Factors Influencing Extreme Precipitation Associated With Tropical Storm Fay (2008) Across North Florida and Southwest Georgia

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Introduction

As Tropical Storm Fay tracked westward across the Florida Panhandle between 22-24 August 2008, widespread flooding was observed across North Florida and Southwest Georgia (e.g., NHC 2009). Localized areas north and east of Tallahassee, FL received in excess of 500 mm of precipitation from Fay, much of which occurred with an intense rainband on 23 August. In this research, we aim to understand the physical processes contributing to the extreme rainfall observed across the region with Fay's passage.

Climatological Perspective

The observed rainfall of 11.44" (291 mm) at Tallahassee, FL from Fay between 22-24 August 2008 is the second-highest three-day rainfall total on record there between 1948-2010. Of the top twenty highest three-day rainfall events, eight are from tropical cyclones and twelve are from non-tropical cyclone events. Both composites feature large-scale ascent and warm air advection in a moist environment (Figure 1). Fay is unique among the tropical cyclone events for moving west, rather than north or east, during the period of heaviest rainfall.

Methods and Forecast Verification

To better understand the factors influencing the observed extreme precipitation amounts associated with Fay, a nested 4/1.33 km simulation of Fay using version 3.2.1 of the WRF-ARW forecast model is conducted. Only output from the 1.33 km simulation is shown. The simulated cyclone track and intensity (Figure 2), base reflectivity (Figure 3), and precipitation location and amounts (Figures 4 and 5) all compare well to observations, lending confidence to simulation output.

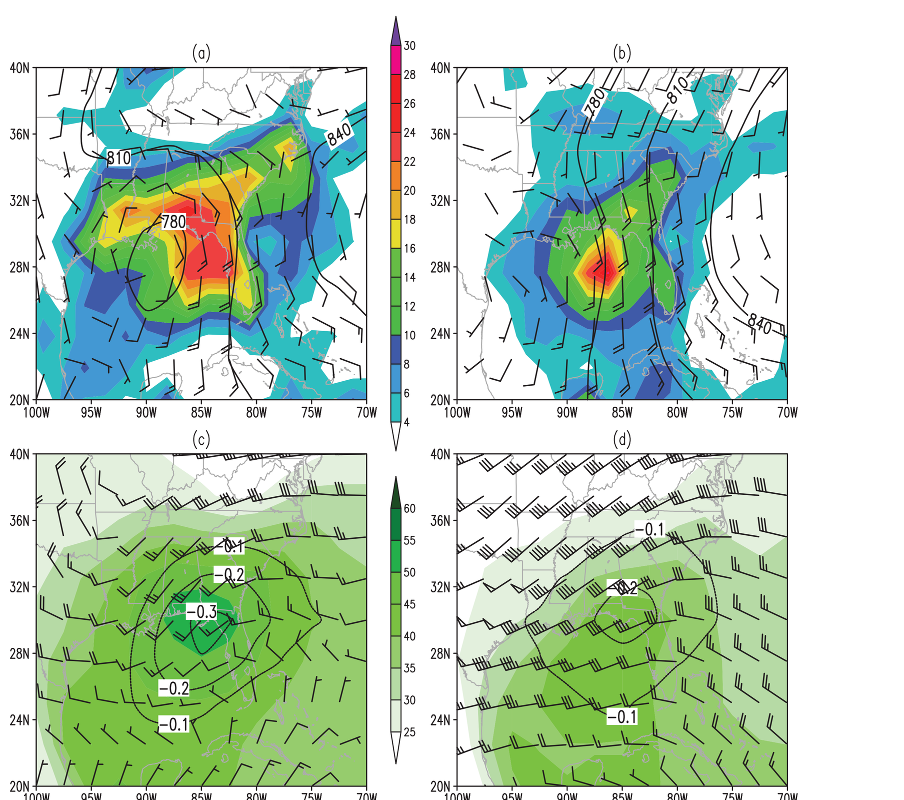

Figure 1: NCEP-NCAR Reanalysis composite means for (top) 925 hPa height (m; contoured), 925 hPa winds (kt; half: 5 kt, full: 10 kt) and precipitation rate (mm day-1; shaded). (bottom) 600 hPa vertical motion (m s-1; contoured), 300 hPa winds (kt; half: 5 kt, full: 10 kt, pennant: 50 kt), and precipitable water (mm; shaded). The TC (non-TC) composite is on the left (right).

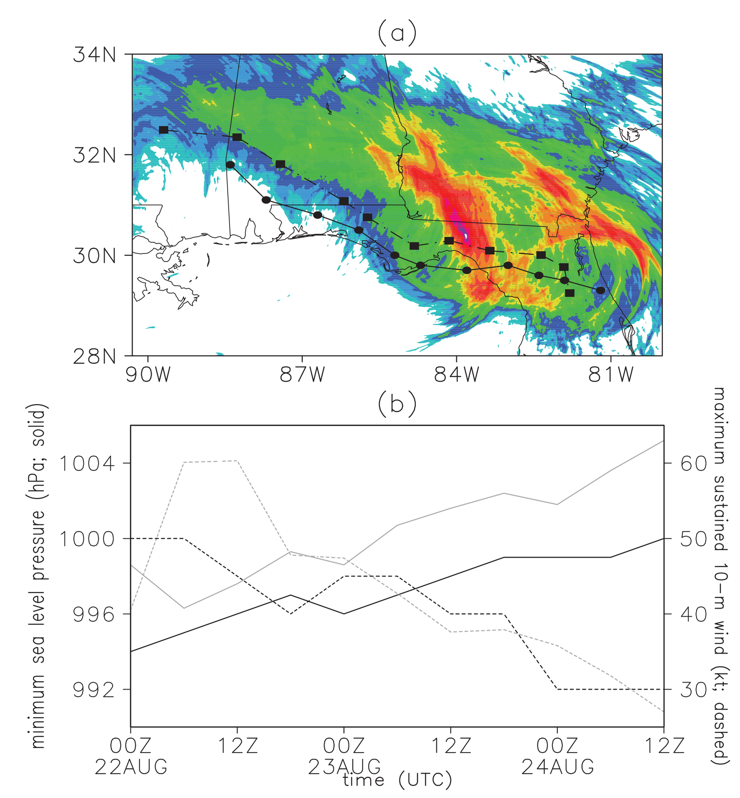

Figure 2: (top) Observed (solid) and simulated (dashed) tracks of Fay, 22-24 August 2008. Shaded is simulated precipitation (in; scale in Fig. 4)) through 0600 UTC 24 August 2008. (bottom) Observed (black) and simulated (gray) intensity measures, labeled per vertical axes.

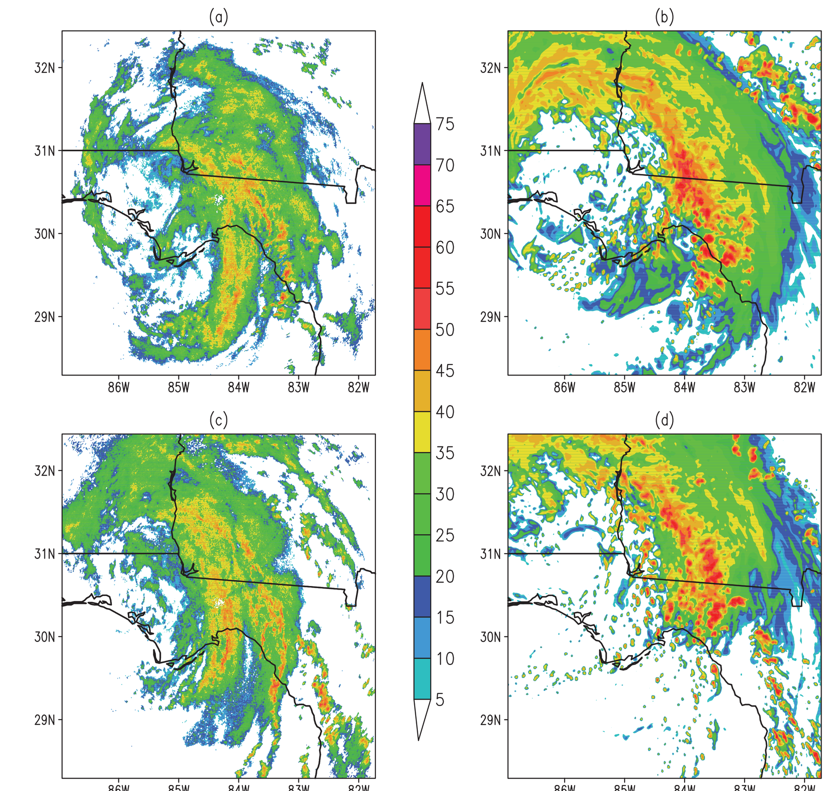

Figure 3: (left) 0.5° Level II base reflectivity (dBz; shaded) from the KTLH WSR-88D radar. (right) Simulated composite reflectivity (dBz; shaded) from the 1.33 km WRF-ARW simulation. The top (bottom) panels are valid at 1200 (1800) UTC 23 August 2008.

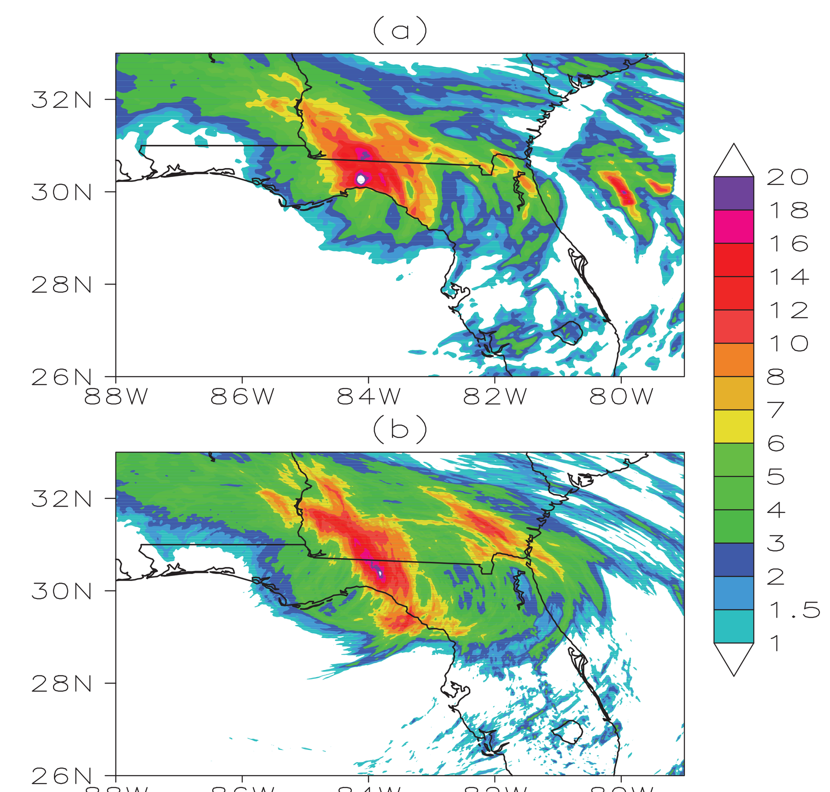

Figure 4: (top) NCEP Stage IV accumulated precipitation (in; shaded) between 0600 UTC 22 August-0600 UTC 24 August 2008. (bottom) As in top, except from the 1.33 km WRF-ARW simulation of the event.

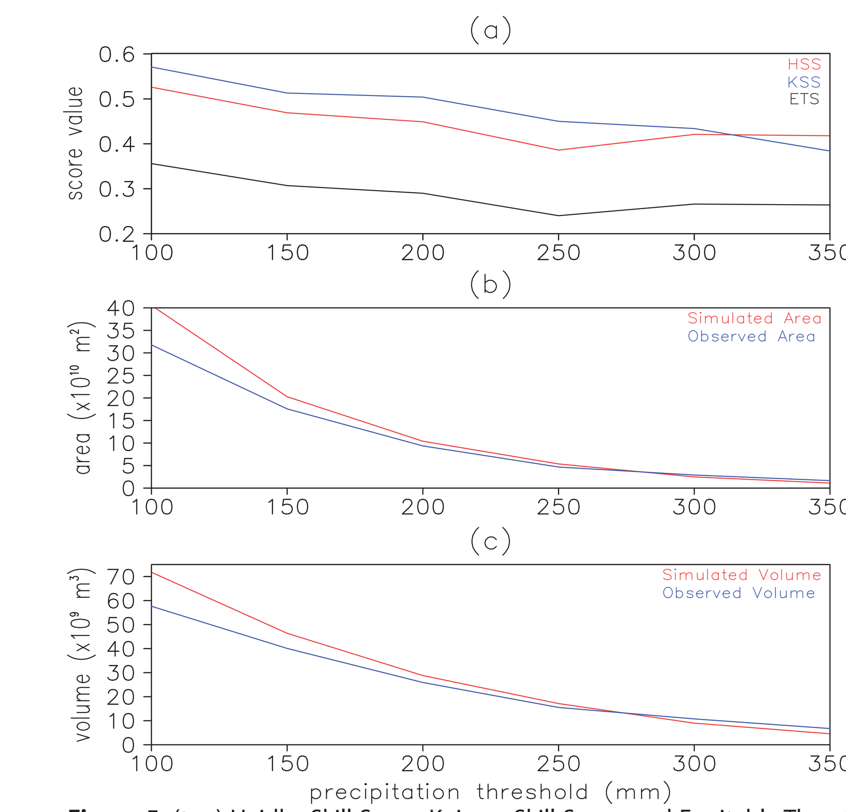

Figure 5: (top) Heidke Skill Score, Kuipers Skill Score, and Equitable Threat Score for selected total precipitation thresholds. (middle) Area of precipitation exceeding said thresholds. (bottom) Volume of precipitation exceeding said thresholds. All calculations are over the area in Fig. 3.

Synoptic-Scale Overview

Precipitation development and persistence occur in response to lower tropospheric convergence (Figures 6a,b) in a moisture-rich environment (Figures 6b, 6d, 7). Rainfall primarily occurs in an approximate moist neutral environment characterized by predominantly warm rain processes (not shown). Late on 23 August 2008, rainfall diminishes across the region as lower tropospheric convergence weakens (Figure 8d) and low entropy air in the middle troposphere enters the area (not shown). No appreciable large-scale middle-upper tropospheric triggers for precipitation formation can be identified in the external environment (Figures 6c,d).

Mesoscale and Convective-Scale Overview

Subtle changes in the outer near-surface circulation of Fay appear to be responsible for rainband development and persistence across the region (Figure 8). In particular, the near-surface flow across the Florida Peninsula becomes increasingly radial in nature, leading to enhanced lower tropospheric convergence across North Florida even as Fay continues to move westward. Precipitation associated with Fay's primary rainband on 23 August 2008 is both more efficient (Figure 9) and associated with greater vertical moisture flux (Figure 10) than that at other times. In an abundantly moist environment, these follow from the enhanced lower tropospheric convergence associated with rainband development.

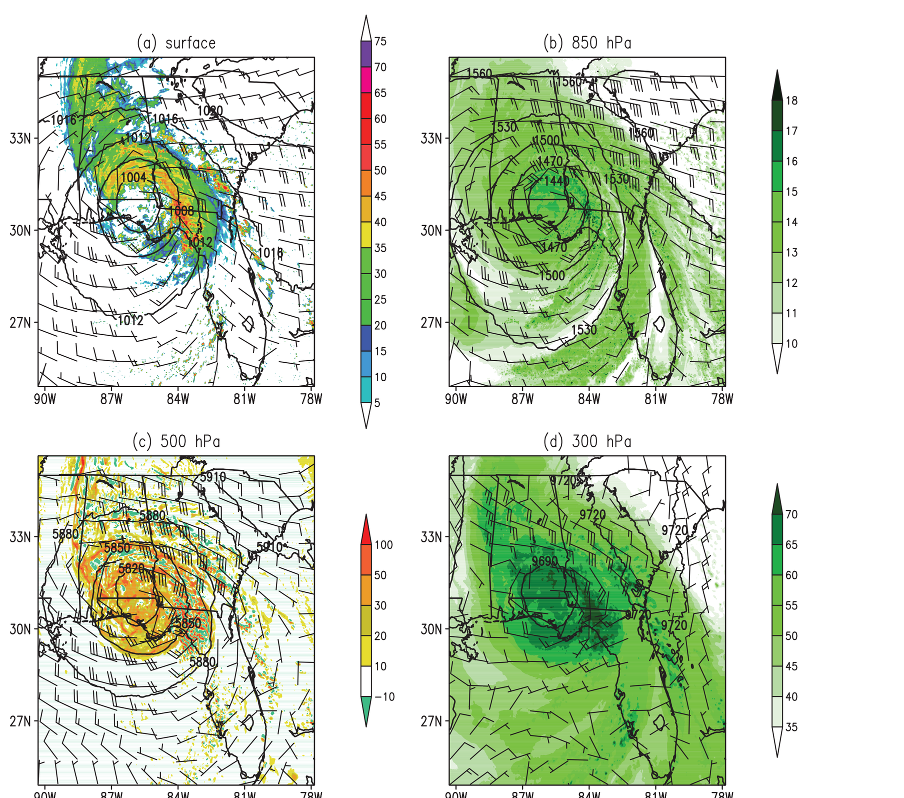

Figure 6: Synoptic analysis valid at 1200 UTC 23 August 2008. (a) Composite reflectivity (shaded; dBz), 10-m wind (barb; kt, convention in Fig. 1), and mean sea-level pressure (contour; hPa). (b) 850 hPa mixing ratio (shaded; g kg-1), wind (barb; kt), and height (contour; m). (c) 500 hPa absolute vorticity (shaded; x10^5 s-1), wind (barb; kt), and height (contour; m). (d) Total precipitable water (shaded; mm), 300 hPa wind (barb; kt), and heights (contour; m).

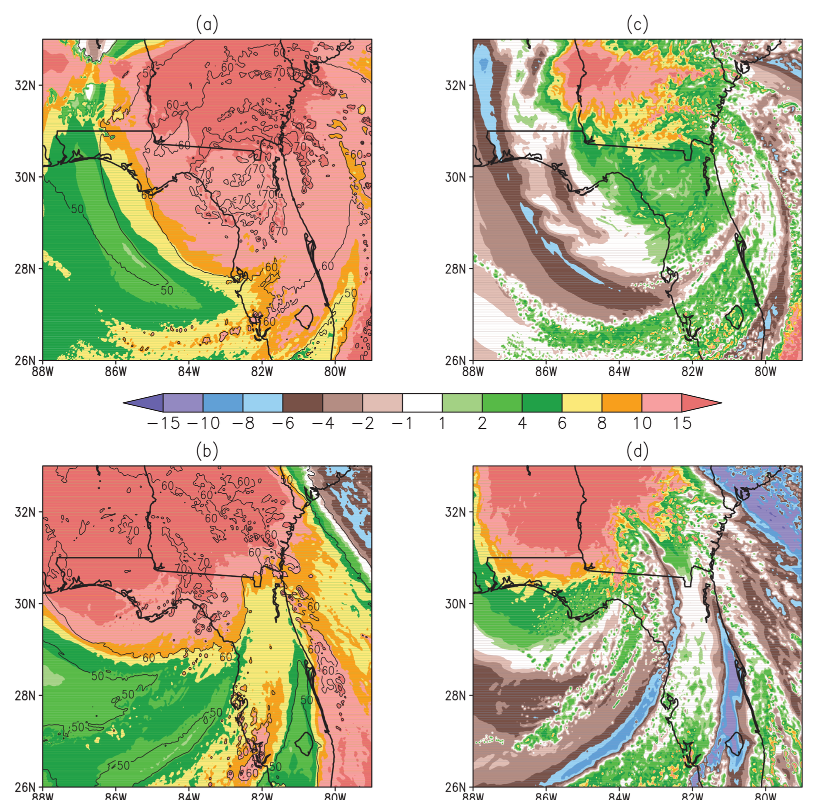

Figure 7: (left) Total precipitable water standardized anomaly (shaded) and simulated total precipitable water (contoured; mm). (right) 850 hPa mixing ratio standardized anomaly (shaded). The top (bottom) panels are valid at 1200 UTC 22 (23) August 2008. Standardized anomalies are computed from the 23 August 1948-2010 NCEP-NCAR Reanalysis climatology.

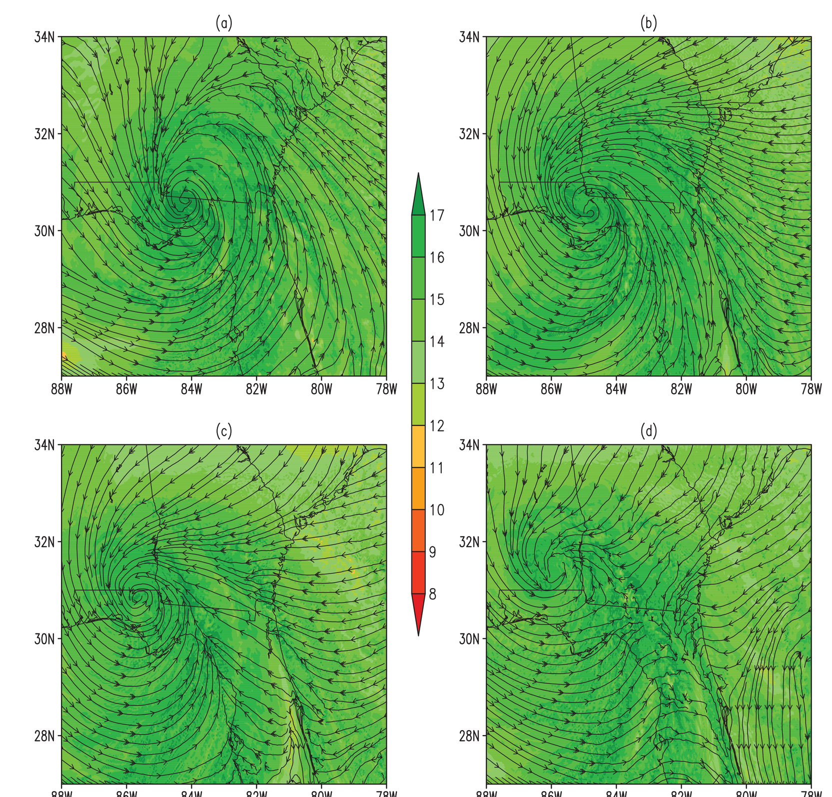

Figure 8: Simulated storm-relative 10-m streamlines and 925 hPa mixing ratio (shaded; g kg-1) valid at (a) 0100 UTC, (b) 0700 UTC, (c) 1300 UTC, and (d) 1900 UTC on 23 August 2008. Storm motion estimates are obtained via objective tracking of the surface pressure minimum.

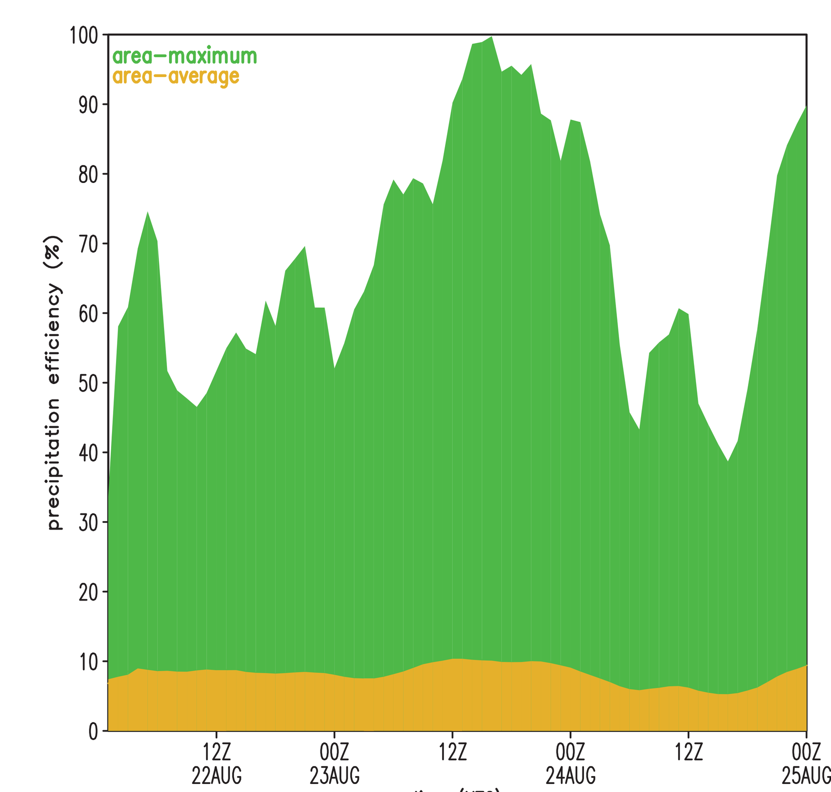

Figure 9: Area-averaged (yellow) and area-maximum (green) precipitation efficiency (%) between 0100 UTC 22 August 2008 and 0000 UTC 25 August 2008. Precipitation efficiency is computed following Market et al. (2003). The area used for these computations is depicted in Figure 3.

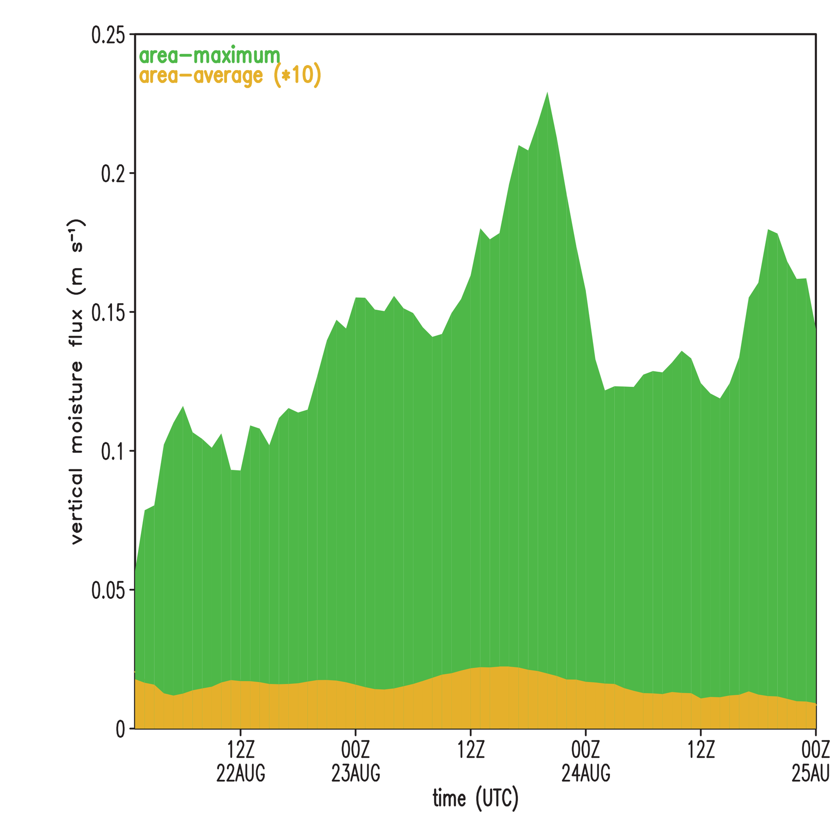

Figure 10: Area-averaged (yellow) and area-maximum (green) vertical moisture flux (m s-1) between 0100 UTC 22 August 2008 and 0000 UTC 25 August 2008. Precipitation efficiency is computed following Doswell et al. (1996). The area used for these computations is depicted in Figure 3.

Conclusions

The evolution of Fay's near-surface circulation is crucially important toward Fay producing an extreme, rather than merely heavy, precipitation event across North Florida and Southwest Georgia. Subtle changes in its character in the vicinity of the Florida Big Bend enable the development of highly efficient precipitation within a warm, abundantly moist environment lacking appreciable large-scale forcing for ascent.

Ongoing and Future Work

A sixteen member 4 km grid spacing ensemble of simulations of this event is currently being used to explore the mesoscale predictability of the heaviest rainfall and the utility of high-resolution ensembles to the operational forecast process. Sensitivity simulations will be used to explore factors influencing rainband placement. A moisture budget analysis will be conducted to better understand the increase in precipitation efficiency seen with the heaviest rainfall.

Acknowledgments and References

This research is funded by a subaward (Z11-91832) with UCAR under the sponsorship of NOAA/DOC as part of the COMET Outreach Program. Climatological precipitation data were obtained from the Utah Climate Center. Base reflectivity data were obtained from NCDC. Observed gridded precipitation data were obtained from NCEP Stage IV analyses. A full list of references is available upon request.