Cloud Radiation Feedback in the CINDY/DYNAMO MJO events

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Introduction

The recently completed CINDY/DYNAMO field campaign observed several Madden-Julian oscillation (MJO) events in the equatorial Indian Ocean from October to December 2011. During the active phases of these events, the most prominent feature viewed from space is its extensive spreading cloud systems. These clouds dominate the transfer of solar and infrared radiation, reducing the radiative cooling of the atmospheric column. It has been argued that such cloud-radiation feedback effect has important implications on the dynamics of the MJO. We will study cloud-radiative feedback in the DYNAMO MJO events using observational analysis and cloud-resolving simulations based on the DYNAMO Northern Sounding Array, which was located mostly north of the equator in the central equatorial Indian Ocean, and experienced coherent variability in deep convection associated with two active MJO phases during late October and early November 2011 (e.g., Johnson and Ciesielski 2013).

A. Observation analysis of moist static energy for the Northern Sounding Array

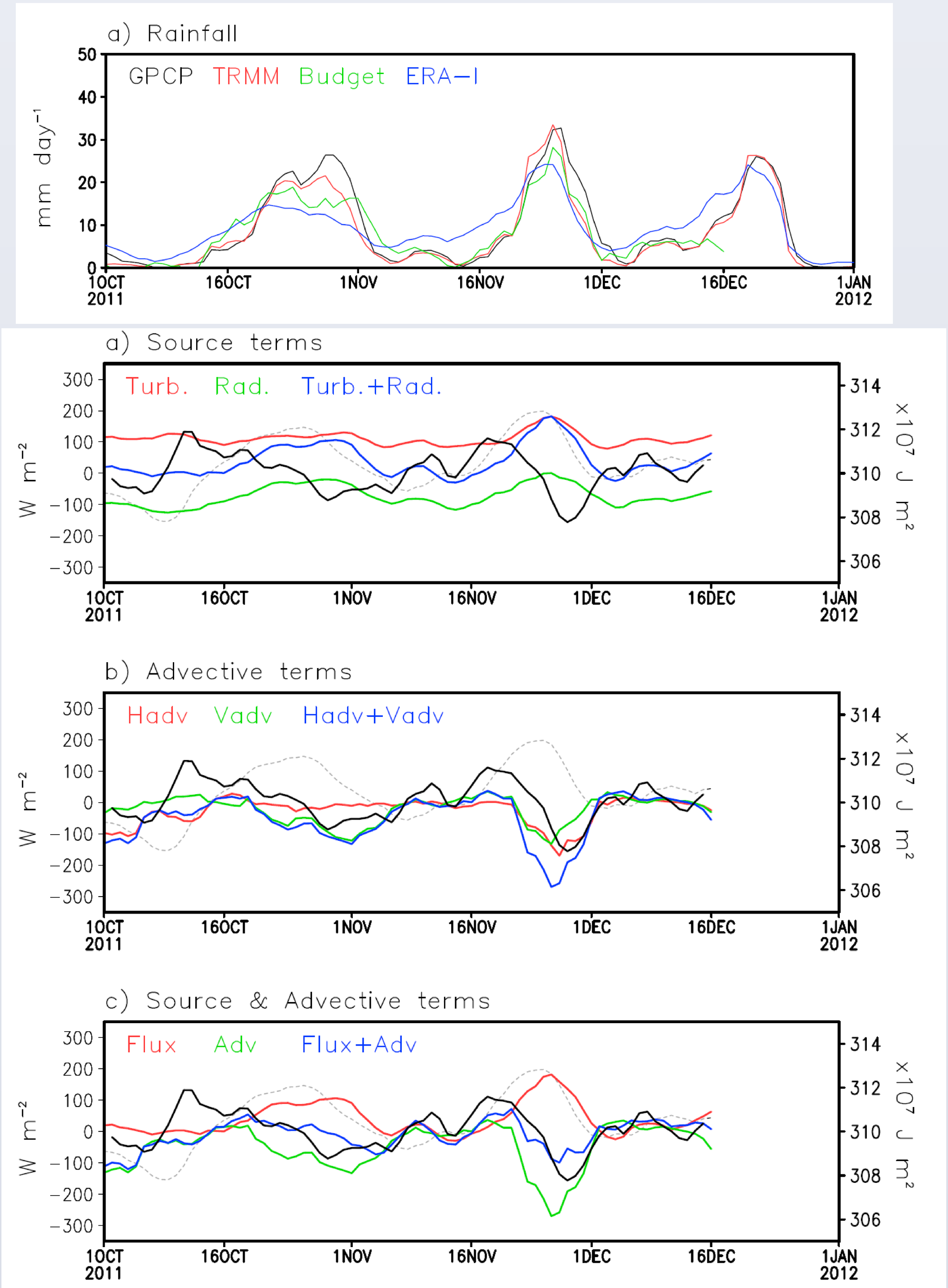
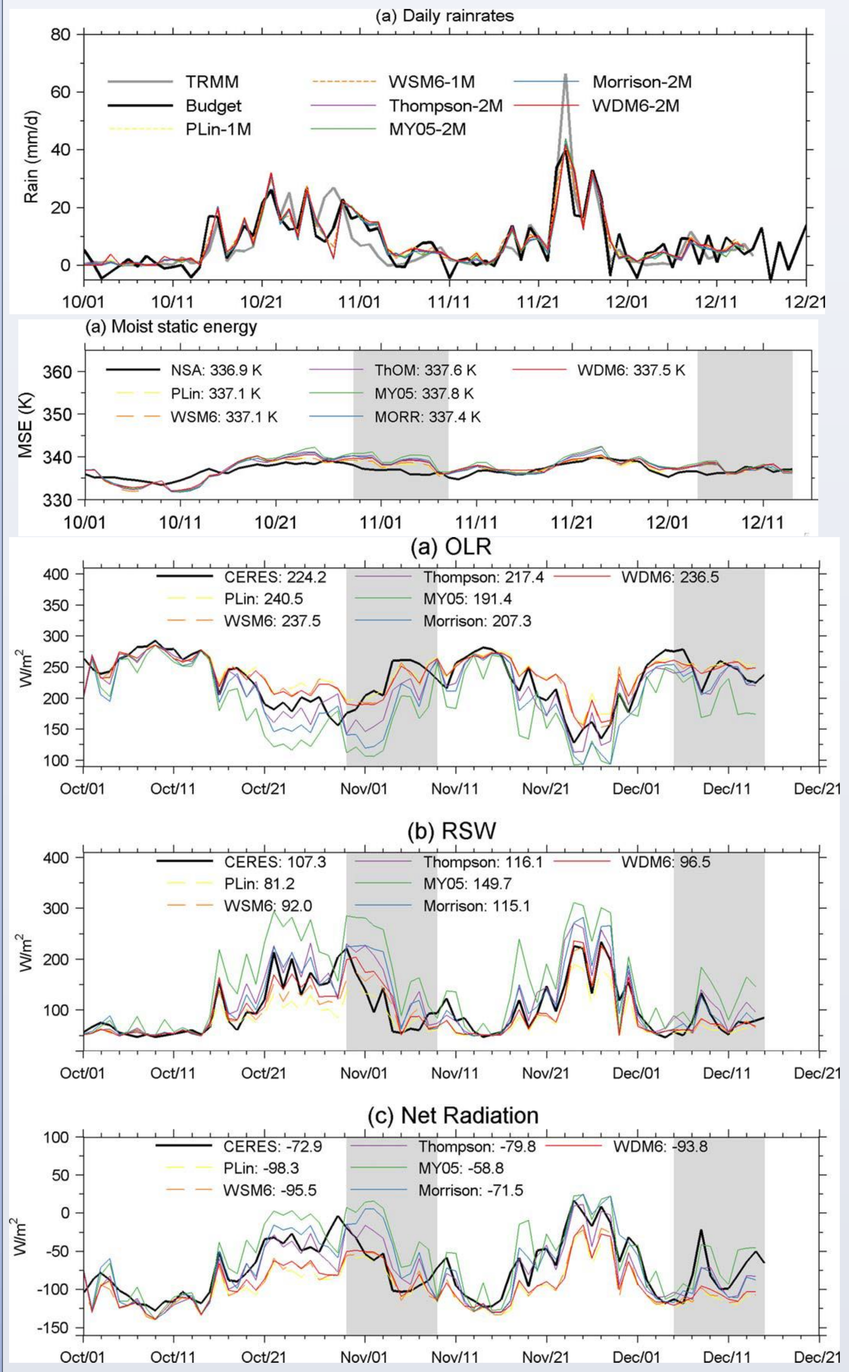


Figure 1. Top: Area-averaged (08–58N, 738–808E) time series of (a) rainfall (mm/day). (a-c)Column-integrated MSE budget terms derived from the DYNAMONSA. (a) Source terms: surface turbulent flux (red), column-integrated radiative flux (green), and their sum (blue). (b) Advective terms: horizontal advection (red), vertical advection (green), and their sum (blue). (c) Source and advective terms: sum of all source terms (red), sum of all advective terms (green), and sum of all source and advective terms (blue). All variables are 5-day moving averages. Dotted gray and solid black curves in each panel represent column-integrated MSE (with the vertical axis on the right) and its time derivatives, respectively.

- Precipitation and column-integrated MSE are approximately in phase. Radiative heating is approximately in phase with both column-integrated MSE and precipitation.
- The moist static energy anomalies associated with the MJO are maintained by radiative feedbacks associated with cloud and water vapor, with surface flux feedbacks playing a significant but perhaps secondary role.
- Vertical advection is approximately out of phase with MSE. Horizontal advection is relatively moistening in the buildup to the active phase, and drying in the later part of the active phase itself.

B. Cloud-resolving simulations with large-scale forcing

Cloud-resolving simulations driven by large-scale forcing from NSA show large discrepancy in radiative heating with different choices of microphysics.



- Numerical models: WRF v3.5.1,
- dx = 1 km,
- 256x256x22 km3. doubly-periodic.
- 6 microphysics schemes

- The 1M schemes tend to underestimate radiative flux anomalies in the active phases of the MJO events
- The 2M schemes perform better, but can overestimate radiative flux anomalies.

Figure 2. Precipitation, column-integrated MSE, OLR, RSW, and net radiative heating from the CRM.

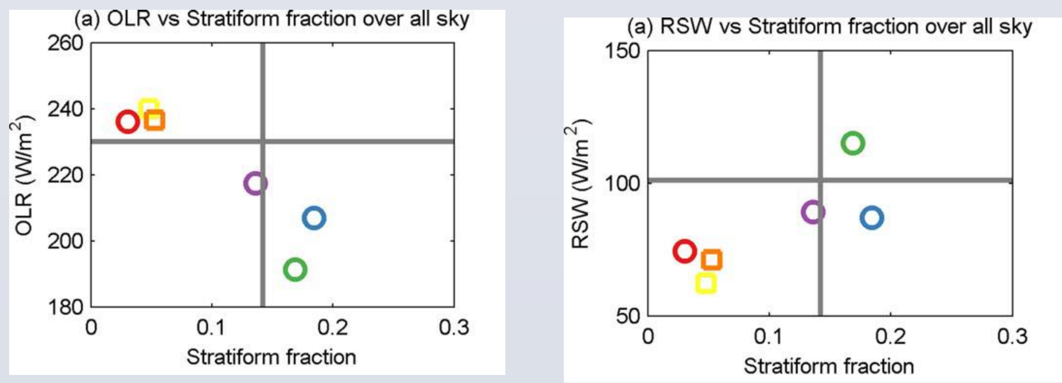
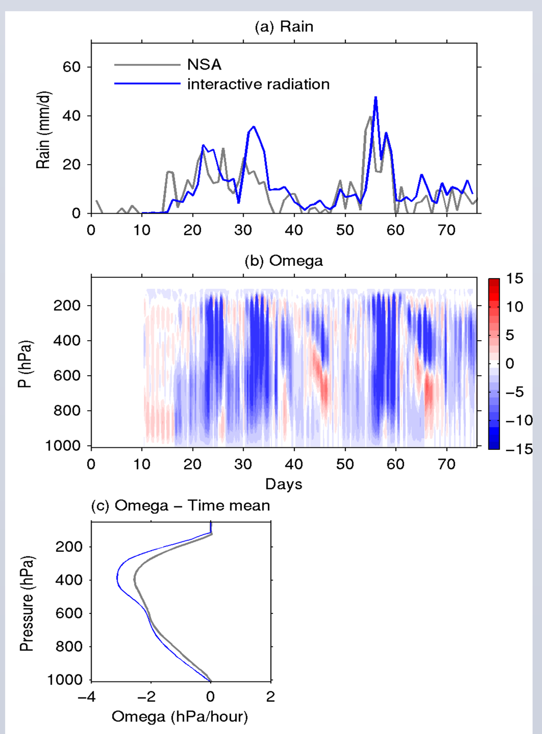


Figure 3. (a) Stratiform area fraction versus domain-averaged OLR. (b) Stratiform area fraction versus domain-averaged RSW at local time 11 A.M.

C. Simulations with parameterized large-scale dynamics

Three methods have been tested: Weak temperature-gradient (WTG , Sobel and Bretherton 2000, Raymond and Zeng 2005), a modified spectral WTG (Hermann and Raymond 2015), and damped-gravity-wave approach (Blossey et al. 2009, Kuang 2011, Romps 2012 a and b). Results from SWTG show better agreement with observation.



- Results from the SWTG simulation with fully interactive radiation

Figure 4. a) precipitation, b) large-scale pressure vertical velocity, and c) time-mean large-scale pressure vertical velocity compared to that derived from the sounding observations.

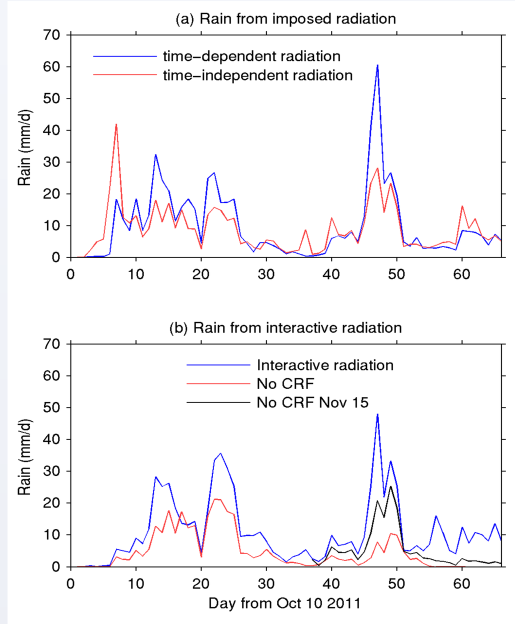


Figure 5. (a). Daily rain rates from the two simulations with (a) imposed time-dependent radiation (blue) and imposed time-independent radiation (red); (b) as (a), but with interactive radiation (blue), radiation scheme without CRF (red, cloud fields are not used in the computation of optical thickness), CRF switches off from Nov 15.

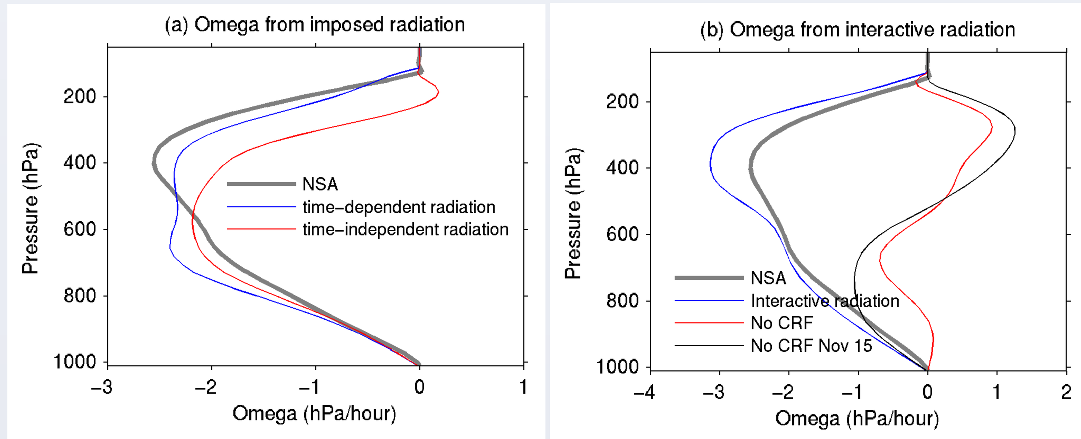
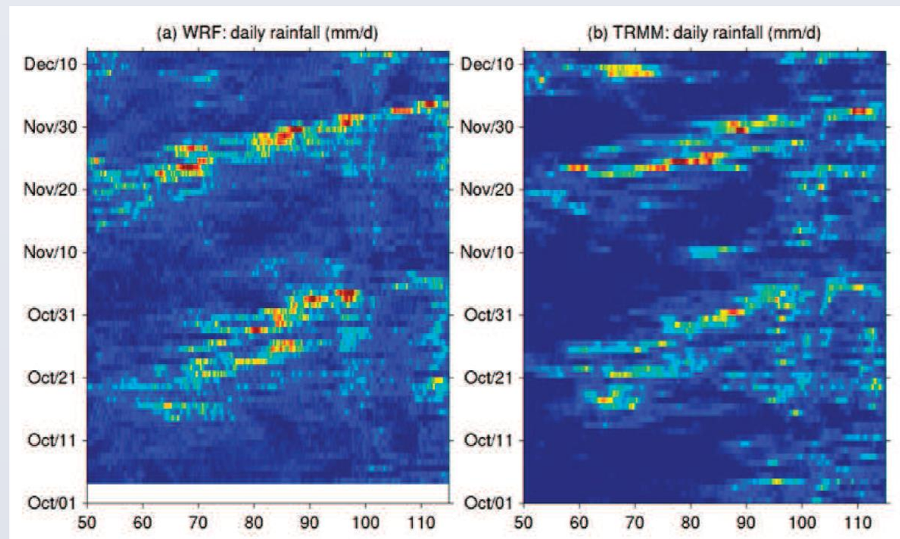


Figure 6 Time averaged pressure velocity.

D. Regional simulations of the MJO events



- WRF, dx = 9km
- No convective parameterization

Figure 7 Daily surface precipitation (mm day21) from (a) WRF and (b) TRMM averaged over the latitudes 0–5N.

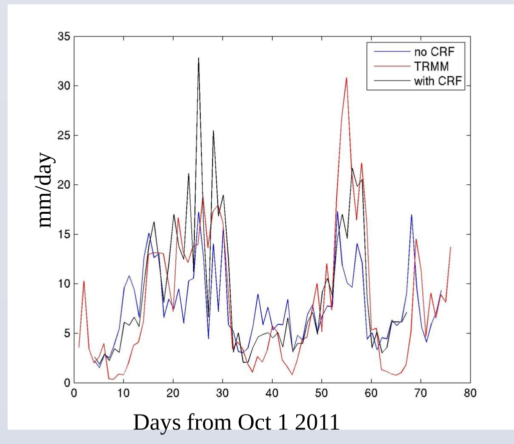


Figure 8 Rain at NSA from TRMM, simulations with and without cloud-radiation feedback

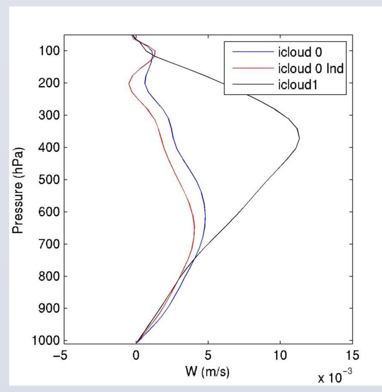


Figure 9 Time mean W.

Conclusion

1. Cloud-radiative feedback:
- Significant source of moist static energy anomalies.
- Important source of uncertainty in numerical models even with state-of-the-art microphysics

2. CRM simulations with convection-circulation interaction indicates that cloud-radiative feedback significantly amplifying the MJO. This is also confirmed by regional simulations

References

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