

## 12A.3 RADAR OBSERVATIONS OF CONVECTION IN A LARGE-SCALE DISTURBANCE DURING NAMMA

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### 1. INTRODUCTION

The NASA African Monsoon Multidisciplinary Analyses (NAMMA) campaign was conducted primarily to explore the relationship between African Easterly Waves (AEWs) and tropical cyclogenesis in the Atlantic basin, as well as the role of the Saharan Air Layer (SAL) in modulating the intensity of the waves and incipient tropical cyclone growth. This paper presents an overview of TOGA radar observations that were collected in the Republic of Cape Verde (CV) during the NAMMA campaign. Preliminary analyses of convection associated with an AEW observed by TOGA in early September are also presented.

### 2. RADAR DESCRIPTION AND OBJECTIVES

The NASA TOGA radar is a C-band scanning radar with a beam width of  $1.65^\circ$ . The radar was deployed on the southern tip of São Tiago ( $14.92^\circ\text{N}$ ,  $23.48^\circ\text{W}$ ), the southern-most island in the CVs (Fig. 1). The radar operated nearly continuously from 15 August–16 September, 2006, collecting measurements of horizontal radar reflectivity (ZH), radial velocity (VR) and spectral width (SW).



Figure 1. Location of TOGA radar approximately 100m above coastline on southern tip of São Tiago.

The objectives of the TOGA deployment were to:

- Assist in the guidance of the NASA DC-8;
- Analyze precipitation and circulation structures within maritime mesoscale convective systems (MCSs) in the vicinity of the CV islands and describe the progression of their structure and behavior as they transition from the African continent to a more maritime environment; and
- Document kinematic, microphysical, and precipitation features, internal to these MCSs, that are relevant to tropical cyclogenesis.

A combination of scanning strategies was performed to achieve the TOGA radar objectives. The radar operated on a 10-minute repeat cycle, consisting of a single, low-level surveillance sweep (maximum range  $\sim 270$  km) and one 18-21 sweep volume scan (maximum range 150 km) to sample the 3-D structure of convective systems (Table 1). All sampling was accomplished using a 150m bin size.

Scan Name	Samples	Elevation Angles ( $^\circ$ )
SURV	50	0.8
FAR	64	0.8, 1.3, 1.8, 2.3, 3.4, 4.5, 5.7, 6.9, 8.2, 9.6, 11.3, 13.0, 15.0, 17.2, 19.8, 22.5, 26.5, 29.5
NEAR	64	0.8, 1.5, 2.3, 3.4, 4.5, 5.7, 6.9, 8.2, 9.6, 11.3, 13.0, 15.0, 17.2, 19.8, 22.5, 26.5, 33.0, 39.0, 45.8, 53.4
EVAD	64	0.8, 1.5, 3.2, 5.5, 7.9, 10.3, 12.7, 15.1, 17.6, 20.0, 22.6, 25.1, 27.8, 30.5, 33.2, 36.1, 39.1, 42.2, 45.4, 48.9, 53.4

Table 1. Description of scans used for TOGA radar operations during NAMMA.

### 3. OBSERVATIONS OF NAMMA CONVECTION

The CV islands are located approximately 600 km west of the African continent and occupy a transition region between continental and maritime precipitation regimes. Although the ITCZ is generally located south of the CV islands, AEWs occasionally move across the CVs during the July-September time period and many Atlantic basin tropical cyclones have their roots traceable to the CV region (e.g., Bosart and Lackmann, 1995).

During NAMMA, the TOGA radar documented at least six major episodes of convection (defined as significant echo within 150 km of the radar lasting at

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least 6 hours and exhibiting significant mesoscale organization). These features were associated with the passage of AEWs, two of which later developed into tropical storms (Debby and Helene, respectively). TOGA observed a variety of convection associated with the AEW passages, including: linear bands, leading line trailing stratiform MCSs, orographically forced convection and flash flooding, and embedded mesoscale vortices in stratiform precipitation.

The passage of the AEWs can be inferred from a time series of radiosonde data collected at the Praia airport (Fig. 2). The relative humidity time series shows a persistent dry layer between about 2-4 km, punctuated by periods of higher humidity during wave passages (e.g., 22 August, 3 September, 12-13 September). Time series of 700 mb winds and satellite imagery confirmed the wave passages.

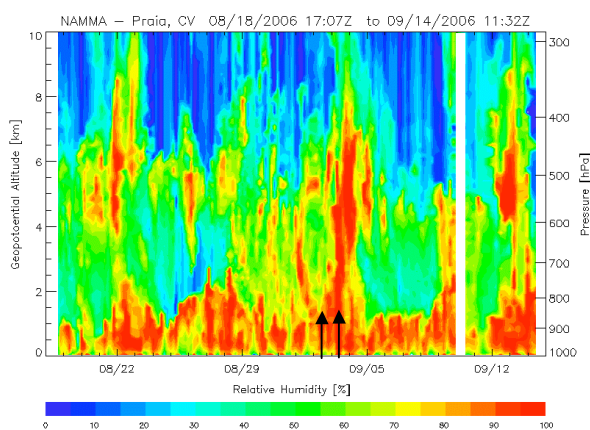


Figure 2. Time series of relative humidity spanning the period 19 August–14 September, 2006. The image is based on radiosonde data collected at the Praia airport during NAMMA (image courtesy of Brian Morrison and Frank Schmidlin, NASA WFF). Left (right) arrows indicate times corresponding to first (second) convective pulses described in the text.

#### 4. QUALITY CONTROL PROCEDURES

Prior to analysis, a series of quality control (QC) procedures was applied to the TOGA radar data. The QC included the removal of multiple trip and other transient echos from the radar reflectivity field using a threshold on the radial velocity field. The QC also included the development of a ground clutter template to remove clutter and side lobes sampled over São Tiago, as well as several nearby islands.

The removal of sea clutter was more problematic and was performed using a threshold on the vertical gradient of radar reflectivity between the two lowest sweeps (e.g., Berenguer et al. 2006). The threshold was successful at removing the majority of sea clutter; however because of the overlap in the threshold gradient between sea clutter and precipitation, residual clutter occurred in the volume that required manual intervention to completely remove.

Finally, overpass comparisons with the TRMM precipitation radar (PR) showed that the TOGA radar

calibration was approximately 4.0 dB above the PR during the NAMMA campaign. The bias was removed subsequent to the clean-up of spurious echoes described above. In this paper, no attenuation correction procedure has been applied to the data; however, the data set will have an attenuation correction applied when released to the NAMMA community (expected during late summer 2007).

#### 5. CASE STUDY

Herein, we briefly describe the evolution of convection embedded within an AEW that passed through the region sampled by TOGA on 2-3 September, 2006. Prior to about 06 UTC on 2 September, the environment in the vicinity of Praia was characterized by a capping inversion near 850 mb (not shown) and radar activity was relatively suppressed. Satellite infrared (IR) data showed an extensive region of SAL in the vicinity of the CV islands (Fig. 3), which was confirmed by visual observations of dust made by the TOGA radar personnel.

NAMMA forecasters and Global Forecast System (GFS) analyses indicated that an AEW wave trough was situated along the west African coast near 12 UTC on 2 September. However, a “pulse” of convection was observed ahead (west) of the trough axis, just east of the Cape Verde islands at this time (Fig. 3). This pulse was coincident with a moistening of the mid-troposphere in Praia after about 06 UTC on 2 September (Fig. 2). Although the majority of this convection passed south of the CV islands, the radar did sample the northern portion of a squall-MCS around 12 UTC associated with the feature observed in satellite imagery (Fig. 4). The western edge of this feature separated moist air to the south and east from the SAL layer to the northwest (Fig. 3).

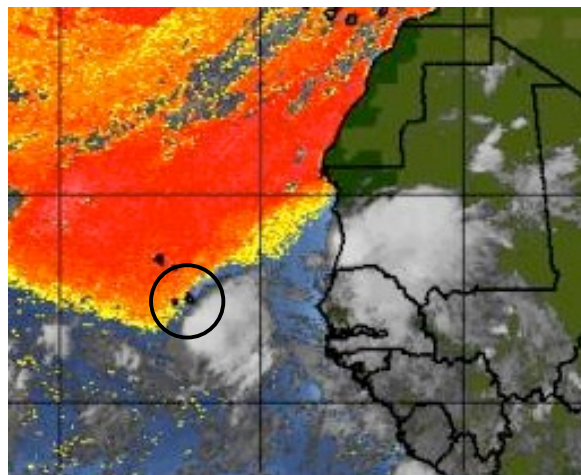


Figure 3. Meteosat-8 IR image on 12 UTC September 2, 2006 showing brightness temperature (grey shading) and relative intensity of SAL (color shading – warm colors indicating larger intensity), based on the difference of the 12.0 and 10.8  $\mu\text{m}$  channels. The black circle indicates the approximate region sampled by the TOGA radar. Image provided by UW-CIMSS and NOAA-HRD.

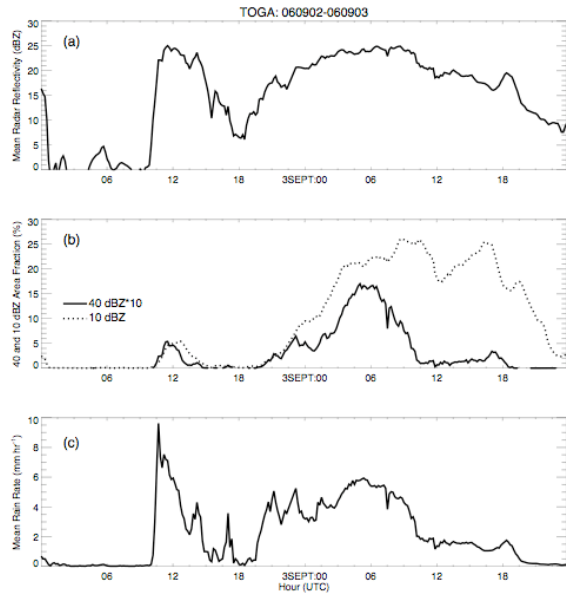


Figure 4. Time series of TOGA radar data from the lowest sweep ( $0.8^\circ$ ) for 2-3 September, 2006. (a) mean radar reflectivity, (b) area fraction (%) of 10 and 40 dBZ echo as indicated in the legend, and (c) conditional mean rain rate using the GATE Z-R relationship ( $Z = 230R^{1.25}$  - Hudlow, 1979).

Subsequent to the passage of this first pulse near 12 UTC on 2 September, convective activity in the vicinity of TOGA waned before increasing again after 18 UTC on 2 September (Fig. 4), in association with the approach of the main region of convection that had moved west from the African coast (Fig. 5).

GFS analyses at 00 UTC on 3 September (Fig. 6) indicated that the second pulse convection observed in IR imagery (Fig. 5) was roughly coincident with the position of the AEW wave trough axis.

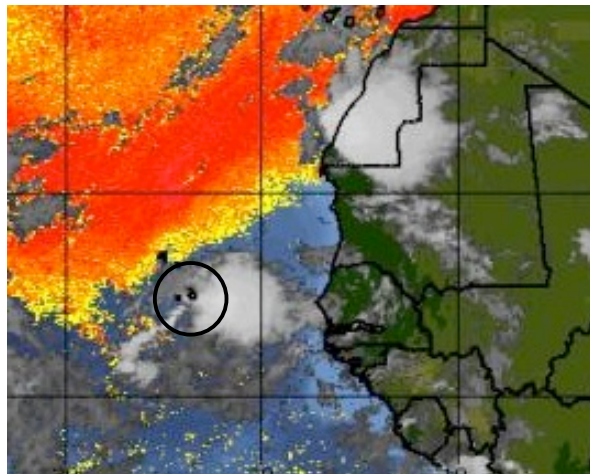


Figure 5. Same as Fig. 3, except for 00 UTC on September 3, 2006.

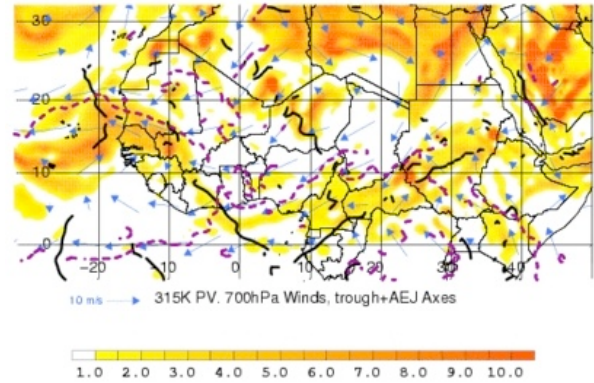


Figure 6. GFS analysis at 00 UTC, 3 September, showing position of AEW trough axis (black solid line), 700 mb wind vectors (blue arrows), African Easterly jet axis (purple dashed line), and 315K potential vorticity (color contour). Image taken from the AMMA web site: <http://aoc.amma-international.org/>

This second pulse of activity was farther removed from the SAL compared to the first pulse (Fig. 5) and was associated with an extensive buildup of humidity in the middle troposphere (Fig. 2) of the Praia soundings.

Based on the change from northerly to southerly component winds at 700 mb, the trough associated with the AEW passed through Praia between 12-18 UTC on 3 September (Fig. 7a). This passage was marked by large decrease in CAPE (Fig. 7b), which slowly recovered over the next few days.

The TOGA radar documented extensive echo associated with the AEW passage and there was local flash flooding in Praia. A NASA rain imaging system (RIS) located at the TOGA radar site recorded over 4 hours of continuous rainfall between about 10-14 UTC and a peak rain rate of  $\sim 70 \text{ mm hr}^{-1}$  (not shown).

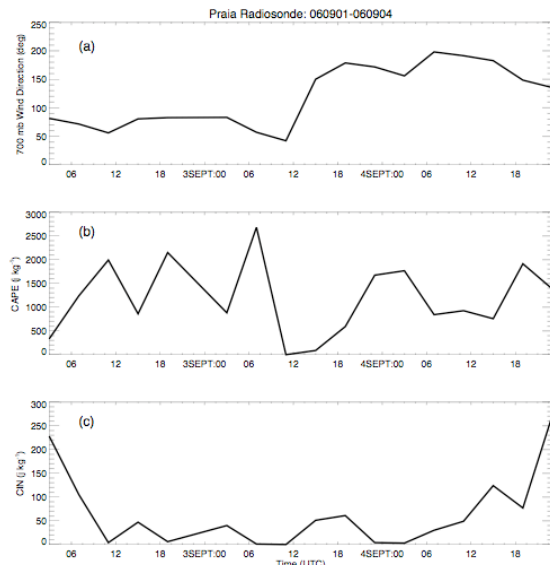


Figure 7. Time series of selected Praia radiosonde parameters spanning 2-4 September, 2006. (a) 700 mb wind direction ( $^\circ$ ), (b) CAPE ( $\text{J kg}^{-1}$ ), and (c) CIN ( $\text{J kg}^{-1}$ ).

The TOGA data showed that convection associated with the approaching AEW trough initially formed as a series of linear bands that were quasi-perpendicular to the 1000-700 mb shear (Fig. 8). After about 06 UTC on 3 September, the bands weakened and more extensive areas of stratiform precipitation developed, as observed in the relative decrease (increase) in 40 (10) dBZ echo fraction (Fig. 4).

The NASA DC-8 performed a spiral through the melting band in the vicinity of TOGA near 12:30 UTC, sampling microphysical characteristics of the precipitation. The TOGA data will be useful for placing the aircraft data within a larger spatial context.

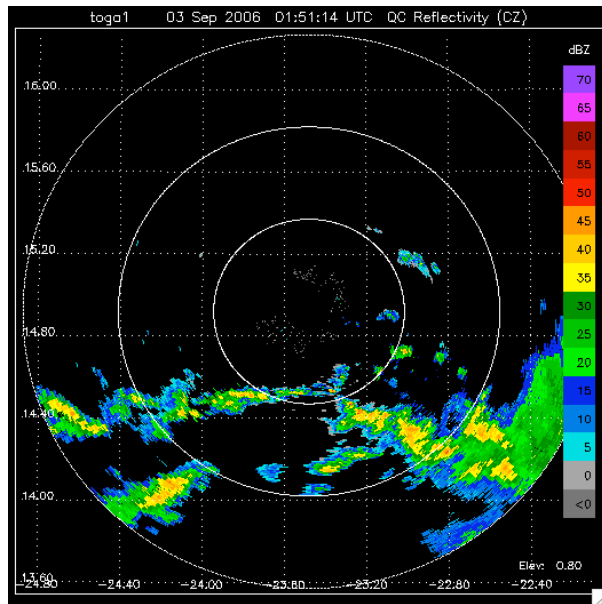


Figure 8. TOGA 0.8° radar reflectivity PPI at 0151 UTC on 3 September 2006. The 1000-700 mb shear vector was oriented approximately N-S at this time. Radar reflectivity scale (dBZ) is indicated in the right portion of the plot.

## 6. SUMMARY

NAMMA instrumentation, including the TOGA radar, has provided a rich data set to study the relationship between AEWs and tropical cyclogenesis. Future efforts will be directed toward examining the relationship between radar echo morphology observed by TOGA and position within the phase of AEWs. Moreover, using data collected by NAMMA and AMMA radars over continental Africa, quantitative comparisons of convective structures over both the continental and maritime regions can be performed.

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## 7. REFERENCES

Berenguer, M., D.S. Torres, C. Corral, and R.S. Diezma, 2006: A fuzzy logic technique for identifying nonprecipitating echoes in radar scans. *J. Atmos. Oceanic Technol.*, **23**, 1157-1180.

Bosart, L.F. and G.M. Lackmann, 1995: Post-landfall tropical cyclone reintensification in a weakly baroclinic environment: A case study of Hurricane David. *Mon. Wea. Rev.*, **123**, 3268-3291.

Hudlow, M.D., 1979: Mean rainfall patterns for the three phases of GATE. *J. Appl. Meteor.*, **18**, 656-1669.