4.5 IMPROVING THE TEMPORAL AND SPATIAL RESOLUTION OF THE FORECAST OF SEA-BREEZE GENERATED CONVECTION ALONG THE SOUTHEAST U.S. COAST

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1. INTRODUCTION

Forecasters along the Southeast Coast of the United States face the difficult job of portraying the daily threat of sea-breeze generated convection, and the resulting rainfall threat, to their customers, and general public during the summer warm season. The daily thunderstorms pose a serious obstacle to outdoor activities, whether for commercial or recreational interests.

The difficulty in forecasting warm season rainfall arises from the complex processes that drive the convection. Daily thunderstorms are produced from the interactions between the large scale synoptic flow and the mesoscale sea-breeze boundaries (Byers and Rodebush 1948; Gentry and Moore 1954). The sea-breeze boundaries can themselves be quite complex, due to variations in shoreline orientation. The rising air parcels generated by these collisions will then encounter large variations in the environmental temperature, moisture and wind fields.

The forecast process over the past decade has transitioned from predominantly text products to high resolution gridded forecasts produced using the Interactive Forecast Preparation System (IFPS), and specifically the Graphical Forecast Editor (GFE). The IFPS and GFE system was first described by Mathewson (1996) and LeFebvre (1996).

This change in the forecast process demands a new approach to the prediction of warm season convection, in order to provide our customers with the temporal and spatial resolution they need to plan their activities. This research attempts to improve the current forecasts methodology for sea-breeze generated convection by creating high resolution spatial and temporal rainfall climatologies from archived Multi-sensor Precipitation Estimate (MPE) data. The secondary goal is to provide the National Weather Service (NWS) forecasters a quick and efficient process to incorporate these climatologies into the forecast process using GFE.

2. PREVIOUS WORK

The effort to improve the forecast of sea-breeze generated convection is certainly not a new idea. Gentry and Moore (1954) were the first to propose an improvement to these forecasts by categorizing or "typing" days according to the low level synoptic flow. These ideas were utilized by Gould and Fuelberg (1996) and Camp et al. (1998) who developed categories of synoptic flow, or wind regimes, for the Weather Forecast Office (WFO) Tallahassee region based on the 1000-700 mb mean vector wind. Watson et al. (2003) used a slightly modified set of wind regimes to incorporate lightning climatologies into GFE as a surrogate for the Probability of Precipitation (PoP).

For consistency the wind regimes used in the Watson et al. lightning frequency study were also used in this research. Figure 1 depicts the low-level wind regimes. Table 1 breaks down the criteria for each individual regime.

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Regime	Wind Direction (degrees)	Wind Speed (knots)
1	Any Direction 135 – 215	< 3 < 5
2	20 – 135	< 5
3	20 – 135	> 10
4	135 – 215	5 - 10
5	135 – 215	> 10
6	215 – 290	< 10
7	215 – 290	> 10
8	290 – 20	< 10
9	290 – 20	> 10

Table 1. Breakdown of nine wind regimes used to build climatology.

3. METHODOLOGY

In order to calculate a spatial grid of PoP values for various mean low-level wind regimes, MPE* data were obtained for the summer months (June, July, and August) during the period 1996 to 2005. The data consisted of hourly precipitation accumulations mapped onto a 4 km X 4 km Hydrologic Rainfall Analysis Project (HRAP) grid. The MPE data was derived by incorporating rain gauge based corrections into radar derived rain rates as described by Marzen and Fuelberg (2005) and Van Cleve and Fuelberg (2007).

The hourly grids for each day were summed over several time periods to create 6-, 12-, and 24-hour precipitation grids. These divisions were chosen in order to generate 6-, 12-, and 24-hour PoP climatologies. For this study, the hydrologic day was determined to start at 1200 UTC and end at 1200 UTC the next day. The various binned time periods are described in Table 1.

6-Hour Periods	12-Hour Periods	24-Hour Period
12 – 18 UTC	12 – 00 UTC	12 – 12 UTC
18 – 00 UTC		
00 – 06 UTC	00 – 12 UTC	
06 – 12 UTC		

Table 2. Time periods used to generate 6-, 12-, a 24-precipitation accumulation grids.

Radiosonde data for site KTLH (Tallahassee, FL) was obtained from the National Climatic Data Center. 1200 UTC soundings for each day of the study period were analyzed and the 1000-700mb vector mean wind was calculated. This value was used to categorize each day of the study period into the appropriate flow regime. Only days where distinct tropical systems directly impacted the region were excluded from the study.

For each day in each particular flow category and each particular precipitation category, the MPE data was analyzed grid point by grid point. If the MPE value was greater than 0.01 in, the day was determined to be a “Rain Day.” The threshold of 0.01 inch was used as a simple noise filter for the precipitation data. The PoP was then calculated as a simple ratio of “Rain Days” to “Total Days” in the flow regime.

4. REGIME RAINFALL FREQUENCIES

The first calculated rainfall frequencies were daily and comprised a 24-hour period from 1200 through 1200 UTC. While distinctive patterns were certainly evident, the 24-hour period did not provide an adequate temporal resolution for the current forecast products.

In order for outdoor activities to be planned effectively, those making the decisions need to not only have a rainfall threat probability, but also a potential timing for the threat. In order to achieve this goal, The 6-hour and 12-hour climatologies were developed for this purpose. Fig. 40 shows the 1200-0000 UTC results for each of the nine regimes, while Fig. 42 shows the higher temporal resolution climatologies from 1800-0000 UTC.

Analysis of the 12-hour and 6-hour temporal frequencies showed distinct rainfall probability patterns associated with each flow regime. Some of the localized rainfall probability differences between regimes were quite significant to daily forecasting. For example, looking at Fig. 40, the probability of rainfall between 1200 UTC and 0000 UTC at Dothan, Alabama during a regime 5 synoptic flow (South to Southeast > 10 knots) is around 60%. However, under a regime 3 synoptic flow (East to Northeast > 10 knots), this probability falls to around 15%. Still looking at Fig. 40, the Tallahassee, FL metropolitan area, experiences rainfall probabilities of around 70% under regime 5, 6, or 7. However, during regime 2 or 8 synoptic flow the rainfall probability at Tallahassee, FL falls to around 30%.

Beginning and ending times of the greatest rainfall threat at a specific location can be determined by looking at the 6 hour progression of rainfall frequencies during a flow regime day. Fig. 65 shows the 6 hour rainfall frequencies during a regime 6 day (West to Southwest 5-10 knots).

Looking at progression of rainfall frequencies from the 1200-1800 UTC panel to the 1800-0000 UTC panel, a forecaster could more confidently give a “window” of dry weather into the early afternoon for locations north of I-10. Any significant convective coverage is likely to hold off until after 1800 UTC. Closer to the Florida Panhandle coast, outdoor activities may want to postponed altogether under this regime as convective coverage begins to increase much earlier in the day.

Another area of note is along the coast of Franklin County Florida, and specifically Saint George Island. For these locations the greatest potential for rainfall exists during the pre-dawn and morning hours associated with the nocturnal land-breeze interacting with the synoptic flow. As the diurnal sea-breeze develops and is accelerated inland by the synoptic flow, the rain chances fall to under 20% for the afternoon and evening hours.

5. RAINFALL FREQUENCIES IN GFE

GFE contains internal routines for saving gridded datasets. These saved static datasets can then be retrieved on demand for population into the forecast database. Once the climatogical rainfall frequencies had been calculated and graphically displayed, these images were manually digitized and saved into the GFE database for each temporal regime period.

As noted by Watson et al. (2003), warm season convection along the Southeastern United States coastline is highly controlled by the interaction of the low level synoptic flow with the daily meso-scale sea-breeze boundaries. The atmosphere is almost always conditionally unstable and often void of other large scale synoptic influences. Therefore, these climatological rainfall frequencies for each flow regime and temporal length can be recalled by the forecaster from the GFE database as a “first guess” forecast POP. An example of the 12 hourly calculated raw rainfall frequencies from Regime 5 (strong west to southwest flow), and the corresponding GFE representations can be seen in fig. 95. Another example showing the 6 hourly calculated raw rainfall frequencies for Regime 6 (moderate south to southeast flow) can be seen in figure 100, along with the corresponding GFE representations.

A convenient system was needed for the retrieval of a desired rainfall climatology and temporal span from the GFE database. To accomplish this task a GFE program was created called the “Tallahassee Sea-breeze Convection Forecast Procedure”. The forecaster interface for this procedure is seen in figure 30. The procedure allows the forecaster to manually select the flow regime for the forecast period, or contains an option requesting the procedure to objectively select the flow regime from model guidance. The forecaster can then select the desired time span (12 or 6 hours). The procedure will recognize the time span being forecast and recall the proper 12 or 6 hour rainfall frequency. For example if the forecast PoP grid being edited with the procedure extends from 1200 through 1800 UTC, the procedure will automatically grab the 1200 to 1800 UTC rainfall frequency for the determined flow regime.

6. THERMODYNAMIC ADJUSTMENTS

An additional feature was incorporated into the Tallahassee Sea-breeze Convection Procedure, designed to modify the climatolgical rainfall frequencies based on thermodynamics properties of the atmospheric column.

It was determined that Convective Available Potential Energy (CAPE), one of the more popular thermodynamic variable used to forecast convection, was not preferred near the Gulf of Mexico coast during the warm season due to relatively high daily values observed through the season. However, the variable that showed the most influence on warm season convective coverage was mid-tropospheric (700-600mb) theta-e.

This relationship between convective coverage and mid-level theta-e (Θ_e) was described by Garstang et al. (1967). This study done in the tropical Atlantic Ocean showed disturbed, or higher coverage convective days, to have higher values of mid-tropospheric Θ_e, and that Θ_e values decreased on undisturbed days (Ramage 1995).

Initial values of mid-level Θ_e associated with departures to the climatological convective coverage were established during a study conducted at the National Weather Service in Tallahassee during the warm season months of 2009.

The influence of mid-level theta-e can be applied to the climatological rainfall frequency through an option on the Tallahassee Sea-breeze Convection Forecast Procedure GUI. If the thermodynamic adjustment option is chosen, climatological rainfall frequencies will be adjusted accordingly at each grid point. Fig. 45 shows a sample GFE representation of a calculated mid-level Θ_e grid. The influence of this Θ_e gradient on the 1800 UTC through 0000 UTC climatological rainfall frequency from regime 8 is seen in Fig. 55. The original rainfall frequency is seen on the left, with the final adjusted grid seen on the right.

7. SUMMARY

The high resolution spatial and temporal gridded forecasts now possible through the IFPS allow those with outdoor interests a superior method for interpreting and understanding the daily threat from warm season convection.

Conventional statistical guidance such as Model Output Statistics (MOS) simply provides too course a network of forecast points to capture the true pattern of sea-breeze induced rainfall frequencies. Our calculated climatological rainfall frequencies for each gridded point allows the forecaster to more confidently relay the specific daily convective threat to a location, or convective threat during a particular portion of each day. Customers will be able to more efficiently plan specific outdoor activities over the forecast period based on the predicted evolution of the low level wind regime.

These climatological rainfall patterns will be further refined by recalculating each temporal field to include the most recent year’s data. This yearly recalculation will allow natural variations in climate to show their signal in the data.

8. ACKNOWLEDGEMENTS

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9. REFERENCES

Byers, H.R., and H.R. Rodebush, 1948: Causes of thunderstorms of the Florida Peninsula. *J. Meteor*., 5, 275-280.

Camp, J.P., A.I. Watson, and H.E. Fuelberg, 1998: The diurnal distribution of lightning over north Florida and its relation to the prevailing low-level flow. *Wea. Forecasting*, 13, 729-739.

Garstang, M., NE. LaSeur and C. Aspliden, Equivalent Potential Temperature as a Measure of the Structure of the Tropical Atmosphere, Dept. Meteor., Florida State Univ. Rept., 67-10; 1967.

Gentry, R.C., and P.L. Moore, 1954: Relation of local and general wind interaction near the sea coast to time and location of air mass showers. *J. Meteor*., 11, 507-511.

Gould, K.J., and H.E. Fuelberg, 1996: The use of GOES-8 imagery and RAMSDIS to develop a sea-breeze climatology over the *Florida panhandle. Preprints*, Eight Conf. on Satellite Meteorology and Oceanography, Atlanta, GA, Amer. Meteor. Soc., 100-104.

LeFebvre, T.J, .C. Bacco, and M. Romberg, 1996: Gridded forecast products and services under development at FSL. *Preprints 17th Conference on Weather Analysis and Forecasting*, Norfolk, VA, Amer. Meteor. Soc.

Marzen J., and H. E. Fuelberg, 2005: Developing a high resolution precipitation dataset for Florida hydrologic studies. *19th Conference on Hydrology*, San Diego, CA, Amer. Meteor. Soc.

Mathewson, M.A., 1996: Using the AWIPS Forecast Preparation System (AFPS). *Preprints, Twelfth International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology (IIPS),* Atlanta, GA Amer. Meteor. Soc.

Ramage, Colin S., 1995: *Forecasters Guide to Tropical Meteorology*. Air Weather Service Technical Report 240 Updated, Air Weather Service, Scott Air Force Base, IL.

VanCleve, D.D., and H. E. Fuelberg, 2007: An intercomparison between mean areal precipitation from gauges and a multisensory procedure, *21st Conference on Hydrology*, San Antonio, TX, Amer. Meteor. Soc.

Watson, A.I., T.J. Turnage, K.J. Gould, J.R. Stroupe, T.P. Lericos, H.E. Fuelberg, C.H. Paxton, and J.E. Burks, Year: Utilizing the IFPS/GFE to Incorporate Mesoscale Climatologies into the Forecast Routine at the Tallahassee NWS WFO. *9th Conference on IIPS*, Long Beach, CA, Amer. Meteor. Soc.

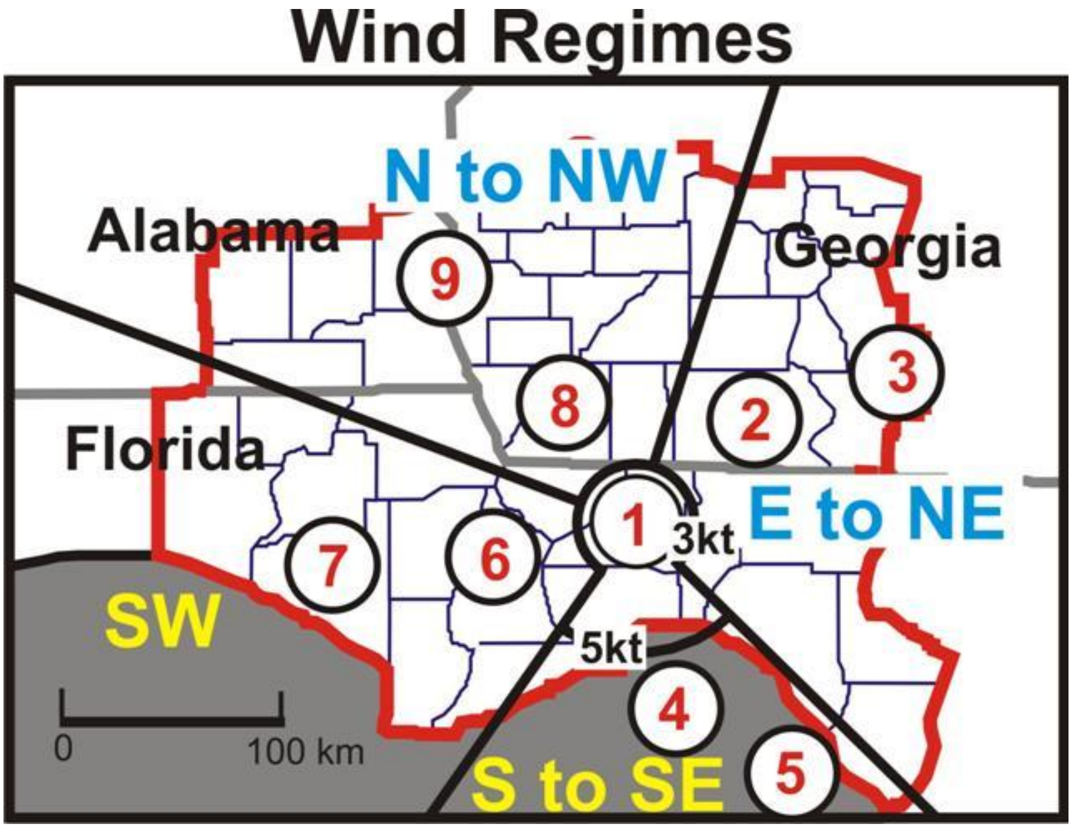

Figure 1. Depiction of the nine wind regimes used to classify the mean low-level flow. The inner numbers respresent light to moderate flow (< 10 knots). The outer numbers represent strong flow (> 10 knots).

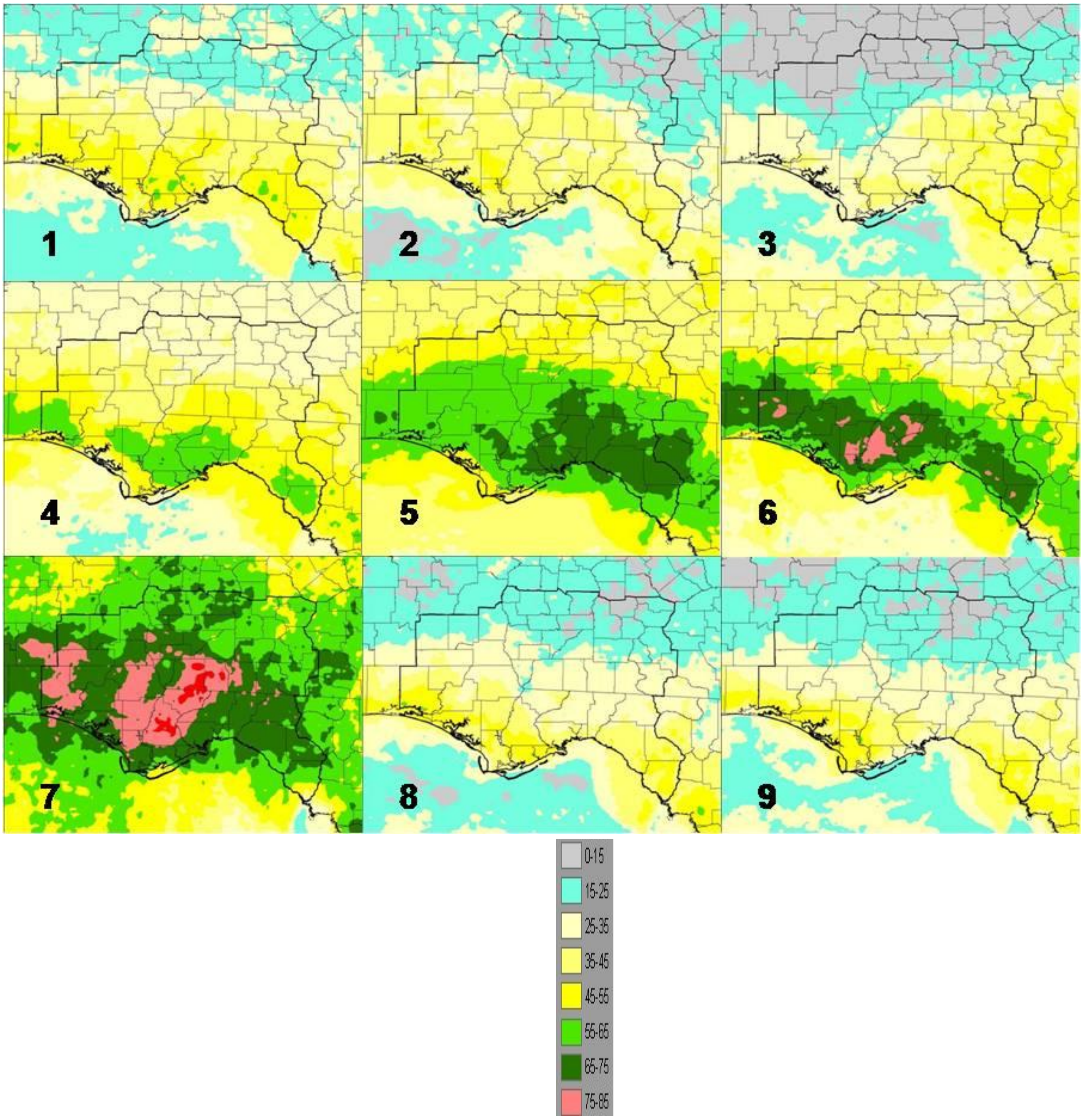

Figure 2. 1200 UTC through 0000 UTC Climatological PoPs for Regimes 1 – 9.

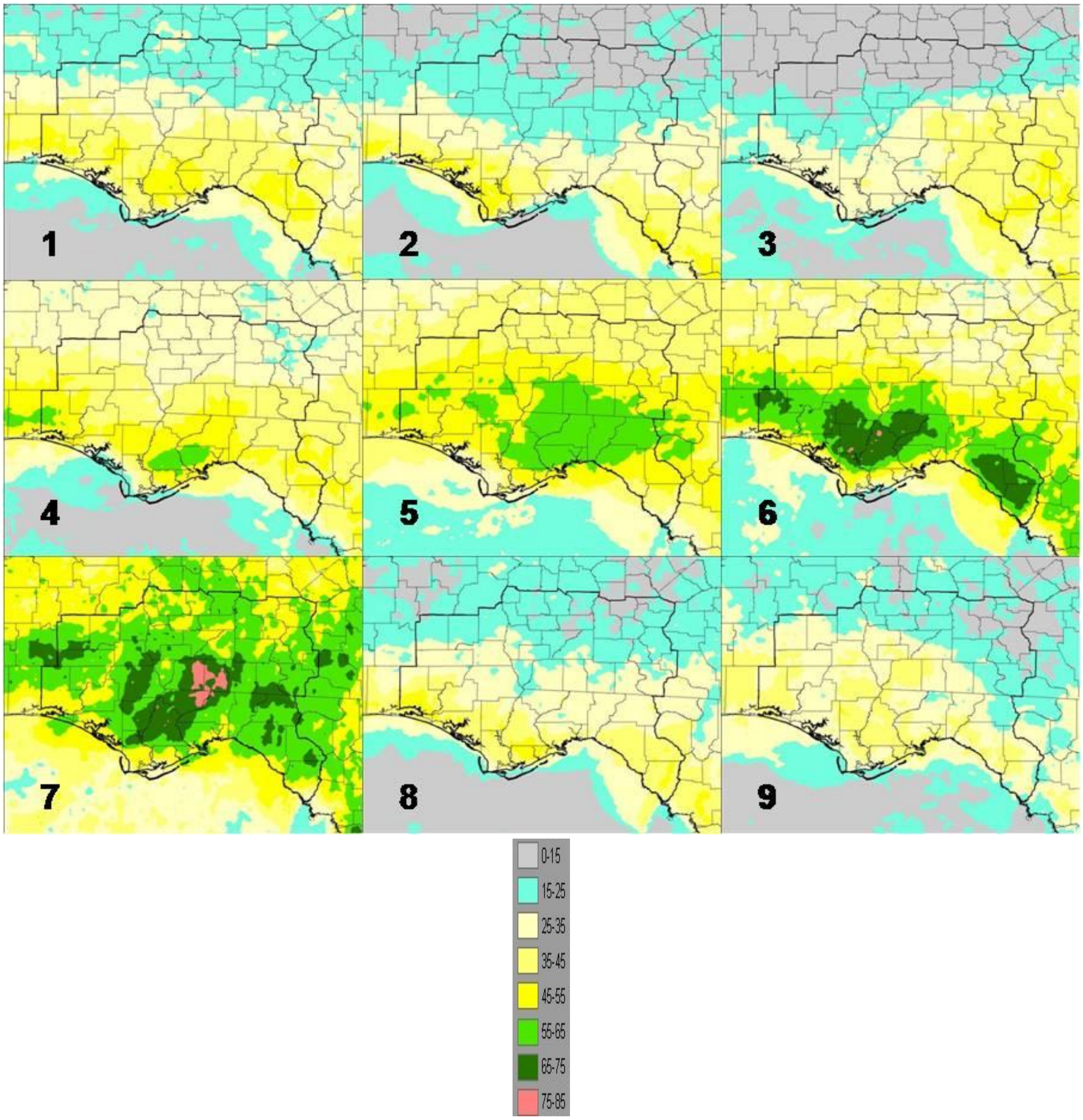

Figure 3. 1800 UTC through 0000 UTC Climatological PoPs for Regimes 1 – 9.

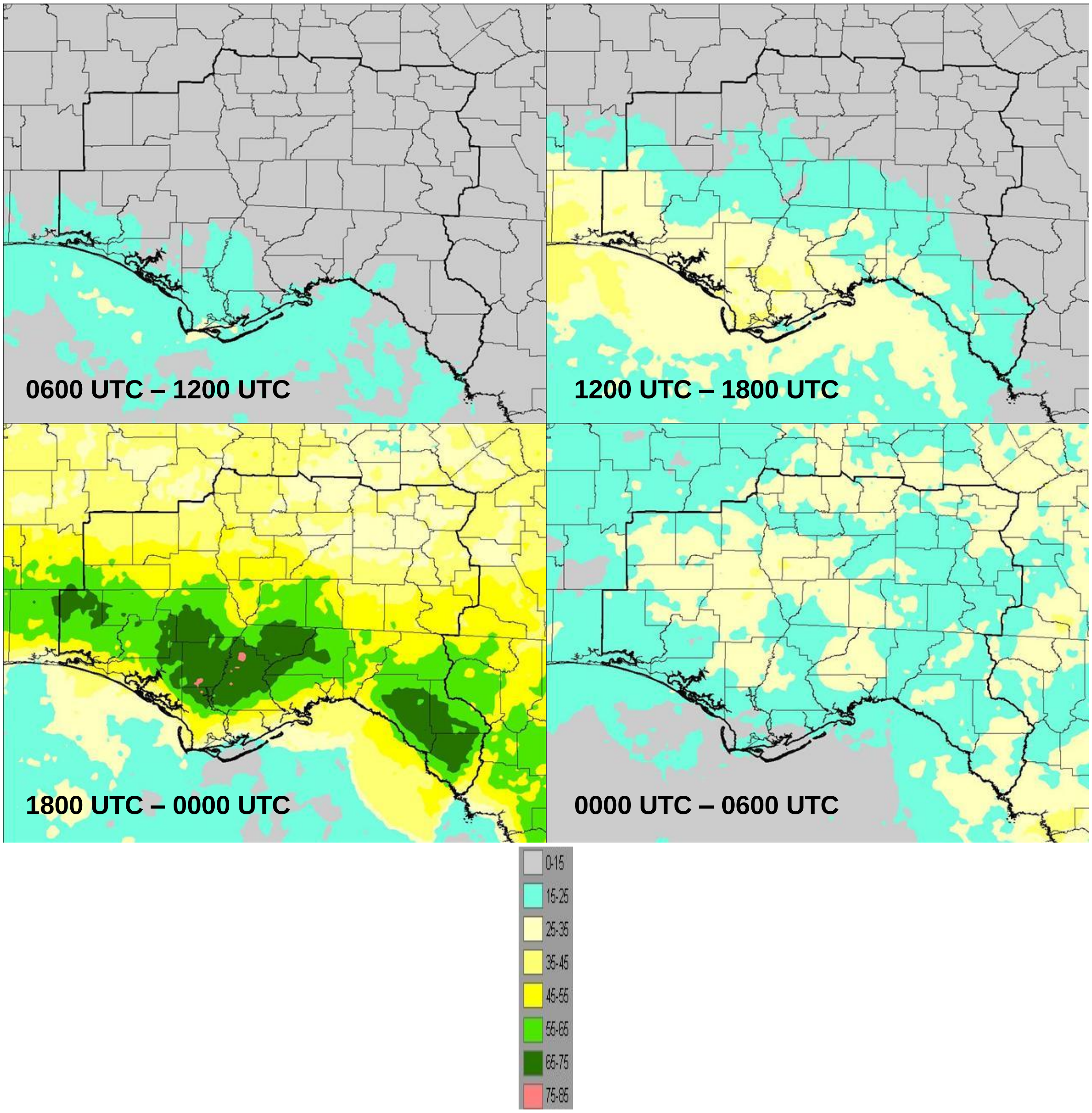

Figure 4. Regime 6 (Moderate Southwest Flow) Rainfall Probability progression. 0600-1200 UTC (top left), 1200-1800 UTC (top right), 1800-0000 UTC (bottom left), 0000-0006 UTC (bottom left).

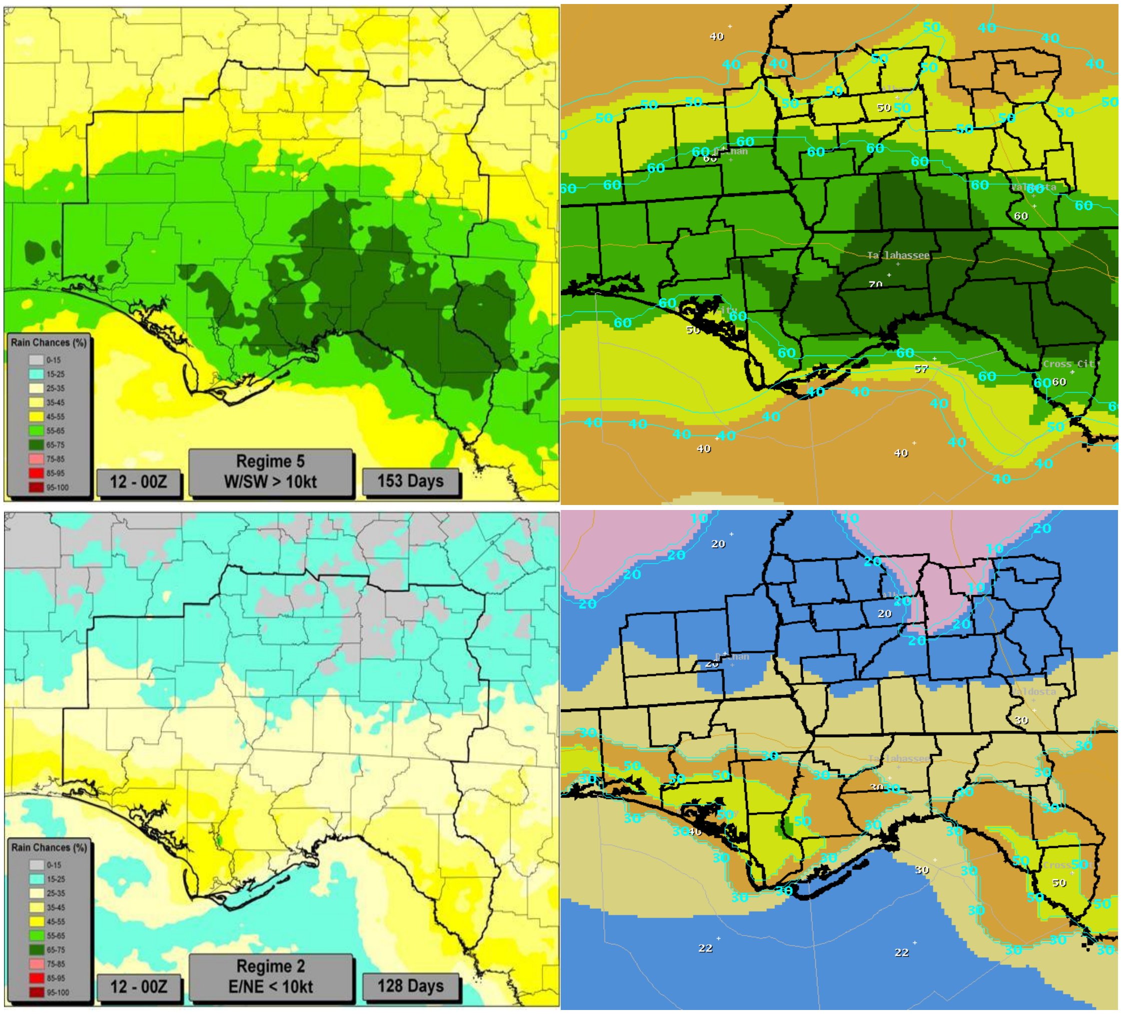

Figure 5. Regime 5 (1200 through 0000 UTC) Climatological PoP (top left) and the corresponding GFE representation (top right). Regime 2 (1200 through 0000 UTC) Climatological PoP (bottom left) and the corresponding GFE representation (bottom right).

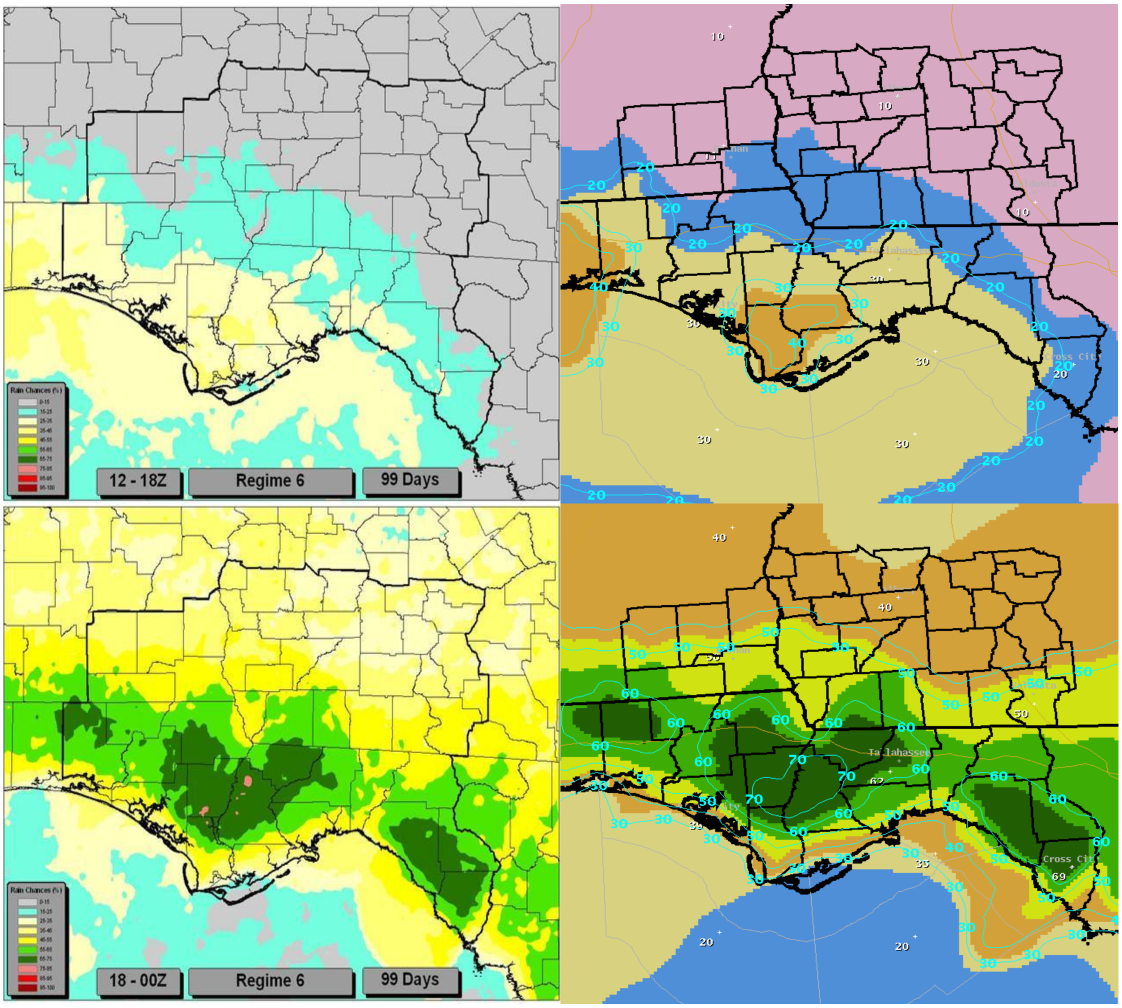

Figure 6. Regime 6 (Moderate South/Southwest Flow). 1200 through 1800 UTC Climatological PoP (top left) and the corresponding GFE representation (top right). 1800 UTC through 0000 UTC Climatological PoP (bottom left) and the corresponding GFE representation (bottom right).

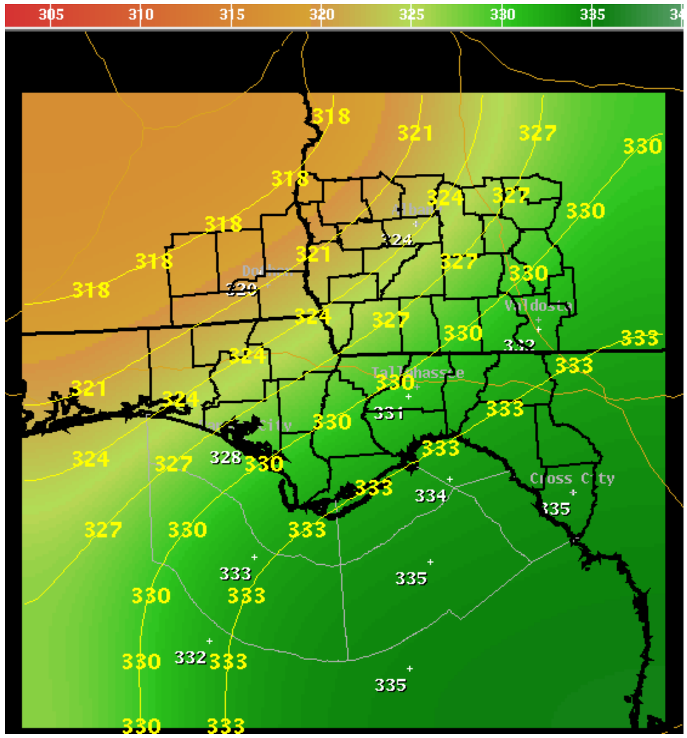

Figure 7. GFE calculated 600mb to 700mb theta-e values.

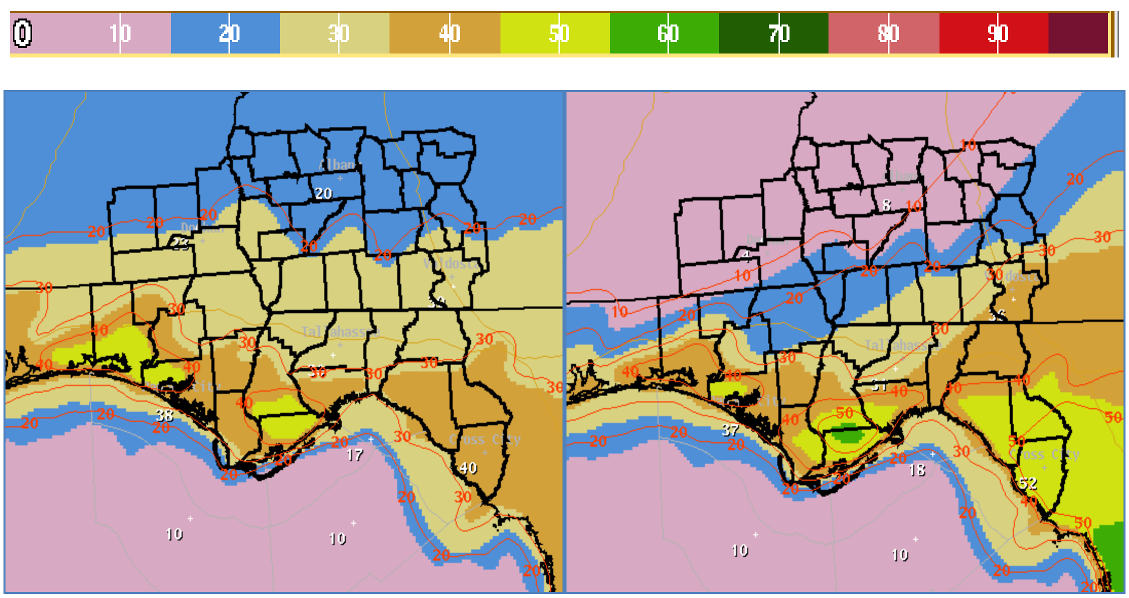

Figure 8. Regime 8 (Moderate North/Northwest Flow) 1800 to 0000 UTC climatological PoP from GFE (left) and adjusted GFE PoP (right) based on 600-700mb theta-e grid shown in Figure 7.