236. Aircraft Radar Observations of Convective Characteristics during a Madden-Julian Oscillation during the DYNAMO Field Project

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1. Introduction

During DYNAMO, the NOAA P-3 aircraft conducted 12 flights (11 Nov – 13 Dec 2011). This mobile platform offers the ability to collect in-situ data from a target of interest, with a flight pattern designed to attain the 3D structure of a convective element.

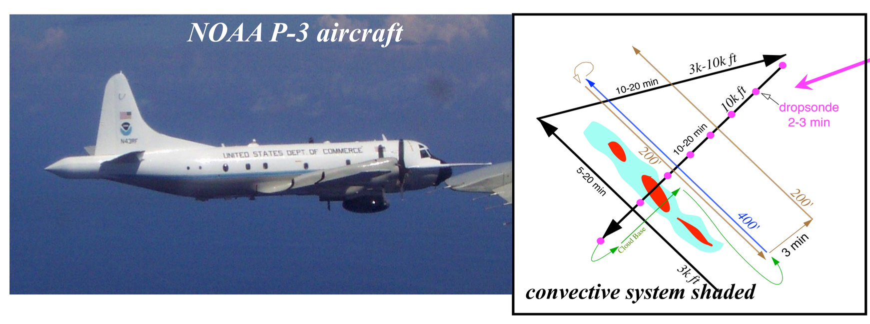


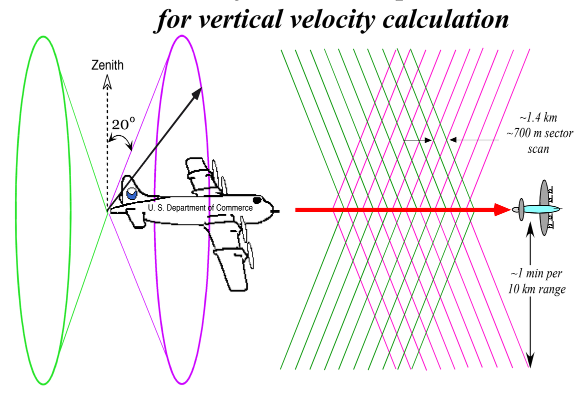
Figure 1. Radar convective element (RCE) flight pattern.

Data from the tail-mounted weather radar (characteristics shown in Table 1) and dropsondes were used to characterize mesoscale convective systems (MCSs).

Table 1. NOAA P-3 Doppler weather radar characteristics.

wavelength	3.22 cm (X-band)
PRF	3200/2400 s^{-1}
Unambiguous range	38 km
Nyquist velocity	±51 m s^{-1}
H beamwidth	1.35°
V beamwidth	1.90°
Pulse width	0.25/0.375 μs
Gate length	150 m
Antenna rotation	10 rpm (60° s^{-1})

Fore/Aft scan technique allows for vertical velocity calculation



Sampling geometry of P-3 tail-mounted radar.

Expanding our understanding of convective dynamic and thermodynamic structure in this region is important to improve modeled MJO characteristics and forecasts. The DYNAMO field project provided an unprecedented quantity of small-scale observations in the climatological MJO initiation region, allowing study of individual convective systems as well as the convective envelope.

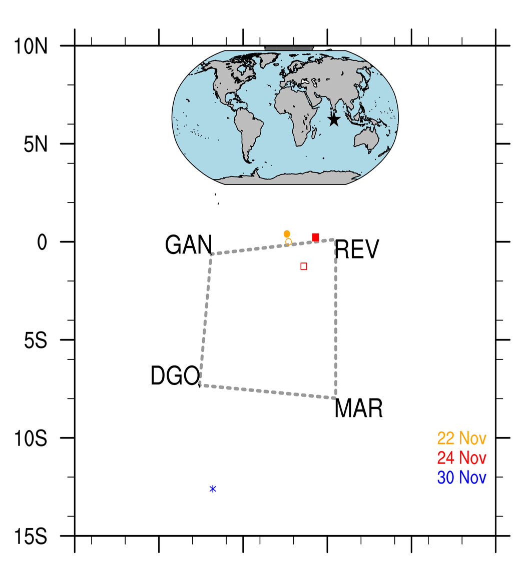


Figure 2. The DYNAMO quadrilateral observational domain, indicated by the solid star on the inlaid map. Symbols correspond to the geographic location of each RCE module presented and are color-coded by date as in legend.

These observations provided measurements to test conceptual models largely developed from satellite observations and simulations. One such example is the verification of the cloud types within phases of the MJO on the mesoscale and improved understanding of the cause of the observed convective characteristics.

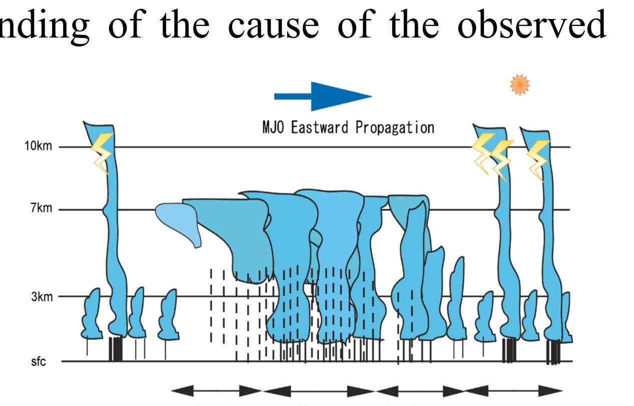


Figure 3. Conceptual model of precipitating clouds characterized by TRMM satellite observations (from Morita et al. 2006).

1. Do small-scale observations agree with current conceptual models of precipitating cloud systems in the MJO?
2. Are there any unique kinematic, and therefore microphysical structure, apparent in this region and between MJO stages?

2. Large-scale case synopsis

Three mission flights occurred on convectively active days during the late November MJO (Fig. 4). In context of space-time filtered OLR anomaly indices (Fig. 4), the flights could be related to onset, active, and decaying phases of the MJO event. A total of five RCE modules were conducted during the missions. Strong MCSs were targeted in each case to ensure optimal data for dual-Doppler analyses.

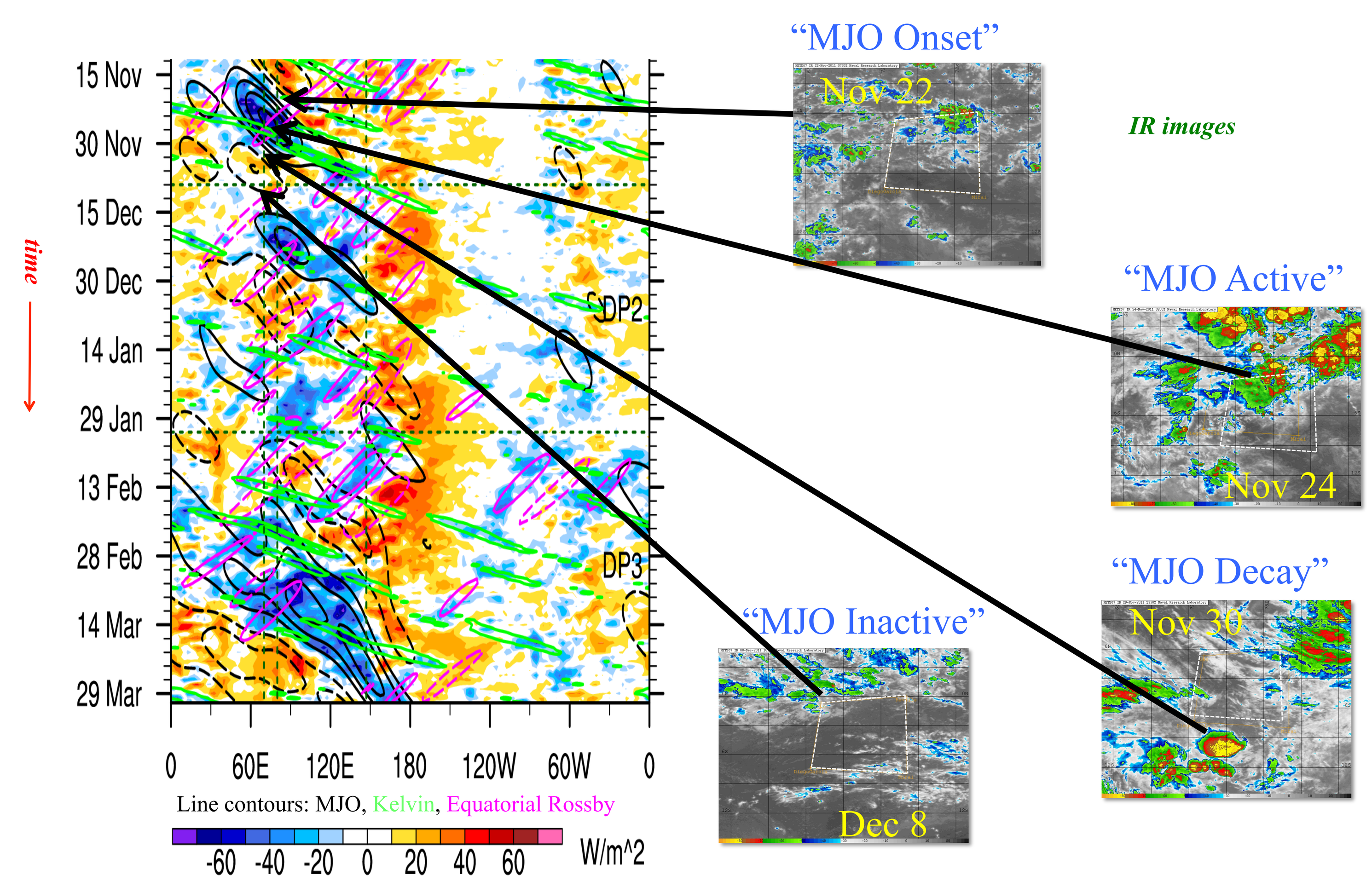


Figure 4. Hovmoeller diagram of outgoing longwave radiation (OLR) anomalies (shaded) averaged from 10S–10N (Gottschalk et al. 2013). Vertical dashed lines near 70-80E represent the DYNAMO observational domain. To the right are infrared images at a representative time for each RCE presented. The DYNAMO quadrilateral domain is indicated by the white box. The arrow indicates the convective system sampled and the time period of observations on the OLR anomaly map.

3. Convective structure

All events exhibited extensive stratiform precipitation and weakly organized convection on the mesoscale. While many convective bands were observed, a less linear organization was evident than previous oceanic field experiments (e.g. TOGA-COARE in the Western Pacific). Weak cold pools were present near the convectively active portion during the 22 and 24 November cases, with little signal apparent on the 30 November (not shown). Generally increasing relative humidity was observed as the MJO event progressed. Figure 5 shows the horizontal and vertical extent of convective systems observed during an RCE flight from the onset, peak, and decaying stages.

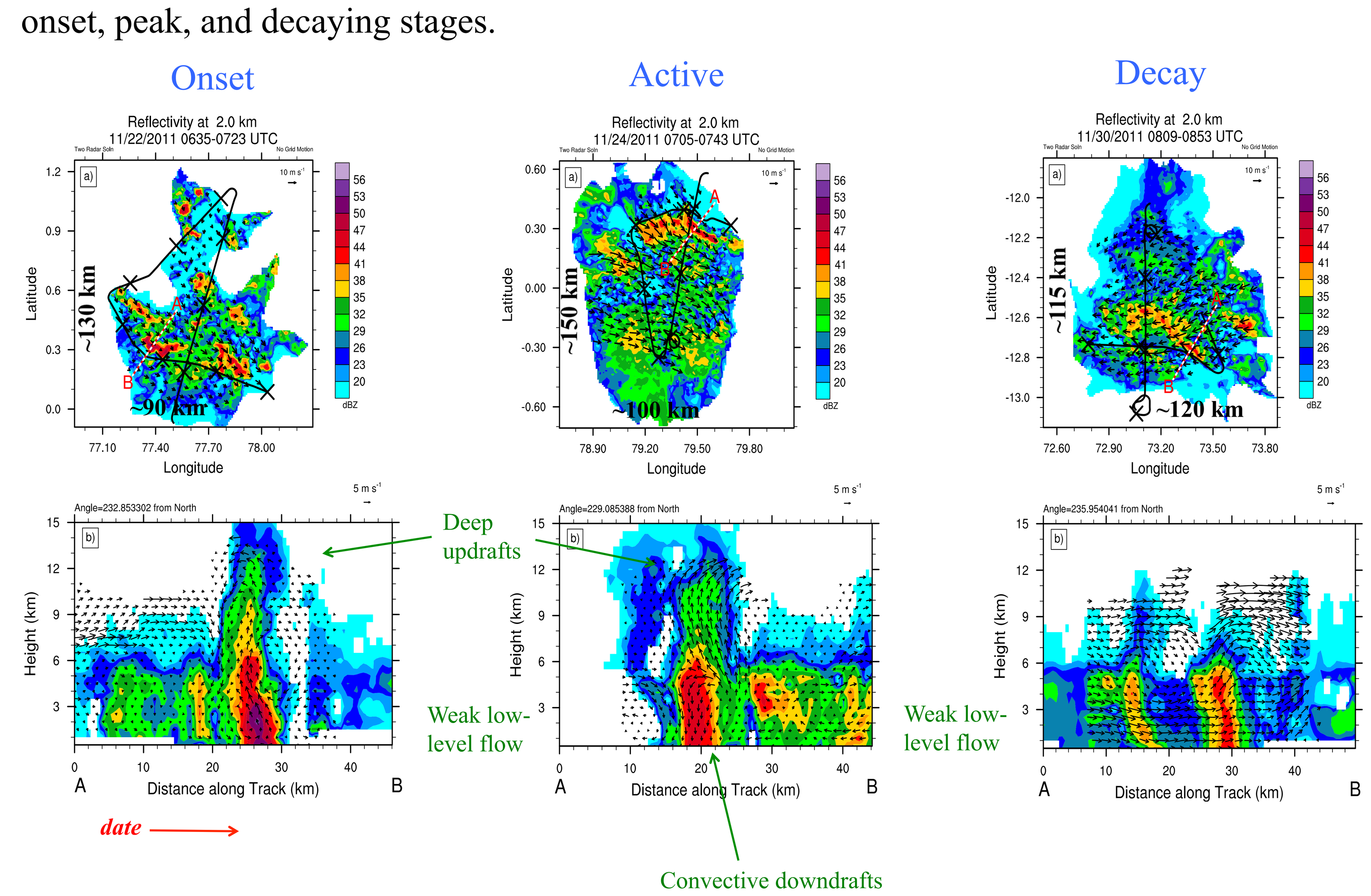


Figure 5. Top panels show radar reflectivity Constant Altitude Plan Position Indicator (CAPPI), overlaid with the quasi- dual-Doppler derived horizontal wind field and NOAA P-3 flight track (black arrows and line, respectively). Bottom panels shows the vertical cross-section indicated by the A-B red-white line in the top panel.

4. Convective characteristics frequency distributions

Convective systems displayed similar organization (Fig. 5; largely due to weak vertical wind shear and cold pools).

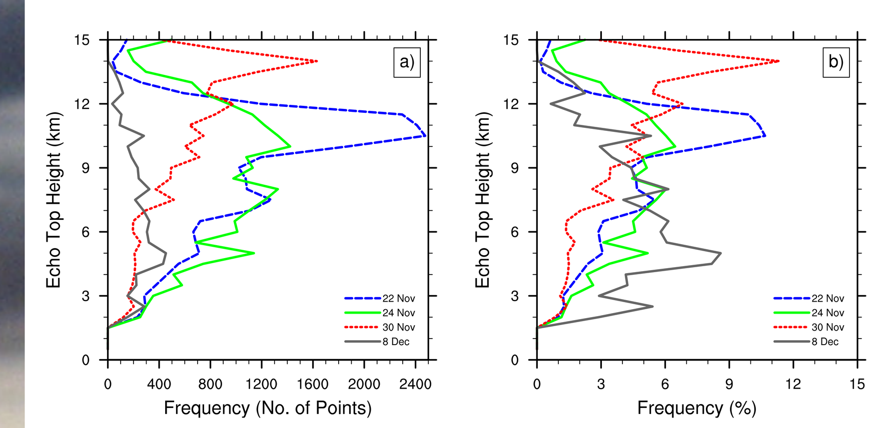


Figure 6. (a) Number and (b) percent frequency distribution of echo top heights (0 dBZ) determined from tail-radar observations.

MJO Onset to MJO Peak saw increased activity and stratiform precipitation

MJO Peak to MJO Decay saw a smaller population of shorter convective systems, though a persistent anvil was present

Isolated convection present during Inactive MJO

Convective life cycle also influenced echo top distributions, where a larger population of building and decaying convection was present during the active phase, acting to broaden the reflectivity distribution. The classic brightband signature was more evident during the onset and active phases, and vertical velocity profiles show variability in observations.

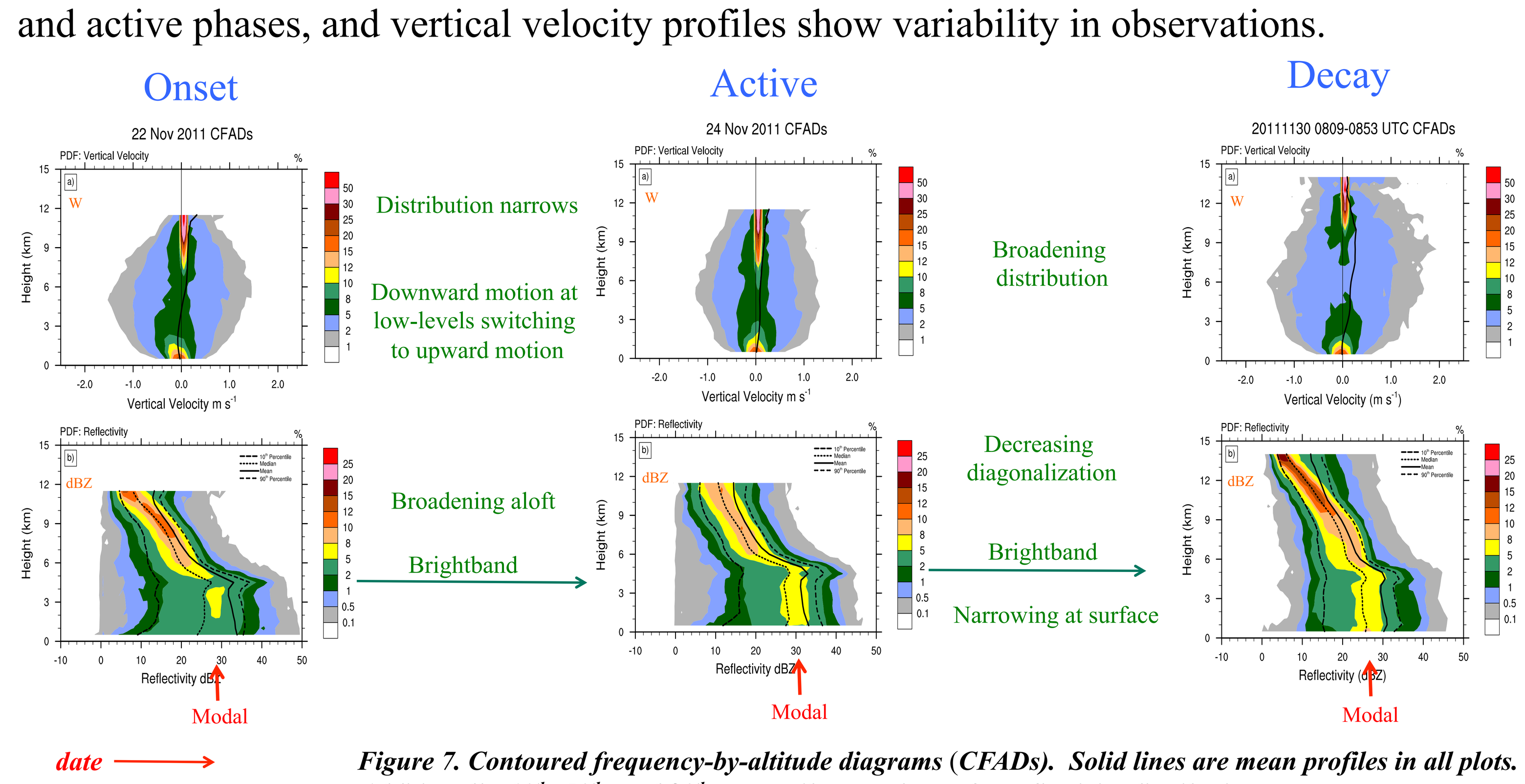


Figure 7. Contoured frequency-by-altitude diagrams (CFADs). Solid lines are mean profiles in all plots. Additionally, 10th, 50th, and 90th percentiles are shown for reflectivity distributions.

5. Summary

Airborne weather radar data were used to compare characteristics of convective systems in the Indian Ocean occurring during "onset", "active", and "decay" stages of an MJO event.

1. Do small-scale observations agree with current conceptual models of precipitating cloud systems in the MJO?
   1. Horizontal composites of radar reflectivity indicated greater stratiform precipitation during the active stage, though a great deal of anvil cloud was observed especially during the decay stage.
   2. Convective precipitation systems were found to display similar peak radar reflectivity values while having varying echo top heights.
   3. Echo top height distributions broadened as the MJO strengthened, followed by a narrowing, consistent with a larger population of systems of varying heights and supportive of the "building-block hypothesis".
2. Are there any unique kinematic, and therefore microphysical, structures apparent in this region and between MJO stages?
   1. Deep updrafts loft hydrometeors to high levels, supporting the importance of ice microphysics in the maintenance of convection during the peak MJO.
   2. Changing stratiform fraction indicate likely changes in drop size distributions
   3. Lack of organized mesoscale in- and out-flows imply weaker horizontal momentum transfer.

Guy, N. and D. P. Jorgensen, 2013: Kinematic and Precipitation Characteristics of Convective Systems Observed by Doppler Airborne Radar during the Life Cycle of a Madden-Julian Oscillation in the Indian Ocean. *Submitted to Mon. Wea. Review*.

Acknowledgments. This research was undertaken as a National Research Council postdoctoral fellow and supported by a grant from the NOAA Climate Office (NA11OAR4310077).