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Partners Project Z15-20543

Severe Convective Storms in Complex Terrain

UCAR Award No. 72033

August 18, 2017

SECTION 1: SUMMARY OF PROJECT OBJECTIVES

- Evaluate the scientific hypothesis that the intensity of convection is enhanced shortly after the intersection of local areas of upslope flow with convection, leading to an increase in lightning flash rate and an enhanced threat of severe weather

- Develop and evaluate the skill of products that integrate both the Global Lightning Mapper (GLM) and High Resolution Rapid Refresh (HRRR) data to provide guidance to forecasters where terrain interactions can increase the probability convection will become severe

- Train forecasters to use the GLM/HRRR products to increase confidence and warning lead time during severe weather events

SECTION 2: PROJECT ACCOMPLISHMENTS AND FINDINGS

We constructed an algorithm to collect the lightning flash rate, severe storm reports, and the upslope flow along individual storm tracks. To track each storm, a pseudo-GLM product was created using total lightning data (cloud-to-ground and intercloud lightning flashes) from the National Lightning Detection Network (NLDN). Lightning clusters were then objectively identified and tracked to form storm tracks. Lightning flash rates were used to determine where lightning jumps, a sudden jump in lightning flash rate by a set standard deviation, occurred along individual storm tracks. Severe storm reports were compiled along each storm track based on the Storm Prediction Center preliminary storm reports database. Upslope flow was calculated using HRRR analyses. We ran this algorithm on days in which there was severe weather in the Northeast during the 2016 warm season.

We analyzed the data collected from the algorithm to assess the project objectives. We calculated the probability of detection and false alarm rates of severe storm occurrence within 45 minutes of individual storms intersecting upslope flow above various thresholds and having a lightning jump above various standard deviations. We found that the probability of detection was high (about 80%), but the false alarm rate was also high (about 80%), which would not be operationally useful. We determined proceeding in this manner was too restrictive and resulted in the misidentification of too many nonsevere storms as severe.

To address these limitations, we decided to use a more sophisticated machine learning tool, called a random forest, to analyze the data without needing to use subjectively defined thresholds for the upslope flow and lightning jump standard deviations. A random forest is a collection of decision trees, each of which is structurally different and trained on a different subset of the data. The end result is a potentially powerful tool to predict whether a storm will be severe or nonsevere, and to assess the overall importance of predictors in making the prediction.

The results of the random forest were very encouraging. The random forest with upslope flow, lightning flash rate, and the change of lightning flash rate with time as predictors yielded a probability of detection of 82% and a false alarm rate of 28%, indicating a skillful model. When we incorporated radar variables, such as the base reflectivity and echo top height, the probability of detection remained the same and the false alarm rate dropped to 23%. The order of importance of various predictors, as determined by the random forest, was upslope flow, lightning flash rate, lightning flash rate change with time, base reflectivity, and echo top height.

The main findings of this project are:

- Upslope flow is important for enhancing lightning flash rates and the threat of severe weather after convection intersects upslope flow.

- Lightning data, such as now provided by the GLM, is valuable for warning on severe convection, but only when combined with other data, such as upslope flow and radar data.

- The random forest tool has potential to be operationally useful for warning on severe convection, but needs further testing.

On the operational side, Tom Wasula participated in the NOAA Hazardous Weather Testbed[1] on 9–13 May 2016 and the GOES-R/16 NWS training course in Kansas City, MO on 7–9 March 2017. In both the testbed and course, Tom found that using the experimental GOES-R/16 satellite data, including the pseudo-GLM total lightning data, and radar data helpful for issuing warnings. Additionally, the experience helped Tom contribute to the first two project objectives by providing feedback and future directions for the COMET project research, and contribute to the third project objective by using materials, such as presentations and Weather Event Simulator job sheets, to train NWS Albany staff.

SECTION 3: BENEFITS AND LESSONS LEARNED: OPERATIONAL PERSPECTIVE

Warning decision forecasters have benefited using various GOES-R/16 data and products during the 2017 severe weather season. GOES-R/16 and radar data have been useful for issuing severe

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[1] http://hwt.nssl.noaa.gov/tales/2016-wk4/

weather warnings. The GLM data is not available in AWIPS as of August 2017, but other lighting datasets from the NLDN, Global Lightning Dataset, and Earth Networks Total Lighting Network are being used to assess severe convective potential in upslope flow environments, as motivated by the COMET project findings. Some of the results from this COMET work will continue to be incorporated in the future, especially when the GLM data is ingested into AWIPS. We are testing using composite reflectivity and reflectivity core heights (50 dBZ, 55 dBZ, 60 dBZ, etc.), combined with increases in cloud-to-ground lighting or total lightning flash density, to improve the accuracy of severe weather warnings.

Forecaster situational awareness has increased with the usage of lightning flash density data. For example, during a severe thunderstorm event in the Albany forecast area on 30 June 2017, a forecaster noted in a quality-assurance or post-mortem report that many of the severe thunderstorm warnings and damage reports were located near lightning jumps. The lightning jumps, combined with upslope flow and other radar data, may be used to increase the confidence of a heightened risk of severe weather in parts of squall lines or quasi-linear convective segments in the future.

Finally, this COMET project and its results have generated enthusiasm among many of the operational forecasters to further explore lightning flash rates and lightning jumps in the warning decision making process and in decision support services for the emergency management community and other customers.

SECTION 4: BENEFITS AND LESSONS LEARNED: UNIVERSITY PERSPECTIVE

This project formed a portion of Pamela Eck's M.S. research. Over the two years, Pamela developed computer skills necessary to perform the research, such as Python coding, statistical methods, and machine learning tools. Pamela also presented the research to NWS forecasters and scientists at professional conferences. As a result, she improved her written and oral communication skills. Pamela finished her M.S. thesis in August 2017.

The knowledge gained from this project also improves our understanding of the interaction between complex terrain and severe convection. These results provide observational evidence that upslope flow can enhance convective intensity, which was previously hypothesized and shown in idealized simulations. Additionally, the research shows that upslope flow can cause changes in lightning behavior, presumably due to changes in convective updraft strength.

SECTION 5: PUBLICATIONS AND PRESENTATIONS

Eck, P., B. Tang, and L. Bosart, 2016: Lightning Jumps as a Predictor of Severe Weather in the Northeastern United States. Oral presentation at the 17th Northeast Regional Operational Workshop, 3 November, Albany, NY.

Eck, P., B. Tang, and L. Bosart, 2016: Lightning Jumps as a Predictor of Severe Weather in the Northeastern United States. Oral presentation at the 28th AMS Severe Local Storms Conference, 9 November, Portland, OR.

Eck, P., B. Tang, and L. Bosart, 2017: Lightning Jumps as a Predictor of Severe Weather in the Northeastern United States. Oral presentation at the 97th AMS Annual Meeting, 25 January, Seattle, WA.

Eck, P., B. Tang, and L. Bosart, 2017: Lightning Jumps as a Predictor of Severe Weather in the Northeastern United States. Oral presentation at the 42nd Northeastern Storm Conference, 12 March, Saratoga Springs, NY.

Eck, P., 2017: Evaluation of Lightning Jumps as a Predictor of Severe Weather in the Northeastern United States. M.S. thesis, Dept. of Atmospheric and Environmental Sciences, University at Albany – SUNY, 90 pp.

Wasula, T. A., B. J. Frugis, and I. R. Lee, 2016: A Comparison of 2 Recent Significant Tornado Events that Impacted East-Central New York. Oral presentation at the 41st Northeastern Storm Conference, 4–6 March, Saratoga Springs, NY.

Wasula, T. A., 2016: Hazardous Weather Testbed (HWT) Experience: GOES-R/JPSS Project – May 9–13, 2016. Oral presentation at the Spring Station Meeting, 15 June, Albany, NY.

Wasula, T. A., B. J. Frugis, and I. R. Lee, 2016: A Comparison of 2 Recent Anomalously Large Hail Events that Impacted the Albany Forecast Area. Poster presentation at the 41st Annual Meeting of the National Weather Association, 10–15 September, Norfolk, VA.

SECTION 6: SUMMARY OF UNIVERSITY/OPERATIONAL PARTNER INTERACTIONS AND ROLES

Interactions between university and operational partners took place at twice-a-year meetings at the NWS Albany office. These meetings were held jointly with NOAA Collaborative Science, Technology, and Applied Research university and operational partners due to the overlapping themes dealing with severe convection. At these meetings, Pamela Eck gave updates on our research progress and operational partners gave feedback on completed work, ideas for future work, and ways in which the research could be transferred to operations.

Brian Tang was responsible for the algorithm development and implementation. Lance Bosart was responsible for identifying severe weather cases in the Northeast, and the synoptic and mesoscale analyses of these cases. Pamela Eck was responsible for the random forest development and verification, which formed a portion of her M.S. thesis. Tom Wasula was responsible for the GOES-R/16 training and interfacing with local NWS Albany staff, saving cases of severe weather in the local area and using experimental GOES-R/16 data in operations.