2012 22nd International Lightning Detection Conference
2 – 3 April • Broomfield, Colorado, USA
4th International Lightning Meteorology Conference
4 – 5 April • Broomfield, Colorado, USA

GLD360 Lightning Observations in relation to the MJO

S. A. Rutledge, P. Hein, T. Lang and R. Holle*
Colorado State University, Fort Collins, Colorado
* Vaisala Tucson, Arizona

1. INTRODUCTION

During the fall of 2011 and early winter of 2012, a large international field project called DYNAMO (DYNAmics of the MJO) was carried out in the central equatorial Indian Ocean region (www.eol.ucar.edu/projects/dynamo/). The purpose of DYNAMO was to identify the atmospheric and oceanographic processes responsible for the periodic initiation of the Madden-Julian Oscillation in the central, equatorial Indian Ocean region. The MJO has profound effects on a host of atmospheric events including modulating tropical cyclone activity, the onset and intaseasonal fluctuations on monsoonal rainfall over Asia, Australia and the Americas, onset, intensification and irregularity of ENSO and teleconnections to the extratropics. Global simulations of MJO initiation are particularly poor and DYNAMO seeks to identify the physics of MJO initiation involving both atmospheric and oceanic processes.

DYNAMO field radars, including the NCAR S-polka radar and Texas A&M SMART-R on Gan Is. (just south of the equator at 72E) and on the R/V Roger Revelle which kept station along the equator at 80.5E. Radiosodes were also launched from these sites and other locations in the regions. A suite of oceanic measurements were made from the Revelle and the Japanese reseach ship R/V Mirai, which also carried a C-band Doppler radar such as that deployed on the Revelle (in that case the radar was the NASA TOGA C-band Doppler radar). The Mirai kept station near 7.5S, 80.5E. Given our interests in tropical convection and lightning, we have examined lightning statistics using the new Vaisala GLD360 lightning network observations in the conext of DYNAMO field observations including radar-derived rainfall, CAPE (Convective Available Potential Energy), CIN (Convective inhibition) and SST (sea surface temperature). The data made available to us from Vaisala spanned the region from 5N to 10S, and 30E to 130E. Months considered were October, November and December. The western most part of the data region covered a portion of the east central coast of Africa whereas the eastern bound of the data exteded through most of the Maritime Continent region (Fig. 1).

2. TIME-LONGITUDE BEHAVIOR

The GLD360 network is set to detect intracloud and cloud-to-ground flashes, peark current, and CG polarity. Its customary in tropical meteorology to show wave disturbances such as the MJO in a time-longitude format of say IR brightness temperature, in so-called Hovmoller diagrams. Zonally-propagating systems can readly be seen. Fig. 2 shows Hovmoller plots for total lightning for the individual months of October, November and December. In all three months the large amount of lightning over the Maritime Continent is readily apparent. There is a hint of westward propagation of these lightning signals associated with easterly steering winds. Lightning frequency over the Indian Ocean region is scarce compared to the Maritime Continent, as well as compared to the east Africa coast (for November and December especially).

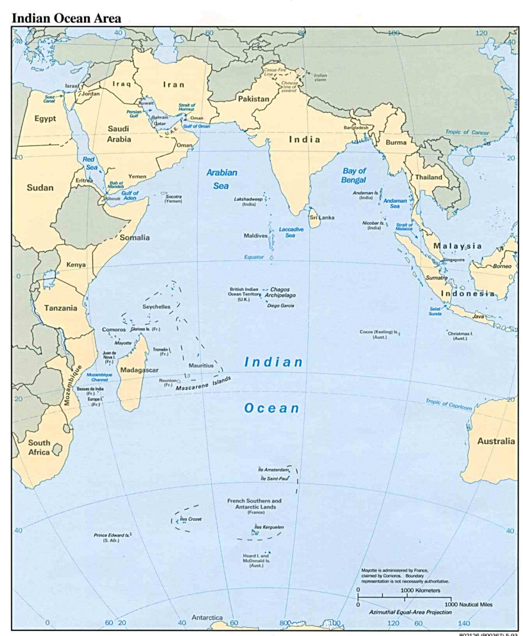

Fig 1. Geographical reference for the study region.

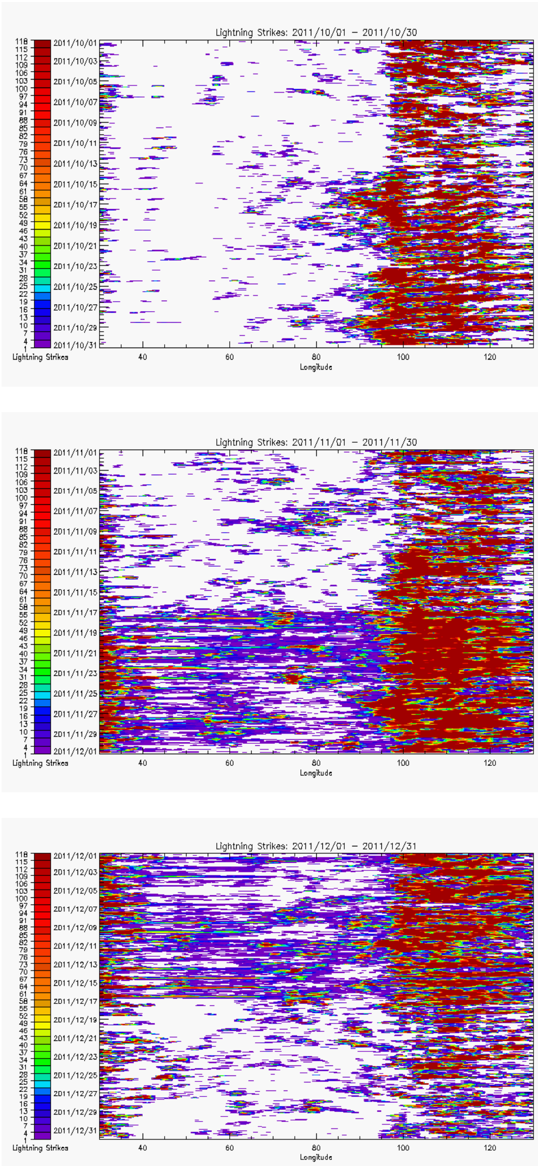

Fig 2. a) Time-longitude of total lightning for October, top panel. b) As in a) except for November, middle panel. c) As in a) except for December, bottom panel.

There are important, subtle lightning patterns in the DYNAMO study region between 70-80E, extending from the Equator to around 5S, during October and November. An MJO initiated in each of these months within the study region. In October, the MJO initiated around 15 October and extended to approximately 28 October. This is the period of heavy rainfall over the DYNAMO study region after which the MJO propagated off to the east beginning their eastward march to the W. pacific and beyond. In many cases these wave disturbances encircle the entire globe.

The pockets of lightning shown on the October Hovmoller near 15-17 October between 70-80 E mark a lightning burst at the beginning of the MJO initiation phase. There is also lightning activity near the end of the rainy period, which occurred around 28-29 October. There was little if any lightning during the entire portion of the MJO heavy rain period which spaned from roughly 19-27 October. We will show more specific plots on this below. For November (middle panel) there is more lightning over the DYNAMO study area due to both a tropical cyclone that developed around 15 November followed by another MJO inset. The ligthning pattern near 17-19 November near 70-75E is lighnting associated with both the TC and MJO. The November MJO heavy rain period extended until approximatly 20 November. Hence the bulk of the lightning assocaited with this MJO occurred roughly in the first half of the heavy rain period. The period of enhanced lightning was longer during the November MJO compared to the October MJO but this may have been due to the TC in the area. Scattered convective systems were present in early December and these are marked by lightning packets on the bottm panel Hovmoller. After mid-December gennerally dry conditons set in over the DYNAMO study area and lightning markedly decreased.

3. RAINFALL, LIGHTNING, CAPE AND SST

Additonal plots were made centered on the R/V Roger Revelle location (0N, 80.5E) and Gan Is. (0.7S, 73E) to futher investigate timing of rainfall and lightning associated with MJO periods. In addition, time series of CAPE and CIN (24 hour average values) were also included to search for linkages with atmospheric instability following the work by Petersen et al. (1996). CAPE represents the amount of potential energy available to drive convective ascent. CIN is the amount of energy that will prevent an air parcel from rising from the surface to the level of free convection. Petersen et al. noted a weak, but positive correlation between diurnal CAPE and CG lightning in the TOGA COARE area (W. Pacific warm pool region). However, they did not examine monthly plots of CAPE and lightning. Rutledge et al. (1992) found a strong positive correlation between CAPE and total lightning at Darwin, Australia, representative of the Maritime Continent region. CAPE and lightning were larger during the “break” period compared to the “monsoonal” periods. Deep, intense convection was noted during break periods. Monsoonal convection was generally weaker and shallower.

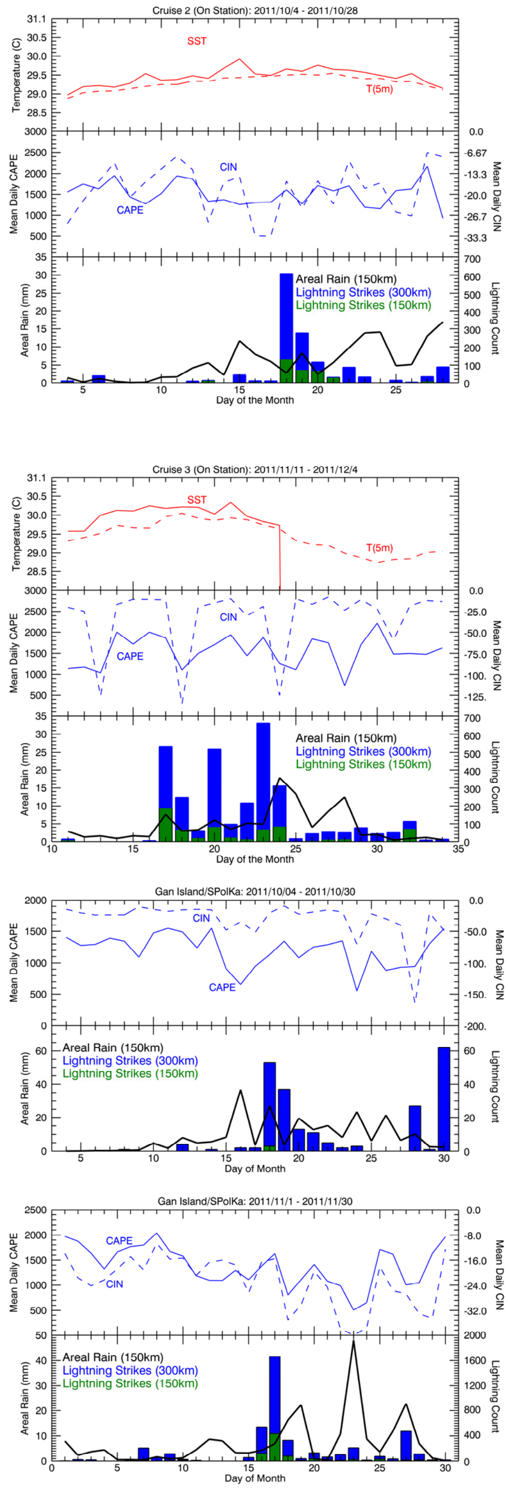

Fig. 3. Time series of SST, CAPE, CIN, areal rainfall (24 hour mean accumulations) and lightning within 300 km of the R/V Revelle (0N, 80.5E), top two panels. Lower 2 panels are the same information less SST for Gan Is. (0.7S, 73E).

For the October MJO, heavy rainfall period was subjectively determined to be 15-28 October. For the November MJO, the period of heavy MJO rain was 16-29 November. For the October times series over Revelle and at gan Is. the peak lightning occurs near the onset of the heavy rain period. The peak rain event during this period at the Revelle was 28 October (when 7 inches of rain was recorded at the ship). There was very little lightning this day, compared to earlier in the event between 18-20 October (when less rain occurred). At Gan Is., peak lightning occurred near the start of the rainy period and again at the end. Visualy, there appears to be little if any correlation between lightning and CAPE. CAPE is sufficiently high throughout the period yet lightning is highly variable. The SST at Revelle continues to increase up to the start of the heavy rain period after which it falls associated with a decrease in solar insolation due to extensive cloudiness and the decrease of sensible heat at the ocean's surface associated with widespread, heavy rainfall. At Revelle, the period between 20-28 October is marked by heavy rainfall in the virtual absence of lightning. The November MJO is also "front-loaded" in terms of lightning. The front loaded signature is clearer at Gan Is. compared to R/V Revelle. A tropical cyclone was northeast of Revelle near 15-20 November with electrically active spiral bands moving by the Revelle. At Gan Is. the heaviest rain days for the November MJO (19 and 23 November) had very little if any lightning assocaited with them.

4. CONCLUSIONS

These preliminary results suggest that deep, vertically developed convection is preferentially present near the beginning of each MJO. Evidently, convective vigor is reduced after the onset, despite the presence of heavy daily rainfall. This observation is consistent with Morita et al. The convection is some sense appears to behave like the break-monsoon rainfall periods around Darwin (Rutledge et al. 1992). Further analysis of the radar structures documented by radars on the Revelle and at Gan Is. will be undertaken to examine this conpect.

References:

Morita, J., Y.N. Takayabu, S. Shige and Y. Kodama, 2006: Analysis of rainfall characteristics of the Madden-Julian oscillation using TRMM satellite data. *Dyn. Of Ocean and Atmospheres*, **42**, 107-126.

Petersen, W.A., S.A. Rutledge and R.E. Orville, 1996: Cloud-to-Ground Lightning Observations from TOGA

COARE: Selected Results and Lightning Location Algorithms. *Mon. Wea. Rev.*, **124**, 602-620.

Rutledge, S.A., E.R. Williams and T.D. Kennan, 1992: The Down Under Doppler and Electricity Experiment (DUNDEE): Overview and Preliminary Results. *Bull. Amer. Meteor. Soc.*, **73**, 3-15.

Acknowledgments: The authors are grateful to the many personnel that work long and hard hours to collect the dataset for DYNAMO. This work was supported by a NSF grant to Colorado State University, AGS-1063928.