# Characteristics of MJOs Deduced from CINDY/DYNAMO/AMIE Sounding Data

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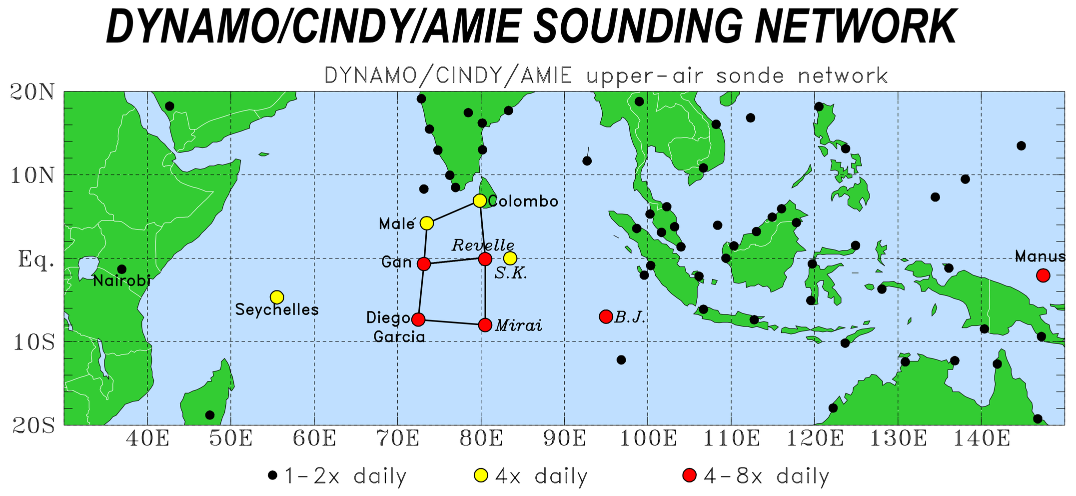
## INTRODUCTION

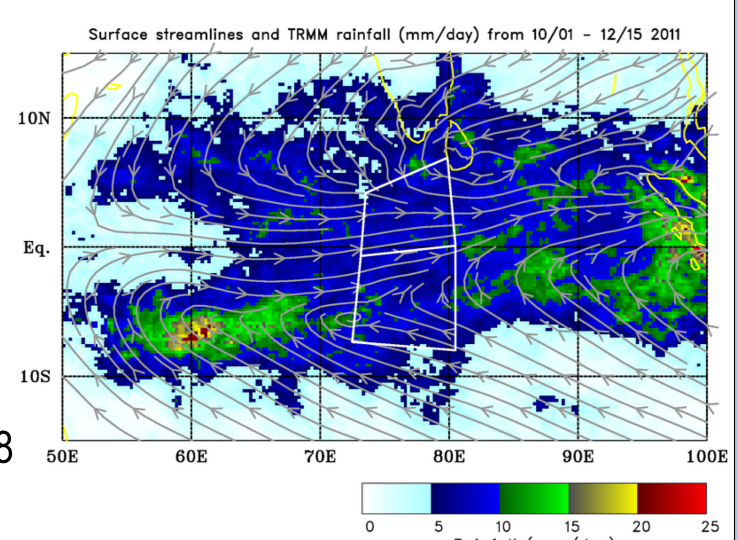
- Overview: preliminary analyses of observations from the two CINDY/DYNAMO/AMIE sounding quadrilaterals north and south of the equator for the period 1 October – 15 December 2011 (Special Observing Period or SOP)
- Focus: mean vertical structure of wind, thermodynamics, divergence/vertical motion, and inferred properties of cloud populations (Johnson and Ciesielski 2013)

### DYNAMO/CINDY/AMIE SOUNDING NETWORK




*DYNAMO/CINDY/AMIE sounding network for the period October-December 2011*

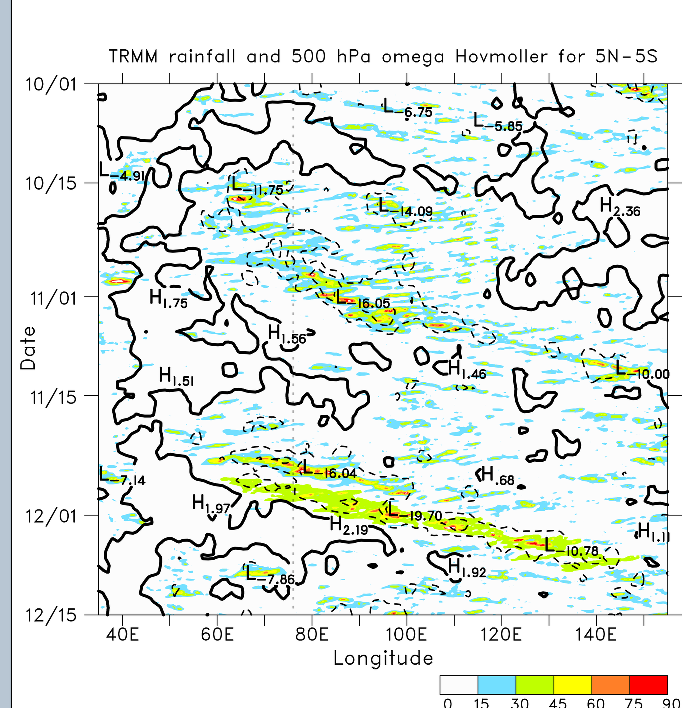
- SOP was characterized by two east-west precipitation bands north and south of the equator within surface streamline troughs
- Nearly equal rainfall amounts fell over the northern and southern arrays during SOP: 7.8 and 8.0 mm day$^{-1}$, respectively




*TRMM 3B42 precipitation (mm day$^{-1}$) and ECMWF operational analysis surface streamlines*

## MJO PASSAGE ACROSS SOUNDING ARRAYS

*The sounding arrays sampled two prominent MJO events, one in October and one in November*

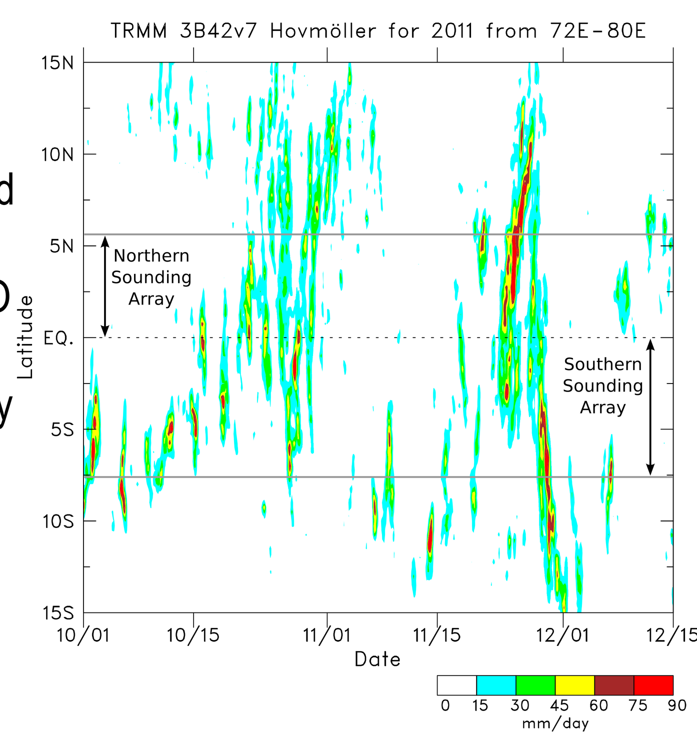



*Time-longitude plot of TRMM 3B42 precipitation (mm day$^{-1}$) and ECMWF 500-hPa vertical motion (hPa h$^{-1}$)*

- MJOs consisted of eastward- and westward-moving disturbances
- Diurnal cycle was evident over longitudes of Sumatra and Borneo (100-120°E)
- Two-day disturbances occurred over sounding arrays with passage of October MJO
- Two prominent Kelvin waves occurred with November MJO
- ECMWF vertical motion agrees well with precipitation

## MJO PASSAGE ACROSS SOUNDING ARRAYS (cont.)

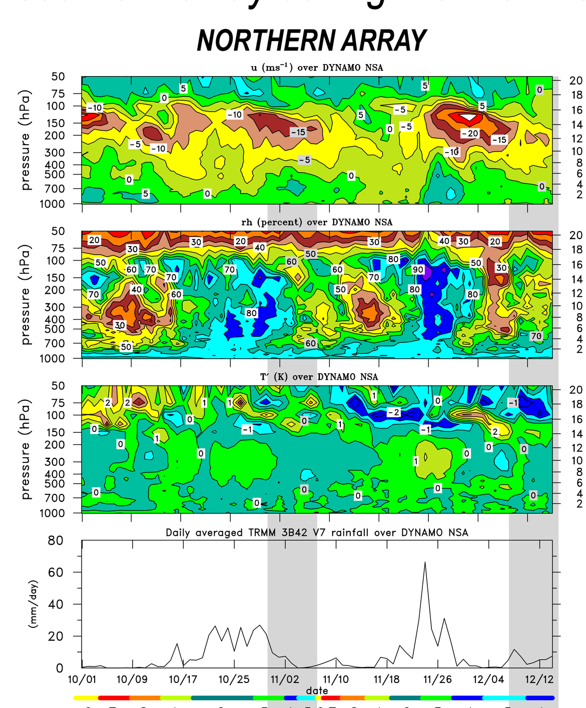
- Latitudinal extent of northern and southern sounding arrays denoted
- Northern array experienced strong MJO precipitation signal
- Southern sounding array had more frequent periods of precipitation
- Two distinct, poleward-moving rainfall maxima associated with November MJO




*Time-latitude plot of TRMM 3B42 precipitation (mm day$^{-1}$)*

## BASIC FIELDS, NORTHERN AND SOUTHERN ARRAYS

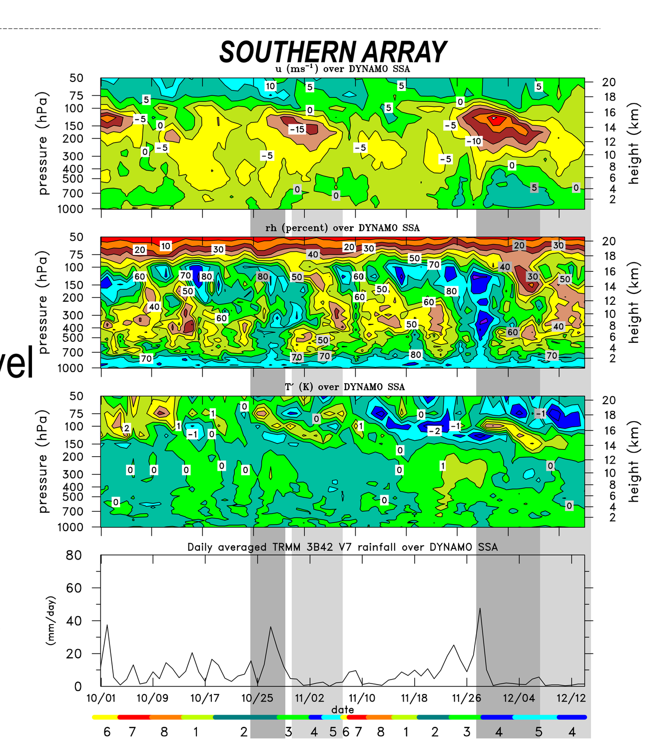
*Northern sounding array experienced a stronger MJO signal than southern array during the months of October and November*




*(from top to bottom) Northern sounding array relative humidity (%; with respect to ice for T < 0°), zonal wind (m/s), temperature anomaly (°C), and daily-averaged TRMM 3B42 rainfall (mm/day). RMM index phases are shown at bottom. Shaded bars refer to times when R/V Revelle was off station.*

- Prominent dry periods at midlevels in early-to-mid October and November; low-to-midtroposphere moistening during latter 2-3 weeks of October/November
- Strengthening of low-level westerlies/upper-level easterlies during MJO active phases
- Near-tropopause descent of upper-level easterlies, moisture and temperature anomalies with MJO passage
- 2-day rainfall periodicity with October MJO; 4-5 day periodicity in November

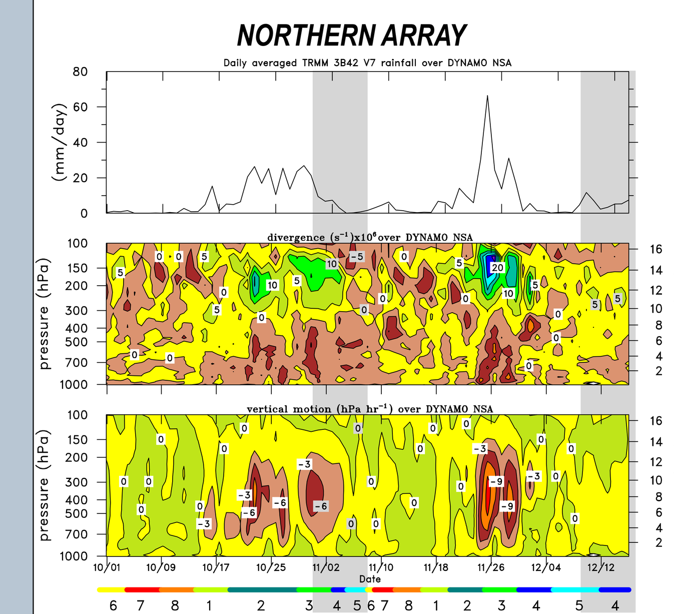
- MJO signal still present, but weaker in moisture field, rainfall
- More frequent periods of midlevel moistening; shorter duration of midlevel moistening during active phases of MJOs
- Tilted, upper-level wind and thermodynamic features also observed in upper troposphere/lower stratosphere




*As in previous figure, except for southern sounding array.. Dark (light) shaded bars refer to times when R/V Mirai (R/V Revelle) was off station.*

## DIVERGENCE AND VERTICAL MOTION

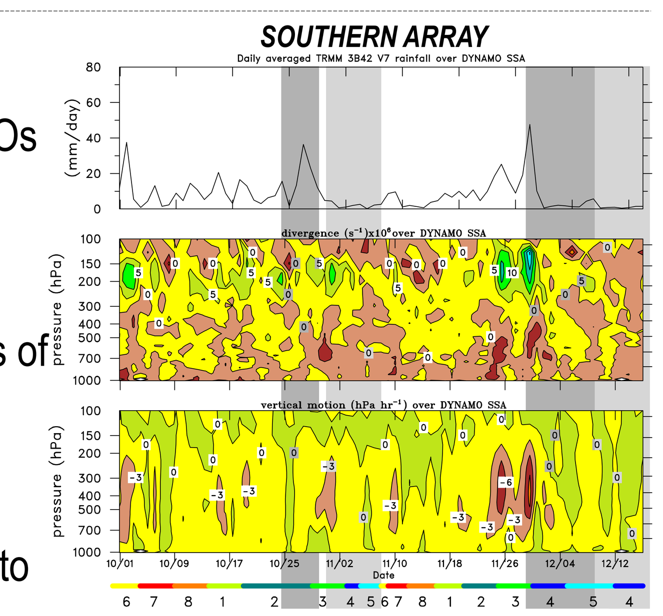
*Divergence and vertical motion over northern array also exhibited more distinct MJO signal than southern array*




*Time series of (top) TRMM 3B42 rainfall, (middle) uncorrected divergence (10$^{-6}$ s$^{-1}$), and (bottom) vertical motion (hPa h$^{-1}$) for northern sounding array. Color bars at bottom refer to phases of RMM index. Vertical shaded bars refer to times when R/V Revelle was off station.*

- Two prominent periods of low-level convergence, upper-level divergence, upward motion associated with October/November MJOs
- October MJO experienced ~2-week period of deepening low-level convergence, rising peaks in upper-level divergence
- Two sharp upward motion maxima associated with November MJO Kelvin waves
- Upper-level divergence peaks descend following peak rainfall

- October/November MJOs still evident, but less prominent, particularly October event
- More frequent episodes of rainfall, upward motion
- Note extended periods when sounding quadrilateral collapsed to a triangle

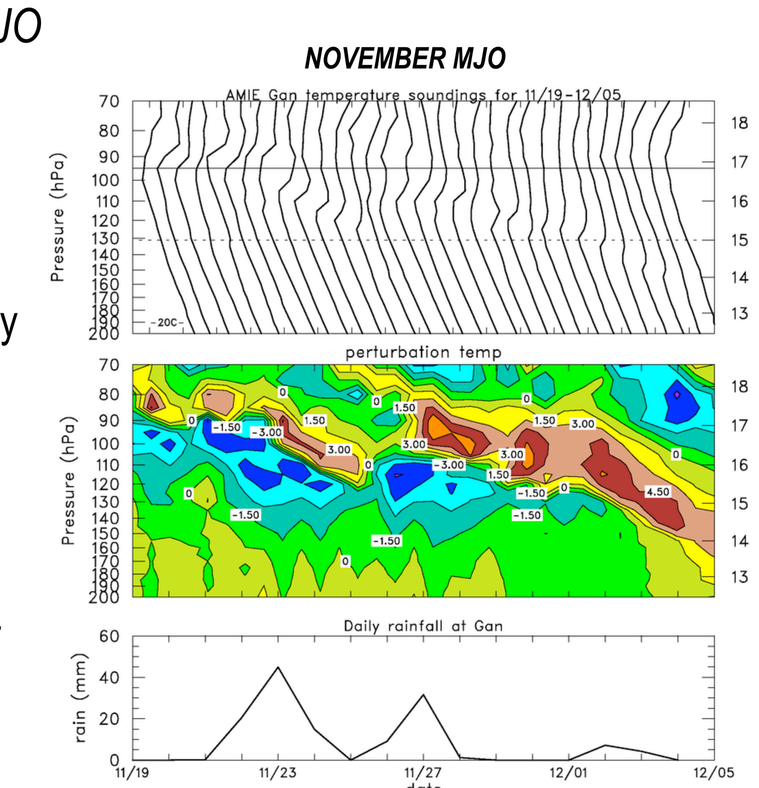



*As in previous figure, but for southern sounding array. Dark (light) vertical shaded bars refer to times when R/V Mirai (R/V Revelle) was off station.*

## TROPOPAUSE VARIABILITY

*Pronounced modulation of temperature structure near tropopause during passage of MJO*

- Warm/cold anomalies descend with time during MJO active phase
- Feature attributed by Kiladis et al. (2001) to gravity wave response to aggregate MJO convective heating
- Leads to descent of cold-point tropopause, then reestablishment at upper levels

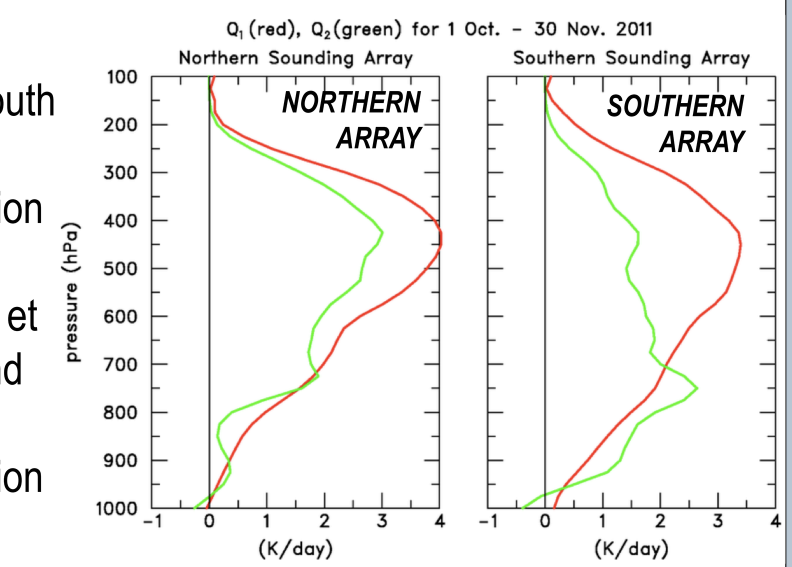



*(top to bottom) Temperature profiles, temperature anomalies, and rainfall at Gan Island for period 19 November – 5 December*

## MEAN PROFILES OF $Q_1$ AND $Q_2$

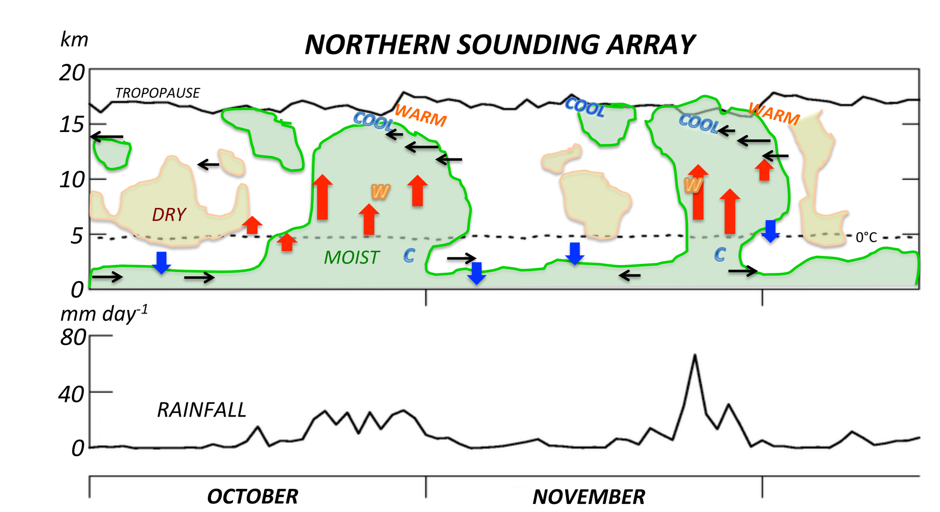
*Although work is still underway to correct for humidity biases in the soundings, as well as flow-blocking effects by Sri Lanka on the Colombo soundings, preliminary computations have been made of the apparent heat source $Q_1$ and moisture sink $Q_2$*

- Less separation of peaks in northern array than to the south
- Suggests greater stratiform rain fraction in northern array
- Consistent with Lin et al. (2004) who found MJO has larger stratiform rain fraction than annual mean
- Result yet to be corroborated with radar data




*October/November-mean profiles of apparent heat source ($Q_1$) and apparent moisture sink ($Q_2$) for northern and southern sounding arrays.*

## SUMMARY OF FINDINGS




*Schematic depiction of passage of two MJOs over northern sounding array in October and November 2011. Green (brown) shading denotes areas of relative humidity > 80% (< 40%), respectively. Arrows denote locations of zonal wind and vertical motion maxima. Cool and warm anomalies are shown. At upper levels, these anomalies have a tilted structure as do the easterly wind maxima. The 0°C level and cold-point tropopause level are indicated. TRMM 3B42 daily-averaged rainfall over the northern sounding array is shown at the bottom*

## REFERENCES


- Johnson, R. H., and P. E. Ciesielski, 2013: Structure and properties of Madden-Julian Oscillations deduced from DYNAMO sounding arrays. *J. Atmos. Sci.* (submitted)
- Kiladis, G. N., K. H. Straub, G. C. Reid, and K. S. Gage, 2001: Aspects of interannual and intraseasonal variability of the tropopause and lower stratosphere. *Quart. J. Roy. Meteor. Soc.*, **127**, 1961-1983.
- Lin, J., B. E. Mapes, M Zhang, and M. Newman, 2004: Stratiform precipitation, vertical heating profiles, and the Madden-Julian Oscillation. *J. Atmos. Sci.*, **61**, 296-309.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