# Radiative Heating Rate Estimates for AMIE/DYNAMO/CINDY

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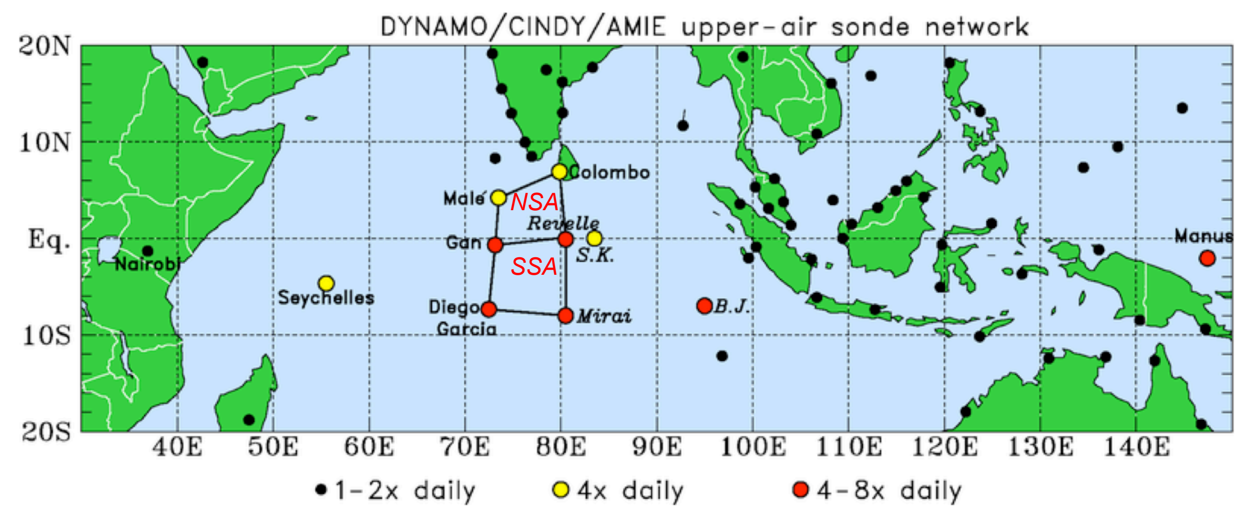
## Introduction

The ARM MJO Investigation Experiment (AMIE) field campaign, along with companion projects DYNAMO and CINDY, was carried out in the Indian Ocean to study atmosphere and ocean processes associated with the initiation of the Madden-Julian Oscillation (MJO). Here we report radiative heating rate estimates from heat and moisture budgets, comparison with PNNL CombRet (Feng et al. 2014) and CERES (Wielicki et al. 1996) products, and an assessment of the possible role of radiative-convective instability in the October and November MJOs.



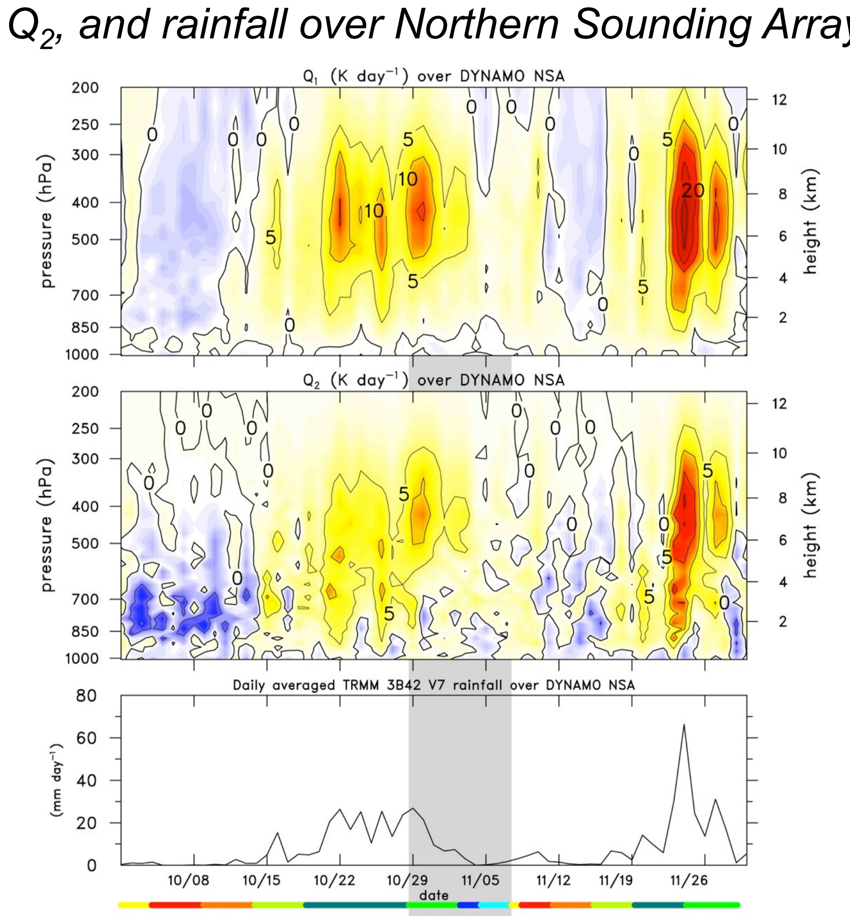

Column net radiative heating rates are computed for the northern and southern sounding arrays (NSA and SSA, respectively, depicted above) as a residual from

$$\langle Q_R \rangle = \langle Q_1 \rangle - \langle Q_2 \rangle - S_0 - LE_0$$

where $S_0$ and $LE_0$ are the surface sensible and latent heat fluxes from TropFlux and angle brackets indicate integrals through the depth of the troposphere.

## Time series of $Q_1$ and $Q_2$ for NSA

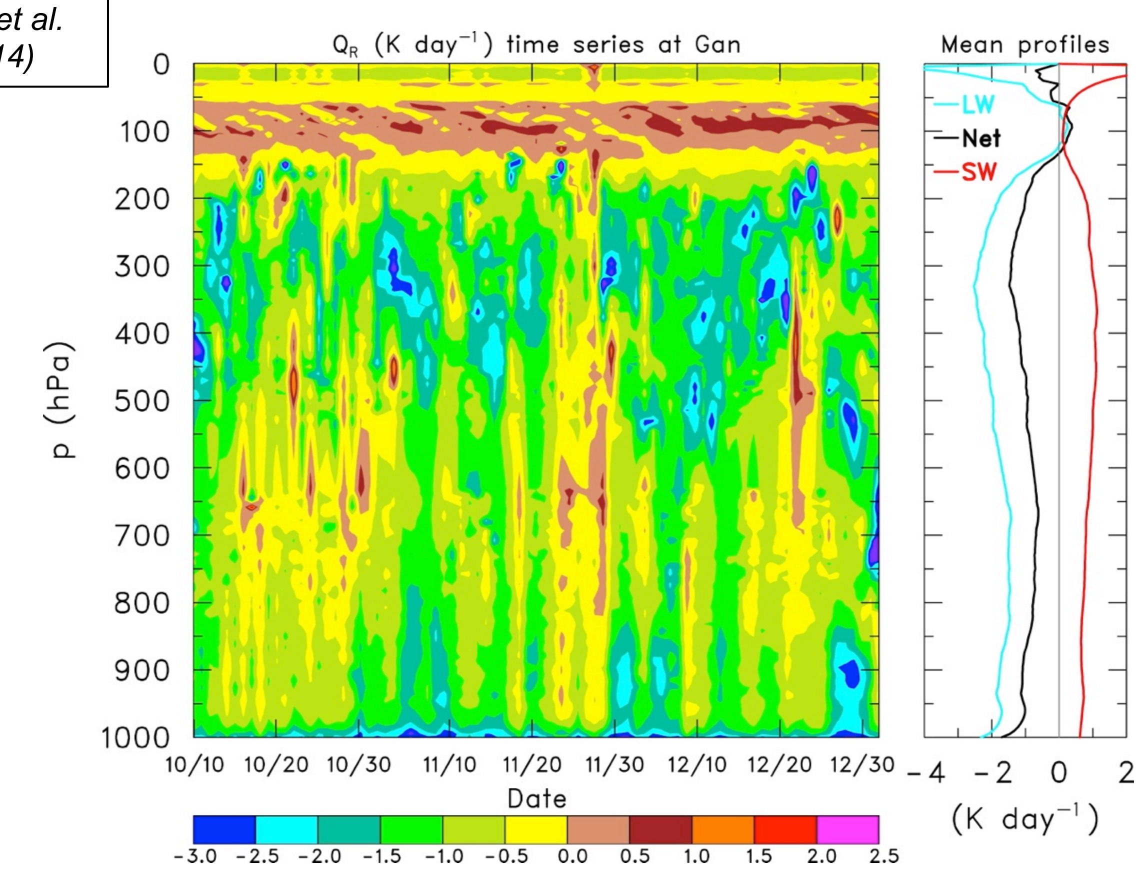
*$Q_1$, $Q_2$, and rainfall over Northern Sounding Array NSA)*




*Time series of $Q_1$ and $Q_2$ for NSA, TRMM 3B42 rainfall and Wheeler-Hendon MJO Index (bottom color bar). Shading denotes time when R/V Revelle was off station (from Johnson et al. 2015).*

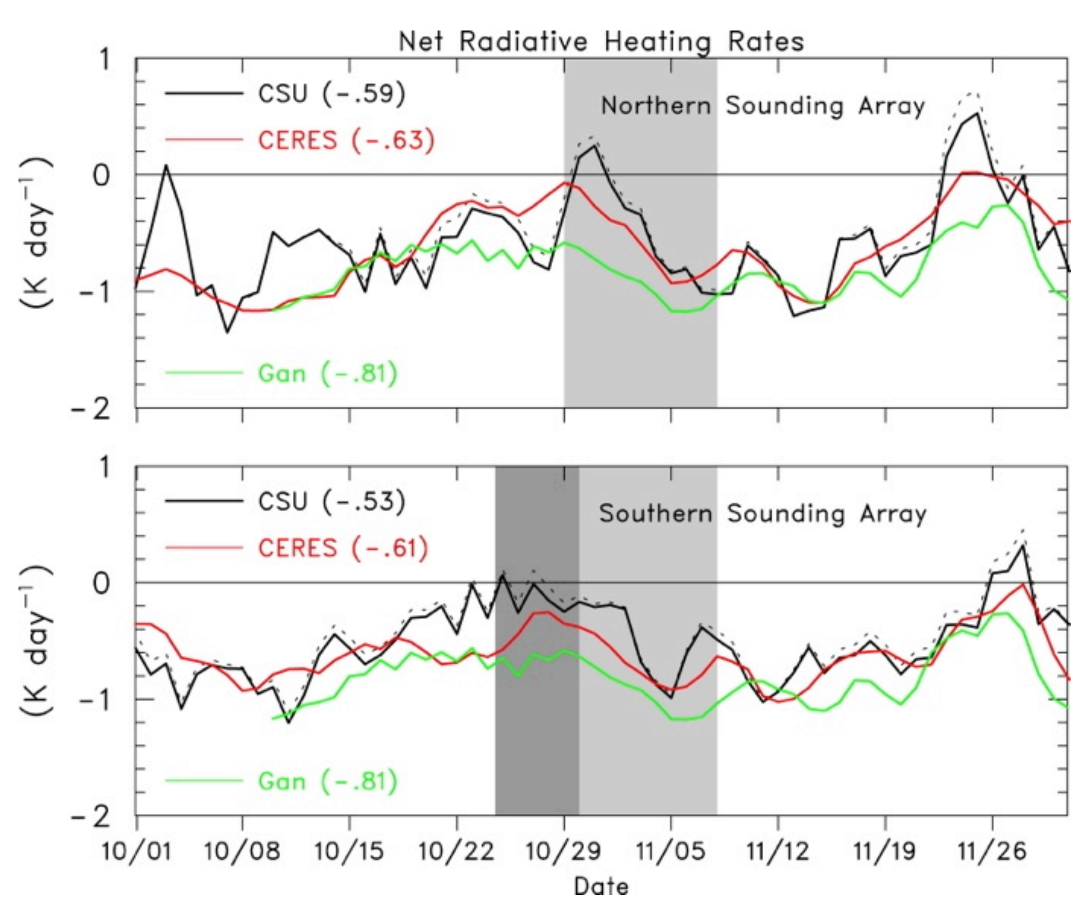
- Northern array sounding network captures prominent signals of heating/drying associated with active phases of each MJO
- Inferred evolution of dominant convective modes for both MJOs: shallow, non-precipitating clouds to congestus to deep convection to stratiform precipitation
- Shorter duration of each convective mode for November MJO than October

## Radiative heating rates at Gan Island from CombRet




- Net radiative cooling in mid-troposphere reduced, even reverting to warming at times, during active phases of MJOs
- Cooling in upper troposphere, though likely overestimated due to undersampling of cirrus by instrumentation on Gan Island

## Comparison of $\langle Q_R \rangle$: budgets and other products




- Net tropospheric cooling significantly reduced during active phases of MJOs
- Temporal variability in qualitatively good agreement among all products
- Experiment-mean values of $\langle Q_R \rangle$ for sounding arrays (numbers in parentheses) in good agreement for CSU budgets and CERES; value from CombRet for single site (Gan Island) shows greater cooling, probably due to undersampling of cirrus

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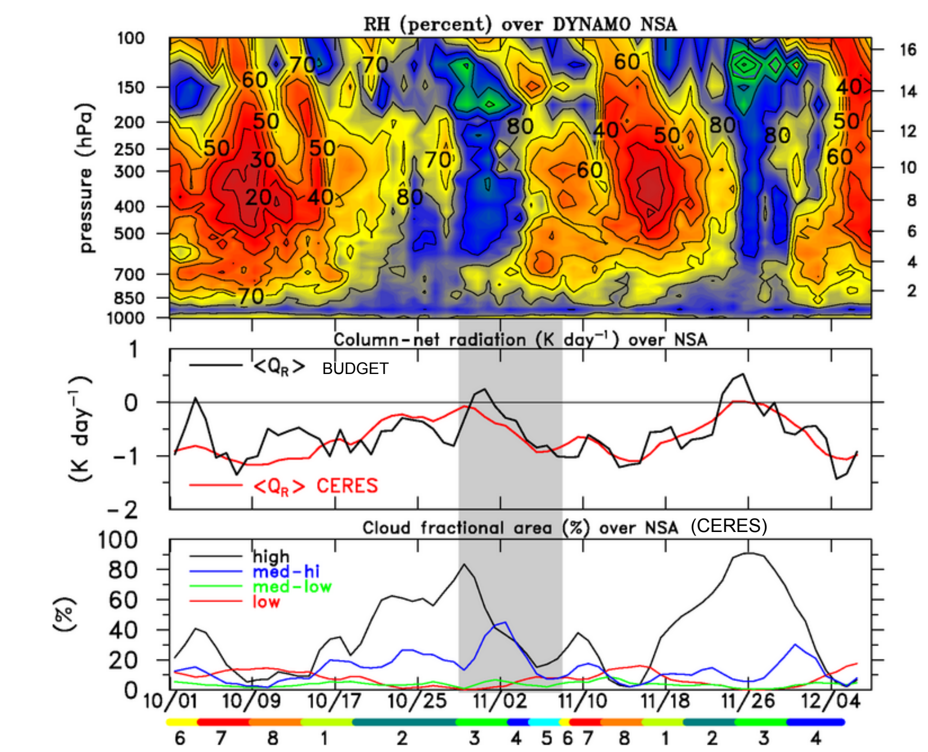
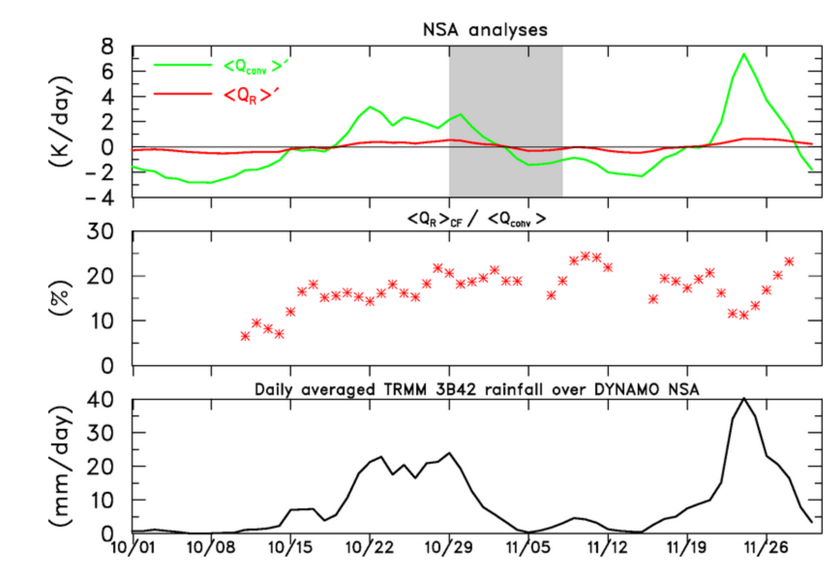
## Implications for radiative-convective instability

*Relative humidity, net tropospheric radiative heating rate $\langle Q_R \rangle$, cloud cover*




- Time series of $\langle Q_R \rangle$ from budgets and CERES repeated (middle panel)
- Arrival of cirrus (high cloud fraction) prior to active phases of MJOs (also seen in RH time series) accompanied by reduction in net radiative cooling

*Relationship between latent heating and $\langle Q_R \rangle$*




- Cloud radiative forcing is ~20% of convective heating
- Value is of comparable amplitude to normalized gross moist stability (NGMS) (Sobel et al. 2014) ➡ possible role of cloud-radiative instability in MJOs

## Conclusions

- ***Evolution of $Q_1$ and $Q_2$ consistent with shallow cumulus-congestus-deep convection-stratiform cloud population evolution***
- ***Good agreement of $\langle Q_R \rangle$ from budgets and CERES data; undersampling of cirrus on Gan Island yields slightly greater cooling in CombRet retrievals***
- ***Results suggest possible role of radiative-convective instability in MJOs***

## References

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