FINAL REPORT

University: Hobart & William Smith Colleges (HWS)

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NWS Office: Buffalo, NY

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Project Type: Partners

Project Title: Using Satellite Imagery to Improve Monitoring and Nowcasting of Intense Lake-Effect Snow Bands

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Section 1: Summary of Project Objectives

The objective of this project was to use GOES imagery and GOES-R simulated products in combination with currently existing operational data (e.g., WSR-88D, surface, model output) and rapid scan and/or super rapid scan GOES data collected during winter 2011/2012 events to better understand, monitor, and nowcast the development and evolution of intense lake-effect snow bands.

Section 2: Project Accomplishments and Findings

2011-2012 Winter Portion of Project:

Neil Laird (HWS) visited NWSFO Buffalo during November 2011 and presented details of the funded COMET Partners project to create greater awareness within the WFO. The presentation discussed the scientific and operational foundations for the project, as well as the proposed timeline and potential outcomes for the project. A brief overview of available simulated GOES-R products was provided with a focus on explaining how this project has the potential to benefit the WFO operations by enhancing forecasts through a greater use of GOES and simulated GOES-R information. Two main goals of this discussion were to answer any questions about the COMET project and to maximize participation of forecasters during the lake-effect season of 2011/2012.

Neil Laird and David Zaff collaborated on developing a brief questionnaire that was used by forecasters during lake-effect events in the winter of 2011/2012 to give greater insight into the operational use of satellite information, especially in monitoring and nowcasting intense lake-effect snow bands over Lakes Erie and Ontario. The WFO BUF implemented the questionnaire operationally. A good sample of responses was collected, despite an unusually mild winter with a much-below normal occurrence of lake-effect snow.

2012 Summer Research Portion of Project:

The HWS summer research announcement was distributed to colleges and universities across the United States in December 2011. Approximately 105 undergraduate student applications were received for the COMET-funded positions. Two undergraduate students worked on the COMET-funded project for 8 weeks during June-August as part of the 2012 summer research program at HWS. The two student participants were Brian Crow, a rising senior at the University of Missouri, and Chad Hecht, a rising junior at Hobart College.

Two projects were undertaken at HWS. The first project examined two intense lake-effect events, both impacting the southern and eastern shore of Lake Ontario, and the second project examined the relations of Lake Erie ice cover to past lake-effect events. This second project was undertaken because of the limited number of intense lake-effect events that occurred during the unusually warm winter of 2011/2012 in the Great Lakes region. This report will focus on the results from the first research project, an examination of two intense lake-effect events over Lake Ontario.

While synoptic conditions required for the development of lake-effect (LE) snow events in the Great Lakes region are generally understood, short-term forecasting of the development and evolution of LE (LE) snow bands remains a substantial challenge. During the winter of 2011-2012, questionnaires were completed by forecasters at the NWSFO in association with LE events to better understand current forecast practices during these events, particularly with regards to the use of satellite imagery. Based on the feedback from the NWSFO questionnaires and the LE events which occurred, two case studies were conducted to determine how forecasts may have benefited from using a variety of data and model resources. The two cases, 17-18 November 2011 and 30 January 2012, were selected for detailed examination due to interesting evolutions in LE snowbands, as well as the richness of available data and challenging real-time forecasts. The November case underwent a transition from widespread cellular convection over Lakes Erie and Ontario to the development of a solitary linear snowband over each lake; the January case involved an intense band over Lake Ontario that persisted in the same location for nearly ten hours then dissipated rapidly.

The 17-18 November 2011 case was significant not because of extreme impacts on a localized area, but because it was an event comprised of two distinct modes of LE convection: cellular and banded. An example of this transition in LE convection can be seen in Figure 1. A cellular mode of LE snow is much less common than banded modes and presents a greater challenge to short-term forecasters trying to determine when and where snowfall will occur, as well as how much accumulation will occur. The transition to banded snowfall during the later portion of the event is also significant because it indicates a change in synoptic and mesoscale environments in the vicinity of Lake Ontario during the event. As is often the case, the greatest snowfall occurred where the bands remained stationary; in the Fulton, NY vicinity; reports of up to 31.7cm were received. In addition, the early season warmth of the lake and depth of the boundary layer resulted in deeper LE convection, and the occurrence of lightning and thunder were observed in isolated areas.

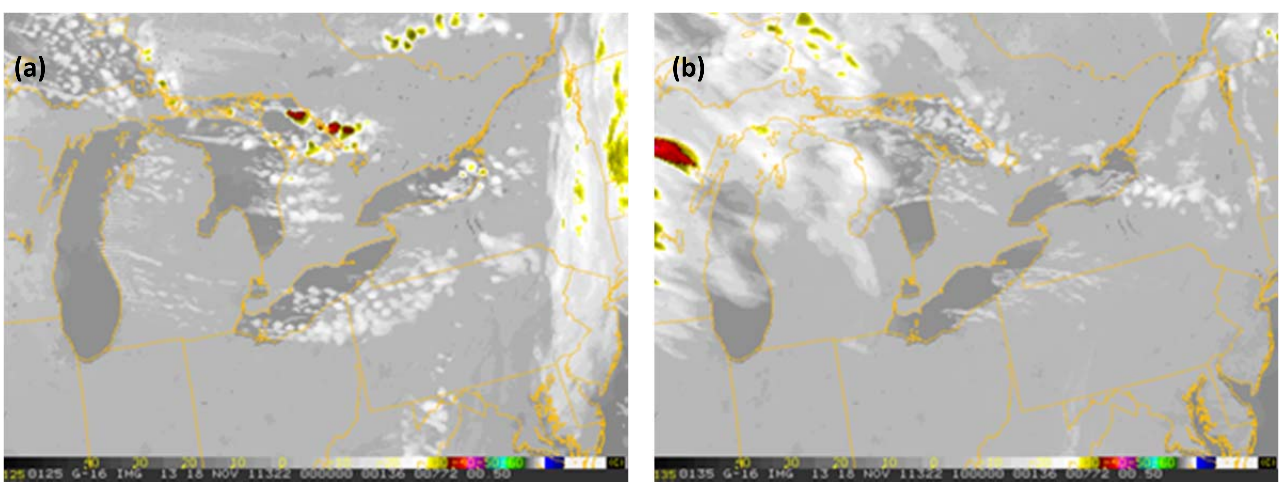

Figure 1. GOES-R demonstration cloud top temperatures product for (a) 00z on 18 Nov 2011 showing cellular convection over Lakes Ontario and Erie reaching altitudes of over 5km based on cloud top temperatures around -30°C, and (b) 10z on 18 Nov 2011 showing banded LE structure extending from eastern Lake Ontario.

The 30 January case had an extreme impact on a localized area. During the 12-hour period from 06z to 18z on 30 January, many locations in southwestern Oswego County received in excess of 30cm of snow. The snowfall maximum for the event was in Fulton, NY where 82.6cm of snow was recorded, of which 63.0cm fell during the time period from 1120z to 1730z. This suggests that from mid-morning to early afternoon local time snowfall rates averaged approximately 10.2 cm hr^{-1} over a thin strip of southwestern Oswego County where the band remained quasi-stationary. During this time, snowplows were pulled from local roads due to the dangerously low visibilities produced by the intense snowfall. This type of high impact winter weather requires use of our best capabilities to monitor and provide sound short-term forecasts.

In order to determine if use of available satellite data may have provided any additional benefit to forecasters issuing nowcast products during the two case study events, available satellite imagery and GOES-R Demonstration products were reviewed by HWS researchers for the 3 hours prior to each forecast product issuance through the end of the forecast period. This time period was chosen to see if trends in the evolution of LE snowbands may have been identified prior to the forecast. Products that were reviewed were based upon availability, since not all operationally available GOES-R products for these events were archived or available with a high temporal frequency. The list of products included; traditional visible and infrared imagery, as well as the cloud top temperatures (CTT), fog/stratus differentiation, simulated water vapor, and IR channel differencing GOES-R Demonstration products.

Through independent analysis, HWS researchers found that warning and advisory products from the two case studies generally verified well. For the 17-18 November 2011 case, 4 out of 4 Lake Effect Snow Warning and 4 out of 7 Lake Effect Snow Advisory products verified. Only 1 of the 3 counties under advisories during the 30 January 2012 event had reported advisory-criteria snowfall. This may be partially attributed to the lack of snowfall reports in areas affected. Had a greater density of data been available, all of the advisories might have verified, as well as 3 warning product issuances for northern Cayuga County. The difference in the verification of the forecasts between the cases can largely be attributed to forecast challenges with the cessation time and changes of intensity associated with the solitary LE snowband over eastern Lake Ontario.

The survey of forecasters at NWSFO BUF during the winter 2011-2012 revealed that in many LE snow forecasting situations, satellite data is either not used based on forecaster preference or is unusable due to obscuration from synoptic-scale cloudiness. However, in instances where satellite data is used, cloud-top temperatures, surface properties, and synthetic satellite imagery were among the GOES-R Demonstration products used in conjunction with traditional GOES-13 visible and infrared imagery. Other products, such as the fog/stratus differentiation product and the IR channel differencing product, were less useful for monitoring LE snow, as both products generally showed very limited contrast between the surface and LE clouds or LE clouds and higher synoptic clouds. However, when not obscured by synoptic cloudiness, traditional visible imagery could be a valuable monitoring and short-term forecasting tool, as demonstrated during both cases. Both visible and infrared imagery during the event of 17-18 November 2011 were useful for monitoring the transition from cellular to banded LE convection. Visible imagery during the 30 January 2012 case was useful for monitoring the continued development and eventual decay of the Lake Ontario snowband.

Based on what was seen with both of the cases discussed, the cloud top temperature GOES-R Demonstration product can be an extremely helpful tool for short term forecasting. Cloud top temperatures, in combination with a recent, nearby sounding or model sounding, can help the forecaster determine the inversion level and therefore the sustainability of the area of LE snow. If the cloud top temperatures are seen to warm over a period of time, the forecaster can infer that the inversion layer is descending, reducing the depth of the convective layer and gradually reducing the snowfall that can be expected. This is not a new finding, and current GOES IR satellite imagery can be used for the same purpose in its present state, but the enhanced spatial and temporal resolution of GOES-R products should increase the utility of such a product. In addition, the increased measurement accuracy of the Advanced Baseline Imager of GOES-R should be capable of differentiating more effectively between relatively warm surface features and warm LE clouds.

As seen in the 30 January 2012 case, changes in the appearance of ongoing LE snowbands on visible satellite imagery may be an indicator of imminent changes in the strength and motion of the snowband. As previously observed during the LOWS Project (Reinking et al. 1993), wind shear of sufficient depth and magnitude may cause snowbands to develop curvature and rotation. If the curvature or rotation brings a band into an orientation that opposes the primary wind direction, the band may transition into smaller, weaker bands, or dissipate entirely. The 30 January Lake Ontario snowband showed an increase in curvature and apparent waviness on visible satellite imagery shortly before its decay and eventual northward movement. The change in appearance of the snowband on visible satellite imagery also preceded the change in appearance of the snowband observed by local WSR-88D radars. This is important to highlight because it demonstrates that the forecaster can use satellite imagery to gain valuable short-term forecast lead time by observing changes in the structure of the LE snowband in over-lake areas not observed well by WSR-88D radars.

Section 3: Benefits and Lessons Learned: Operational Partner Perspective

Although the NWS BUF Forecast area had an underwhelming 2011-2012 winter season in terms of lake effect, forecasters were still able to get a glimpse of some of the capabilities of GOES-R by using existing GOES and MODIS datasets. Two of the GOES RSO scans were useful for near term forecasting. In addition GOES-R simulated data from MODIS was found to be useful as well. Although this data was not available in real-time, forecasters were able to see the benefits of higher resolution imagery for observing multiband structures over the lakes and noting cloud/snow discrimination during the daytime, when it is sometimes difficult to distinguish ground from cloud features. There were some attempts to use synthetic (forecast) satellite imagery based off of the WRF as well. This data, available through CIRA, provides a 24 hour forecast of WV and IR imagery. Initially available over the CONUS, the forecast staff was able to get CIRA to create a zoomed in view that covers much of the Great Lakes Region and all of Western and Central NY. This imagery of course is only as good as the model. If the model is missing a lake effect event, the synthetic imagery will similarly miss the event. Using these datasets, forecasters were therefore able to get a better understanding of the potential of GOES-R and other proposed satellite products.

Section 4: Benefits and Lessons Learned: University Partner Perspective

The COMET partnership has provided benefits to HWS by (1) creating student awareness of new observing systems, (2) generating greater awareness by current and prospective undergraduate students of the opportunity to study atmospheric sciences at Hobart & William Smith Colleges, and (3) strengthening the collaborative relationship with NWS personnel.

Section 5: Publications and Presentations

1. Crow, B., N. F. Laird, and D. Zaff, 2012: Forecast Assessment of Two Challenging Lake-Effect Snow Events in the Eastern Great Lakes Region. *National Weather Association 37th Annual Meeting*, Madison, WI

Section 6: Summary of University/Operational Partner Interactions and Roles

In October 2011, Neil Laird and about 15 undergraduate students from HWS traveled to NWSFO Buffalo to assist David Zaff with a rawinsonde launch and were given a tour the NWSFO by David Zaff. These undergraduate students were part of Dr. Laird's first-year course titled, the Science and Communication of Weather, and student from several other meteorology courses at HWS.

Dr. Laird visited the Buffalo, NY NWSFO during October 2011 to provide an overview and details of our COMET Partners Project to use GOES imagery and GOES-R simulated products in combination with currently existing operational data (e.g., WSR-88D, surface, model output) to better understand, monitor, and nowcast the development and evolution of intense lake-effect snow bands.

In November 2011, David Zaff traveled to Hobart & William Smith Colleges to present and discuss the forecasting process during lake-effect events that have impacted the city of Buffalo with Dr. Laird's first-year students participating in a course titled, the Science and Communication of Weather.

As part of the forecasting process in the Buffalo, NY NWSFO, forecasters completed a questionnaire to help provide the research project real-time assessment of the degree that satellite imagery/products were used during lake-effect events and what information resources (satellite, composite radar, and/or models) were utilized by forecaster to monitor and nowcast lake-effect events for the winter of 2011-2012.

COMET funds provided an opportunity for two undergraduate students to participate in the 8-week Hobart & William Smith Colleges (HWS) 2012 summer research program. During the summer research program in June, Dr. Laird and undergraduate students in his research group traveled to NWSFO Buffalo to discuss the early stages of the research phase of the COMET project with David Zaff.

In October 2012, Neil Laird and about 15 undergraduate students from HWS will travel to NWSFO Buffalo to assist David Zaff with a rawinsonde launch and get a tour the NWSFO by David Zaff. These undergraduate students are currently part of Dr. Laird's first-year course titled, the Science and Communication of Weather, and student from several other meteorology courses at HWS.