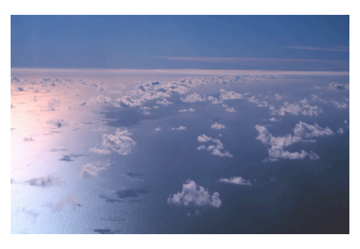
Characteristics of the MJO in a CSU Multi-scale Modeling Framework Simulation

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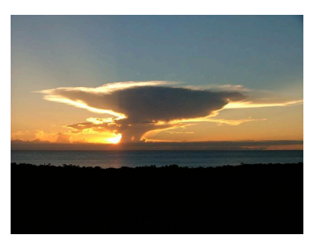


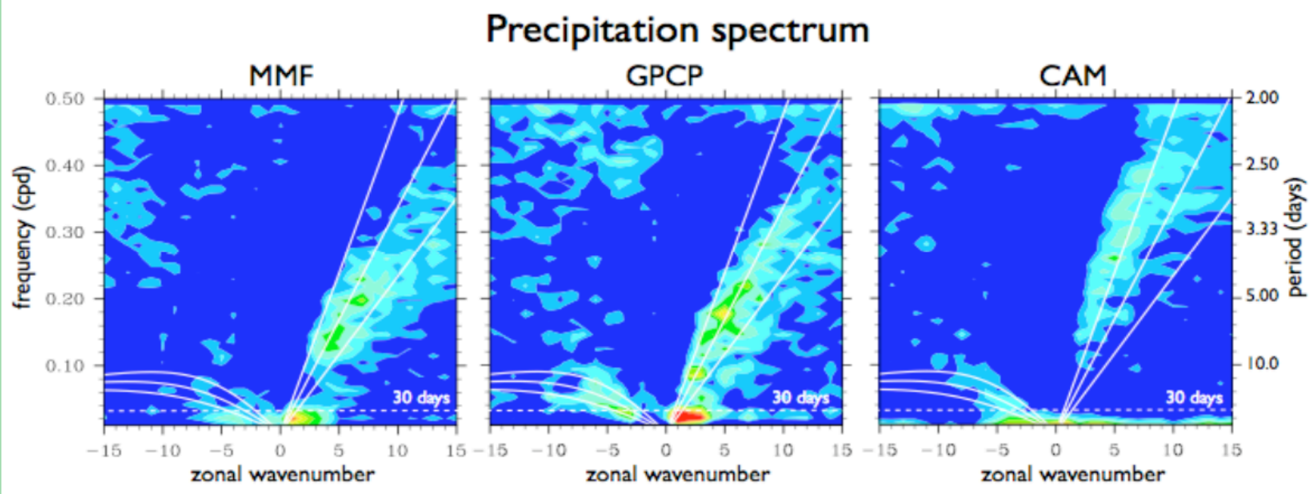

1. Background

The Madden-Julian Oscillation (MJO) involves cloud and precipitation processes spanning a wide range of space and time scales. Its impact on radiation, heat, and moisture budgets over large spatial scales as well as its ties to the higher latitudes attest to the importance of the MJO. Despite decades of research, the combination of a poor representation of this tropical disturbance in most current **GCMs** and a lack of comprehensive understanding of several of its mechanisms highlights the need for continued exploration of the MJO. No single theory of yet has been able to accurately synthesize *all* of the prominent features of the MJO, including its formation in the west-central Indian Ocean, its detailed vertical structure, and its eastward propagation.

A relatively new approach in GCM studies involves the **MMF**, a set-up in which conventional cloud parameterizations are replaced with a small-domain cloud-resolving model (**CRM**; often called "super-parameterization") that is embedded within each GCM grid column to explicitly depict clouds and their effects. Recently, a 19-year **AMIP**-style simulation was conducted using the **CSU** MMF and observed monthly **SST**s. From this dataset, we select and composite MJO-like disturbances based on the location and time of maximum rainfall for each convective episode. The MJO composite results will be compared to composites based on **GPCP** rainfall and **ERA40** using identical event selection procedures. The selection procedure and full observational results are detailed in our upcoming paper, ***Observed Characteristics of the MJO Relative to Maximum Rainfall (JAS, July 2007)***.

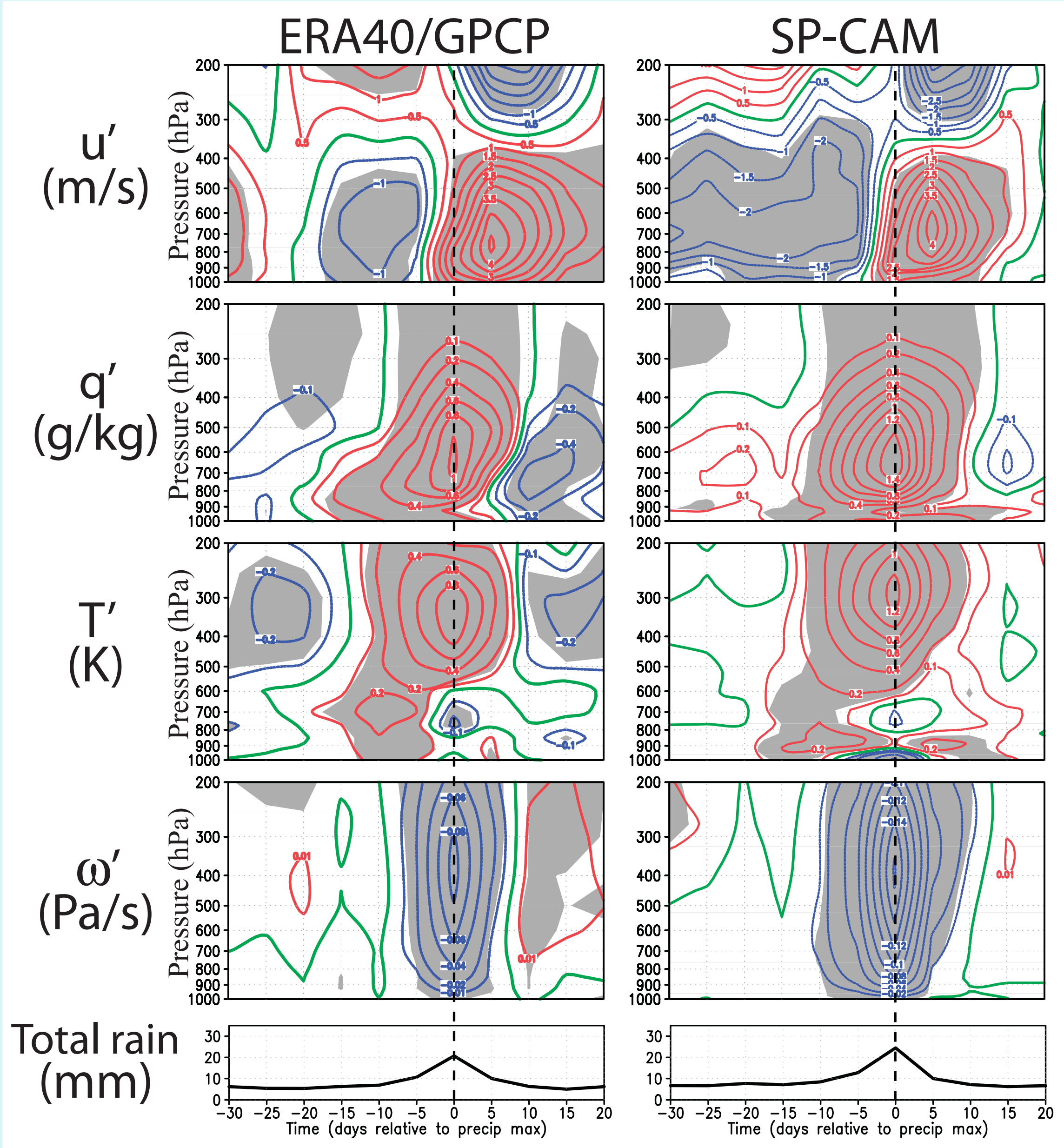
2. Motivation

Overall, intraseasonal atmospheric variability is poorly simulated in most conventional GCMs. Additionally, the computational costs of simulating atmospheric processes over several years using a global CRM remain prohibitively large. The MMF-GCM acts as a bridge between conventional GCMs and global CRMs. Preliminary results of the 19-year AMIP-style CSU-MMF (here called **SP-CAM**) simulation indicate an improvement over other conventional GCMs, such as **NCAR**'s **CAM**, based on analyses of intraseasonal variance and spectral characteristics (pictured; Khairoutdinov et al., in press, **JC**). The results shown here provide an enhanced view of the detailed characteristics of the MJO in the CSU-MMF simulation beyond those associated with basic spectral and seasonal variability.



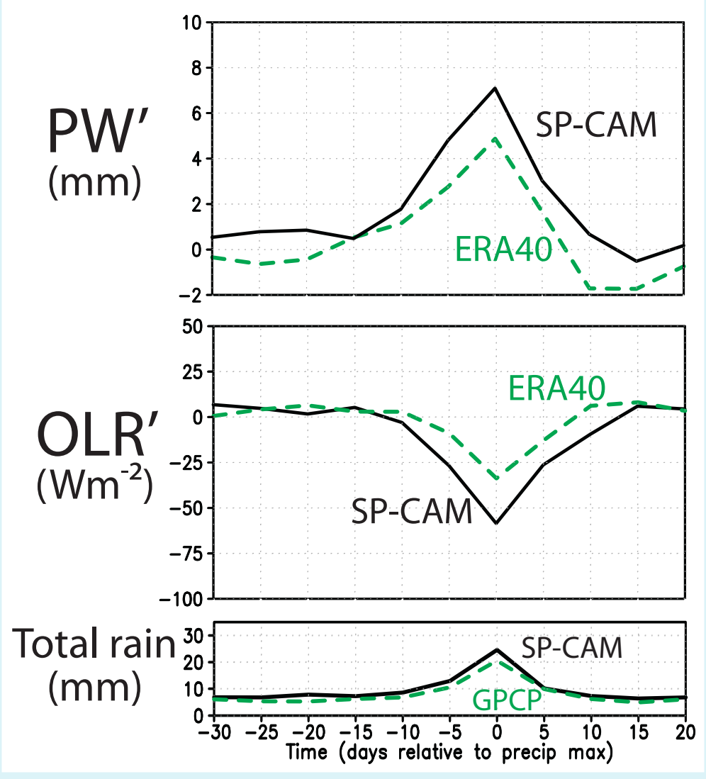
3. Time-height Composite MJO Structures

Using identical selection procedures, both datasets—observed (**GPCP**) and simulated (SP-CAM) rainfall—yielded 46 MJO events each. Composite time-height cross-sections were made based on rain maxima for each event along with the corresponding reanalysis (**ERA40**) and simulated (SP-CAM) dynamic and thermodynamic fields. In the following plots, contours (blue negative, green zero, red positive) are identical between observations and simulations. Gray shading is 90% significant.

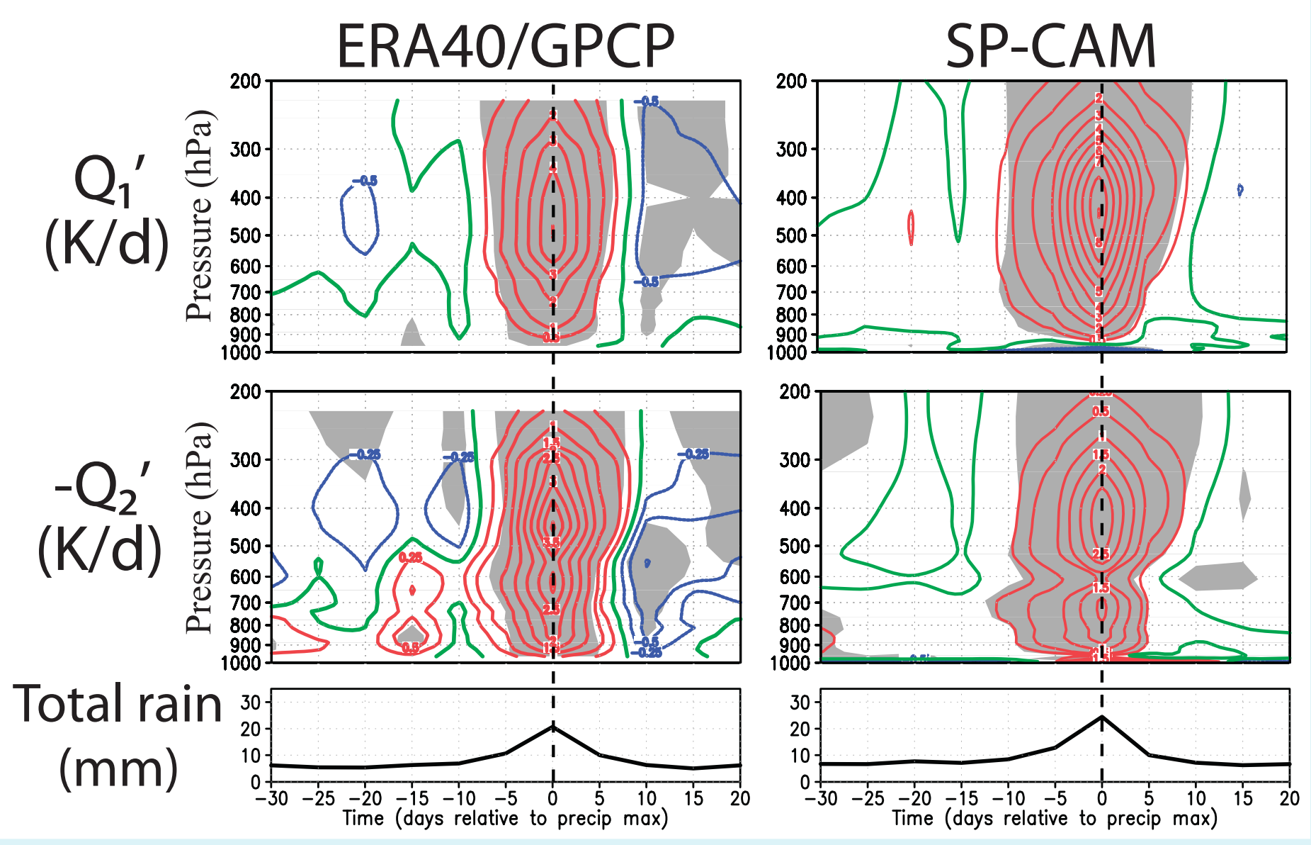


Overall results indicate a close resemblance of the SP-CAM composites to those generated from observations and reanalysis products. A few notable deficiencies exist, however. The results:

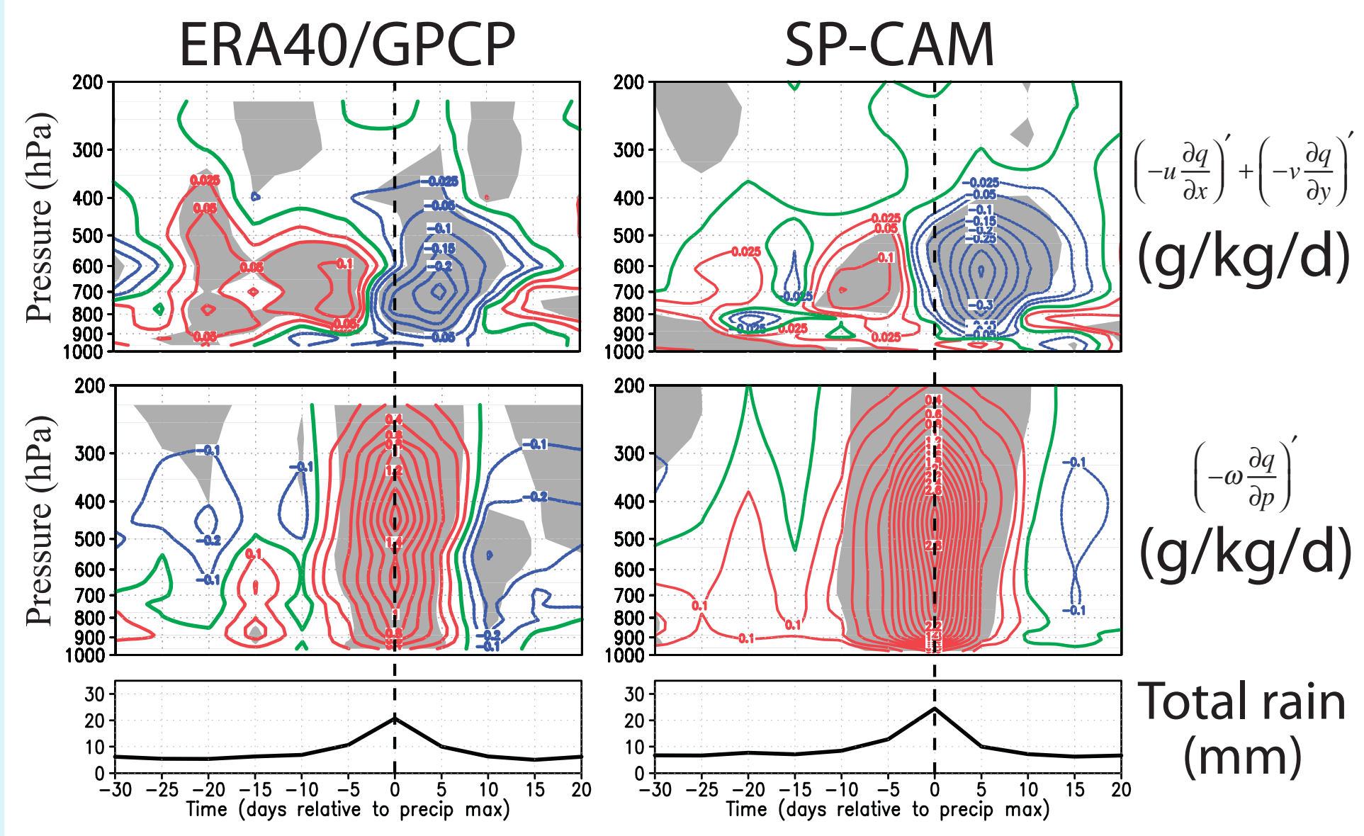
- **Zonal wind**: The baroclinic structure and related sign reversal after deep convection is depicted well, although easterlies preceding rain maximum are stronger and more extensive in the SP-CAM. The timing and structure of the onset and maximum of low-level westerlies is consistent.
- **Water vapor**: Positive moisture anomalies (perturbations from detrended calendar-day means) are too prevalent in the SP-CAM, particularly 2-4 weeks prior to maximum rain (the significance of this feature is marginal, however). Also, simulated post-convective dry anomalies are too weak.
- **Temperature**: General structural evolution of warm low-level anomalies followed by deep-layer warming with low-level cooling is similar between the two composites. Day-0 boundary-layer cooling is likely better represented in the SP-CAM than in ERA40. Upper-level cool anomalies well before and after maximum rain are too weak in the SP-CAM.
- **Vertical motion**: Subsidence outside of deep convective area is too weak and convective rising motion is too strong in the SP-CAM, but the overall structure is consistent.
- **Rainfall**: Similar rainfall timeseries are noted, but the SP-CAM maximum rain is 19% larger than that for GPCP.



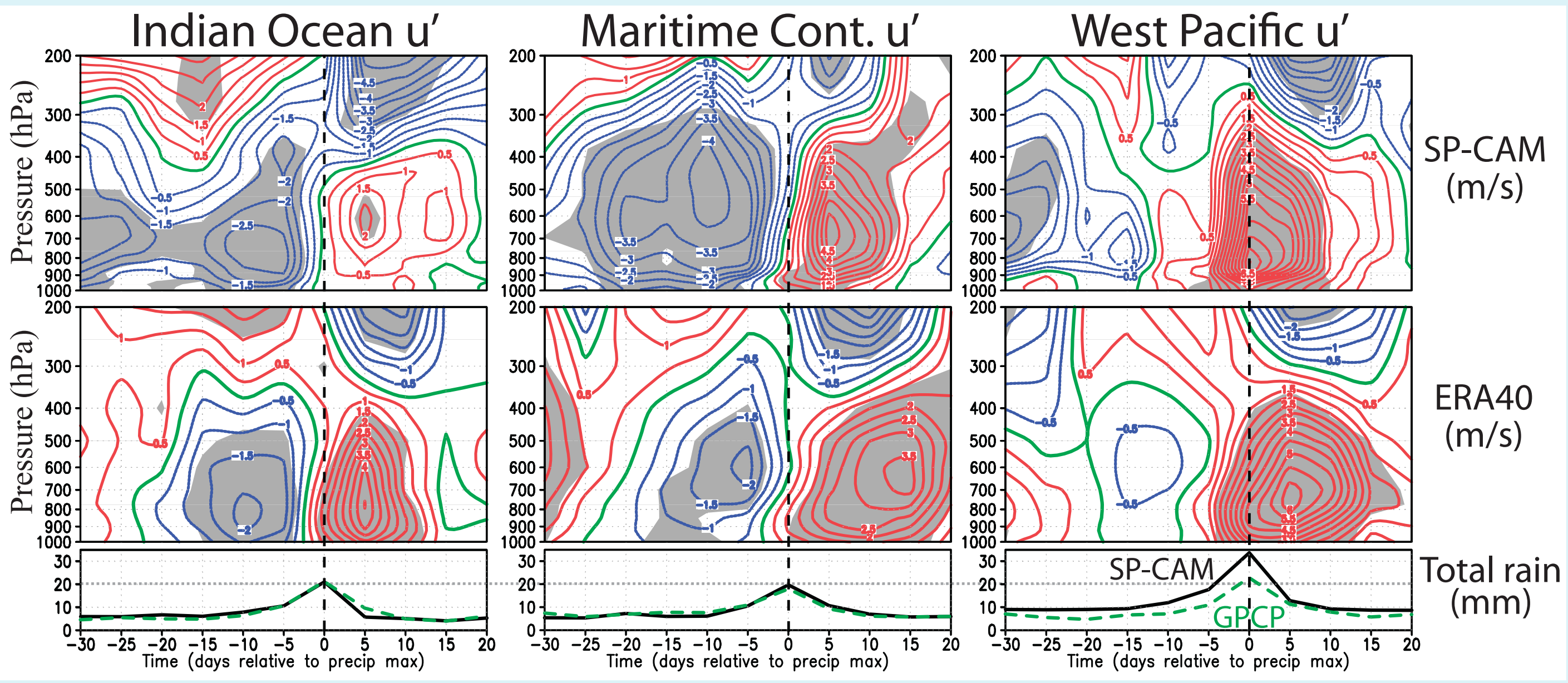
- **Precipitable water**: Consistent overestimation by 30-40% for the SP-CAM. The background atmospheric state during MJO events appears to be a time of heightened moisture levels relative to the SP-CAM 19-yr climatology.
- **OLR**: Particularly between days -13 and +15, OLR anomalies are more negative suggesting greater relative high-cloud coverage.



- **Convective heating (Q_1')**: Although general structures are similar, SP-CAM values are uniformly too positive (e.g., mid-upper level cooling outside convective region—likely due to radiative effects—is nearly absent in the simulations).
- **Convective drying (-Q_2')**: MJO-related variance of Q_2' is notably underestimated in the SP-CAM, although the structural evolution of maxima at low (upper) levels before (after) maximum rain is consistent.



- **Horizontal *q* advection**: Simulated horizontal moisture transport closely follows ERA40.
- **Vertical *q* advection**: At the time of heaviest rain, SP-CAM substantially overestimates upward *q* transport. This term likely helps to explain why simulated -Q_2 is underestimated in the previous plot.



- **Geographical differences in *u'* and rain**: The timing and structure of westerly onset and the relative strengths of the easterlies are well-simulated. Also, the geographic distribution of day-0 rain totals are fairly consistent (max values in W. Pacific). However, simulated Indian Ocean max westerlies are too weak and too high, and in the Maritime Continent the easterlies are too strong and the westerlies too early. West Pacific max westerlies occur too early (day 0) and the corresponding rain is too intense. Overall, SP-CAM easterlies are too extensive.

4. TWP-ICE: A Preliminary Look

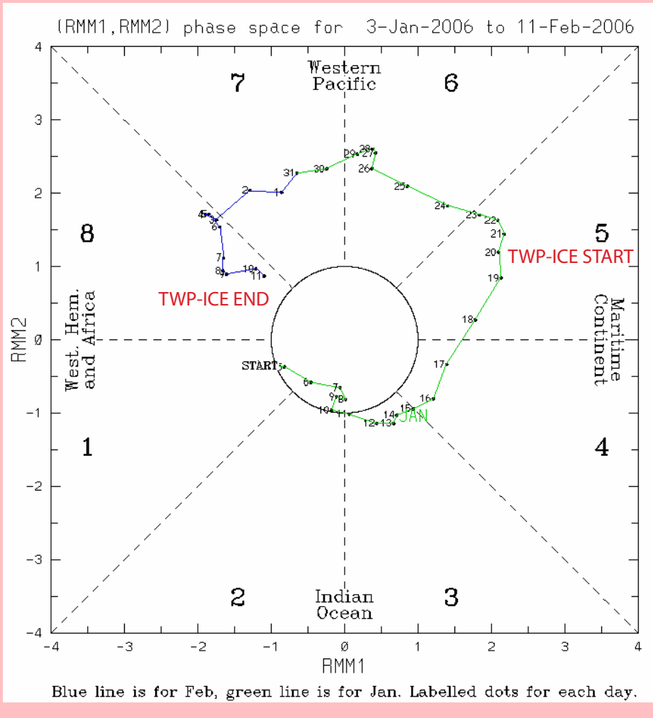
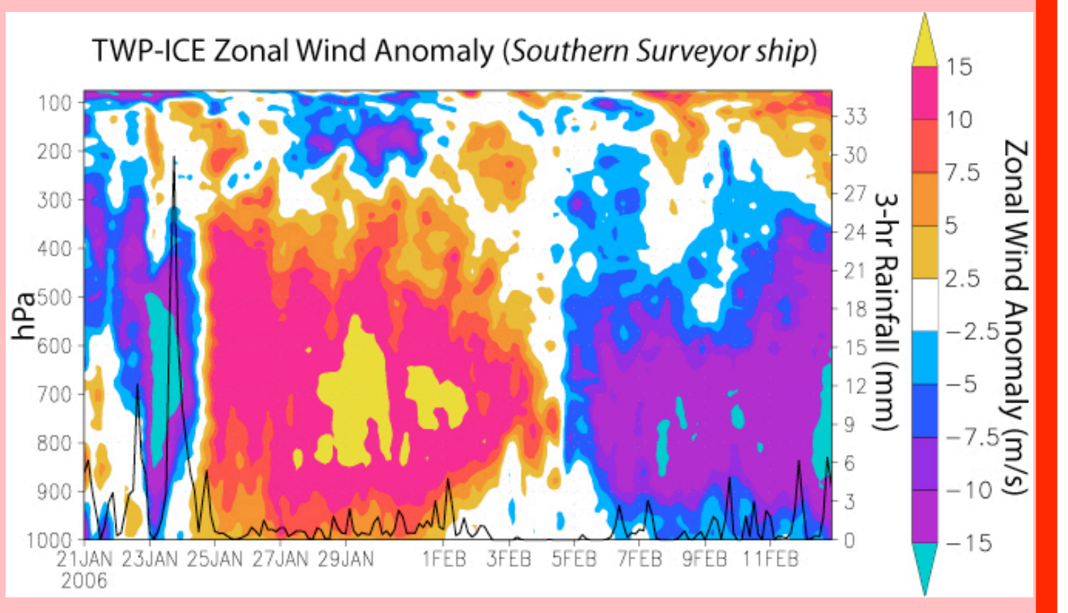
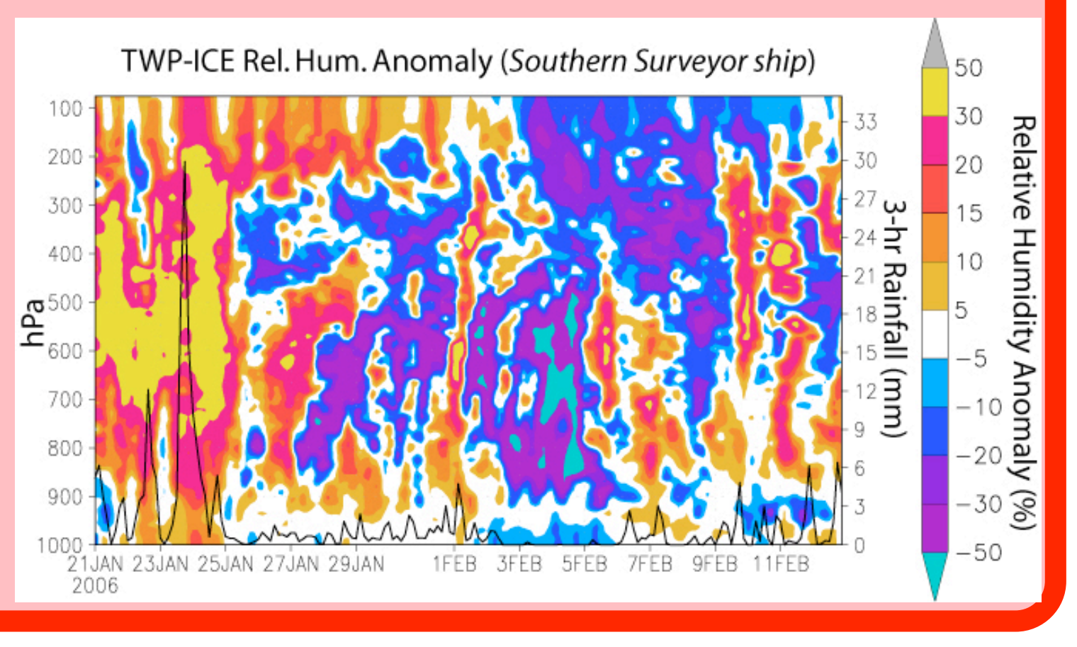


Diagram of MJO index; distance from center of circle represents amplitude of MJO, quadrant represents geographic location of maximum deep convection. (Diagram courtesy of M. Wheeler at BMRC)

TWP-ICE (Jan-Feb 2006) was conducted in Darwin, Australia. The field campaign occurred during a time of intense MJO-related convection followed by a transition to the suppressed phase. The TWP-ICE weather balloon array provides sounding data of very high temporal resolution (3 hour), offering a detailed look at this wet-to-dry phase transition. As the region of most intense convection departed Darwin to the east, strong westerlies (25 m/s at 800 hPa) were observed. Also, a series of tropical cyclones—Daryl, a monsoon depression, and Jim—formed along the southern edge of maximum westerlies.

The timeseries of total rain (black lines) and anomalous relative humidity (shaded, right bottom) from the *Southern Surveyor* ship indicate the presence of deep convection and its transition to the dry phase as westerly zonal wind anomalies (shaded, right top) develop. Increased upper-tropospheric moisture, likely evidence of cirrus anvils, extends one week beyond peak rainfall. At this time, the strongest westerlies are observed. After deep-layer drying around 4 February, a general increase in low-level relative humidity occurs as anomalous low-level easterlies redevelop (right top).





LIST OF ACRONYMS

AMIP — Atmospheric Model Intercomparison Project
CAM — Community Atmosphere Model
CRM — Cloud Resolving Model
CSU — Colorado State University
ERA40 — ECMWF 40-year Reanalysis
JC — *Journal of Climate*
GCM — General Circulation (or Climate) Model
GPCP — Global Precipitation Climatology Project
NCAR — National Center for Atmospheric Research
SP-CAM — Superparameterized Community Atmosphere Model
TWP-ICE — Tropical Warm Pool International Cloud Experiment