COMET-BGMPartners-project Z12-93222-Final-report

FINAL REPORT

University: Hobart & William Smith Colleges (HWS)

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Project Type: Partners

Project Title: Using Satellite Imagery to Improve Forecasting of Lake-Effect Snow Bands with a Multiple Lake Connection

UCAR Award No.: Z12-93222

Date: October 28, 2012

Section 1: Summary of Project Objectives

This project undertook two research objectives in order to help develop a greater understanding and operational awareness of lake-effect events with a multi-lake connection that impact areas in the vicinity of Lakes Ontario and Erie. Our two objectives included a (1) 15-winter satellite climatology of eastern Great Lakes multiple-lake lake-effect events and (2) comparative analysis of GOES-R satellite demonstration products and currently-available GOES satellite imagery for multi-lake connection lake-effect events which occurred during the winter of 2011/2012.

Section 2: Project Accomplishments and Findings

2011-2012 Winter Portion of Project:

Neil Laird (HWS) attended the WFO BGM Winter Workshop on 18 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 Michael Evans 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 identifying and considering the potential contribution of multiple lake interactions. The WFO BGM implemented the questionnaire operationally by including a link to an online version of the document from their lake-effect checklist, which is completed every day when lake-effect snow is possible. The WFO information technology officer set up an online archive of the forecaster responses to the questionnaire, so that the forecaster feedback could be shared in real-time with the science operations officer at the WFO, along with the principal investigator at HWS. A good sample of responses was collected, despite an unusually mild winter with a much-below normal occurrence of lake-effect snow. Responses indicated that multi-lake connections were identified with a wide range of methods, including satellite, radar, and high resolution models. Responses also indicated that identification of a multi-lake connection often impacted the forecast, from increasing the confidence of the current forecast, to occasionally helping with the decision to upgrade snow amounts. In addition, the content of morning forecast briefings and area forecast discussions issued by the WFO also indicated that there appeared to be an increased awareness of the potential for multi-lake connections to impact the forecast. The current WFO BGM forecast staff now includes 4 meteorologists who have been forecasting for the NWS in central New York for 3 years or less, and it appeared that the project may have especially heightened the awareness of the multi-lake lake-effect snow issue for these newer forecasters.

2012 Summer Research Portion of Project:

The HWS summer research announcement for undergraduates to participate in the project 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 Carlee Loeser, a rising junior at Salisbury University, and Christine Bloecker, a rising junior at the University at Albany.

The research conducted at HWS examined the trends in the development of lake-effect cloud bands using satellite imagery in order to better understand their frequency and behavior across a 15-winter time period (i.e., October-March of 1997-1998 through 2011-2012). Lakes Superior, Michigan, and Huron had a higher frequency of lake-effect clouds than Lakes Erie and Ontario with a climatological maximum over each lake occurring in December or January. Wind-parallel bands (WPB; identified as Type II snow bands by Niziol et al. 1995) generally decreased in frequency from west to east, and the frequency of shore-parallel bands (SPB; identified as Types I and IV snow bands by Niziol et al. 1995) increased from west to east.

Table 1. Number of lake-effect cloud band events on the Great Lakes by type and month

Number of Lake-Effect Days on the Great Lakes by Month								
Lake	Type	Oct	Nov	Dec	Jan	Feb	Mar	Overall
Superior	WPB	75	105	209	239	187	110	925
	SPB	10	11	27	32	40	22	142
	MSV	0	2	6	5	7	3	23
	UNCLEAR	71	57	44	48	59	59	338
	FOG	6	0	0	1	1	2	10
	Overall	162	175	286	325	294	196	
Michigan	WPB	79	106	184	178	141	91	779
	SPB	29	29	39	49	45	28	219
	MSV	4	0	2	8	2	2	18
	UNCLEAR	59	55	33	55	44	53	299
	FOG	8	4	0	0	1	6	19
	Overall	179	194	258	290	233	180	
Huron	WPB	72	82	157	159	136	82	688
	SPB	34	33	68	74	53	29	291
	MSV	1	0	2	5	2	2	12
	UNCLEAR	82	64	65	51	59	49	370
	FOG	6	4	0	0	1	3	14
	Overall	195	183	292	289	251	165	
Erie	WPB	49	63	103	86	63	33	397
	SPB	42	31	57	31	11	7	179
	MSV	2	0	1	2	0	0	5
	UNCLEAR	60	54	43	43	35	31	266
	FOG	2	1	0	0	2	0	5
	Overall	155	149	204	162	111	71	
Ontario	WPB	36	41	97	104	88	39	405
	SPB	32	30	67	87	72	29	317
	MSV	1	0	1	1	0	0	3
	UNCLEAR	48	51	55	47	47	40	288
	FOG	8	4	1	0	2	1	16
	Overall	125	126	221	239	209	109	

Lake-effect events with multi-lake connections were also identified during the investigation (i.e., Type III snow bands identified by Niziol et al. 1995). The graph below shows the types of multi-lake lake-effect connections observed over the 15-winter period. Most multi-lake cloud bands originated over Lake Superior, with Lakes Huron and Michigan also associated with a fair amount of these bands (Figure 1). Multi-lake connections exclusively between Lakes Erie and Ontario were highly uncommon, as were connections between Lakes Michigan and Erie due to the large over-land distance bands originating from Lake Michigan would have to extend across while maintaining their structure before reaching Lake Erie.

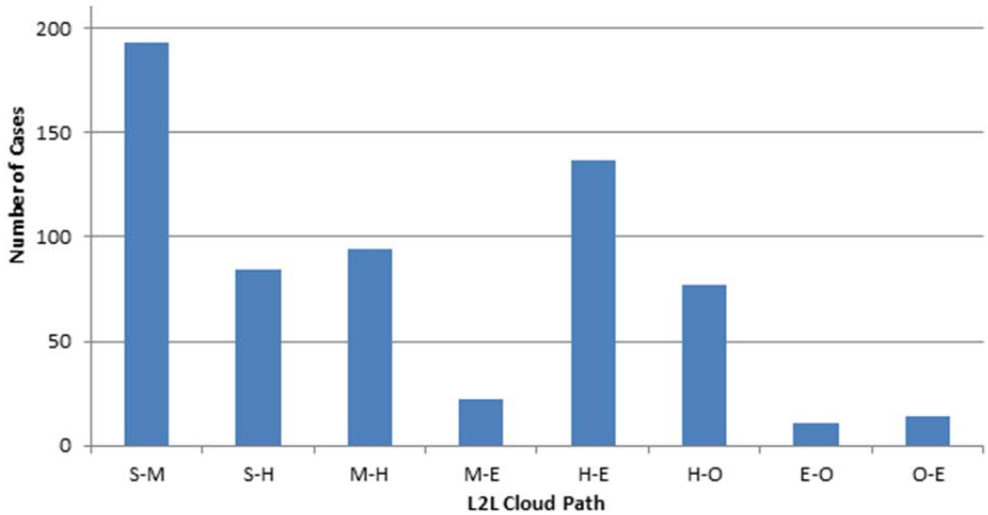

Fig 1. Total number of multi-lake lake-effect cloud band events per lake combination. The lake combination is represented as a two-letter sequence. The first letter is the upwind lake and the second letter the downwind lake.

Lake-effect cloud bands have the potential to produce large amounts of snowfall downwind of the Great Lakes every winter, but not all of these bands produce significant snowfall accumulation. However, the intensity of snowfall for a given band may be influenced by a connection to an upwind lake (i.e., multi-lake connections). According to Rodriguez et al. (2007), upwind lake connections can enhance snowfall, but Niziol et al. (1995) stated that multi-lake bands (Type III) from Lake Huron to Lake Ontario generally produce much less snowfall than single-lake shore-parallel bands (Types I).

In order to determine if snowfall is enhanced by connections to upwind lakes, it is important to study the snowfall amounts that result from both single-lake snow events and multi-lake snow events. A second portion of the summer research at HWS focused on lake-effect snow events in the central upstate New York region, particularly the areas east and south of Lake Ontario. The county boundaries that were used to define the study region included west to Orleans County, east to Hamilton County, south to Chenango County, and north to St. Lawrence County. Snowfall totals from multi-lake wind-parallel bands and shore-parallel bands originating off of Lake Huron extending to Lake Ontario were compared to snowfall totals from single-lake wind-parallel band and shore-parallel band events that developed over Lake Ontario. This comparative analysis addressed the issue of whether multi-lake snow bands have produced more intense snowfall over these areas than single-lake snow bands. The multi-lake bands were classified based on the structure of the cloud band over Lake Ontario, rather than the form the band may have originally had over Lake Huron.

To perform this comparative analysis, the U.S. Daily Snowfall and Snow Depth data from the National Climatic Data Center was used. The dates that were chosen for observation were derived from the 15-winter climatology of lake-effect cloud bands, but snowfall data were only available for the winter of 2005-2006 onward, so only events that occurred during this period were used for the precipitation study. There were 157 SPB events over Lake Ontario during or after the winter of 2005-2006 with only

134 having measureable snowfall and 108 WPB events over Lake Ontario with 97 having measureable snowfall. During the same time period, 37 multi-lake events were identified and all but one of these cases produced measureable snowfall. It is important to note that our SPB classification contains both Types I and IV bands, as defined by Niziol et al. (1995). Type I snow bands are associated with strong winds parallel to the long axis of a particular lake and often result in significant localized snowfall at the downstream intersection of the band with the lake shoreline. Type IV snow bands are also typically oriented parallel to the long axis of a particular lake; however, these events often develop from land breeze circulations along one or two lake shorelines. The snowfall associated with these more weakly forced (Type IV) events often have a larger variation in snowfall at the location where the band intersects the lake shoreline as compared to the large snowfall amounts of Type I events.

The events included in the snowfall analyses were categorized as - Lake Ontario shore-parallel bands (OSPB), Lake Ontario wind-parallel bands (OWPB), multi-lake shore-parallel bands (L2LSPB), and multi-lake wind-parallel bands (L2LWPB). These events were identified as only having the one type of lake-effect band over Lake Ontario during the event. There were events were shore-parallel and wind-parallel bands occurred over Lake Ontario during one event; however, these were not included in our snowfall analysis so that WPB and SPB events could be treated independently and more reasonably compared.

ArcGIS was used to create a visualization of the average composite snowfall distribution from each cloud band type over the study region (Figure 2). The statistical analysis of the snowfall data for each individual reporting station within the study region (Fig. 2 black dots) was conducted using SPSS.

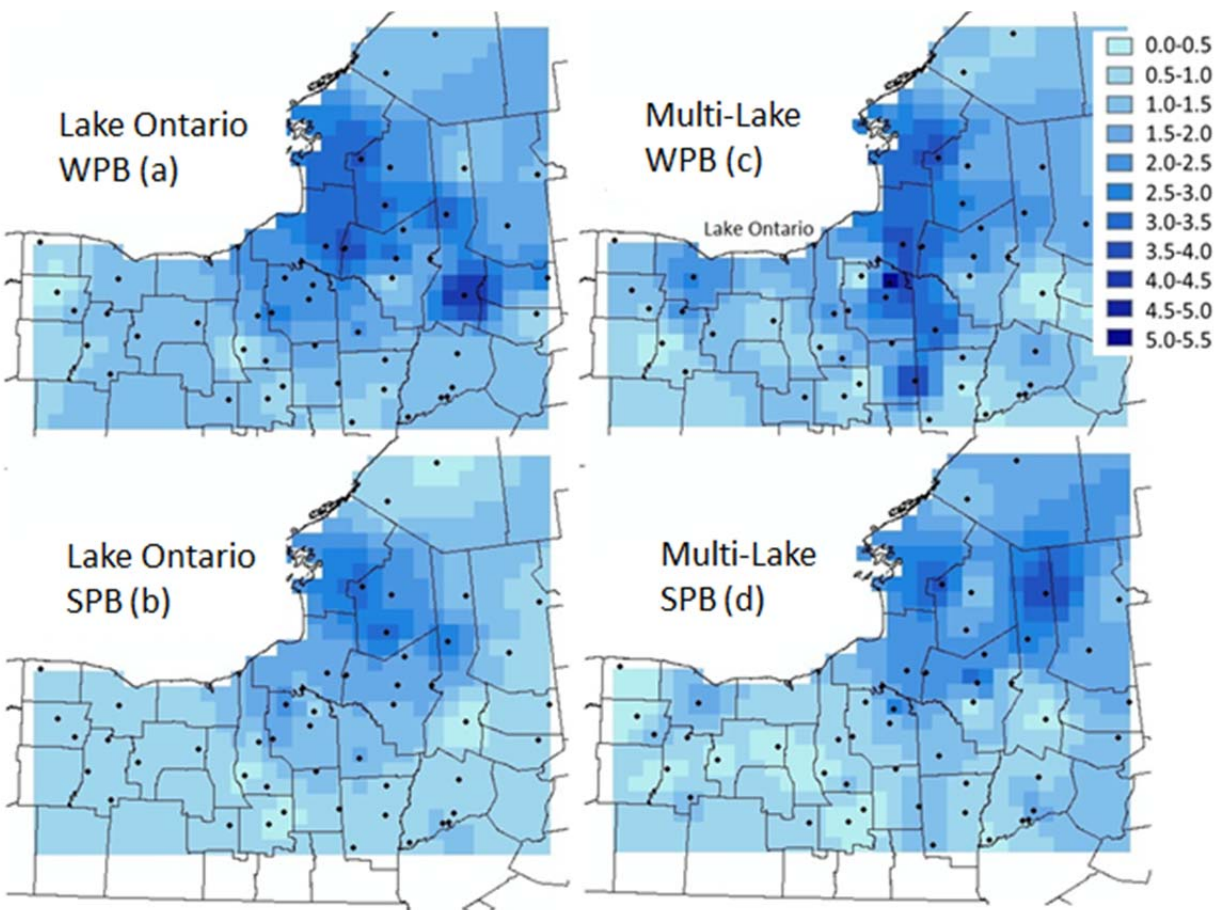

Fig 2. New York state snowfall analyses showing the mean snowfall distributions for (a) Lake Ontario wind-parallel bands (WPB), (b) Lake Ontario shore-parallel bands (SPB), (c) multi-lake wind-parallel bands, and (d) multi-lake shore-parallel bands. Locations of surface stations are shown as black dots. The snowfall scale is in units of inches.

The mean, median, standard deviation, skewness, and maximum of the distributions of snowfall at each station were determined using all events within each type (i.e., OSPB, OWPB, L2LSPB, and L2LWPB). ArcGIS was then used to spatially interpolate the station snowfall statistics to a uniform grid and visualize the results. Events when snowfall was not reported at a particular station were not included in the statistical analyses for that station (i.e., the statistics were only based the number of events when snowfall was reported at the station). For example, if a snow band resulted in snowfall only east of Lake Ontario, then the event would not be included in the statistics for stations south of Lake Ontario. For OSPB and OWPB categories, the number of events having reported snowfall at individual stations was typically greater than 25; however, since there were much fewer multi-lake events the number of events having reported snowfall at individual stations for the L2LSPB and L2LWPB categories was often less than 10. A larger sample of multi-lake events would be desired for the statistical analyses. The current study chose to work with the on-line snowfall data for New York state stations since the winter of 2005-2006 (i.e., 7 winters). Subsequent research studies that continue this investigation may want to increase the number of winters of snowfall data to increase the robustness of the statistical analyses.

The mean snowfall distributions show that for each type of lake-effect snow band, the highest concentration of snowfall occurred over Jefferson, Oswego, and Lewis counties, the counties directly east of Lake Ontario (Fig 2). Counties south of Lake Ontario generally have greater values of mean snowfall from multi-lake bands than from single-lake bands, especially Monroe County.

The following are the primary results from the spatial analyses of snowfall for Lake Ontario single-lake compared to multi-lake events.

- **The averaged snowfall across the region for multi-lake SPB events was greater than for single-lake SPB bands** (Fig 2 panel (d) compared to panel (b)). **Additionally, the spatial distribution of average snowfall for multi-lake SPB events showed greater inland extend of higher snowfall amounts.** These results emphasize the need to understand multi-lake connections better and develop greater awareness of tools that can be used to improve monitoring of these situations (e.g., satellite imagery and trajectory models).
- **The averaged snowfall across the region for single-lake WPB events was greater than for multi-lake WPB events.** Typically Lake Ontario single-lake WPB events will have a northerly flow across the lake (perpendicular to the lake's long axis) where multi-lake WPB will have a northwesterly flow. We would expect that the polar/arctic airmass will have undergone greater modification in the multi-lake situation. Our results may suggest that WPB are more efficient at producing greater snowfall when there is a greater forcing (less modified polar/arctic airmass or greater difference between lake and air temperature) even though the over-lake fetch and amount of atmospheric moisture are less than in the multi-lake situation.
- **Across the study region, the averaged snowfall was greater for WPB events than SPB events for both the single-lake and multi-lake snow bands.** This is an unexpected result since typically SPB can deposit significant snowfall totals during events. This result suggests that for the time period of this study (2005/06 – 2011/12), WPB events may have provided more uniform, moderate snowfall across the region while SPB events where more spatially distributed with a greater variability of snowfall totals at individual stations and fewer significant snow amounts.

Section 3: Benefits and Lessons Learned: Operational Partner Perspective

Increased awareness of possible impacts of multi-lake lake-effect snow events was noted in area forecast discussions and briefings issued by the WFO, particularly in regard to newer forecasters. In particular, the anticipation of potential multi-lake connections were sometimes used to confirm current forecasts or to upgrade snow amounts in current forecasts.

Operational use of new data sets was also noted as a result of the increased emphasis on identifying multi-lake events. Based on area forecast discussions and briefings, it appeared that forecasters were placing an increased emphasis on analysis of satellite data, and model-based trajectory forecasts.

Section 4: Benefits and Lessons Learned: University Partner Perspective

The COMET partnership has provide 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. Loeser, C., C. Bloecker, N. F. Laird, and M. Evans, 2012: Lake-Effect Cloud Band Frequency and Snowfall with Emphasis on Multiple-Lake Connections. *2012 Joint Annual Meeting of the Pennsylvania Geographical Society and the Middle Atlantic Division of the Association of American Geographers*, Salisbury, MD.
2. Loeser, C., C. Bloecker, N. F. Laird, and M. Evans, 2012: Lake-Effect Cloud Band Frequency and Snowfall with Emphasis on Multiple-Lake Connections. *67th Southeastern Division of the Association of American Geographers*, Ashville, NC.
3. Loeser, C., C. Bloecker, N. F. Laird, and M. Evans, 2013: Lake-Effect Cloud Band Frequency and Snowfall with Emphasis on Multiple-Lake Connections. *12th Annual AMS Student Conf*. Austin, TX.

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

In September 2011, Mike Evans traveled to Hobart & William Smith Colleges to present and discuss the process of severe weather damage assessment with Dr. Laird's first-year students participating in a course titled, the Science and Communication of Weather.

Dr. Laird visited the Binghamton, NY NWSFO to participate in their annual winter weather workshop during October 2011. As part of the workshop, Dr. Laird provided an overview and details of our COMET Partners Project on utilization of GOES and GOES-R products to improve monitoring and forecasting of lake-to-lake snow bands.

As part of the forecasting process in the Binghamton, 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 for initial recognition of L2L connections 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 first week of the summer research program in early June, Mike Evans and a group from NWS Binghamton visited HWS to discuss the start of the research phase of the COMET project. In late July, Dr. Laird and students in his summer research group visited the NWSFO in Binghamton to discuss the results of the summer research projects being conducted both at HWS and NSWFO.

Two summer student volunteers at the WFO Binghamton (Michael Murphy and Kara Kerschner) participated in the project. The students worked closely with Michael Evans and Eric Hedien on performing research case study analyses on two lake-effect snow event from the winter of 2011-2012, with an emphasis on potential multi-lake connections. Their findings were presented to the researchers from HWS in July, 2012.