Boundary Structure Experiments with Central Minnesota Profiling (BaSE CaMP): Project Summary

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1. INTRODUCTION

For a one-week period in late September-early October of 2012, Saint Cloud State University was visited by a Mobile Integrated Sounding System (MISS) provided by NCAR’s Earth Observing Laboratory. While the visit was primarily geared toward the meteorology program's Radar and Satellite Meteorology course, educational benefits were expected for other courses (such as the following semester's Meteorological Instrumentation course) and for the department's student who were at any stage in their major progression. K-12 outreach was also planned with a visit to a local high school.

Due to the limited time period of the visit, field deployments were planned to study any possible frontal passages and the performance of the instruments in documenting the evolution of the boundary layer structure. After a site survey on Thursday, September 27, where deployment plans were confirmed or revised, operations and educational activities began on the following Friday. This report summarizes the Boundary Structure Experiments with Central Minnesota Profiling (BaSE CaMP) and documents the expected future value of the collected data.

2. EDUCATIONAL OUTREACH

The first opportunity students in the radar course had to observe the instrumentation they would be using for the following week was on the morning of Friday, September 28. For the regularly scheduled course lecture, students met at the south end of campus where the MISS was located when not deployed at a remote site. In addition to seeing the MISS firsthand, the class of twenty also received a lecture from the project scientist for the first half of the deployment. Topics included the organization and mission of the Earth Observing Laboratory, as well as the principles of the various components of the MISS system. Students were also able to first handle the radiosonde packages which would get frequent use throughout the week.

There were two outreach activities which included students outside of the meteorology program. One morning prior to field deployment, the MISS was taken to a local high school to visit a senior AP physics class.
Fig. 3: Activities during IOP Alpha: (Upper left) The first radiosonde is launched at the start of solar heating. (Upper right) Students leave to collect additional observations. Additionally, they would examine current online data (lower left) and calibrate instruments with MISS’s surface station (lower right).

discussion of the instrument was capped off with a balloon launch from a nearby parking lot. Additionally, on the evening of Thursday, October 4, the project scientist for the second half of the experiment gave a seminar which was open to the public. While SCSU radar meteorology students were again present, students from a wide range of other majors were also in attendance. The focus of this seminar was more on the field programs in which the ISS and GAUS instrumentation had been used and on the various challenges of finding the right conditions and collecting the data. This presentation was quite exciting to some of the department students present. One stated: “The most interesting thing to me probably was that NCAR hires student workers to assist in their research projects, which I will definitely apply for when the time comes”.

3. FIELD DEPLOYMENTS

Due to potential conflicts with other coursework, the majority of operations in BaSE CaMP were planned to occur between the hours of 5-8 p.m. on a near-nightly bases. This schedule precluded traveling large distances to follow the most significant synoptic systems. Therefore, the field sites were chosen on the basis of unique topography or the ability to intercompare observations from MISS with independent instrumentation. The following is a brief summary of the conditions during each Intensive Observing Period, the experiments performed by the students, and the data which was collected for future use.

3.1 Intensive Observing Period Alpha

Due to the typical student work schedules of many students, Saturday, September 29th was intended to be the most extensive deployment in terms of operations length and the number of student volunteers. The goal was to study a particular weather phenomenon, but the constraint of operating on a single day meant that flexibility was required. For this reason, operations were located in the vicinity of complex terrain to the southeast of Saint Cloud. An operations center was available in the Sauk River valley, a short distance from a prominent hill making up part of the north sidewall. This site served as an ideal setup location for MISS, as well as providing internet
access for monitoring the larger-scale operational observations.

The synoptic pattern for this day turned out to be dominated by high pressure and ridging, which was well suited for examining a cold pool breakup and the possible presence of thermally driven slope circulations. Operations began with a radiosonde launch at 1230 UTC, only twenty minutes after the astronomical sunrise. As the balloon was ascending, students were sent out in teams to collect surface observations nearer to the base and at the top of the hill. Their equipment included Kessler handheld units, sling psychrometers, and toy store bubbles for estimating wind direction and vertical motion. The sounding profile revealed a shallow, but sharp (≈ 10K) temperature inversion, which was verified by student observations of a large temperature difference between the top and bottom of the hill and calm winds at low levels which became light northerlies above. Several students were excited to see how their observations matched the data from the balloon launch. In one’s words: “Using the radiosondes, surface observations, and field observations to put together all the pieces of data in regards to the warming temperatures and the winds picking up was a great hands-on way to observe local effects of a morning temperature inversion”.

In total, four radiosondes were used during IOP Alpha, with students returning to the operations center for each launch and then redispersing to collect their remote observations. The second sounding at 14 UTC showed the inversion still in place though weaker in magnitude, while a significant dry layer (≈ -5°C dewpoint) had developed at 600 mb. This dry layer subsequently descended in the 1530 UTC sounding, which also showed only a small remnant of the morning inversion. The final launch at 17 UTC showed the inversion had completely been removed, while the dry layer had descended even further. Also of interest from the soundings was the wind profile, which contains low-level northerly flow, mid-level flow from the east, and weak northwesterly flow in the stratosphere.

In addition to the radiosondes, the MISS surface station was operated throughout the IOP, and after 14 UTC, the RASS system was deployed to take advantage of the colder, drier conditions. The initial placement of the surface station allowed for a good illustration of instrument response, as the thermometer took several minutes after being removed from the trailer to adjust to the colder environmental temperatures. The wind observations were also of interest, as at 13 UTC the direction shifted to be SSE, which is in the direction of the topography being studied. After 1515 UTC, the wind speed increased and the direction shifted to northerly in agreement with the large scale flow. After the breakup of the inversion, the wind profiler began receiving better returns, adding vertical wind information to the RASS profiles.

3.2 Intensive Observing Period Bravo

Due to the high noise levels involved with running RASS, the system was generally not used when private homes were in the vicinity. Due to this limitation, one deployment was scheduled for the Saint Cloud Municipal Airport to ensure that RASS profiles could be made. The specific site was adjacent to the airport’s ASOS station allowing for intercomparisons with this operational instrumentation. Eleven students in the Synoptic Meteorology course used their Monday class time to prepare forecasting support for Monday and Tuesday evenings which was presented during the subsequent Current Weather Analysis course. The consensus was that there would be no significant synoptic systems during the next 48 hours, so IOP Bravo was declared to experiment with the RASS system at the airport site.

Another benefit of the airport location is the large amount of open space. Therefore, after students toured the various components of the ASOS station, a single radiosonde was launched which students attempted to manually track from the ground using combination compasses and slope indicators. Two sets of observations were made from a baseline of 150’ of the balloon’s bearing and elevation angle at a number of irregularly spaced intervals. The final calculation of position to compare with the GPS values has still not been completed, but the hypothesis is that it will be far less accurate for a variety of reasons.

Fig. 4: The final radiosonde of IOP Alpha was launched after complete breakup of the inversion.
3.3 Intensive Observing Period Charlie

The SCSU Atmospheric and Hydrologic Sciences Department maintains three meteorological instruments on the 150 m radio tower of KVSC at heights of 80-, 100-, and 140-m. In addition to providing intercomparisons with a radiosonde launch, the instruments are also ideally located to fill in the gap between the MISS surface station and the lowest range gate of 150 m. While the road leading to the base of the tower was not appropriate for transporting MISS, a commercial business located across the highway was less than 0.5 km away, providing an ideal deployment site. Since Monday’s briefing for no synoptic systems appeared to be valid, IOP Charlie was declared for this site on Tuesday evening.

In addition to collecting routine RASS observations at half-hourly intervals, which were consistent with a well-mixed convective boundary layer, a second experiment was performed to assess the effect of the location of the RASS speakers on the received signal. After the 23 UTC consensus, the speakers were moved to a location directly upwind, but further in distance from the trailer for another measurement and then upwind, but nearer for a third measurement, before being returned to the original location. Interestingly, the upwind measurements resulted in a higher profile than at 23 UTC, but the 2330 UTC also had higher returns as did previous RASS profiles, so it is likely that variations in the turbulence are more significant than the location.

A final experiment with RASS involving replacing the normal acoustic signal with a sampling of student music (including, but not limited to, “Bad Moon Rising”). The end result was that no usable returns could be detected in this manner. It was suggested that the audio should have less bass and more soprano similar in frequency to the normal RASS signal.

In addition to these surface layer observations, three radiosonde launches also documented an intriguing low-level feature. Early in the day, a sounding from Tech High School showed an extremely dry (RH=2%) layer at the top of the mixed layer near 800 mb. Two soundings from the tower site captured the evolution of this feature. At 22 UTC, the main dry layer was still in place, while a second one of lesser magnitude and higher in altitude had appeared. By 2330 UTC, it appeared that these two layers had merged to create a region of low relative humidities significantly deeper than had existed earlier in the
day. Besides the low dewpoints, another feature of this inversion was the dramatic ninety degree wind shift from southerly to westerly. This was evident to the students observing the first balloon launch, who were impressed by the dramatic change in location as the balloon penetrated the inversion layer. One of these students, who was not yet enrolled in the radar course, stated that attending and actually launching these balloons was "...the highlight of my year so far".

3.4 Intensive Observing Period Delta

With precipitation still not in the forecast for Wednesday evening, IOP Delta was declared for the south end of campus with two objectives: 1) to test MISS's precipitation sensor using artificially produced rain drops, and 2) to perform a radiosonde launch with attached flares for increased visibility. While low cloud cover quickly eliminated visual contact with the balloon, the sounding data did serve to further document the evolution of the dry layer at the top of the mixed layer and served as an important pre-frontal skew-T. As the data was being transmitted, students were particularly interested in the lack of saturation at the low-level cloud layer which they could observe from the surface, though the conditions did saturate at mid-levels.

Artificial rain was produced over the surface station using syringes: one for "small" drops and two for "large" drops. While attempts were made to calculate the difference between the produced and measured water amounts, more intriguing were which trials did and did not produce a data point in the sensor. In two separate trials, small drops which were dropped at a low rate produced a measurable amount of precipitation. However, trials using small drops at a fast rate or large drops at any rate were not recorded by the instrument. Various ideas were proposed as the results were recorded, but no conclusions have been reached at this time.

Regarding this particular IOP, one student later made the following comments. "The MISS visit was a great experience, because I personally don’t have a lot of instrumental experience, and the MISS got me very excited for my future as a meteorologist. My favorite part of the MISS visit was actually seeing the radiosonde launch and watching its observations of the upper atmosphere being recorded." This student would later inquire of a planned visit to an NWS balloon launch if real-time data would be displayed like in the MISS radiosondes.

3.5 Intensive Observing Period Echo

Since a cold front passage was forecast for the early morning hours of Thursday, October 4, it was decided at the end of IOP Delta to leave the MISS profiler and surface station running at the same location overnight and launch a radiosonde the next morning. This set of observations would be designated as IOP Echo. While students were not involved in the data collection for this event (though a student from a previous radar class did visit the site during this time), the results would prove to be immediately beneficial.
The surface front passed at 09 UTC which began with an increase in wind speed that actually raised the nocturnal temperatures several degrees. However, as the front continued to pass, there was a large drop in the temperature, at a rate which was not captured by the lower-resolution ASOS observation. There was also a pronounced wind shift which was observed both by the surface station and at upper-levels by the wind profiler. The post-frontal radiosonde showed the dramatic change in air mass, with the previous day’s exceptional dry layer now replaced by saturated conditions at lower levels. These special observations of the frontal passage were used by a student presenter during Friday’s Current Weather Analysis class to better illustrate the characteristics of the change in weather regime.

3.6 Intensive Observing Period Foxtrot

With one radiosonde remaining on the last day of the experiment, IOP Foxtrot was declared for the evening of Friday, October 5 to attempt another flared radiosonde launch and to document the weather associated with a weak disturbance propagating from the north. This IOP was also announced as the last opportunity to observe the MISS in operations. As a result, students who had taken the radar course during previous semesters which lacked field instrumentation came to examine the trailer and interact with the project scientists during and after the balloon launch.

Approximately halfway through the balloon flight, light snow and graupel was observed to be falling at the trailer, and an individual observation of precipitation was recorded by the surface station. Examination of the wind profiler data revealed enhanced signal-to-noise ratio and downward vertical velocities associated with the precipitation. This event achieved the final goal of the experiment: to obtain a dataset which could allow for intercomparisons between the vertically pointing radar and surface station and a laser disdrometer located on the roof of the university’s science building. The equipment was left running overnight to extend the dataset, and the project officially ended with a shutdown at 14 UTC on Saturday.

4. ADDITIONAL RESEARCH AND CLASSROOM USE

As described, the collected data was utilized in a classroom setting while the experiment was still ongoing. The observations will continue to be used in the coursework for the next two semesters. At the end of the semester, students in the Radar and Satellite Meteorology course are required to write a review paper and give an oral presentation summarizing a recent professional article on satellite research. In the fall of 2012, certain students will have the additional option of writing a paper and presenting a report summarizing the results of one of BaSE CaMP’s IOPs, while still referencing the relevant literature. Additionally, the Meteorological Instrumentation course meets in the spring, and the use of actual raw data in the unit on radiosondes will mark a departure from previous years. Finally, the MISS data was used to illustrate the use of the Integrated Data Viewer to display wind profiler, radiosonde, and surface point data in the Meteorological Analysis Software course.

Another benefit of BaSE CaMP related to the instrumentation course was the exposure to commercially available items and discussion with experts on radiosonde instruments. The relevant faculty member has already started to investigate acquiring the same type of surface station used with MISS, as well as a more affordable radiosonde unit which was described by the NCAR project scientists. In addition to this course, having equipment of this nature will enhance the ability of students to collect their own special observations for use in research projects.

This leads to one of the most important benefits of the BaSE CaMP dataset: its future use in the department’s Senior Research Project course. The current sequence has students researching and developing a proposal in the spring of their junior year, performing the research over the summer or early in their semester of choice, and preparing an oral presentation and written paper in the fall or spring of their senior year. The majority (17 of 21) of students in the radar course are in their junior year, which means that there is a large pool of students who may be interested in further analyzing data from the various cases and supplementing it in various ways. One example of this would be performing numerical simulations with the WRF-EMS and using the results to provide further insight into the observations. Since the data is permanently archived, it will also be available to every future student as they consider the direction of their research project.

Acknowledgments: The department would again like to thank the scientists and technicians from EOL for participating in this visit, as well as NSF for providing the funding, and various local residents of St. Cloud who allowed their property to be used for deployment sites.
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Note: These totals do not attempt to estimate future use of the MISS data in the instrumentation course, research projects, or the planning of future deployments.