of the Madden-Julian Oscillation on Tropical South American Precipitation During Austral Summer

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Introduction:

Whether and how the Madden-Julian Oscillation (MJO) can influence the rainfall over the South American Monsoon region has been a subject of debate for years. Our work uses composite analysis of rainfall and atmospheric circulation through life cycles of the MJO during austral summer. This oscillation with characteristic periods of 30-60 days is shown to have a significant influence on the intra-seasonal variation of precipitation over South America. Two phases, 15 days apart, are isolated in its life cycle. The first (second) one characterized by easterly (westerly) equatorial 850-mb wind anomalies over eastern Pacific is accompanied by enhanced (suppressed) precipitation over eastern South America.

Objectives: • Study these 2 phases to better understand the effect of MJO on precipitation over eastern South America and the cross-equatorial low-level flow.
• Use a barotropic model to study influence of MJO on SACZ.

Data:

ECMWF Reanalysis: wind fields and precipitation in pentad average.
Analysis period: 1979 to 1993.

Methods:

Composite Technique:

• MJO index: as in Maloney and Hartmann (1998).

EOF is done on the 20-80 day bandpass-filtered equatorial averaged zonal wind at 850-mb.

Index(t) = PC1(t) + [PC2(t+2) + PC2(t+3)]/2

• Identify MJO events: index>1 and minima must be negative.

• Composite: Each event is divided in 9 phases (1 phase=5 days). Then composites are done for different variables (wind, precipitation...) for each of the 9 phases of MJO cycle.

V-index technique:

Based on area-averaged (5ºS-5ºN, 65º-75ºW, see red rectangle in Fig. 1) daily 925-hPa meridional winds. Defined by Wang and Fu (2002).
It is dominated by northerly regime in the austral summer.

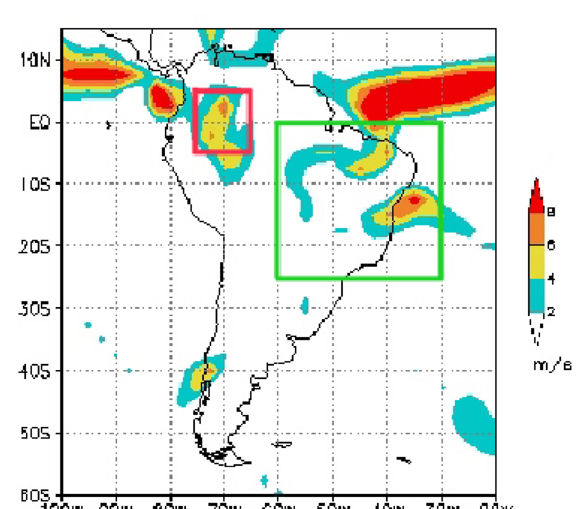

Figure 1

Composite Study:

Fig. 2: represents the area-averaged of eastern South America (see green rectangle in Fig. 1) precipitation anomaly (mm/day) and V-index (m/s) for the 9 phases of MJO.

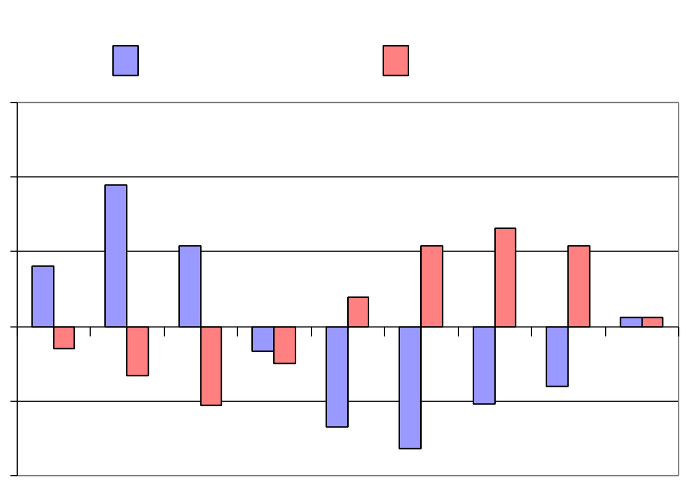

Figure 2

- **Both vary systematically with MJO**
- **Phase 2 and 6 are the peaks of rainfall anomalies**
- **V-index lags rainfall anomalies by 1 phase**

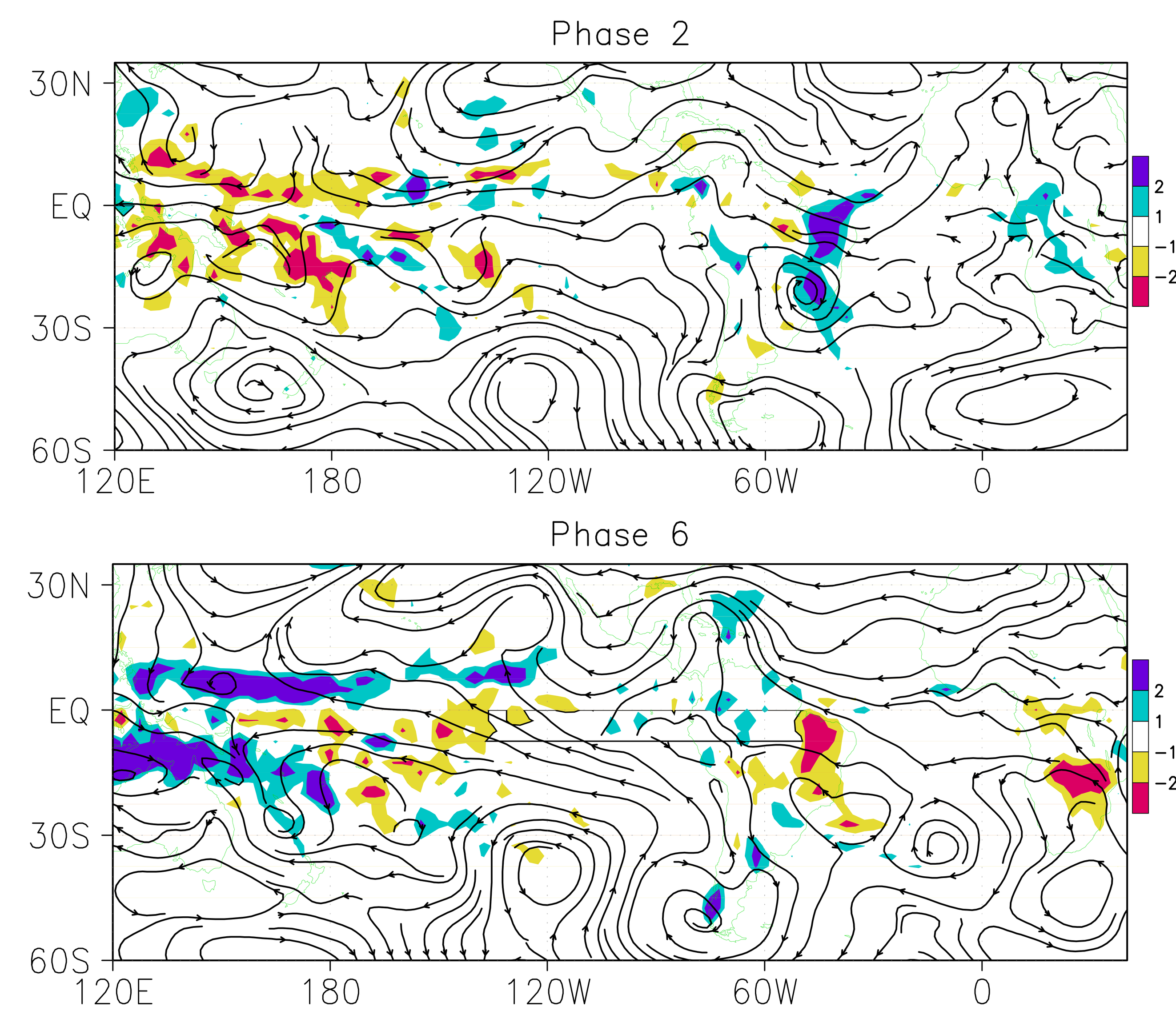

Fig. 3: Composite of 850-mb wind (streamlines) and precipitation anomalies (mm/day) for phase 2 and 6

Phase 2: Westerlies in the equatorial Pacific; negative precipitation anomalies (red shaded areas) in the western Pacific are associated with strong positive precipitation anomalies (blue shaded areas) and a cyclonic motion at 850-mb in the eastern South America.
Phase 6: Opposite features.

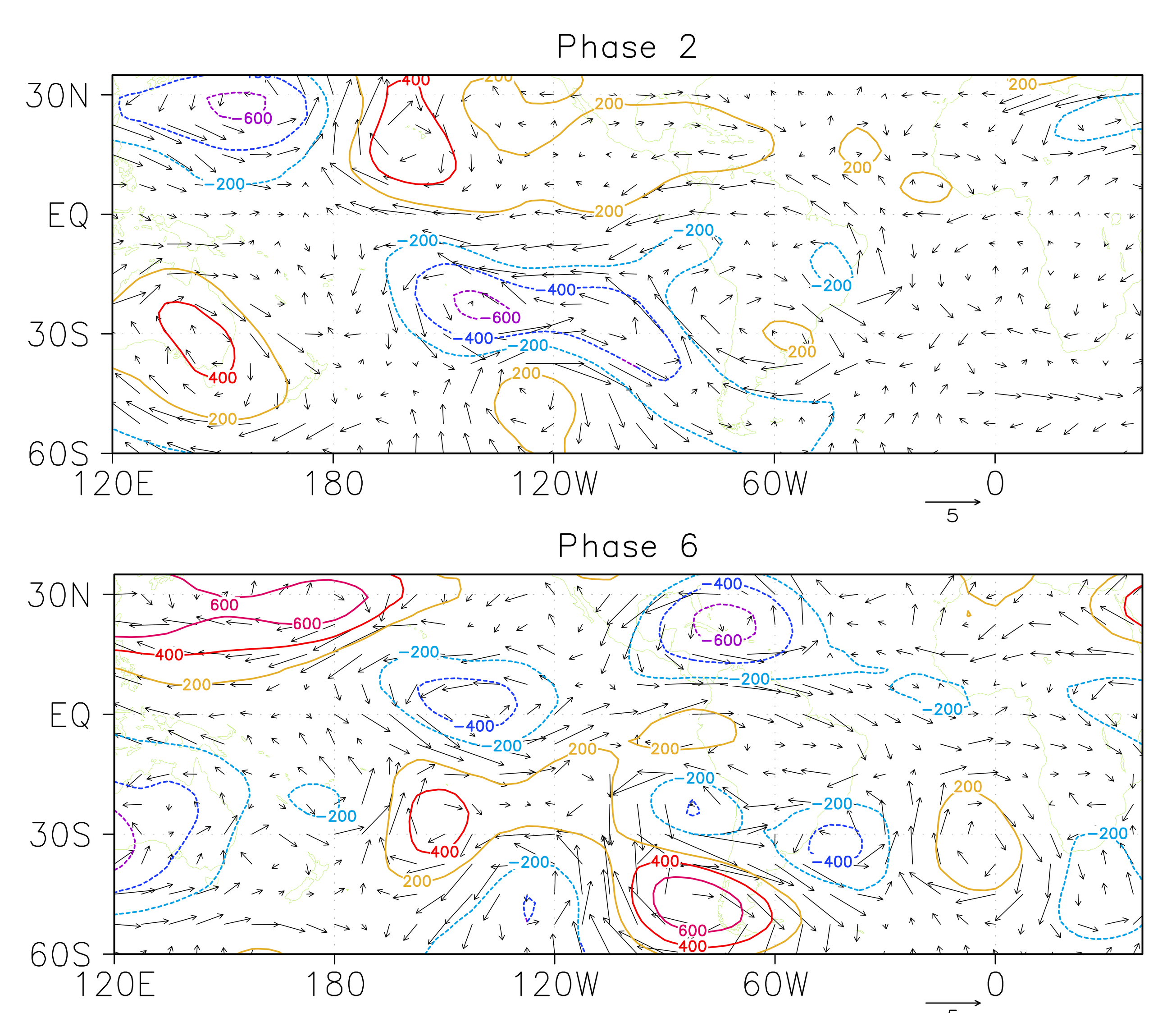

Fig. 4: Composites of 200-mb wind vectors (m/s) and Streamfunction (contour interval 200×10^7 m/s^2) for phase 2 and 6

Phase 2: Around the equator, opposite flow at 200 and 850-mb, which is characteristic of Kelvin waves. Around 30ºS, Rossby wave train links the central Pacific to eastern South America.
Phase 6: Opposite phase of Kelvin and Rossby waves.

Barotropic Model:

In phase 1 of MJO, strong positive precipitation anomalies in the middle of the Pacific Ocean, see Fig. 5. It makes SPCZ stronger and eastward from its climatological position (to 120°W). In phase 2 rainfall anomalies in SPCZ decrease, and SACZ increases as seen in Fig. 3. The relationship between these 2 convergence zones was pointed out by Kalnay et al. (1996). Here we use a barotropic model (Ting 1996) to examine the relationship between SPCZ and SACZ.

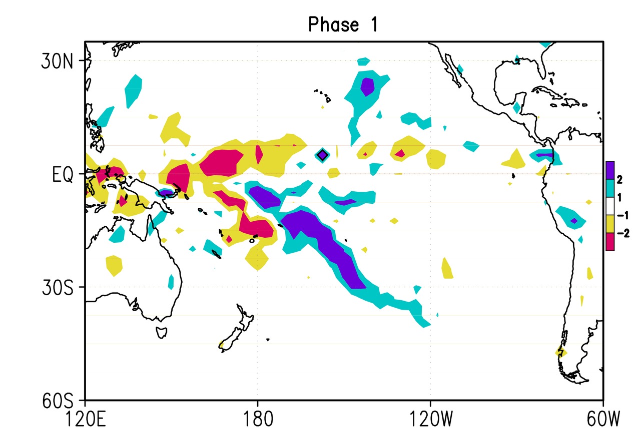

Fig. 5: Composite of precipitation anomaly (mm/day) for phase 1

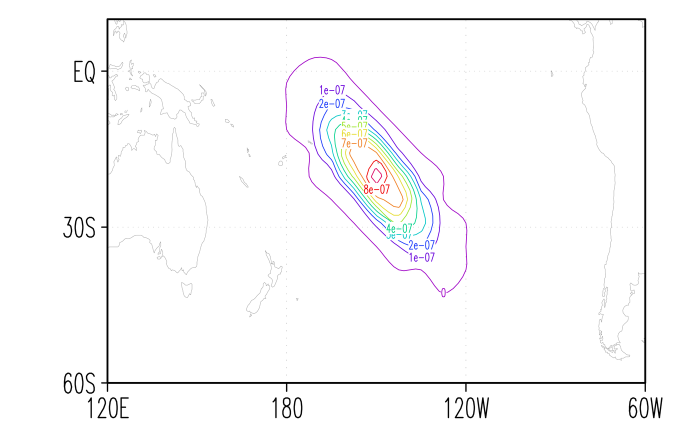

Fig. 6: Forcing of upper level divergence (s^{-1})

Model characteristic:
- Resolution: R15
- Input: mean zonal flow at 200-mb

Model forcing:
- Model forced by upper-level divergence
- Location: Eastern part of SPCZ
- Elliptical shape

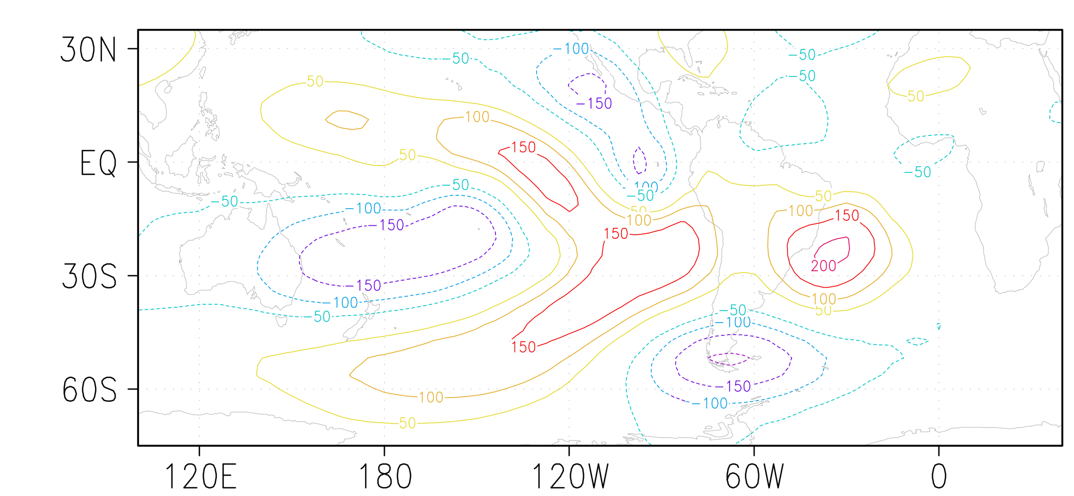

Fig. 7: Output of model: Streamfunction at 200-mb (contour interval 50×10^7 m/s^2)

Wave train linking middle of Pacific Ocean to South America around 30ºS.
The barotropic model demonstrates eastward extension of the SPCZ is responsible for the formation of the Rossby wave that strengthens the SACZ.

Summary:

1. MJO makes precipitation variations in eastern South America. Maximum positive precipitation in phase 2, and maximum negative one in phase 6.

2. Eastward extension and intensification of SPCZ during phase 1 of MJO excites Rossby waves toward South America. It strengthens SACZ one phase later.

3. Whether strengthening of SACZ could impact one the cross-equatorial flow is under investigation.

References:

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