Role of Radiative Convective Instability in Madden Julian Oscillation

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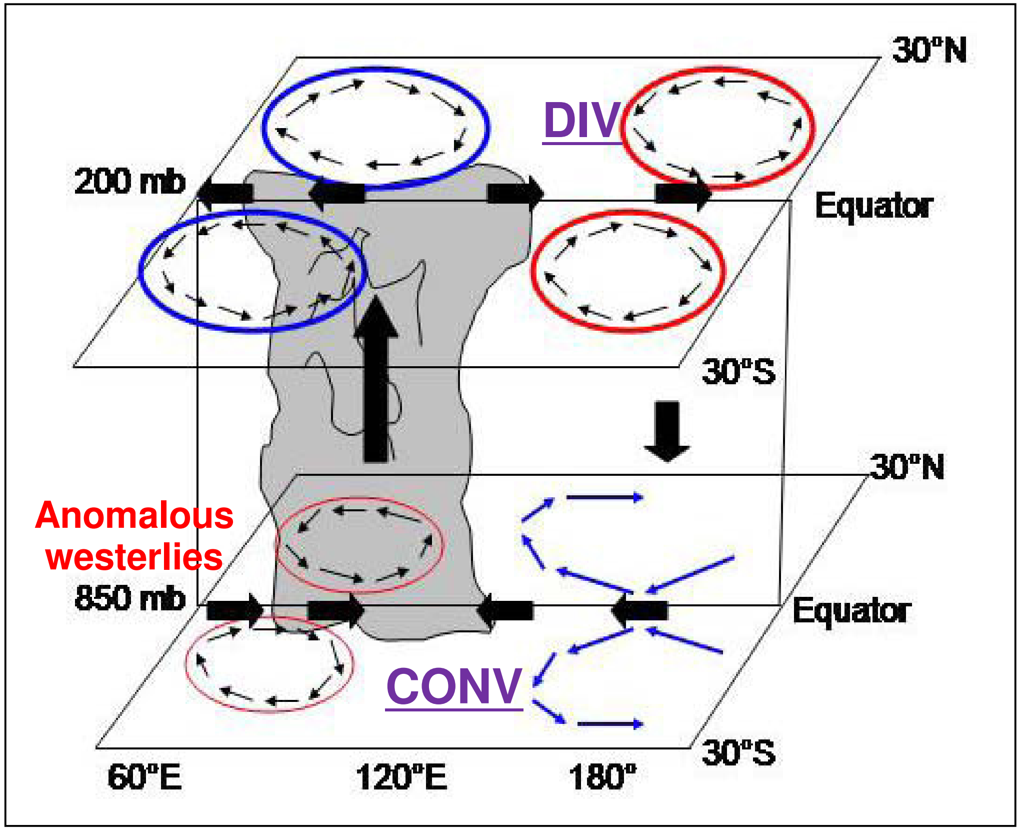
The Madden-Julian Oscillation (MJO)

Idealized representation of the MJO 3D structure.

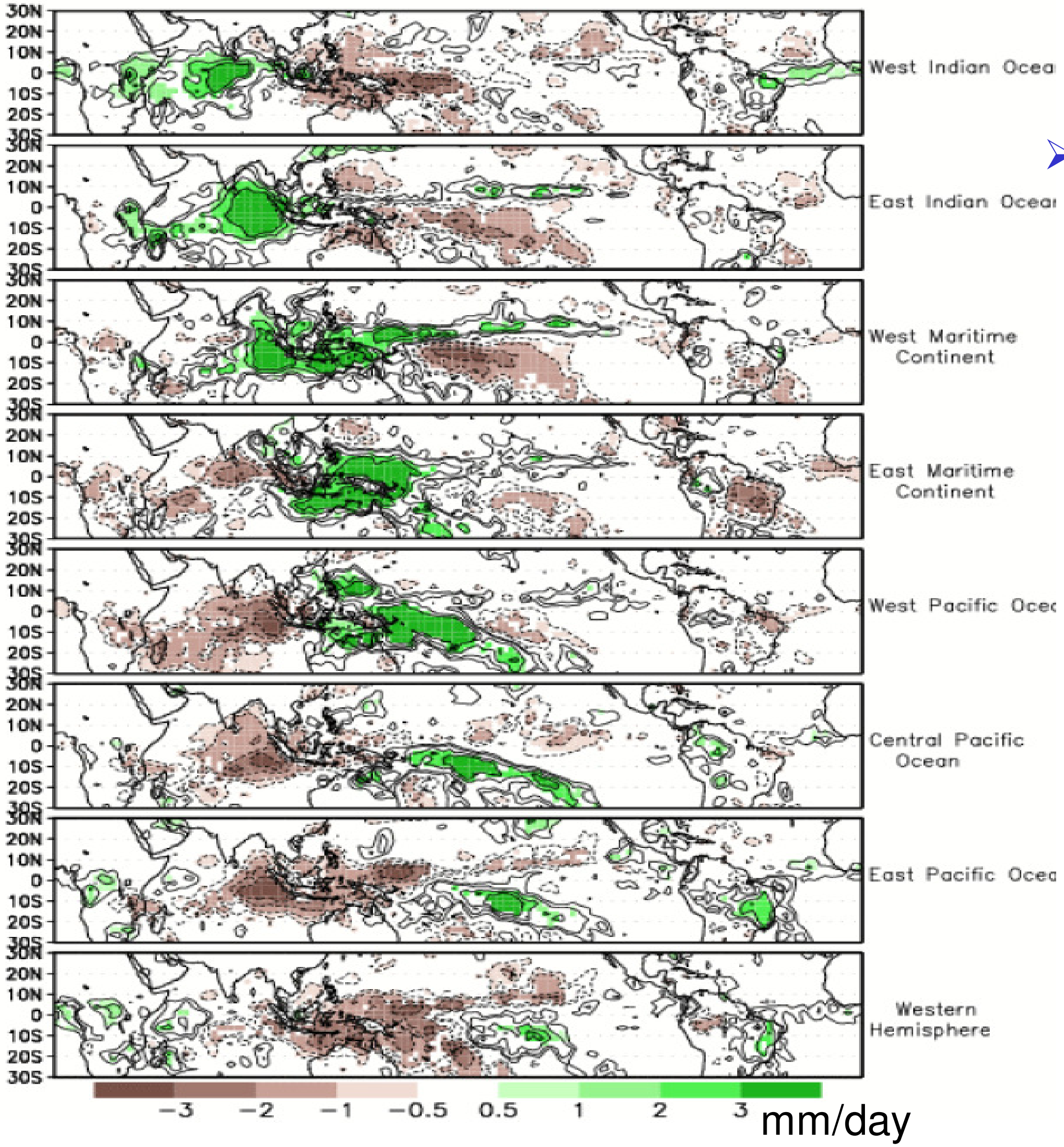


Source: Climate Prediction Center (CPC/NCEP)

- **Discovered by R. Madden and P. Julian at NCAR in 1971**
- **Convective envelope ~10,000 km wide, moving eastward at around 5 m/s**
- **Most active over regions of high SSTs > 27°C**
- **Large impact on the extratropical circulation**
- **Poorly represented in GCMs, if at all (Lin et al 2007, Hung et al. 2013).**
- **Scale interactions, from convective cells, MCSs to equatorial waves**

The Madden-Julian Oscillation (MJO)

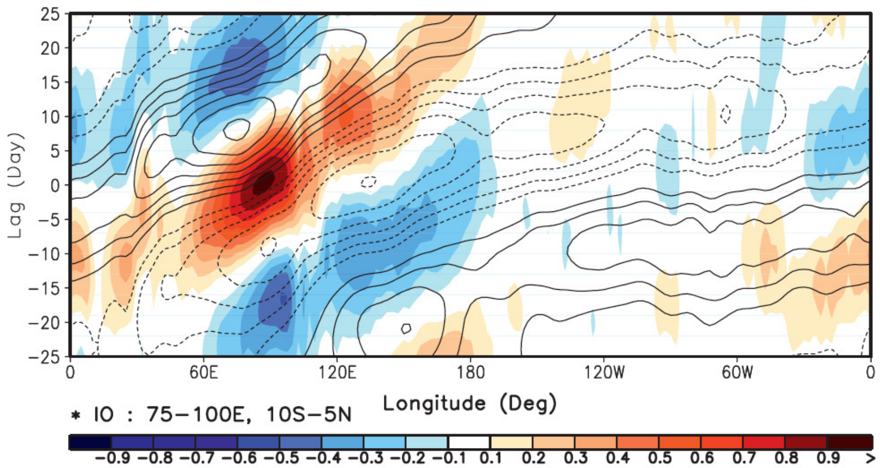
Winter (NDJFM) MJO life cycle: composites of precipitation anomalies



Source: Climate Prediction Center (CPC/NCEP)

- **Several methods for detection:**
  - **The 8 phases of Wheeler and Hendon (2004), using Principal Component Analysis.**
  - **Regression over 20-100-day filtered precipitation averaged over specific domains (e.g., Indian Ocean)**

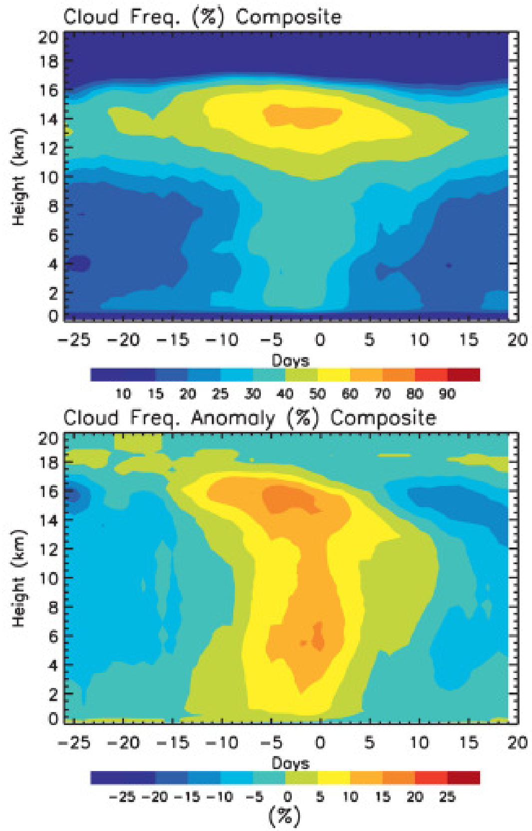
Correlation between IO filtered precipitation and precip/U850 [10S-10N]



Waliser et al. (2009)

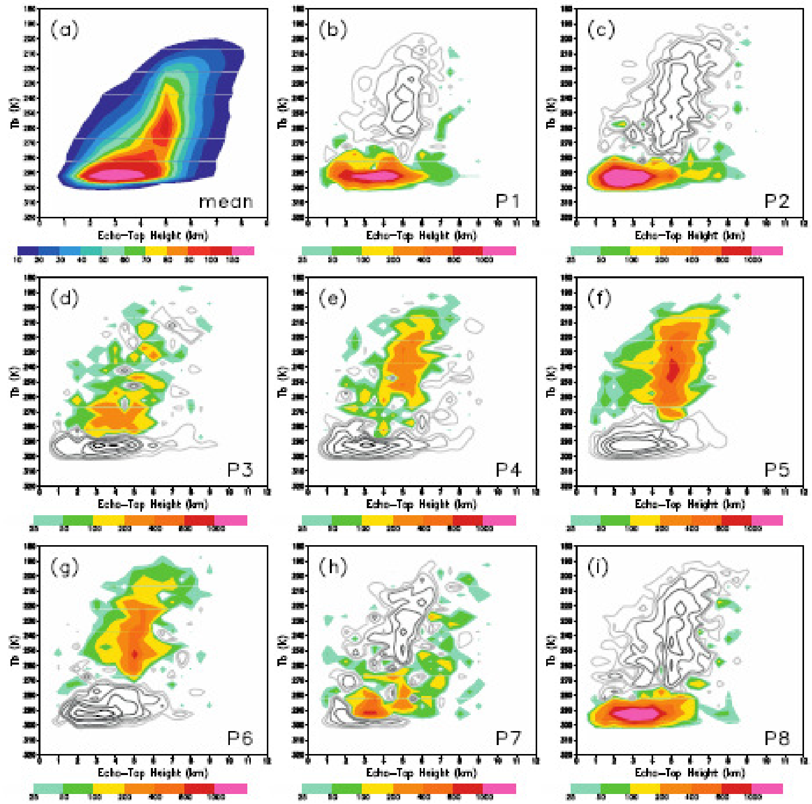
Cloud and Radiation within the MJO

CALIPSO/CloudSat cloud fraction



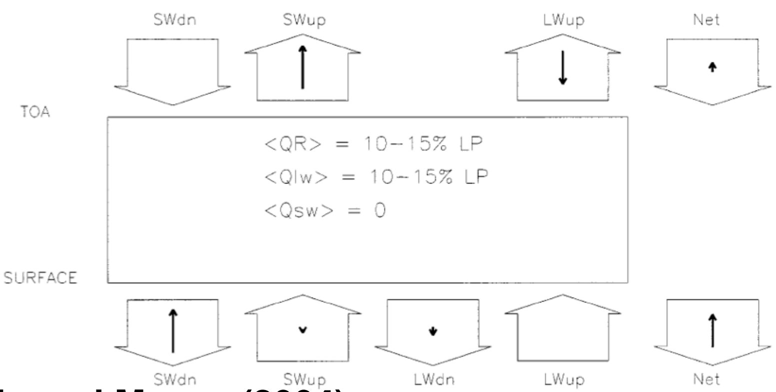
Del Genio et al. (2012)

Tb vs Echo-Top Height Histogram



Lau and Wu (2010)

Radiative budget during the MJO active phase



Lin and Mapes (2004)

Cloud and Radiation within the MJO

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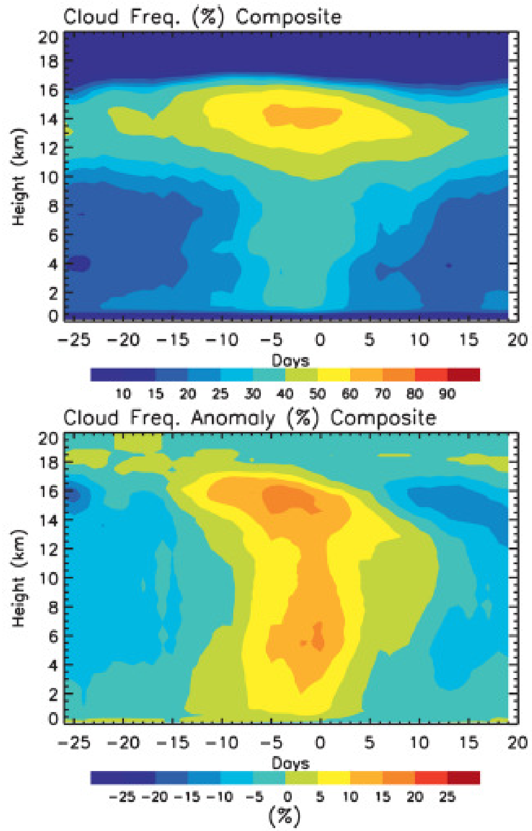

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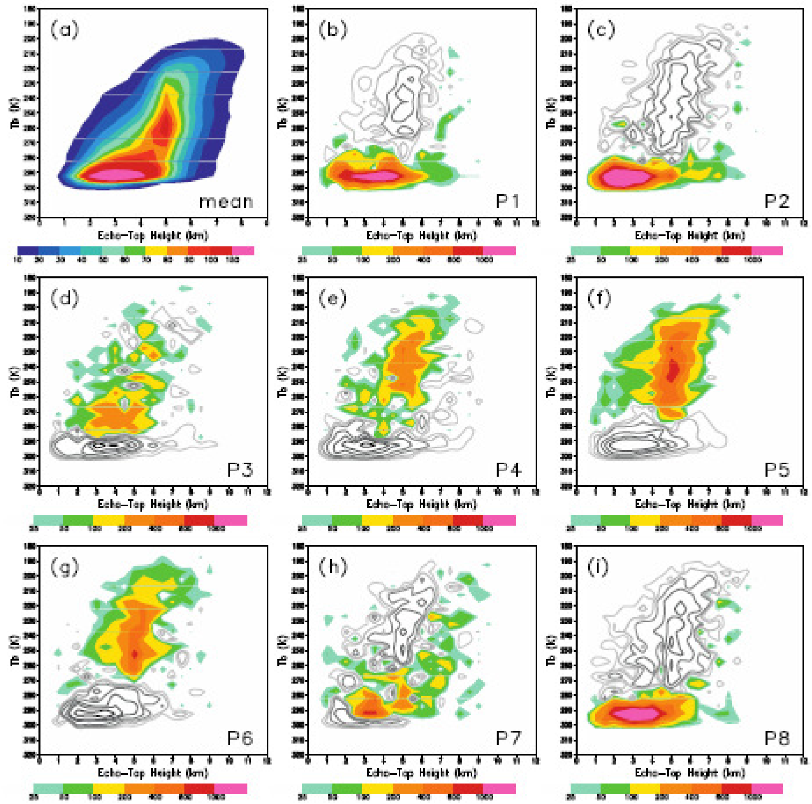

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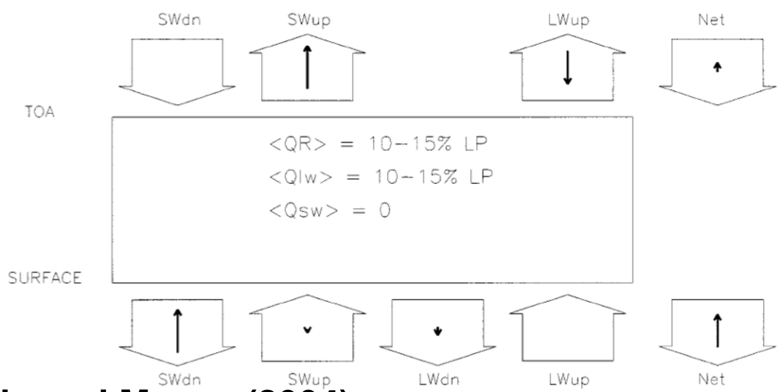


Lin and Mapes (2004)

Rationale of the present study:

- Provide an update of the MJO radiative budget, with the most recent datasets;
- Evaluate the cloud and radiative component of the MJO in the CNRM-CM5 (and other) models;
- Better understand the radiative role of clouds in the MJO.

OUTLINE

- Introduction
- Model and Datasets used
- Radiative budget of the MJO in Observations
- Evaluation of the Radiative Component of MJO in CNRM-CM5
- Radiative Convective Instability
- Conclusions

Observational and model datasets

- **Observations:**
  - **CERES data: TOA and parameterized surface fluxes [2000-2011, 1°x1°].**
  - **Combined Cloudsat/CALIPSO data [2006-2009,2°x2°].**

- **Model:**
  - **CNRM-CM5: Historical, AMIP [1979-2008].**

- **The column integrated diabatic heating**

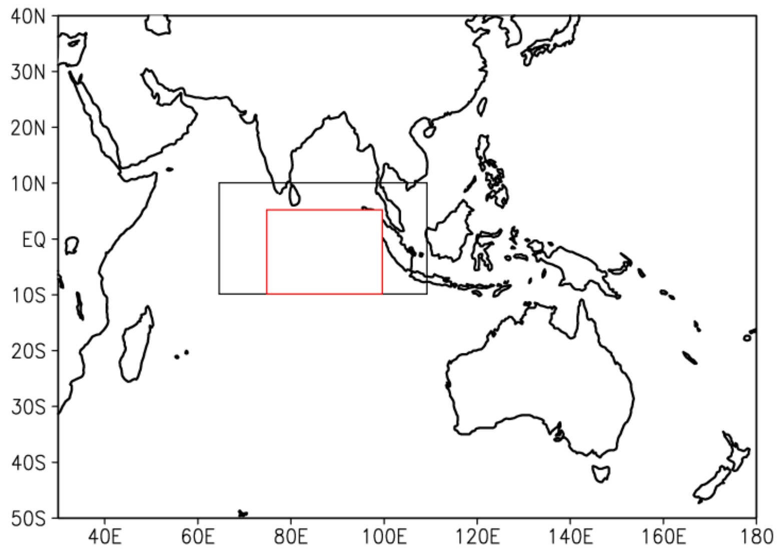
$$\langle Q_1 \rangle = \langle Q_{\text{conv}} \rangle + \langle Q_R \rangle \\ = LP + S + \langle Q_R \rangle,$$

where

$$\langle\ \rangle = \int_{p_t}^{p_s} dp$$

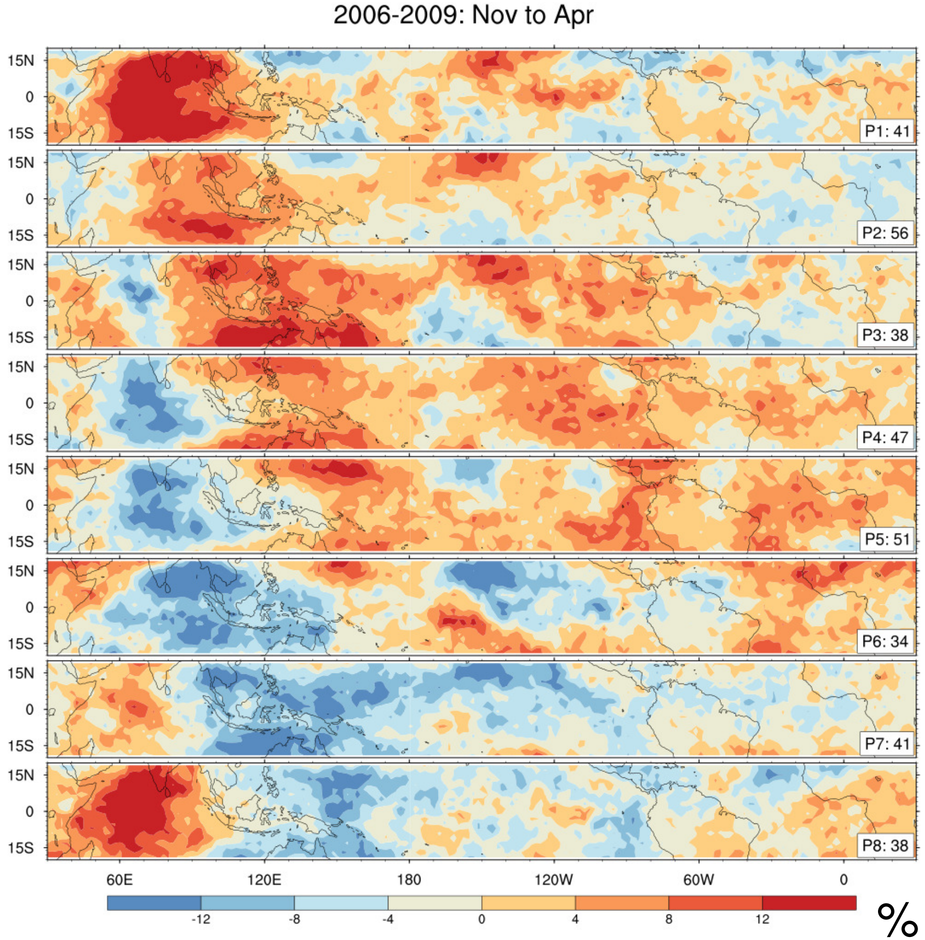
- **Region of Study:**
  - **Reference: Indian Ocean**

- **Season: Winter (NDJFM)**

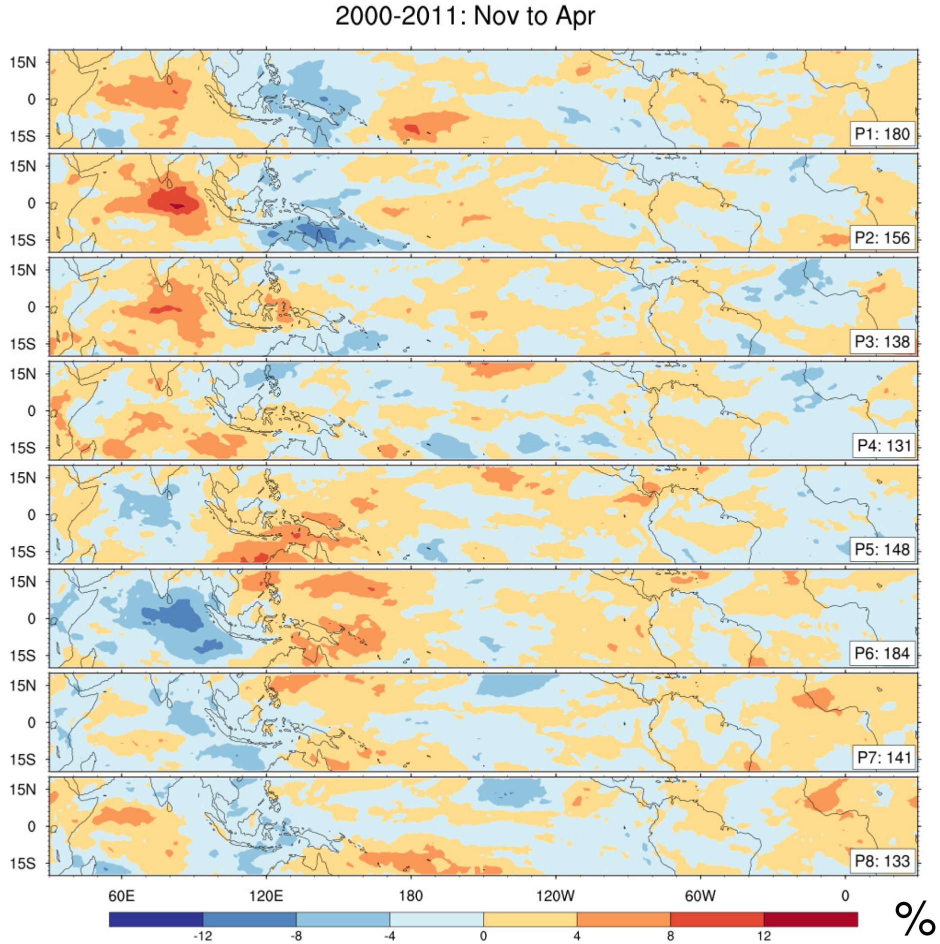


Observations: Clouds in the MJO life cycle

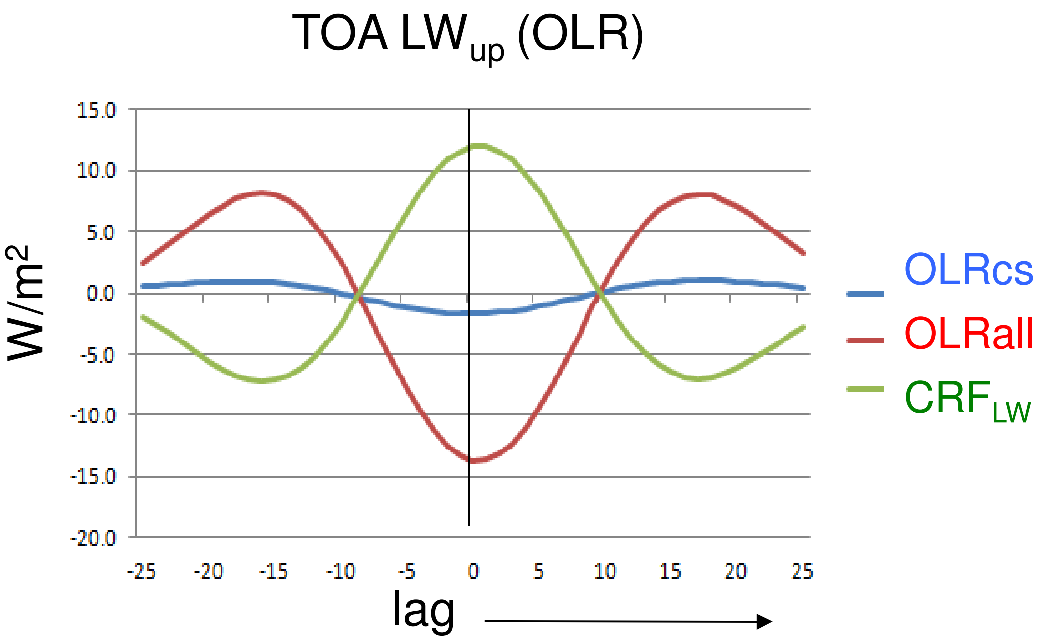
CLOUDSAT+CALIPSO TOTAL CLOUD AMOUNT

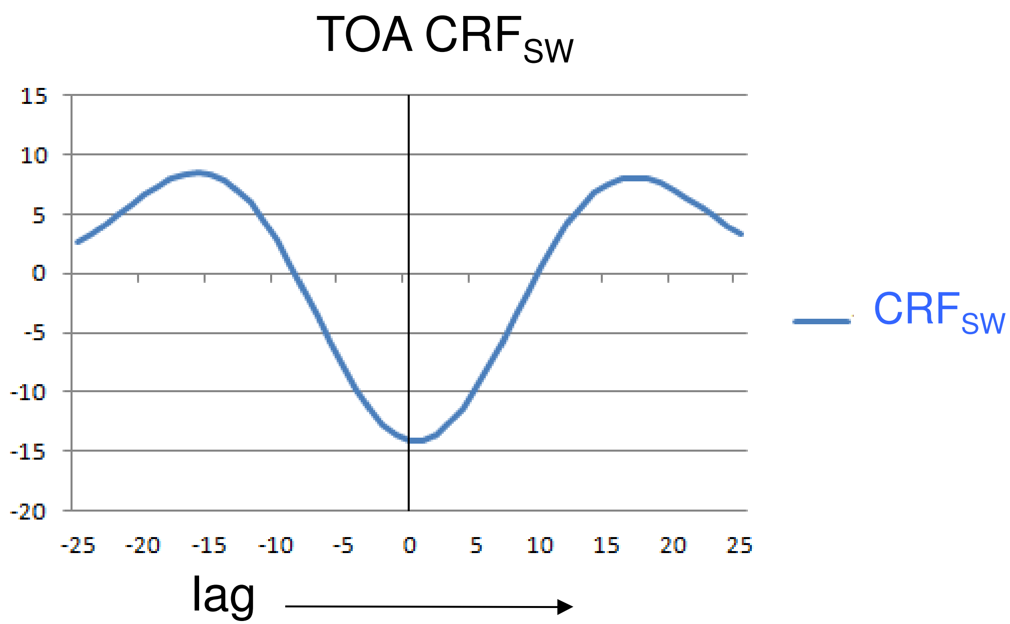


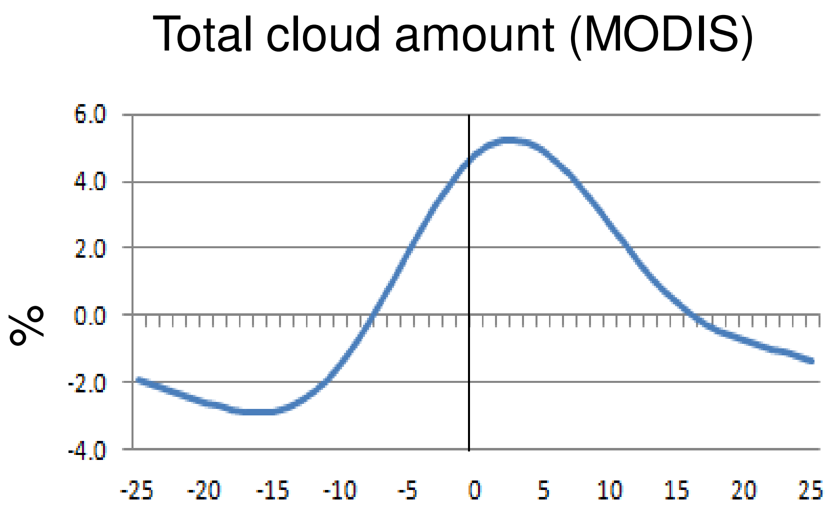
MODIS TOTAL CLOUD AMOUNT (used in CERES)



Observations: TOA radiative budget (CERES)

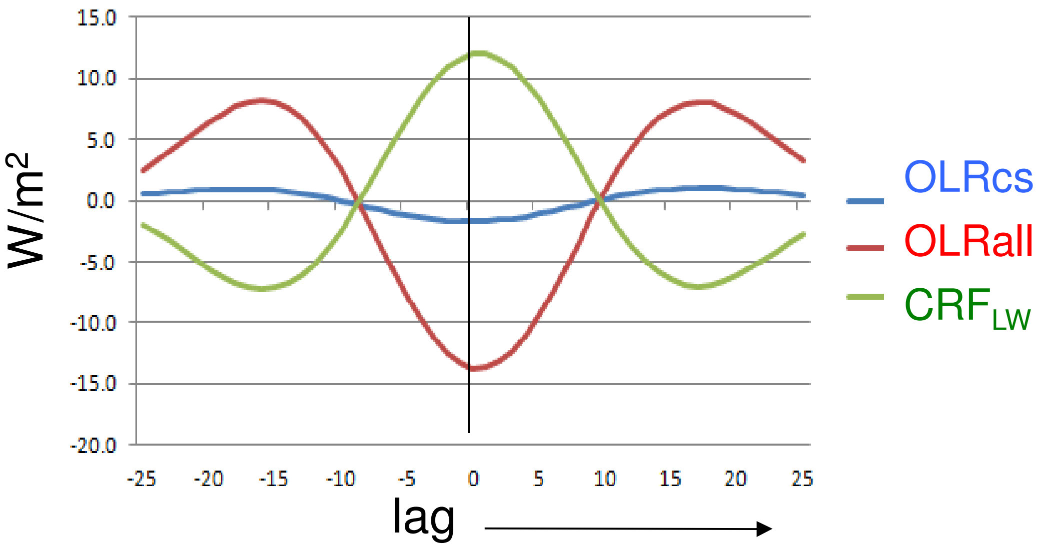




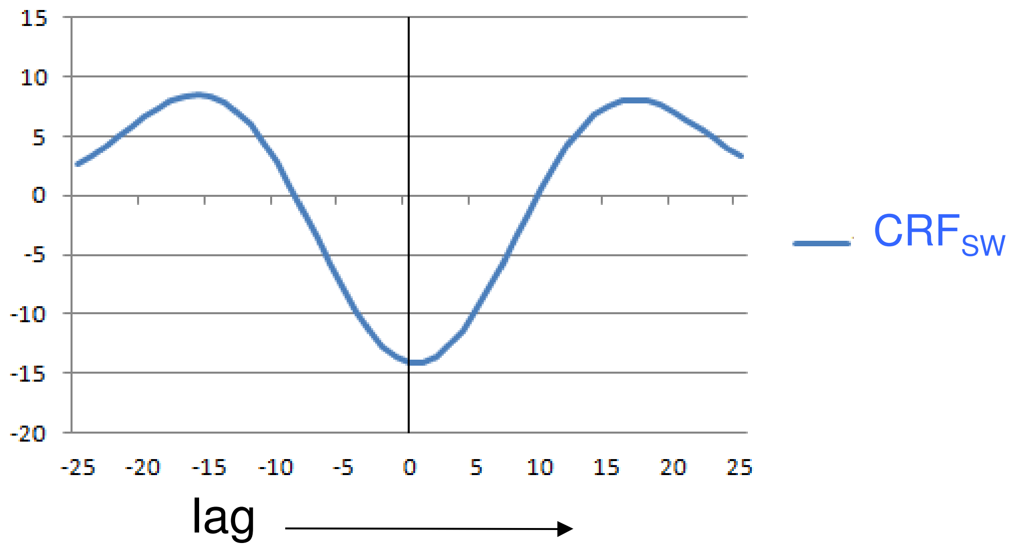


Observations: TOA radiative budget (CERES)

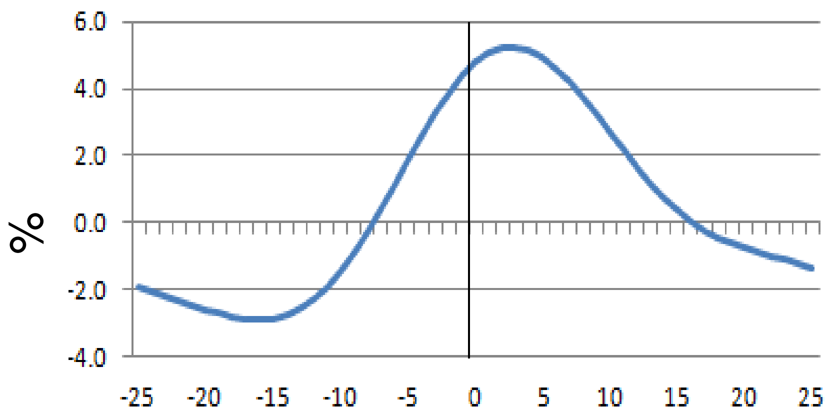
TOA LW_{up} (OLR)



TOA CRF_{SW}

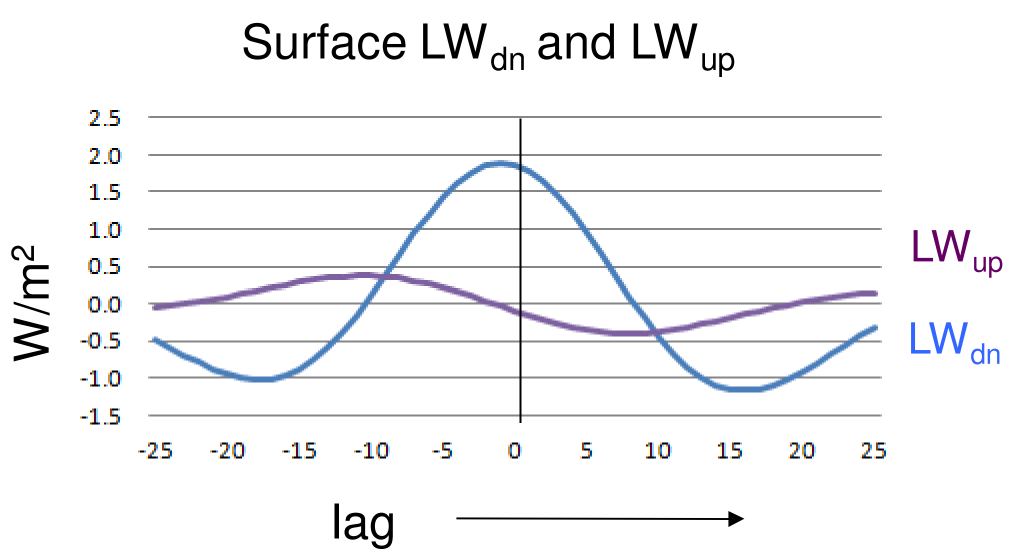


Total cloud amount (MODIS)

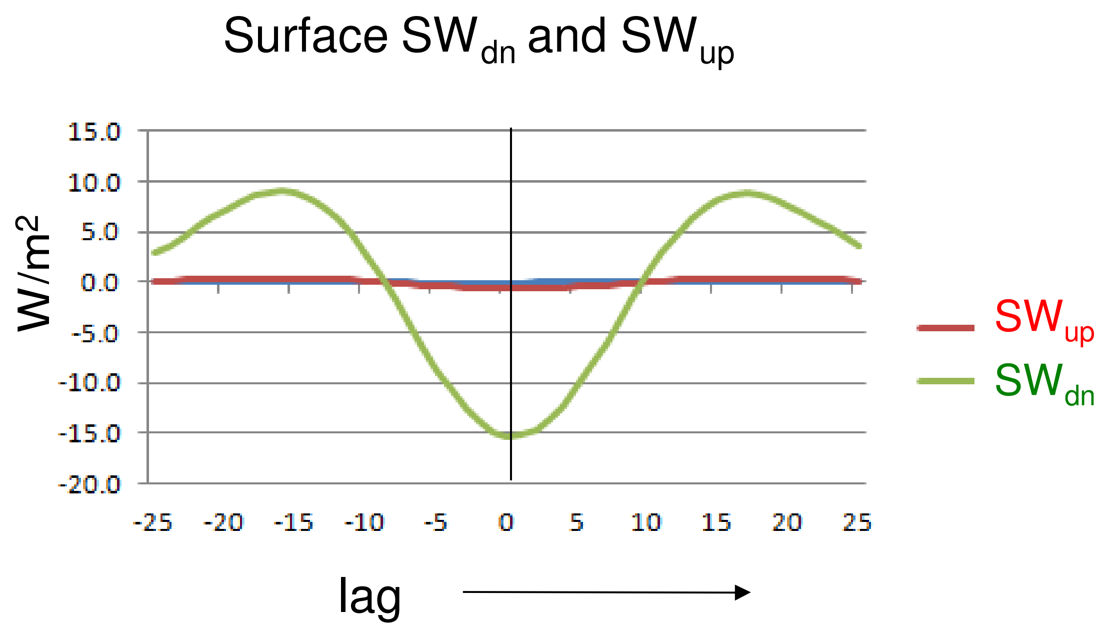


CRF_{SW} is dominant so that CRF_{net} <0 during the MJO active phase.

Observations: Surface radiative budget (CERES)



LW_{up} consistent with SST anomalies observed during the MJO (Zhang, 1996)



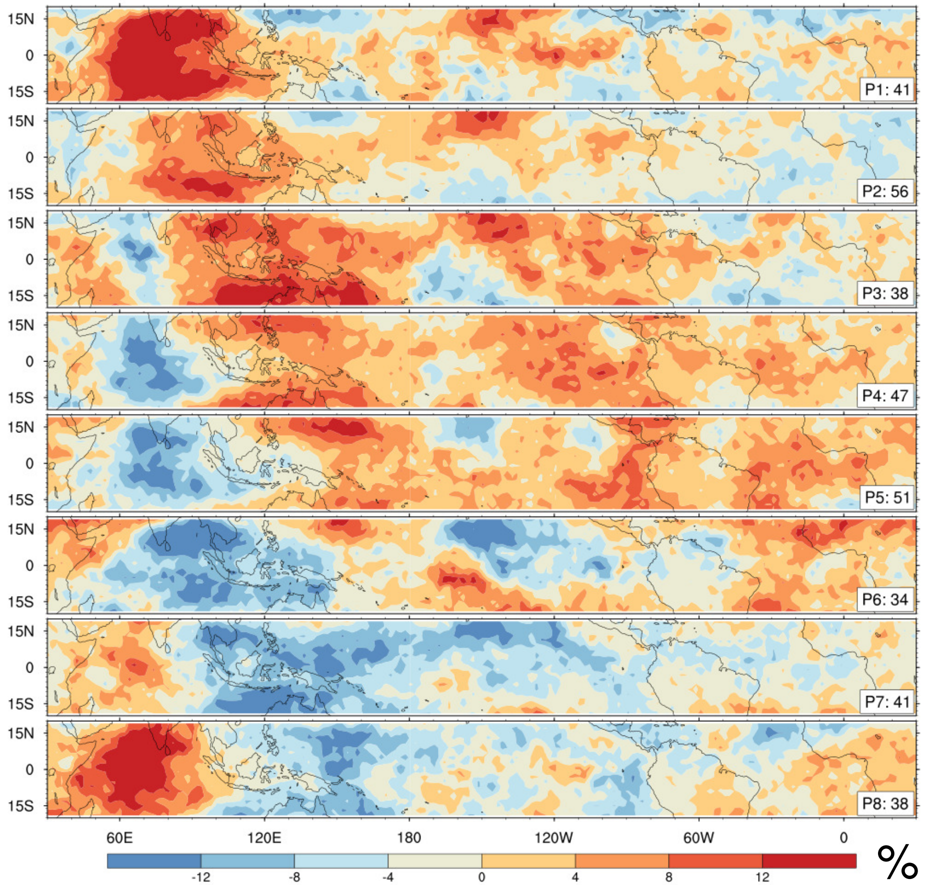
Surface budget dominated by surface SW_{dn}

MJO life cycle in CNRM-CM5 (Historical)

Total cloud amount

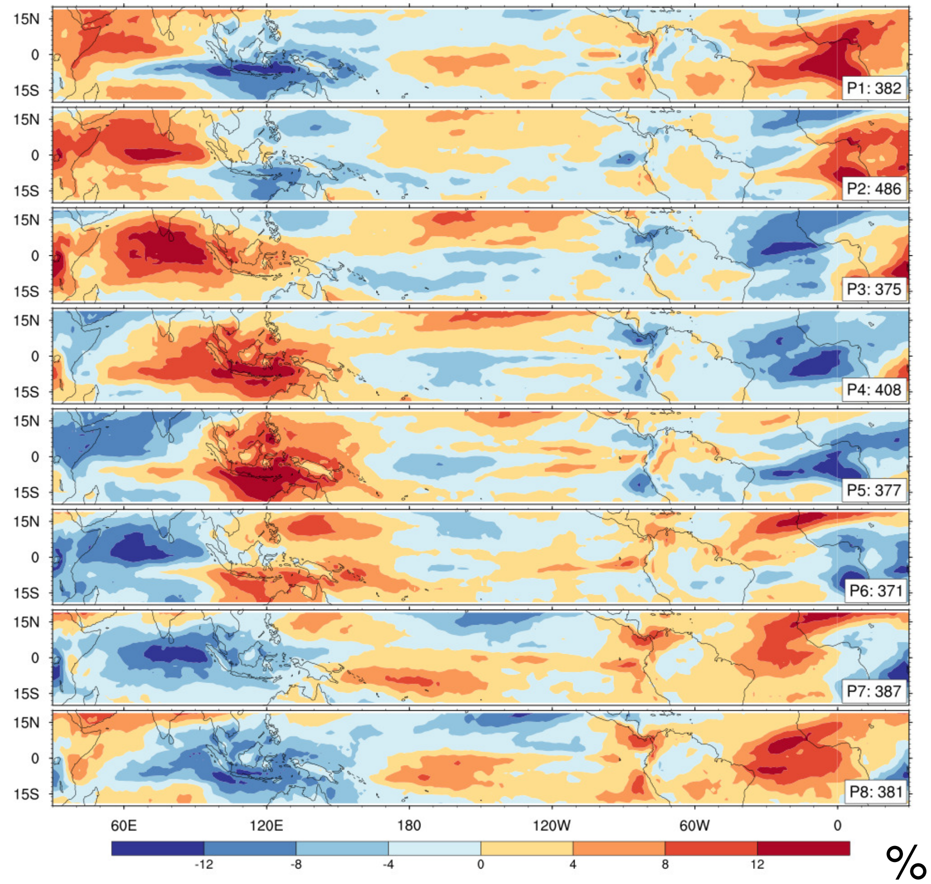
CALIPSO+CloudSat

2006-2009: Nov to Apr



CNRM-CM5

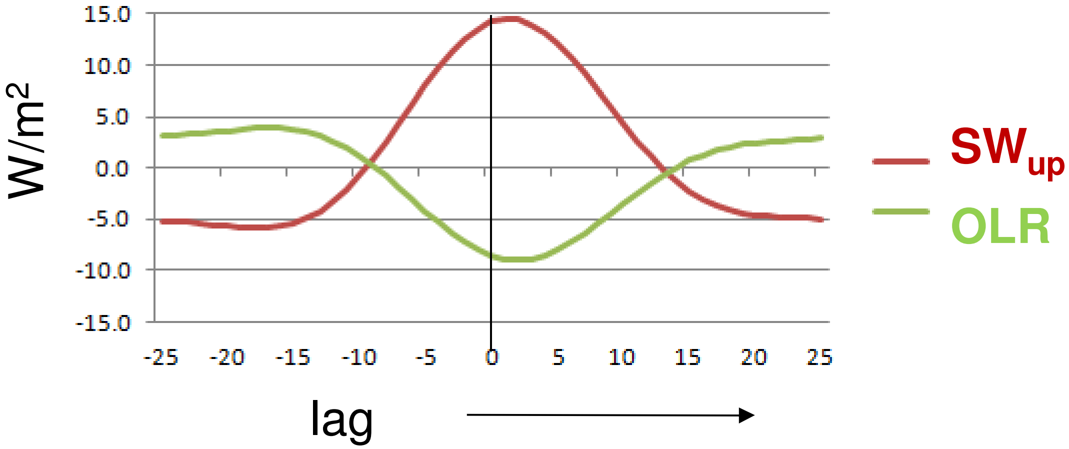
1979-2005: Nov to Apr



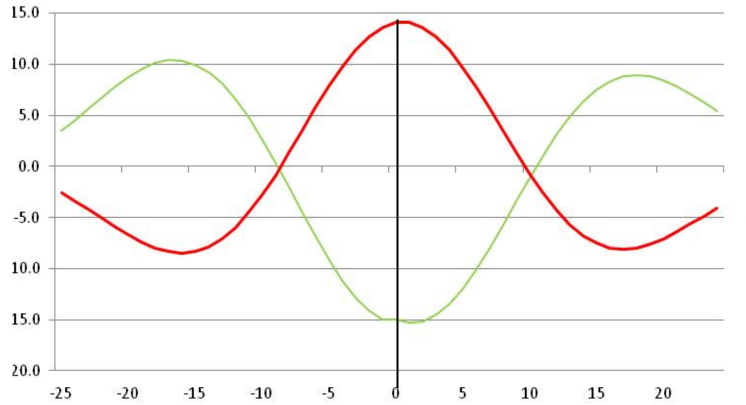
MJO TOA radiative budget in CNRM-CM5 (Historical)

TOA SW_{up} and LW_{up} (OLR)

CNRM-CM5

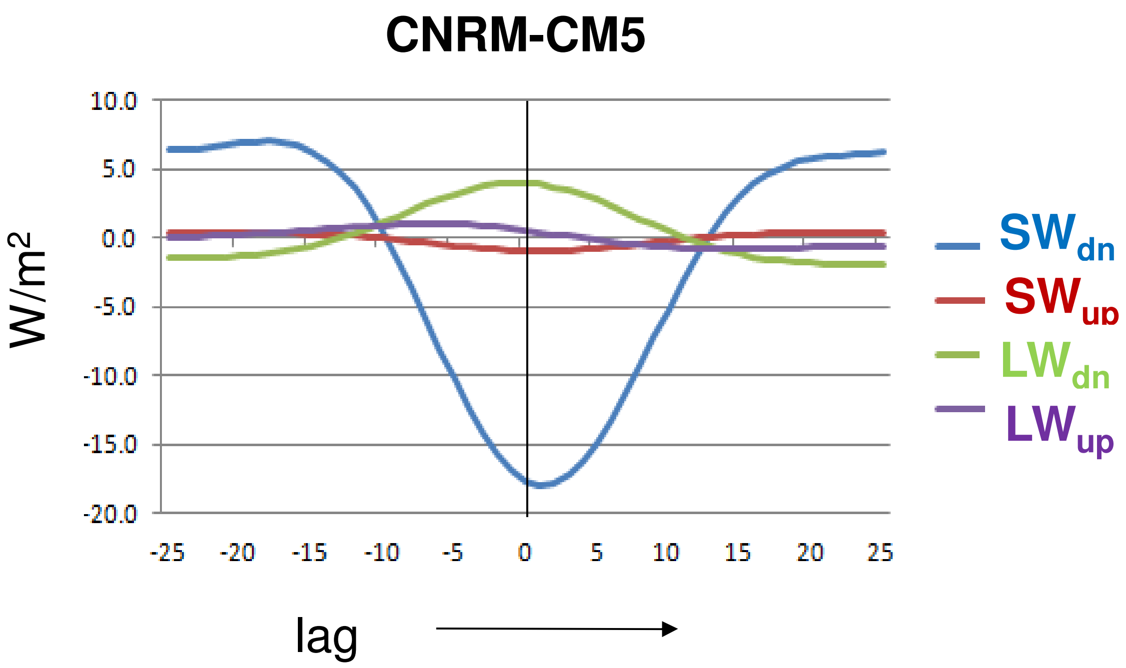


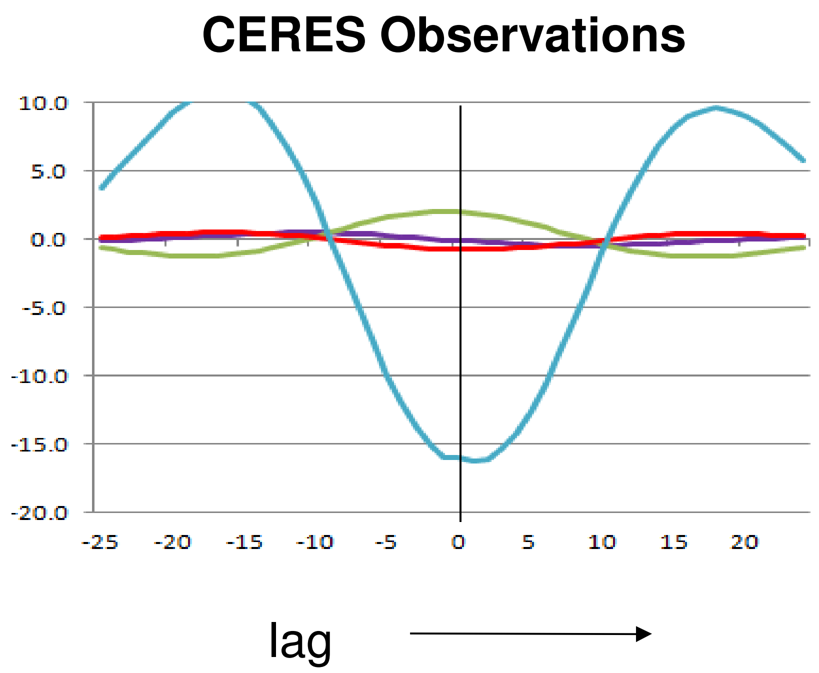
CERES Observations



MJO Surface radiative budget in CNRM-CM5 (Historical)

Surface radiative components

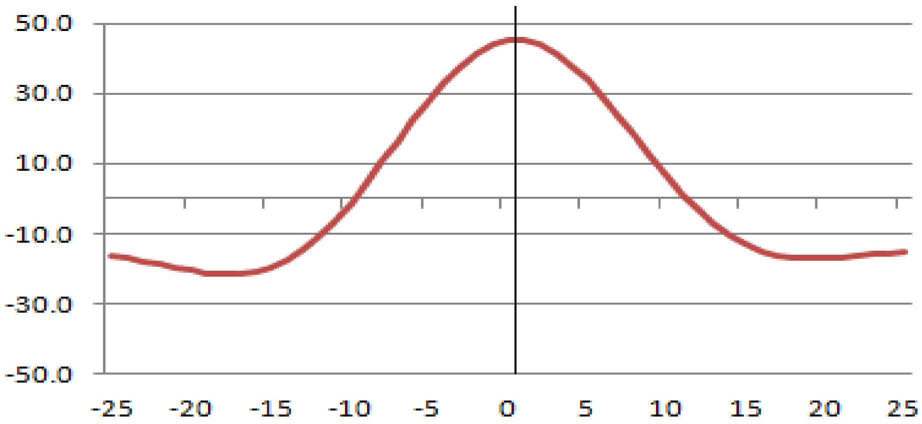




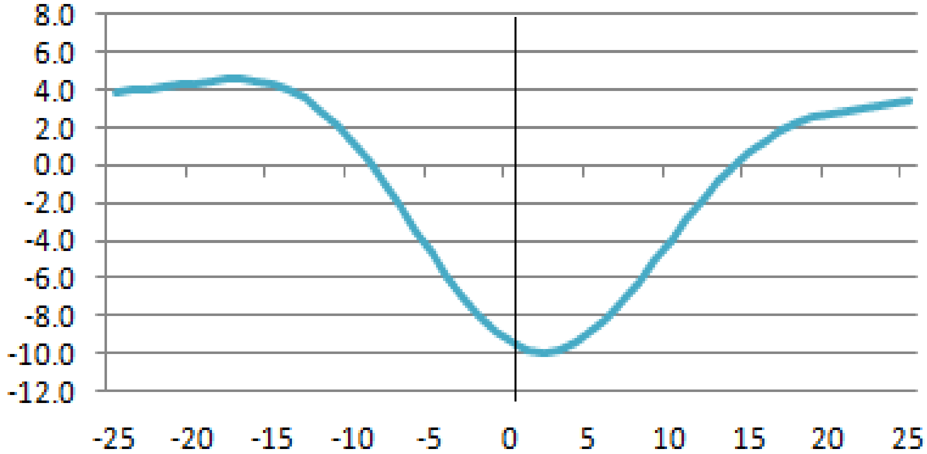
lag

MJO Atmospheric diabatic budget in CNRM-CM5 (Historical)

Convective Heating: $\langle Q_{conv} \rangle = L_v$*Precip



Radiative Heating: $\langle Q_r \rangle = Net_{TOA} - Net_{Surface}$



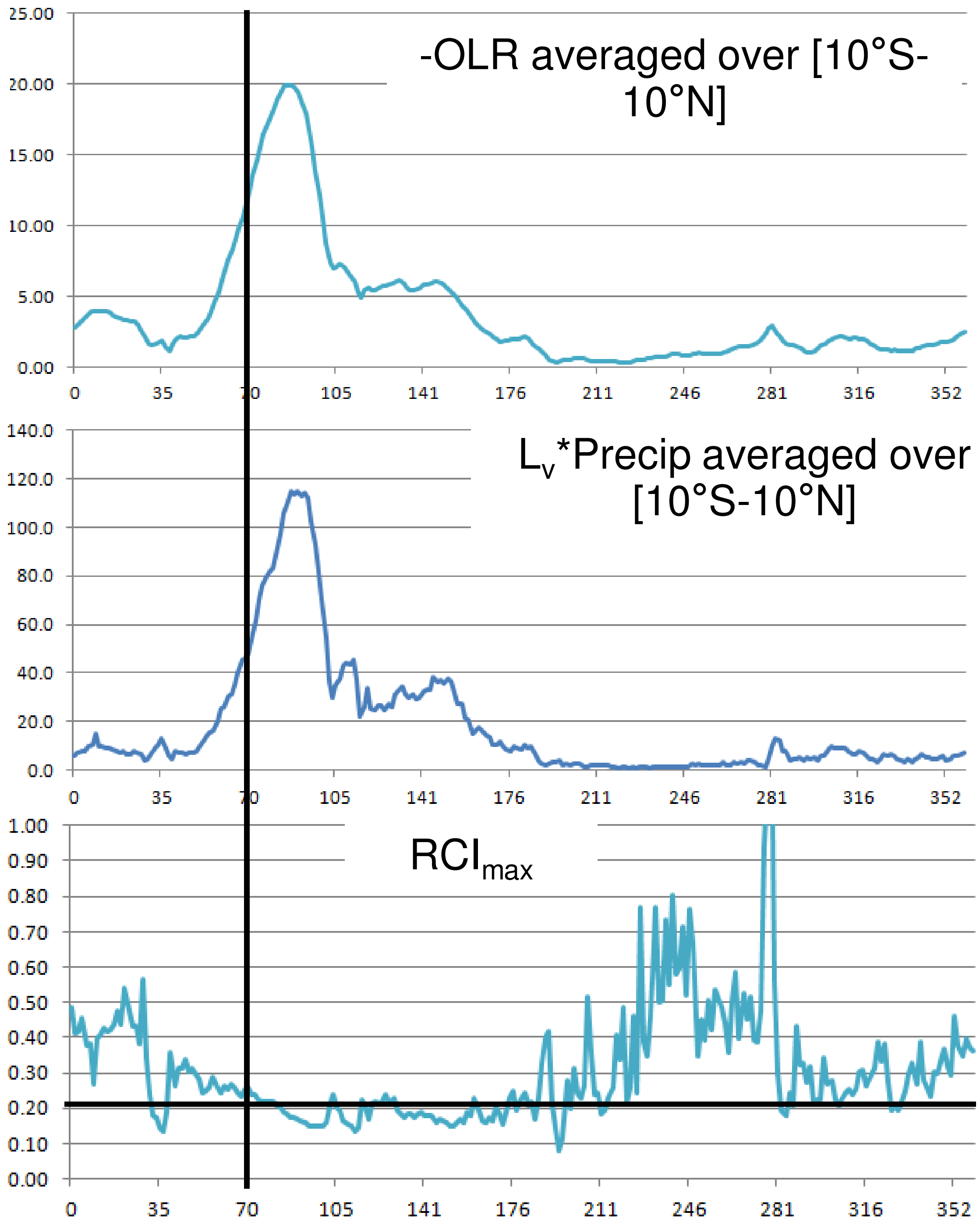
Radiative-Convective Instability

Enhancement factor

Ratio of column integrated radiative heating to column integrated convective heating [Raymond, 2001]

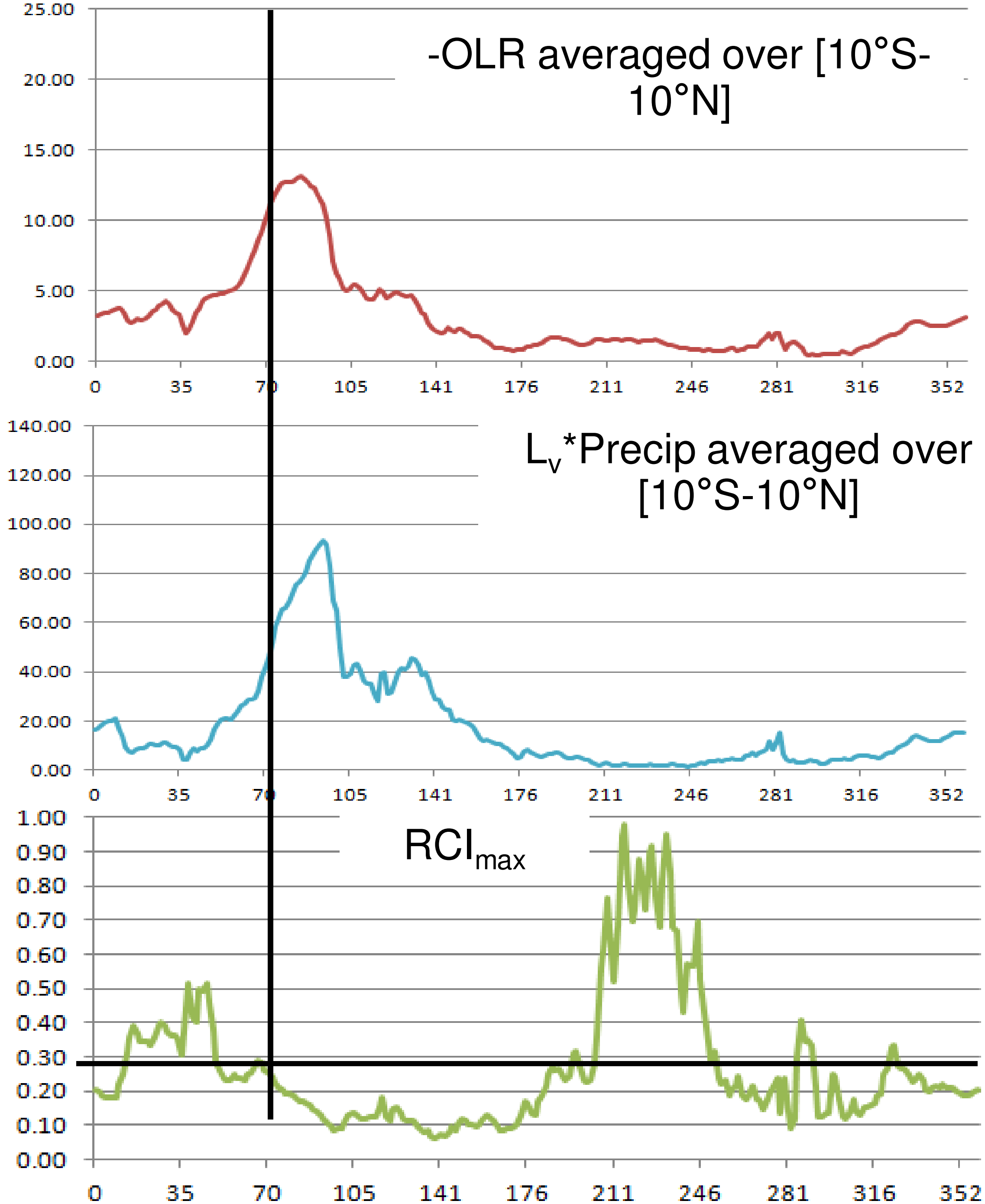
$$RCI = \frac{-\langle Q_r \rangle}{\langle Q_{conv} \rangle} \le \frac{-OLR}{L_v \times precip} = RCI_{\max}$$

Radiative-Convective Instability in the MJO: Observations



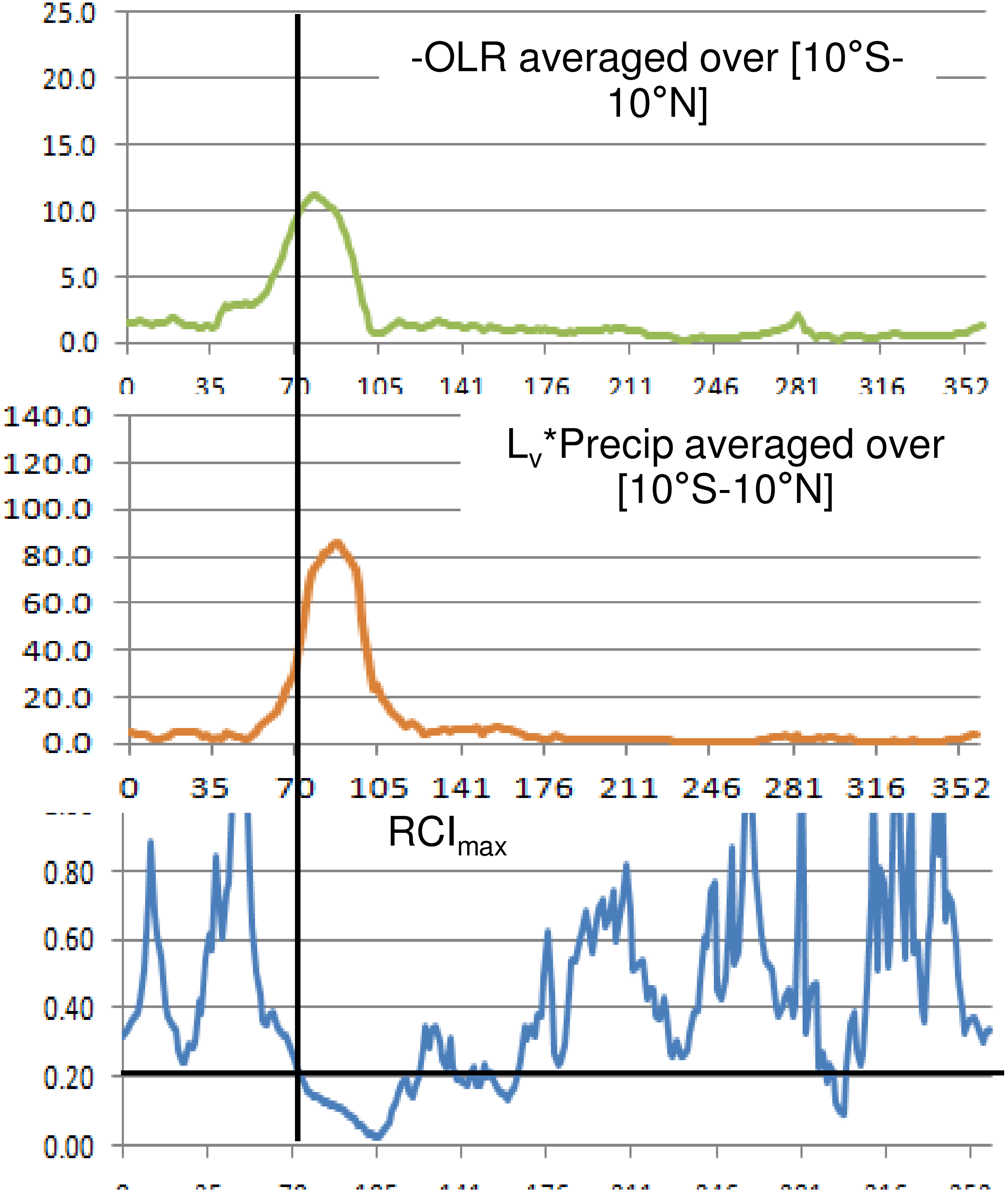
For each longitude, the values correspond to the time (lag) when MJO precipitation anomaly is maximum (Lin and Mapes 2004).

Radiative-Convective Instability in the MJO: CNRM-CM5 (Hist)



For each longitude, the values correspond to the time (lag) when MJO precipitation anomaly is maximum (Lin and Mapes 2004).

Radiative-Convective Instability in the MJO: CNRM-CM5 (AMIP)



For each longitude, the values correspond to the time (lag) when MJO precipitation anomaly is maximum (Lin and Mapes 2004).

Conclusions and Perspectives

Conclusions:

- The radiation budget analysis reveals that the radiative heating lags the convective heating by 2-3 days.
- For the TOA radiation budget, surface upwelling shortwave radiation anomalies are dominating and for the surface radiation budget, surface downwelling shortwave radiation is dominant.

- The CNRM-CM5 model, in its coupled version, is able to simulate the MJO very well compared to the observations.

- The enhancement factor which is a measure of radiative-convective instability is high in the Western India Ocean in both the CNRM-CM5 simulations and in observations.
- It seems highly overestimated in the AMIP simulation.

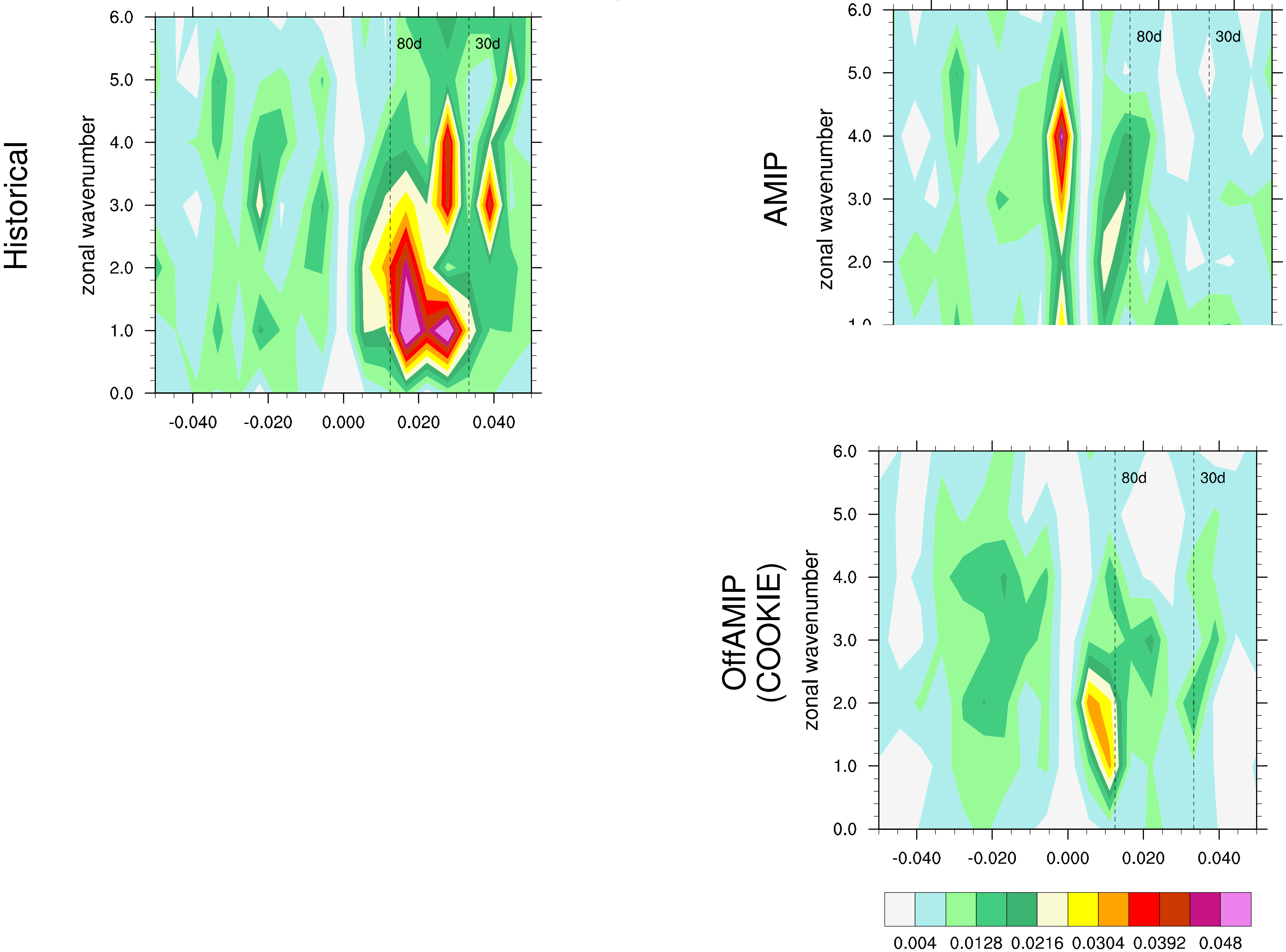
  → How does it impact the MJO simulation?

Future work:

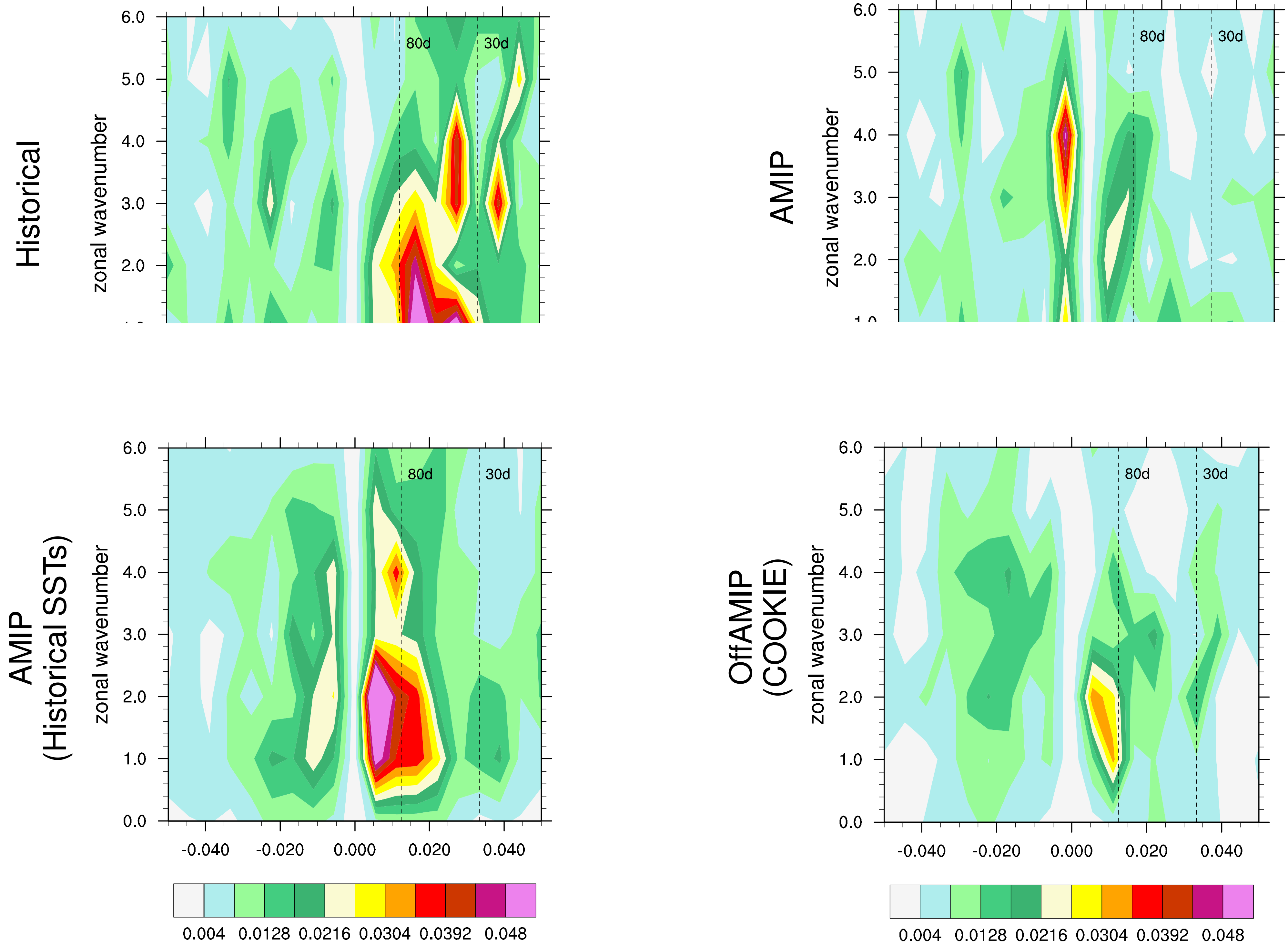
- Continue to analyze in detail the simulated cloud and radiative budget in CNRM-CM5.

- Continue to investigate the role of clouds within the MJO in particular using the COOKIE framework.

Perspectives



Perspectives



THANK YOU