9.2 ANALYSIS OF SUMMER CONVECTION OVER CENTRAL ALABAMA

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1. Introduction

Short-term forecasting throughout the southeastern United States during the summer season can be very challenging for operational forecasters. Often, forecasters are mistakenly under the impression that thunderstorm development during the summer months is "random" and can "pop-up" at any location throughout a given area. However, as noted in studies in Colorado (Wilson and Schreiber 1986), and North Carolina (Koch and Ray 1997), it is readily acceptable that to produce deep layer convection, some kind of triggering or lifting mechanism is needed in the lower boundary layer to lift surface air parcels to their level of free convection.

During the summer of 2009 (June through September), forecasters at the National Weather Service Office in Birmingham, Alabama (WFO BMX) attempted to identify several of these triggers for convective initiation through the use of detailed mesoscale analyses using conventional surface observations. These analyses were augmented with other remote sensing operational tools, such as NEXRAD, and high resolution visible and infrared imagery from the Geostationary Operational Environmental Satellite (GOES). The radar and satellite datasets, along with the surface mesoanalyses, were used daily, in real-time, to detect a variety of boundaries that often initiated summertime thunderstorm development.

In this study across Alabama, numerous boundaries were found to initiate convection, including thunderstorm outflow boundaries, ridge top or orographic boundaries, sea-breeze fronts, shallow fronts (defined as fronts without the presence of dynamical upper level support), deep synoptic fronts, convective horizontal rolls, boundaries caused by differential heating, and boundaries of unknown origin. A total of 467 boundaries were identified during the summer of 2009 over Alabama, and statistics were gathered to determine the convective nature of these triggering mechanisms. Upper-air sounding information was also used as a supplement for thunderstorm initiation based on the amount of instability present on a given day, along with *in-situ* calculations of the LFC and LCL heights. The data and statistics from this study were compared to a previous study done by Koch and Ray (1997), where they identified different boundaries typically associated with summertime convection in central and eastern North Carolina.

The findings in this presentation will present initial statistics of boundary interactions to aid forecasters in the often difficult, short-term forecast process. Also, additional high resolution satellite imagery and products, such as those created by the Short-term Prediction and Research and Transition Center (SPoRT), will be described for the future of determining boundary locations (Goodman, S.J. et al. 2004). The experimental products such as those developed at the SPoRT Center,

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could be utilized throughout many National Weather Service Forecast Offices across the southeastern United States to improve short-term convective initiation and precipitation forecasts during the summer season.

2. Methodology and Preliminary Results

Daily analyses during the summer months June through September of 2009 are attempted daily beginning each morning. Mesoanalyses of surface observations over Alabama and throughout the surrounding region of Mississippi, Southern Tennessee, Georgia, and the Florida panhandle were manually performed. Mesoscale Analysis and Prediction System (MAPS) Surface Assimilation System (MSAS) and the Local Analysis Prediction System (LAPS) were both utilized as an aid in locating larger scale features in the analyses. The daily mesoanalysis was performed to determine possible locations of synoptic, or possibly mesoscale boundaries, based on surface data alone. Next, 1200 UTC sounding data were analyzed to determine the amount of instability present, along with additional sounding parameters, including the LFC, which an air parcel must reach for thunderstorm formation. GOES 1km visible resolution satellite imagery was also employed to compliment the mesoanalysis due to the course resolution in the various surface reporting stations. However, on multiple occasions, the viewing angle from GOES imagery became obstructed as thick cumulonimbus anvil generated from the initial deep layer convection made subsequent boundary identification difficult at times. This was also noted in Wilson and Schreiber (1986) and Koch and Ray (1997). NEXRAD radar data throughout the region, including KBMX, KMXX, KHTX, KGWX and KEOX were then utilized. Due to the cumulonimbus anvil development, radar data became the principal tool used for mesoscale boundary identification. As was found in Koch's study in North Carolina, boundaries were viewed within 50 nm from the radar due to Rayleigh scattering from insects, most likely. Boundaries identified farther from an individual radar were most likely from Bragg scattering, where a thermal plume or cloud was present. Each radar was analyzed from throughout the coverage area, and boundaries were identified from each separate field of view to determine the total boundaries for that particular day. The study that was performed was very different from Koch's study in 1997, due to the fact that radar coverage was much more extensive for the Alabama study. Typically, only one WSR-88D was utilized for the North Carolina study.

A sample of the daily detailed mesoanalysis performed on 28 June 2009 at 2100 UTC is shown in figure 1. As the initial convection formed along previous outflow in northern Alabama, additional convection initiated along a slow-moving synoptic front (extreme northern periphery of the study area), and along a prefrontal shallow boundary and sea breeze boundary, both located across the southern-third of the analyzed region. Subsequent deep layer convection also formed along outflow boundaries across central Alabama as boundary interactions incurred. Note the utilization of remote sensing data to identify and label the various boundaries present.

Once boundaries were identified, they were categorized using the same methods as in Koch and Ray (1997). Boundaries were labeled as autoconvective if they are able to initiate convection alone, with no other boundary interactions. Other boundary interactions were labeled as mergers (one boundary overtaking another boundary), intersections (boundaries colliding at an angle of >30°), and collisions (boundaries colliding at an angle <30°). Seven boundary types were subjectively identified and documented into a statistical spreadsheet. The boundary types identified include convective outflow, sea breeze, unknown boundaries, horizontal convective rolls, shallow fronts, synoptic fronts, and boundaries caused by differential heating.

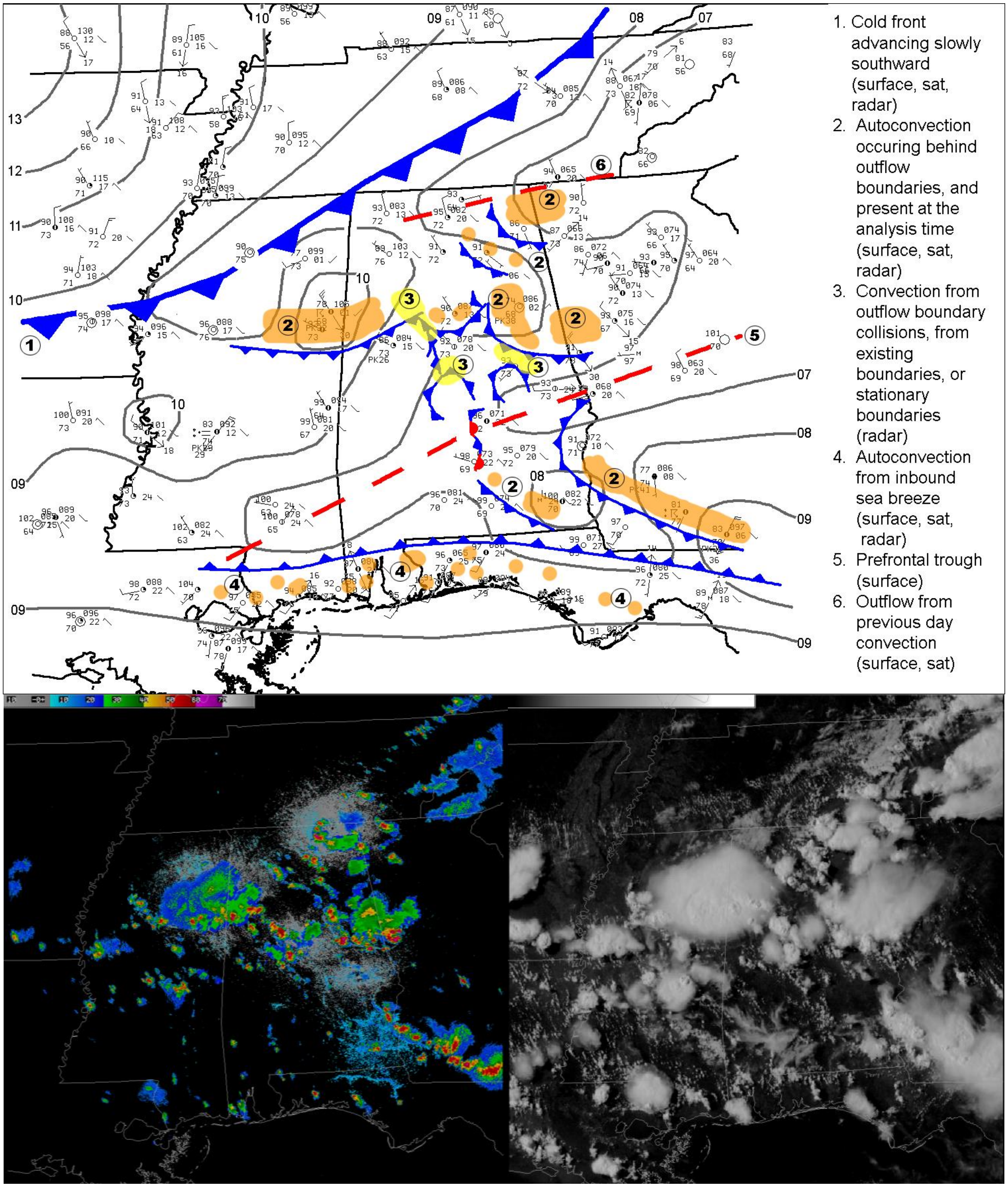

Figure 1. Detailed mesoanalysis (top) from 28 June, 2009 at 2100 UTC, with areas of autoconvection highlighted in orange and additional convection initiated from boundary interactions highlighted in yellow. Composite base reflectivity (bottom-left) and 1km visible GOES-East imagery (bottom-right) are also shown.

The boundary statistics were then compared with the previous work done by Koch and Ray (1997).

Boundary identifications were performed for a total of 71 days over the study period. Overall, 467 boundaries were subjectively identified by operational forecasters. Sixty-six percent (66.4%) of those boundaries were identified as thunderstorm outflow boundaries, 15.4% sea breeze, 7.7% were unknown, 4.9% horizontal convective rolls, 2.1% shallow fronts, 1.7% differential heating, and only 1.7% synoptic fronts due to the exclusion of most synoptic frontal events that occurred throughout the period of study. Of the different boundary types, 90% of the outflow boundaries were labeled as being autoconvective, while 84% of all fronts (shallow and synoptic), 80% of the topographical boundaries, and 55% of the unknown boundaries were also autoconvective. Combining the shallow and synoptic fronts into one category, fronts are convective 94% of the time, while 85% of the outflow boundaries were convective, 49% of the topographical boundaries (which also included sea breeze fronts), and 28% of the unknown boundaries were also associated with convection. The North Carolina study showed thunderstorm outflows were convective 90% of the time, 84% for fronts, 80% for topographical and sea breeze, and 55% for unknown boundaries. Figure 2 depicts the comparisons between the present study over Alabama and the eastern North Carolina study by Koch and Ray (1997).

The most significant difference between the two studies was seen in the percentage of topographical boundaries that were convective. The number of convective topographical boundaries observed in North Carolina was more than double the number identified in Alabama, likely due to the frequency of sea breeze fronts. Past research indicated that mean low-level flow affected the distance the sea breeze propagated inland as well as the potential for the boundary to become convective. As noted in Koch and Ray (1997), onshore synoptic flows helped the sea breeze front form early in the day and pushed it well inland, whereas offshore synoptic flows impeded the development and propagation of the front. Additionally, this collision-like interaction between the offshore synoptic flow and the boundary triggered strong deep layer convection along the boundary. This relationship between the background synoptic-scale flow and sea breeze fronts suggested that such boundaries observed within the Birmingham CWA (central Alabama) have to propagate around 150km inland, and are often weak signatures that are not as likely to be convective. Because the immediate coastal region was included in the observational study in Koch and Ray (1997), the active sea breeze fronts that are isolated near the coast were observed and documented, while they were not frequently analyzed across central Alabama.

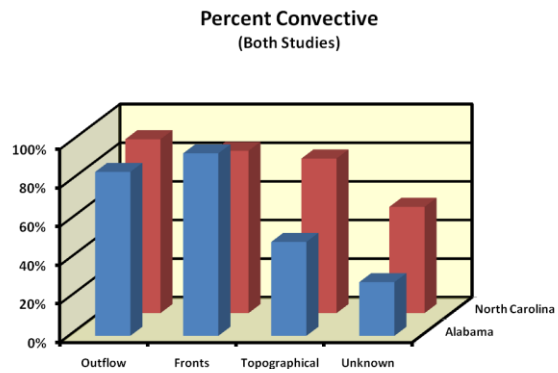

Figure 2. Frequency of boundaries producing new convection as observed across Alabama and eastern North Carolina (after Koch and Ray 1997).

3. Future Summer Convection Studies

As technology continues to advance throughout the weather forecasting science, new tools for short-term forecasting are becoming available. As these new tools become readily accessible and operational at NWS Weather Forecast Offices, collaboration between offices can be made to improve short-term summertime convective forecasting on a region-wide scale. The entire region, not just the state of Alabama, can therefore benefit from this new technology. A great method of achieving this type of collaboration and implementing new forecast tools can be done in conjunction with the SPoRT Center housed at the NASA Marshall Space Flight Center and the University of Alabama in Huntsville. The SPoRT program was created to accelerate the implementation of NASA earth science operations, data assimilation, and modeling research into National Weather Service Forecast Offices and decision making operations (Goodman, S.J. et al. 2004). The experimental products utilized through SPoRT are designed to focus on the regional scale with emphasis on high impact weather forecast improvements on a time scale from 0-24 hours. The SPoRT program is an excellent resource that WFO's can use to improve short-term forecasting for their respective CWA's throughout the southeast. One particular product that the SPoRT program is beginning to implement is the Land Information System (LIS). The LIS integrates satellite-derived datasets, ground-based observations, and model reanalysis data to form Land Surface Models (LSM's) that characterize surface states and moisture fluxes on the earth's surface (Case, J.L. et al. 2007). Figure 3 presents two of the parameters (soil type and vegetation type) that LIS takes into account. The LIS can be implemented into local Weather Research and Forecasting (WRF) models at each office, or become available within each forecast workstation database. Due to the complex terrain and soil types within each office's CWA, the LIS can pinpoint soil moisture and vegetation type differences that could possibly lead to differential heating and associated boundaries, or moisture boundaries that can possibly initiate thunderstorm development. Forecasters will then be able to add this information, which was previously unknown, into their arsenal for short-term prediction of summertime thunderstorm initiation. Figure 4 shows an example of the LIS-Noah Land Surface Model (LSM) latent heat flux from 1800 UTC on 28 June, 2009. As noted from the figure, significant latent heat flux gradients existed along and near the leading outflow boundary in north central Alabama, and coincident to the prefrontal trough present in east central Alabama into central Georgia (refer to Figure 1 for placement of these features). Figure 4 also highlights where the initial deep layer convection was forming along these same gradients.

Furthermore, additional datasets from the MODIS satellite can provide details through high spatial resolution products and imagery that will become readily available on the next generation of GOES satellites. Lifted Index, Convective Available Potential Energy, and total column precipitable water are just a few of the derived products that will be deemed useful in determining favorable areas for convective initiation.

4. Conclusion

Summer weather patterns throughout the southeastern United States can be very complex and extremely difficult to forecast. As stated in Koch and Ray (1997), the misconception that pop-up thunderstorms are random, from the days of pre-WSR-88D radars, has unfortunately been carried over into today's forecast offices. However, these so called "random" summertime thunderstorms are almost always associated with identifiable boundaries. These boundaries can be identified through careful mesoanalyses of surface observations and the use of radar and satellite datasets. The SPoRT imagery and products will add a layer of additional information that may help forecasters better understand the boundaries of unknown origin.

Current methods of forecasting probability of precipitation (POP) and quantitative precipitation forecasts (QPF) fail to give the general public the best forecast possible during the summer months. Multiple products are now available, and new tools will become available in the future, to help determine more precisely the locations of thunderstorm initiation. A more diligent

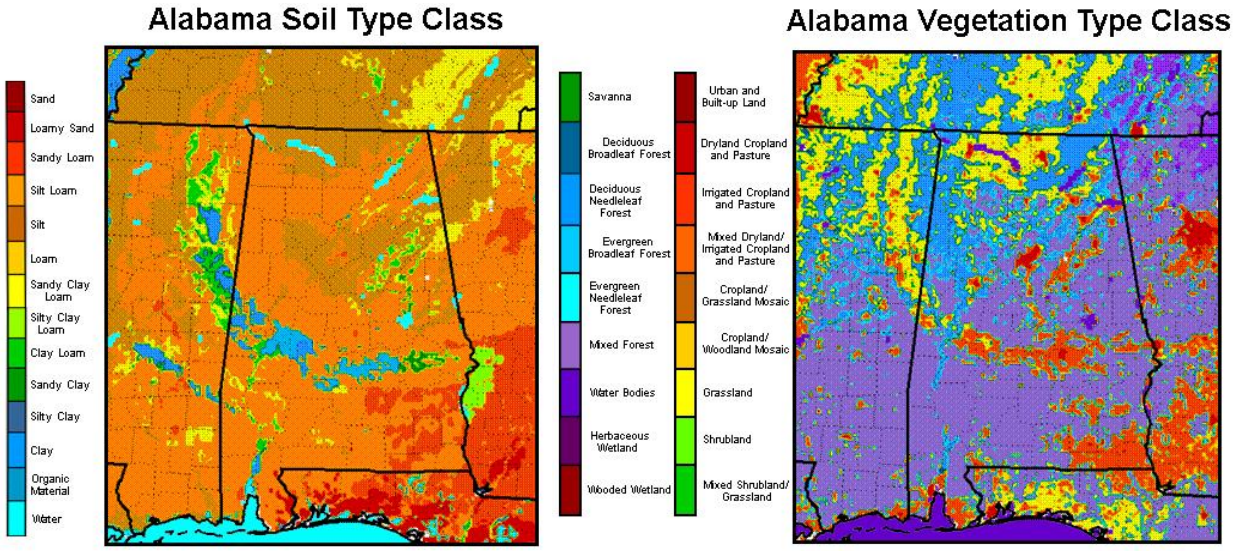

Figure 3. Sample depictions of soil type and vegetation type classes across Alabama. Images provided by the NASA SPoRT Center (Goodman, S.J. et al. 2004) in Huntsville, Alabama.

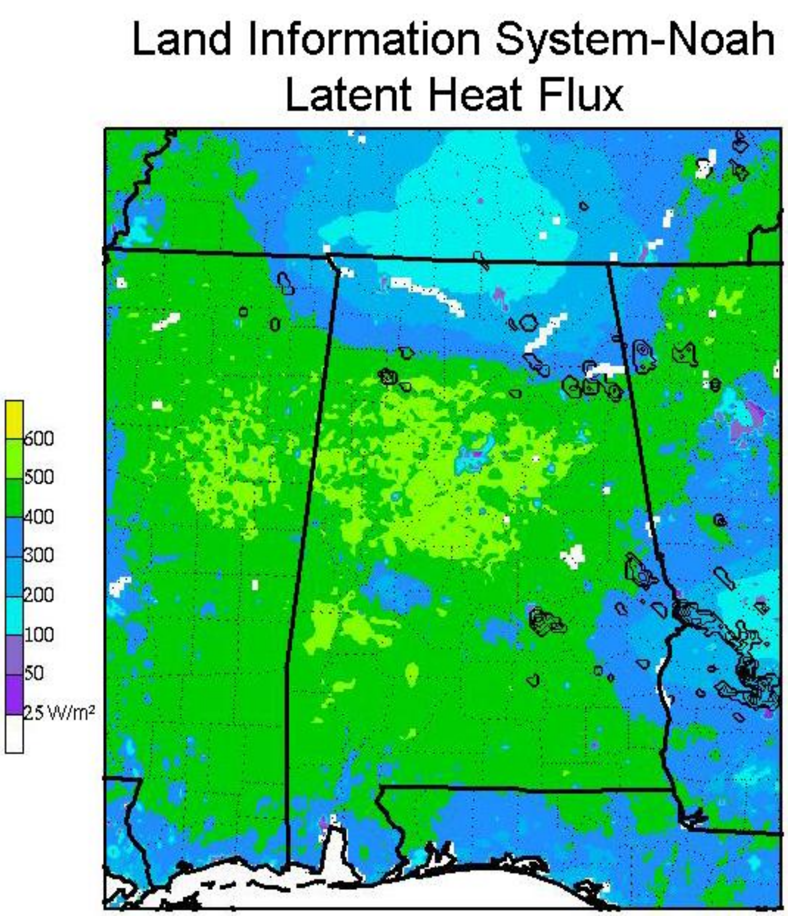

Figure 4. Land Information System-Noah Land Surface Model latent heat flux output from 28 June, 2009 at 1800 UTC. The black contours indicate regions of convective initiation at the current hour.

effort and initiative to utilize these procedures can better serve the public by generating improved forecasts for specific locations, instead of the "shotgun approach" to POP and QPF forecasts, which currently blanket an entire area.

Summertime convection is a regional phenomenon, not just an occurrence that happens throughout central Alabama. Collaborations will be possible with other forecast offices throughout the southeast to develop similar summertime convective forecast methods. Many of the boundaries identifiable in this study crossed into other states and CWAs. The end results of careful and diligent analysis are expected to continue to improve short-term POP and QPF forecasts for summer convection.

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