# An Analysis of the Favorable Synoptic and Mesoscale Environments Associated with the January 22nd 2017 Tornado Outbreak

*Introduction*

The January 22nd 2017 tornado outbreak was the deadliest in South Georgia in nearly 17 years. From the pre-dawn hours through mid-afternoon, 4 significant (EF-2 or greater) tornadoes struck south Georgia, killing 16 people. While strong winds aloft, large height and pressure falls, and a warm, moist airmass were common across much of the Southeast, it appears that the favorable interplay between the synoptic environment and a well-defined, mesoscale boundary focused the strongest and longest-lived tornadoes in south Georgia.

*Forecast Overview*

Forecasters first noticed the potential for severe thunderstorms a week before the event, when some of the more reliable numerical weather prediction models (including the GFS and ECMWF) depicted an unusually strong low pressure system developing over the Southeast the following weekend. On January 16th, the Storm Prediction Center, the branch of the National Weather Service charged with forecasting severe thunderstorms across the continental U.S., placed much of the northeast Gulf Coast region in a "Slight Risk" of severe storms. (Figure 1).


**Figure 1. "Slight Risk" (15% probability) of severe storms, issued 6 days before tornado outbreak.**

On the evening of January 18th, the National Weather Service in Tallahassee posted a message on social media (Figure 2) outlining the forecast track of the upper- level disturbance which went on to produce the January 22nd outbreak. At this time the short wave trough was south of Alaska, over 4,000 miles northwest of Tallahassee, and still beyond the U.S. upper-air network. Thus the only data being assimilated into the forecast models from that region were those collected from satellites and commercial airlines. As a testament to the very fast upper-level winds at the time, this system would travel over 4,000 miles in only 4 days, an average of over 40 MPH.

In many ways the forecast evolution for this event encapsulated the current state of numerical weather prediction. On the positive side, the weather prediction models were able to successfully simulate the unusually-powerful low pressure system which developed across the Deep South, and they did this consistently for the week leading up to the event. This gave forecasters increasing confidence in their expectation of severe weather. However, forecasters recognized that conditions could be **so** favorable for thunderstorms on the weekend of January 21st and 22nd, that there could be multiple rounds of storms during that time. This presented two main forecast challenges, (1) timing the individual rounds of storms, and (2) determining if these complexes of storms would alter the environment in a positive or negative manner for the development of severe storms.

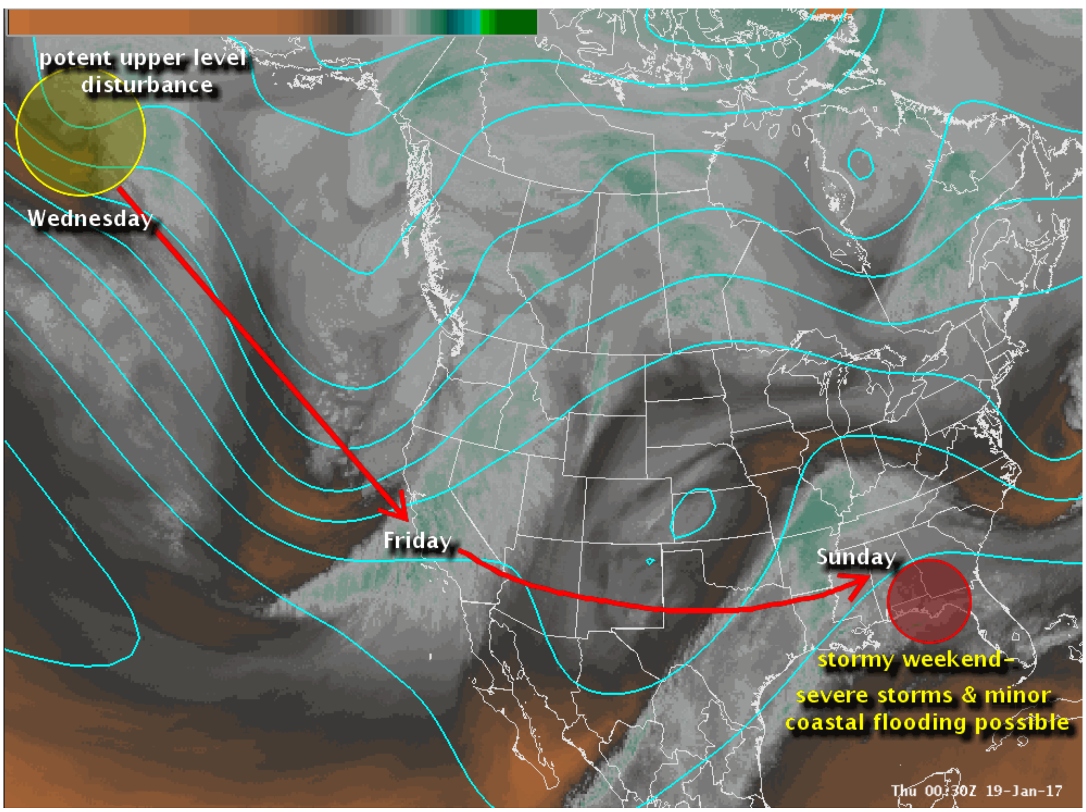


**Figure 2. Wednesday evening water vapor image and GFS 500 mb heights.**

The majority of U.S. tornadoes are relatively weak (EF-1 or less) and travel less than 10 miles. However, in the pre-dawn hours of January 22nd, two significant tornadoes (an EF-2 and an EF-3) struck south Georgia. The EF-3 tornado, with estimated wind speeds up to 140 MPH, killed 11 people in the communities of Barney, Adel, and rural Berrien County in Georgia. The tornado remained on the ground for nearly 25 miles. As these reports, along with new weather data, reached the Storm Prediction Center that morning, forecasters took the rare step of placing much of north Florida and south Georgia in a "High Risk" of severe storms (Figure 3). This was the first "High Risk" outlook for anywhere in the country since June 3rd, 2014. There were numerous reports of wind damage that day, punctuated by 4 more tornadoes. Once again, the 2 strongest tornadoes (an EF-2 and an EF-3) hit south Georgia. The "Albany tornado" produced winds up to 150 MPH (EF-3), and killed 5 people. This unusually large, strong, and long-lasting tornado tracked 71 miles, and was on the ground for more than an hour. At times the twister was 1.25 miles wide.

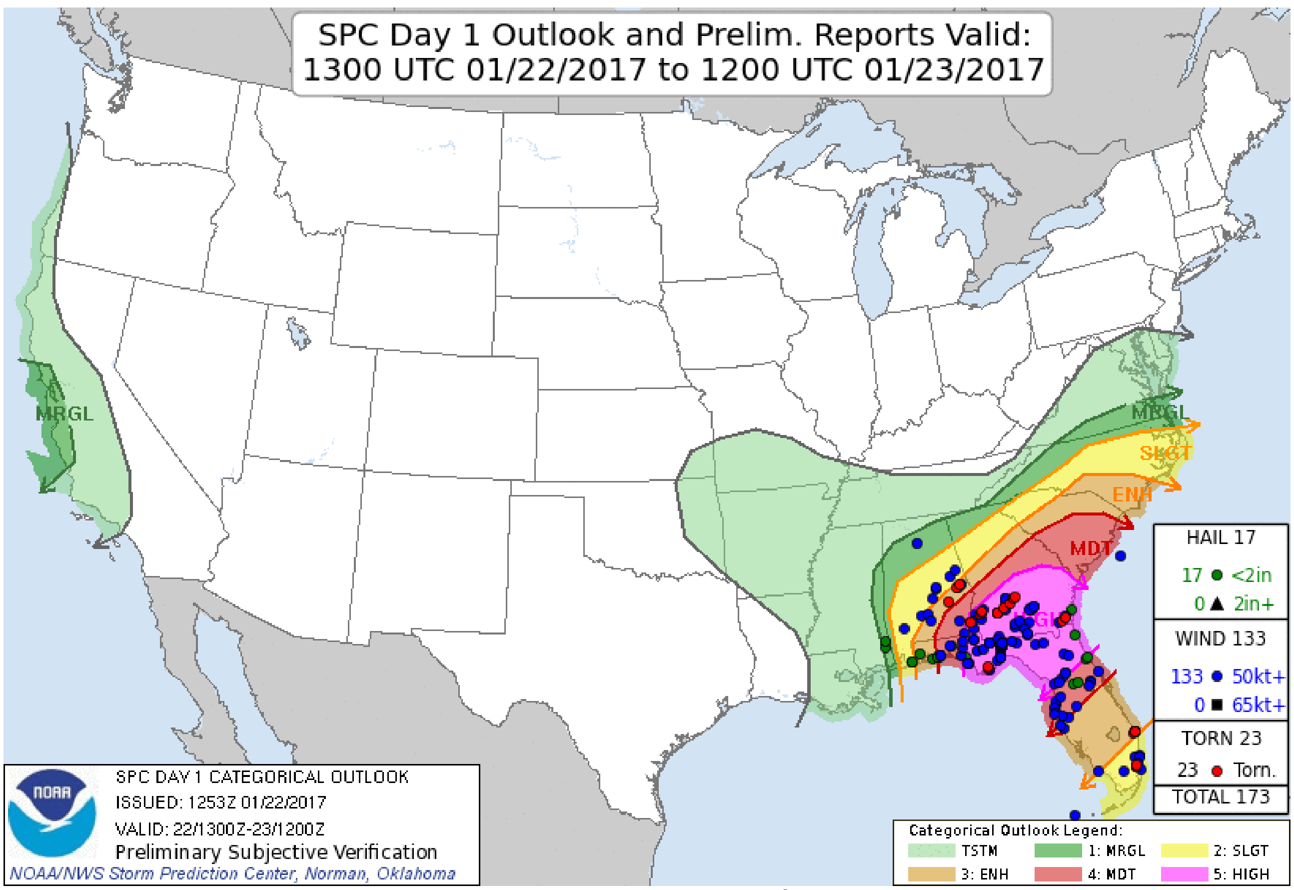

**Figure 3. SPC Convective Outlook from the morning of January 22nd. High risk shaded light purple. Blue dots are wind damage reports and red dots are tornado reports from that day.**

*Synoptic Pattern Overview*

Weather can be broken down into multiple temporal and spatial scales- from a tiny eddy of leaves swirling briefly in a parking lot, to upper level troughs which span thousands of miles and last for days. Although these scales overlap, it's often helpful to study them separately, as each can make important contributions to significant weather events. This section focuses on the *synoptic* scale, which covers large weather systems such as cold fronts and high and low pressure systems. The large size of these phenomena means they are often able to be observed by multiple weather stations, and thus are usually handled well by numerical weather prediction models.

Figure 4 is a subjective analysis (i.e. analyzed by a meteorologist, not a computer program) of heights and wind speeds at the 500 mb level, about 18,000 feet above ground level. It's from 7 am EST, January 22nd, near the time of the tornadoes. An unusually deep, upper-level low centered along the Red River advanced quickly eastward across the Southeast. This system was preceded by very strong southwest winds, especially above 5,000 feet where winds exceeded 50 knots.

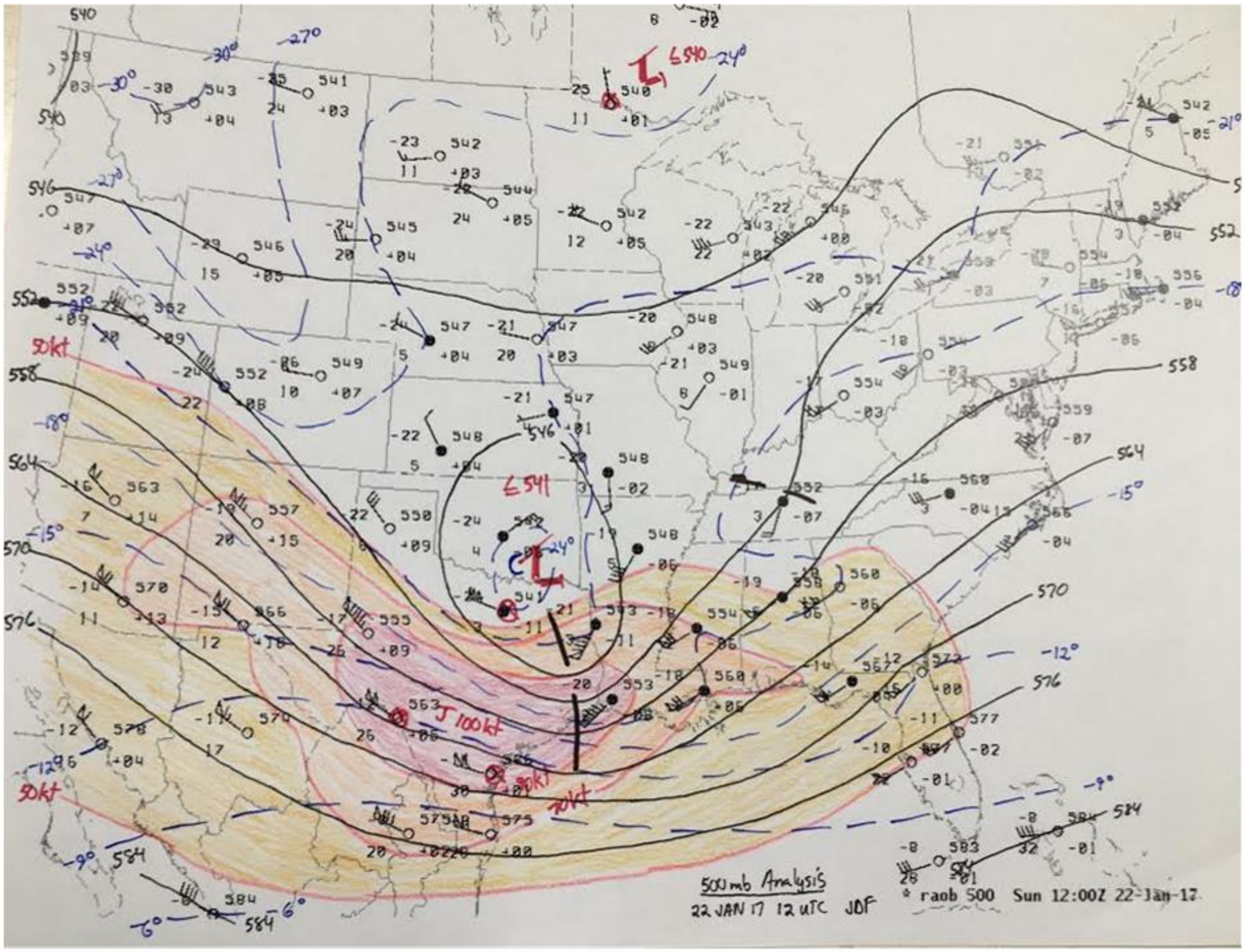


**Figure 4. 500 mb heights (solid black lines, in dm) and isotachs (solid red contours with color shading, in knots). Valid 7 am EST January 22, 2017.**

Rising motion, instability, and ample moisture ahead of the upper-level low/trough created an environment favorable for showers and thunderstorms. The rapidly increasing (and veering winds) from the surface to 18,000 feet was favorable for organized thunderstorms, including supercells (thunderstorms with persistent, rotating updrafts). Supercells tend to produce more severe weather than other types of storms, especially tornadoes. However, not all supercells produce severe weather.

Figures 5-6 help illustrate just how dynamic the synoptic scale storm system was. These figures show the pressure and frontal patterns produced by the Weather Prediction for 7 am and 1 pm EST, January 22nd. The mature low pressure system along the Arkansas-Oklahoma border at 7 am (Figure 5) was quite strong, but over the next 6 hours a new and even deeper low would develop in South Alabama. The pressure went on to deepen from 1000 mb to 989 mb, mostly in the last 3 hours. Such rapid pressure falls are rare, especially in this portion of the country.

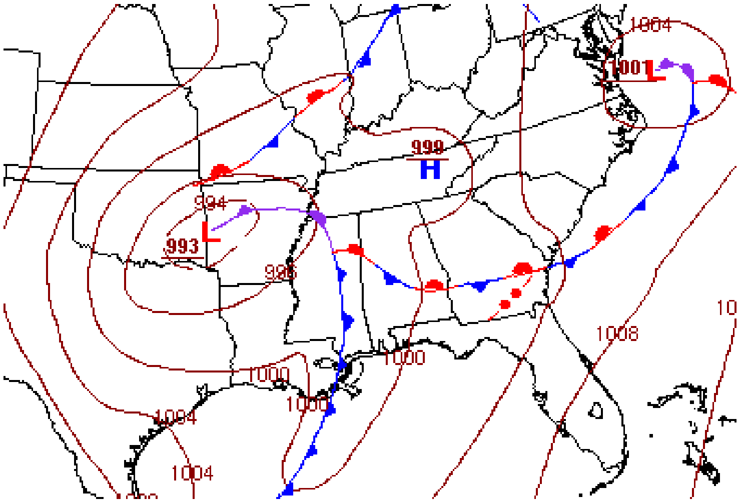


**Figure 5. WPC surface analysis valid 7 am EST January 22, 2017.**

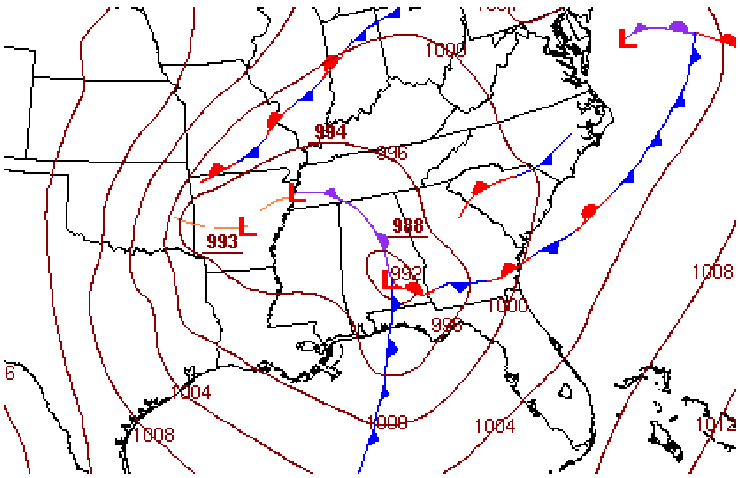


**Figure 6. WPC surface analysis valid 1 pm EST January 22.**

The primary severe storm season for the Gulf Coast region is from November through April. Because this coincides with the cool season, storm systems in this region are often accompanied by large values of vertical wind shear (i.e. winds which increase and veer with increasing height), but poor instability. Instability is necessary for strong updrafts, and strong updrafts are needed to maintain the ice and rain within a thunderstorm. Meteorologists must weigh these competing factors, poor instability vs. strong wind shear, in their forecasts during the cool season. This often results in low-probability severe thunderstorm outlooks.

One of the outstanding factors of this event was the abundance of instability. The MLCAPE, (**M**ixed **L**ayer **C**onvective **A**vailable **P**otential **E**nergy), one of many measures that meteorologists use to assess the instability available for thunderstorms, was at least 1000 J/kg (Figures 7 & 8) across much of the region, owing to unusually steep mid-tropospheric lapse rates of 6.5 to 7.5 C/km, as well as warm, moist conditions at the surface. (Surface temperatures were in the 70s, and dewpoints were in the upper 60s to lower 70s). Additionally, there was little in the way of convective inhibition during the times of the tornadoes.

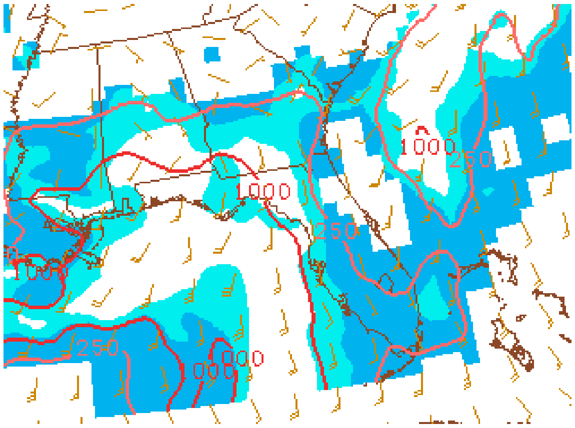


**Figure 7. SPC's RAP analysis of MLCAPE (red contours) and CIN (blue shading), valid 3 am EST January 22.**

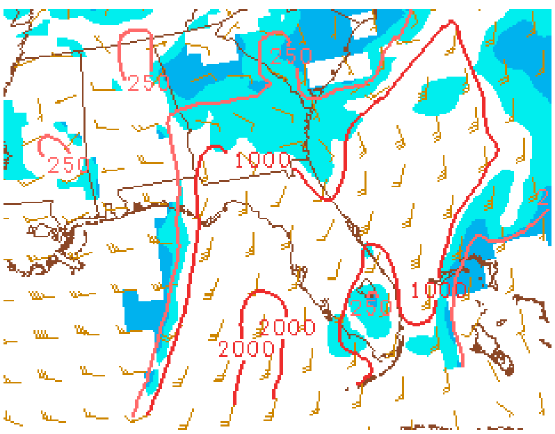


**Figure 8. SPC's RAP analysis of MLCAPE (red contours) and CIN (blue shading), valid 3 pm EST January 22.**

Bulk shear values, a measure of how quickly the winds change with height, were at the top of the spectrum of values associated with severe storms. Of particular interest is the 0-1 km wind shear, which measures the change in wind in the lowest portion of the troposphere. This layer is considered to be critical in the generation of the strong mesocyclones (the persistent, deep, rotating updrafts of supercell thunderstorms). During the cool season, values of 30 knots or greater are considered to be quite favorable for supercells capable of producing tornadoes. However, during the 12-hour period of the tornado outbreak on January 22$^{nd}$, these values were in the 40-50 knot range, which is unusually high.

*Mesoscale Contributions*

Generally speaking, meteorologists use the term *mesoscale* to describe weather phenomena which last for hours and span distances of up to 200 miles or so. Common examples are sea breeze circulations and outflow boundaries. The diminutive nature of these systems means they are often poorly sampled by the relatively sparsely-populated weather observing network, and are therefore difficult for weather prediction models to forecast accurately.

Outflow boundaries are essentially small-scale cold fronts, formed by the collective pooling of rain-cooled air from clusters of thunderstorms. Many tornadoes occur near such features, or their larger-scale cousins, the synoptic-scale fronts. These boundaries help to intensify the parent mesocyclone by focusing the vertical and horizontal *vorticity* (a measure of the “spin” of the air) along the boundary. This vorticity is stretched within the strong updraft of the supercell near the boundary, which further intensifies the spin as its angular momentum is conserved, like a figure skater rotating faster as she pulls her arms in to her body. The resulting intense mesocyclone is then primed to produce a tornado, assuming storm-scale factors (weather which is measured in miles and minutes, and unable to be observed by most weather observing networks) are favorable.

During the afternoon of January 21$^{st}$, numerous showers and thunderstorms were concentrated in south Georgia and Alabama. The synoptic-scale wind profile was favorable for concentrating cold pools into a mesoscale high pressure system. The collective cold pools from these storms produced an outflow boundary oriented east to west along Interstate-10. With strong southwest winds just above the surface, this boundary propagated northward overnight into South Georgia and Alabama (Figure 11). Two significant (EF-2+) tornadoes developed immediately south of this boundary in south Georgia in the early morning hours of January 22$^{nd}$.

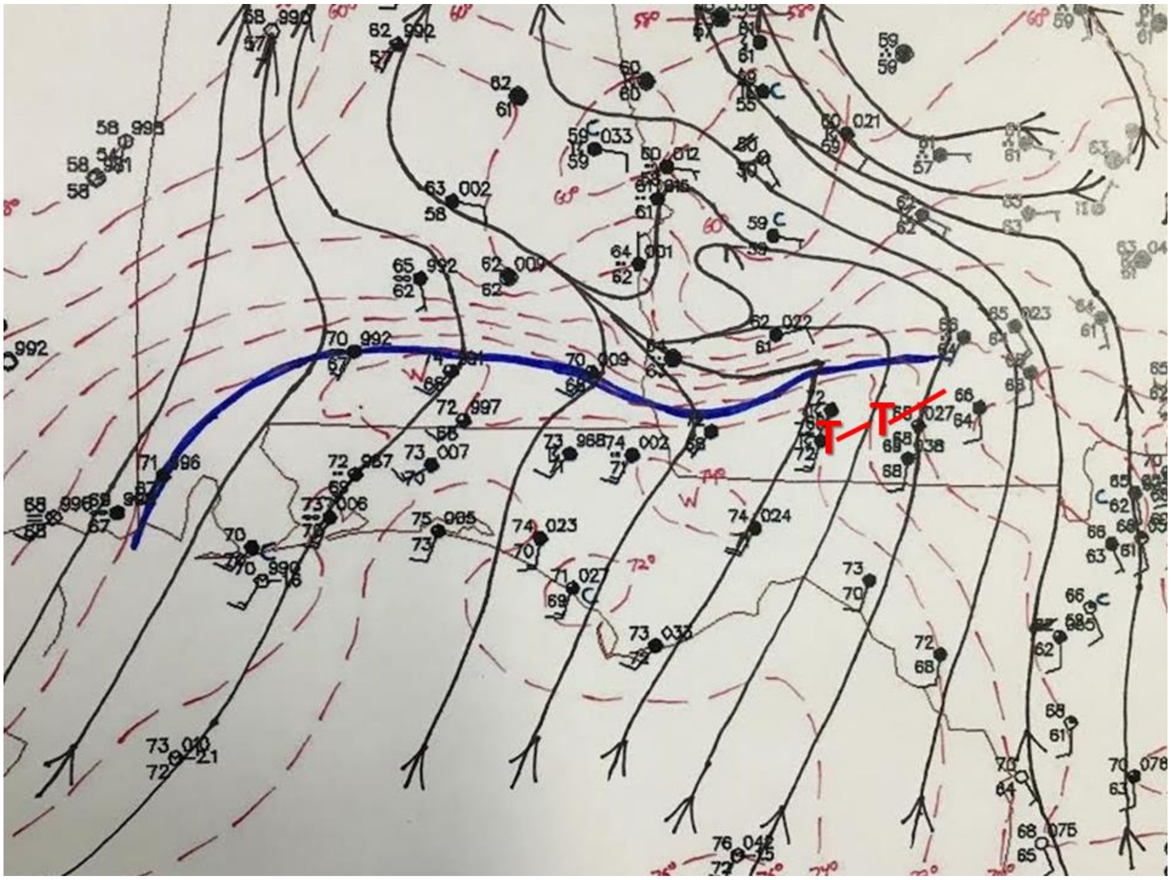

**Figure 9. Subjective surface meso-analysis, valid 3 am EST, January 22, within an hour of both tornadoes. Thick blue line marks the warm side of the thermal gradient. Streamlines are solid black lines, red-dashed lines are 2-meter temperatures in increments of 2º F. Red "T" are approximate touchdown points of significant tornadoes, and the lines are the tornado tracks. Data courtesy of Plymouth State Weather Center.**

Note the extreme backing of the winds (Figure 9) over a very short distance, as southwest winds (south of the boundary) became northeast (north of the boundary) in a distance of approximately 20 miles. Such extreme curvature of the winds undoubtedly contributed to vertical vorticity values which were much greater than the background environment. It's also likely that the strong horizontal thermal gradient led to high horizontal vorticity values.

The numerous showers and thunderstorms which developed near and along the outflow boundary during the early-morning hours of January 22nd generated a large cold pool, with north to northeast surface winds across south Georgia and Alabama. This forced the outflow boundary back to the south, to a position near and along the coast of the Florida Panhandle and Big Bend by mid-morning. As was the case several hours before, the strong southwest winds just above the surface forced this boundary back to the north from late morning through early afternoon, to a position across south Georgia by 3 pm EST (Figure 10).

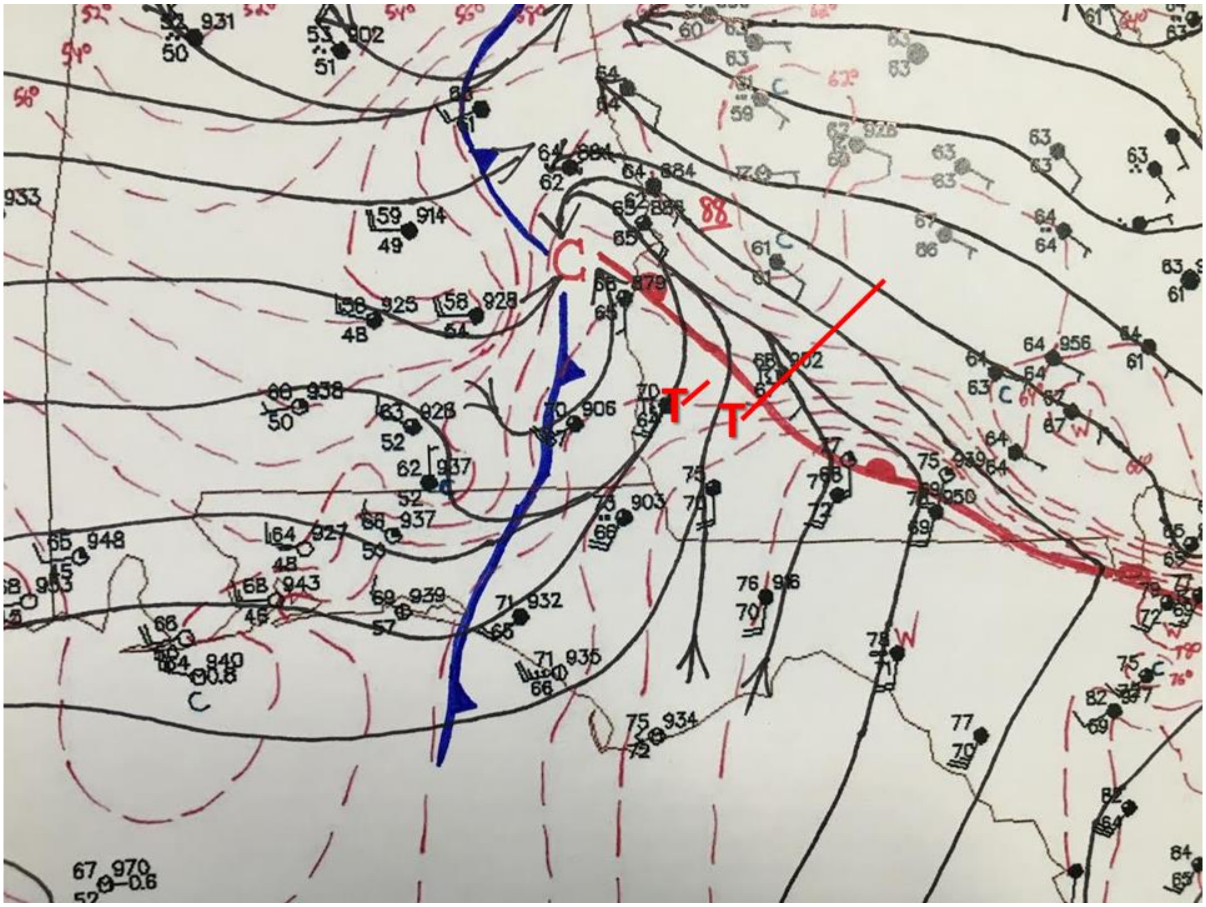

**Figure 10. Same as Figure 9 except conventional frontal notation used. Valid 3 pm EST, January 22, within an hour of both tornadoes. Data courtesy of Plymouth State Weather Center.**

Two more significant tornadoes developed near the northward-advancing boundary (depicted as a warm front in Figure 10) in south Georgia on Sunday afternoon. Research has shown that it's common for significant tornadoes to form near these types of surface boundaries. The caveat is that conditions can quickly become unfavorable for tornadoes if they travel too far into the cooler, more stable air north of the front.

The Albany tornado spent the next hour traveling 71 miles to the northeast. If conditions did not change from the analysis time, the tornado would have encountered progressively cooler air, causing it to dissipate. However, with the synoptic-scale winds being from the southwest at 50 knots at the 850 mb level (about 5,000 feet AGL), it's likely that the warm front continued propagating quickly northward. This would have allowed the tornado to continue to reap the benefits of enhanced vorticity along the surface boundary, while remaining near the warm surface air to its immediate south, which is essential for maintaining a strong updraft.

Unfortunately there is a significant gap in surface weather observing stations in central Georgia, making a subjective mesoanalysis difficult, especially for a detailed temperature analysis. However, a regional streamline analysis an hour later (Figure 11) does suggest that the warm front continued propagating northward in tandem with the tornado.

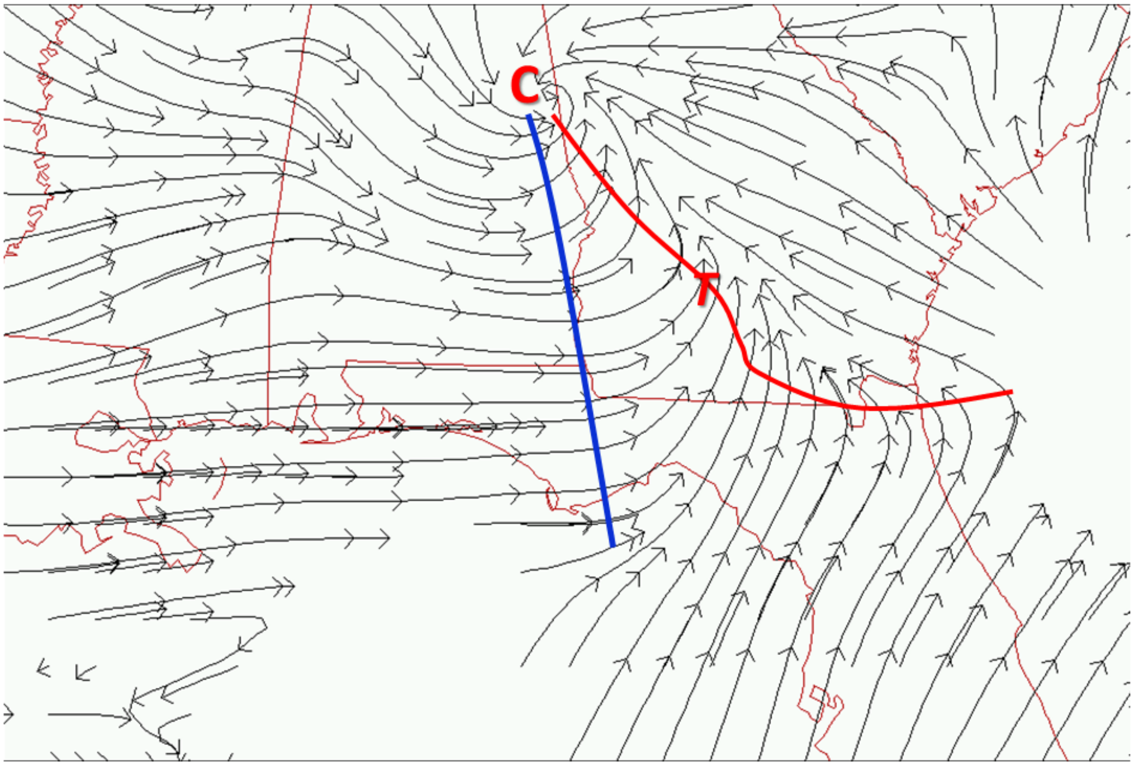


**Figure 11. Objective surface streamline, valid 4 pm EST, January 22. T denotes approximate location of Albany tornado at 4 pm. Data courtesy of Plymouth State Weather Center.**

*Summary*

As is the case with many tornado outbreaks, the January 22nd 2017 event featured the combination of an unusually favorable synoptic environment and a well-defined surface boundary which separated relatively cool northeast winds to its north, from warm south winds to its south. The 4 significant tornadoes during this 12-hour outbreak formed within 20 miles of this surface boundary. The competing forces of mesoscale outflow and strong southwest winds aloft caused the mesoscale boundary to oscillate north and south for several hours, which helped focus the worst of the tornado outbreak across south Georgia.

The most intense and longest-lived tornado of the outbreak was the one which formed closest to the warm front (formerly the mesoscale outflow boundary) near Albany, Georgia. The data suggest that the unusually strong, synoptic-scale southwest winds aloft aided in the rapid northward propagation of the warm front in tandem with the Albany tornado, thus preventing the tornado from getting too far into the cooler, more stable airmass north of the warm front. This is yet another example of tornadoes forming near mesoscale or synoptic-scale surface boundaries, and why it's important for warning forecasters not to lose awareness of the synoptic and mesoscale environments while focusing on storm-scale features.