EMBRY-RIDDLE
Aeronautical University
METEOROLOGY

Embry-Riddle Aeronautical University
Convective-Boundary Research Engaging Educational Student Experiences 2.0

ERAU C-BREESE 2.0
Final Report

Shawn Milrad (milrads@erau.edu)
Chris Herbster (herbstec@erau.edu)
Dan Halperin (halpea17@erau.edu)
Meteorology Program
Applied Aviation Sciences Department
Embry-Riddle Aeronautical University
Daytona Beach, FL

1. Introduction

Embry-Riddle Aeronautical University Convective-Boundary Research Engaging Educational Student Experiences 2.0 (ERAU CBREESE 2.0) was a 15-day Doppler-on-Wheels (DOW) and Mobile Mesonet (MM) educational deployment from the Center for Severe Weather Research (CSWR), funded by the National Science Foundation (NSF) through the NCAR Lower Atmosphere Observing Facilities (LAOF) Program. ERAU CBREESE 2.0 ran from 28 June–12 July 2018 across Central Florida. Building off the success of ERAU CBREESE in May 2015, the educational deployment was designed to observe and measure sea-breeze processes and convection during the warm season, with a specific focus on Central Florida sub-regions that contain multiple mesoscale breezes and boundary collisions. It was the first LAOF educational deployment to involve both a DOW and MM.

The ERAU Principal Investigators (PIs) were Dr. Shawn Milrad, Dr. Chris Herbster, and Dr. Dan Halperin. ERAU CBREESE 2.0 was offered as a "Summer B" (second summer term) three-credit course for ERAU undergraduate Meteorology majors and minors. Nine ERAU students participated in the course (2 meteorology majors, 7 meteorology minors). We had seven Intense Observing Periods (IOPs) over the length of the deployment, as shown in Fig. 1.

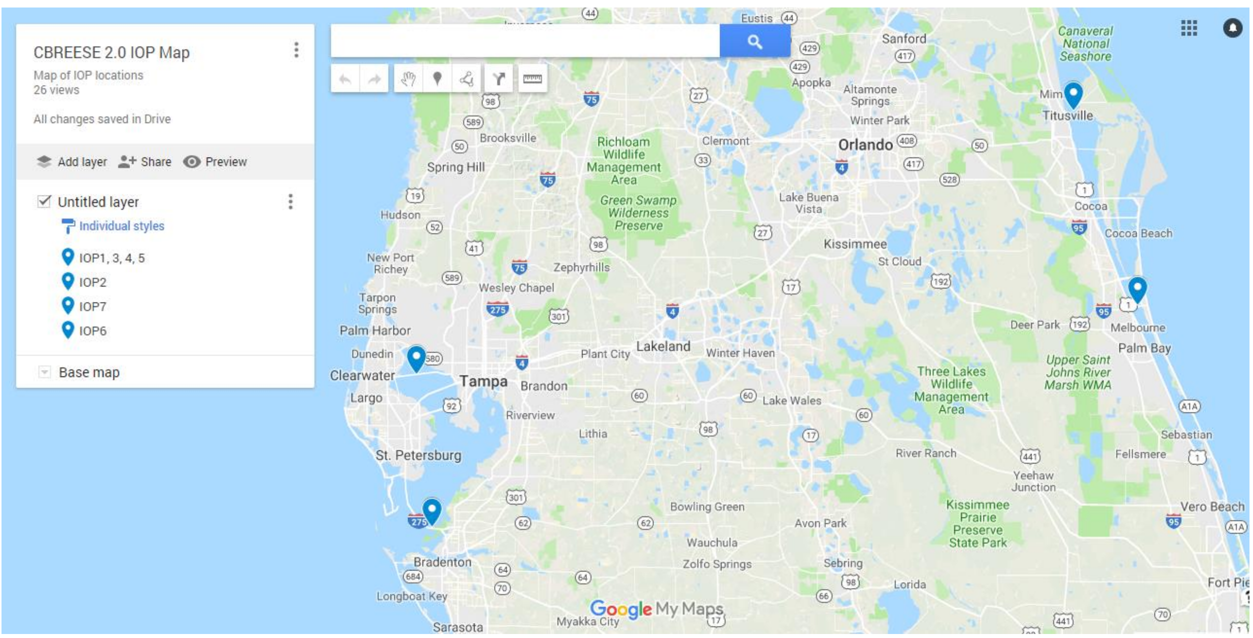

***Figure 1*:** Google map of Central Florida with DOW deployment locations for the seven IOPs marked by the blue pins. Five of seven IOPs were focused on the Cape Canaveral area, with the remaining two focused on Tampa Bay.

The objectives of ERAU CBREESE 2.0 were to:

- Incorporate the DOW, MM, and other mobile observational tools into a three-credit course that provides experience in real-time data collection and analysis.
- Perform scientific and educational outreach to the Central Florida community, including K–12 students.
- Investigate sea-breeze processes and related convection in two Central Florida sub-regions (Cape Canaveral and Tampa Bay) that are known for multiple mesoscale breezes

and boundaries, boundary collisions, and prolific warm-season lightning. Specific scientific questions to be investigated included:

- What percentage of secondary boundary collisions and/or mergers accentuate existing convection? Specifically: bay, lake, and river breezes in both sub-regions will sometimes intensify pre-existing sea-breeze thunderstorms. As such, what are the distinguishing characteristics of mesoscale circulations in intensifying events?
- What role do local secondary (i.e., bay, lake, river) breezes play in lightning initiation and frequency?

The remainder of this report is organized as follows: section 2 recaps IOP and class procedures, section 3 details outreach activities, section 4 reviews PI and student assessments of the deployment, and section 5 discusses lessons learned and future work.

2. IOPs and Class Procedures

a. Training

CSWR DOW-7 and MM arrived at ERAU on 28 June 2018. During the first two days of the deployment, students and PIs were trained by two CSWR technicians, including Alycia Gilliland who remained with DOW-7 for the duration of the deployment. Students learned the difference between high and low frequency pulses, various elevation angles, and about range-height indicator (RHI) scans. They also learned how to operate the DOW computers, properly take notes, and were introduced to the sample outreach displays. In total, nine students and three faculty members were trained to operate the DOW and MM.

Following training, ERAU C-BREESE 2.0 students and PIs met to discuss the forecast for the upcoming week. In addition, a review lecture on sea-breeze processes and convective ingredients was given by the PIs. Unlike ERAU CBREESE, during which DOW scanning locations were not pre-determined, we identified 1–3 locations in each focus sub-region where DOW scanning could be conducted smoothly without obstructions. Scanning locations were primarily located on causeways over intracoastal waterways and were explained to the students on the first day of the deployment using Google Maps. Finally, a forecasting links page was established for students and PIs to use during the length of the deployment: http://www.shawnmilrad.com/forecast.

b. IOPs

IOP locations were determined the day before and/or morning of each IOP based on the background synoptic-scale flow. Easterly background flow typically indicates that afternoon thunderstorms will occur on the Florida Gulf Coast, while westerly flow suggests afternoon thunderstorms on the Atlantic Coast. Group forecast discussions were held each morning as well as over e-mail. Each morning of an IOP, PIs and students would meet in an ERAU Meteorology classroom to examine observational and forecast data and agree on a deployment plan. Weather discussions were informal and collaborative, with active student participation.

Once one of the pre-determined DOW scanning locations was chosen for that day's IOP, students were divided into two teams: DOW and MM. Student roles rotated with each IOP, ensuring that each student would get experience operating both pieces of equipment. Figure 2 shows two ERAU CBREESE 2.0 students operating and taking notes inside DOW-7 during IOP 6. For the DOW team, one student was responsible for taking deployment notes, while the other students were responsible for completing the DOW worksheet (Table 1). The worksheets were stored as a Google Doc so that students could complete it on their mobile devices; this was a change from ERAU C-BREESE, for which we used paper worksheets.

Another change from ERAU C-BREESE was our ability to launch several radiosondes during the deployment. CSWR provided three radiosondes and ERAU provided the helium for the balloons. Figure 2 shows two ERAU C-BREESE 2.0 students inflating a balloon with helium prior to launch around 1800 UTC during IOP 2 in Tampa. All three radiosonde launches (IOPs 2, 5, and 7) were conducted around 1800 UTC, which provided us a glimpse of the pre-convective environment and facilitated post-deployment research. All students present for a particular radiosonde IOP participated in the launch prior to the MM team departing to perform transects. In addition, the DOW team was able to view the sounding data and balloon path in real-time through software owned and operated by CSWR.

***Figure 2*:** Photographs of ERAU C-BREESE 2.0 students (left) in DOW-7 during IOP 6 and (right) preparing to launch a radiosonde with help from CSWR technician Alycia Gilliland on the shore of Tampa Bay during IOP 2.

Once DOW-7 was deployed at the scanning location, the MM team departed to perform transects. The MM team was led by PIs Herbster and Halperin, with 1–2 rotating students participating during each IOP. MM observation paths varied by IOP but were designed to sample multiple local boundary layer and thunderstorm environments. As an example, Fig. 3 displays the MM path and various meteorological parameters during IOP 2 in the Tampa Bay region. The MM drove across sea- and bay-breeze boundaries multiple times, as well as through the core of a thunderstorm. Students on the MM team were also required to take observation notes, as well as complete the MM worksheet (Table 2).

Worksheets and deployment notes were stored on Google Drive and were used to assess student performance. In addition, they were extremely useful in the post-deployment research portion of the course, as students were able to match data visualizations with times/observations detailed in the worksheets and deployment logs.

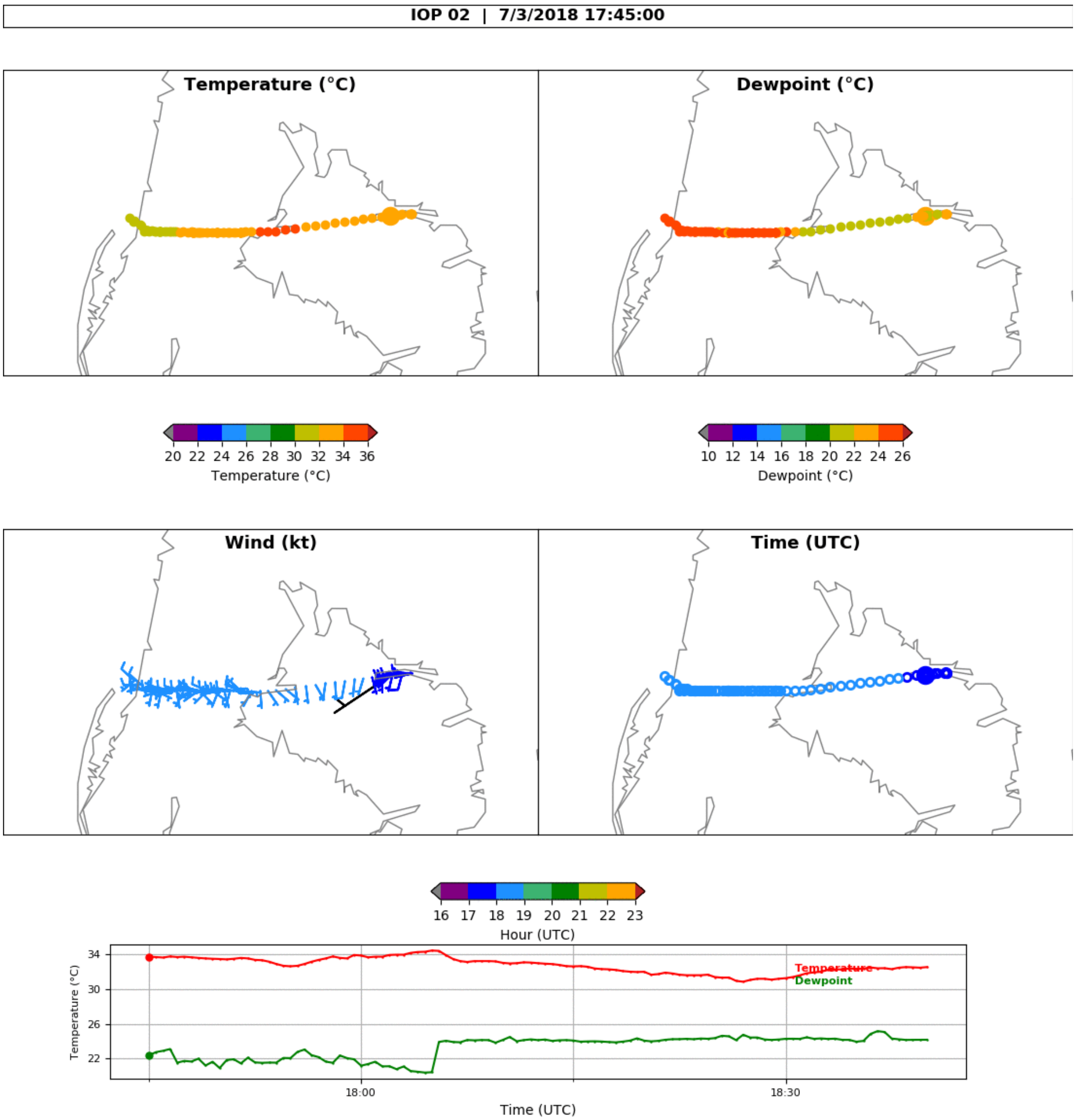

Figure 3**:** Five-panel plot of MM data during IOP2, with the MM path illustrated in the top four panels. The MM started at the DOW-7 deployment location in Tampa, FL (large circle) and completed transects through various mesoscale boundaries over the course of 2–3 hours.

DOW Worksheet Sample	
How frequently is the DOW scanning?	35° per second
Describe the phenomenon that you are scanning. Include approximate location (direction and distance) and time information.	1945 • Scanning a thunderstorm located to the northeast • The maximum reflectivity intensity is about 43.79 away 2009 • Westerlies (sea breeze) moved east • 49.10 dBZ maximum reflectivity 2017 • Boundaries collided
What is the maximum reflectivity intensity?	1925: 51.79 dBZ 2044: decreased to 38.26 dBZ
What are the maximum radial velocity values? Do you see any radial velocity couplets? If so, describe intensity and location. Do you see a downburst signature? If so, describe intensity and location.	1925: -7.8 m s^{-1} 1925:No true couplets, shear aloft • Shear: 9.86 + 1.43 = 11.29 m s^{-1} • Location: 43.79 km away 2025: Downbursts recorded with rain shaft
How do the radar scans compare to what you are seeing visually? Be descriptive.	1925: We see a wall of rain outside the DOW over the bay, matching the location of the strongest reflectivity values.

***Table 1*:** Sample DOW team student worksheet from IOP 2 in Tampa, FL. Times are in UTC.

MM Worksheet Sample	
What is the primary objective of the MM during today's IOP?	To measure the contrast along the line roughly perpendicular to the sea breeze front.
Describe the MM observation route during the IOP.	State road 60 east to I-75 N at 1940 to I-4 E south on I-75 2002 west on 60 2035 on island in Clearwater beach 2115 eastbound 2120
List any interesting MM observations during the IOP.	Drizzle began at 1934 Hit outflow 1937 Rain began 1944 Rain changed to drizzle 1953 Lightning north of position 1958 Rain ended 2002 Drizzle began 2007 Rain began 2008 Lightning 2019, 2023, 2025, 2030, 2032, 3035, 2037 Rain began 2048 Data stopped 2135 Drizzle 2135
How do the MM observations compare to what you are observing visually and/or on radar?	After going through the boundary, temperature decreased about 1°C and RH increased 10%.
Did the MM team achieve its objectives for this IOP? If not, explain what you might do differently next time.	Yes, although getting stuck in rush hour traffic was a bit of a hinderance toward the end of the IOP.

***Table 2*:** Sample MM team student worksheet from IOP 2 in Tampa, FL. Times are in UTC.

c. *Class procedures*
The three PIs participated in all seven IOPs. Student participation rotated based on availability and scheduling, although each student was required to participate in at least three IOPs. Course grades were based on three components: field participation, worksheet completion, and post-deployment research projects/presentations.

Following the end of the deployment, the remaining four weeks of the course were spent on group research projects that were required to incorporate both DOW and MM data. Two of the research projects focused on our most scientifically interesting IOP (IOP 4), during which we observed strong convection over Cape Canaveral followed by the development of a mid-tropospheric meso-low. A sample radar visualization of the meso-low, which was coincidentally centered very close to the DOW scanning location, is shown using DOW 8.5° reflectivity and radial velocity in Fig. 4. The two-panel display (Fig. 4) was prepared and presented by one of the post-deployment student research groups using the Unidata Integrated Data Viewer (IDV). As such, students learned how to utilize meteorological visualization software such as IDV and McIdas, which will be useful to them in future classes and/or careers.

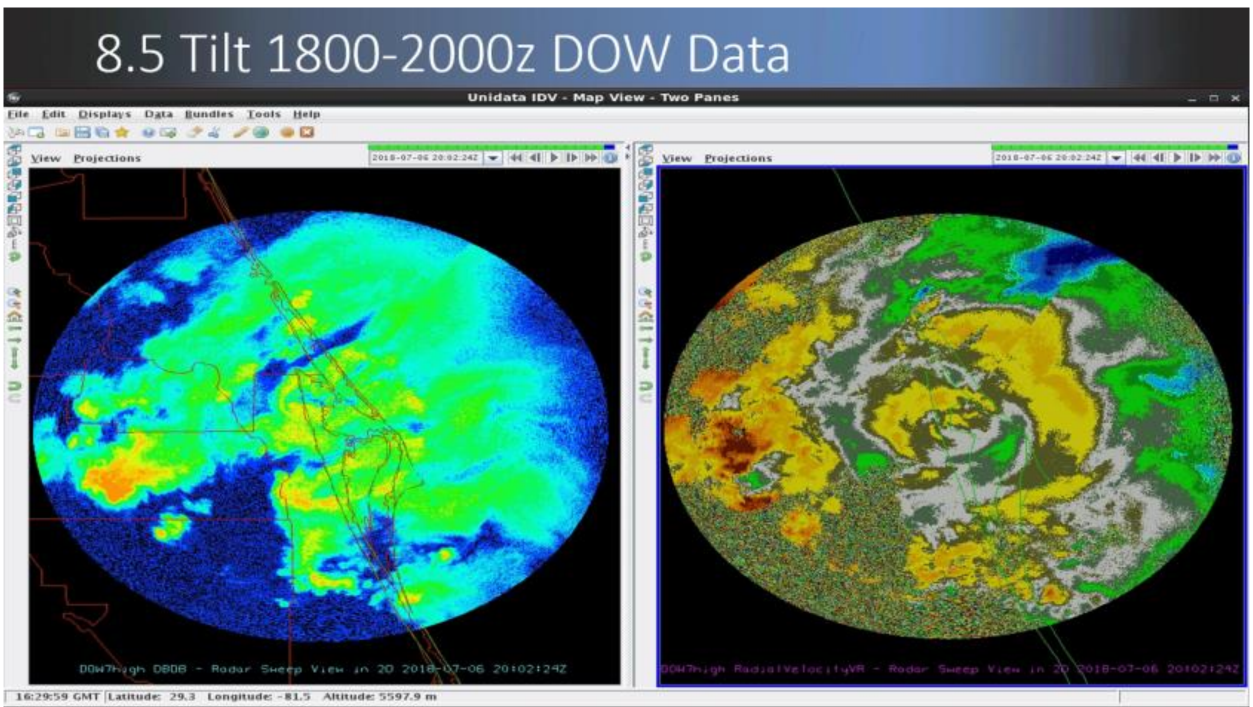

***Figure 4*:** Two-panel display of DOW 8.5° (left) reflectivity (dBZ) and (right) radial velocity (kt) during the IOP 4 meso-low.

3. Outreach
A key mission of ERAU C-BREESE 2.0 was to perform outreach to the local community, including K–12 students. The goals of the outreach were to: 1) increase awareness of mobile observation technology and NSF educational deployments, 2) expose students to field research and instrumentation, and 3) increase the visibility of the ERAU Meteorology Program. We had three main outreach events over the course of the deployment:

- K–12 science summer camps on the ERAU campus

- Local TV news interview during IOP 2 and subsequent special report
- Open house at local Walmart parking lot

Each summer, ERAU hosts K–12 summer camps for local students. On 12 July 2018, a few dozen students toured DOW-7 on the ERAU campus. Figure 5 shows photos from this outreach event, during which ERAU CBREESE 2.0 students explained DOW technology with the help of sample animations from previous CSWR tornado and hurricane field observation campaigns.

Figure 5**:** Photographs of ERAU C-BREESE 2.0 students hosting a DOW outreach event for K–12 summer camps on the ERAU campus on 12 July 2018.

During IOP 2, a television film crew and meteorologist Maureen McCann from News 13 Orlando followed the ERAU CBREESE 2.0 team to Tampa Bay, which resulted in a five-minute special report that aired across Central Florida in mid-July 2018. Both PIs and students were shown in the report, and footage from GoPro cameras in the MM was aired. This report provided great exposure for the NSF/LAOF educational deployment program and ERAU Meteorology. The full broadcast report can be viewed at the following link: https://vimeo.com/281410728.

Overall, we directly reached more than 50 people during the course of the deployment. However, this number does not include the indirect reach of the special TV report, as News 13 is viewed in millions of homes across the Orlando media market.

4. Deployment Assessments

a. PI assessment

Overall, the 15-day educational deployment was an immense success for ERAU Meteorology and its students. ERAU C-BREESE 2.0 was designed to be more scientifically rigorous than ERAU C-BREESE, and we generally achieved our data collection objectives. The collected data will be used by ERAU Meteorology PIs and students for numerous research projects, presentations, and publications in the months and years to come. The IOP 4 meso-low was an unexpected yet unique aspect of the deployment and we look forward to further investigating the characteristics of and mechanisms responsible for its formation and maintenance.

Most importantly, ERAU students involved in ERAU C-BREESE enjoyed a once-in-an-undergrad-career opportunity to actively participate in a real-time field campaign involving hands-on field observation equipment. The meteorological, forecast, data analysis, and outreach skills they gained through these experiences are invaluable and will serve them well in their career endeavors.

b. Student Retrospectives

Comments from the nine students who participated were very positive and complimentary of the ERAU C-BREESE 2.0 experience. Anonymous post-course student comments included:

- "The overall class really helped me learn."
- "DOW, MM, and balloon training, the descriptive leadership by the professors, and the outside vs. traditional classroom experience all helped me learn."
- "I loved the hands-on experience."

5. Summary and Future Work

a. Lessons learned

Lessons learned during ERAU C-BREESE 2.0 included:

- Students work best and collaboratively when everyone has a specified task. Dividing students into DOW and MM teams with rotating roles allowed all students to feel consistently involved during the deployment. In addition, it helped to diversify students' skills and make them feel involved in the decision-making process.
- The student worksheets were an enormous help both during the field campaign and in post-deployment research. Using Google Docs allowed students to more easily complete them by using their mobile devices.
- Hands-on experiential learning results in considerably more engaged and motivated students. Although field campaigns are relatively sparse and expensive, the experience can result in a large positive change in how an individual student feels about atmospheric science.
- Establishing strong scientific objectives prior to the educational deployment allows for a smoother field campaign. We found that this aspect was greatly improved from ERAU C-BREESE in 2015.
- Data transfer and processing in the post-deployment period remains a challenge. Specifically, DOW data must be rotated and formatted properly so that students can view it in software such as IDV that has background geography. It would be helpful in the future if CSWR could establish a canned process to facilitate data transfer and manipulation. While it is not a big issue for graduate students or large field research projects, educational deployments, especially those during summer terms, require data to be ready for analysis immediately after the deployment ends.

b. Future work

Our immediate plans at ERAU Meteorology are to continue data analysis and research, especially for the IOP 4 meso-low case. In consultation with CSWR, we believe this to be the first meso-low ever observed by a CSWR DOW. Two undergraduate students are already conducting research during the 2018 Fall semester using the data collected during ERAU C-BREESE 2.0. By the end of 2019, we hope to have two research publications in AMS journals, as well as numerous student conference presentations. Data analysis may also be conducted as part of our undergraduate Meteorology Capstone course during the next few years.