UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service
Eastern Region Headquarters
630 Johnson Ave. Suite 202
Bohemia, NY 11716

February 22, 2019 W/ER3x1:JSW

Dr. Lorrie Alberta
COMET Outreach Program Manager
University Corporation for Atmospheric Research
P.O. Box 3000
Boulder, CO 80307-3000

Dear Dr. Alberta:

We have reviewed the COMET Partners Project proposal between Hobart and William Smith Colleges and the National Weather Service (NWS) Office in Binghamton, New York, entitled "Understanding the Interaction between Short-Wave Troughs and Lake-Effect Snow Events." Lake effect snow is a mesoscale phenomenon that can have very localized impacts. Conditions can range from sunny and dry to near blizzard conditions on the scale of only a few miles. Improving understanding of the temporal and spatial evolution of lake effect snow events is critical to providing high quality, actionable decision support information for these events. Short-wave troughs can cause sudden shifts in the location, structure, and intensity of lake effect snow bands. Anticipating these changes is vital to minimizing their societal and economic impacts, especially for the transportation sector. For example, proactively closing down interstates during these events can save lives, as well as expedite post event recovery efforts. This project has the potential to considerably improve forecasts and decision support for lake effect snow events. Thus, we strongly support the funding of this project.

This proposed project also aligns very well with another experiment. The NWS offices in Buffalo, Binghamton, and Albany New York are currently engaged in an effort to explore the use of issuing polygon warnings for lake effect snow that vary in space and time during an event rather than the current warnings that cover entire forecast zones (typically counties) for an extended period of time. The objective of the lake effect snow warning polygon experiment is to improve the temporal and spatial fidelity of hazard information for lake effect snow. The results from this COMET Partners project would be directly applicable and potentially greatly enhance the polygon warning effort. Therefore, we enthusiastically endorse this proposal.

Sincerely,

Jason P. Tuell
Director, NWS Eastern Region

Partners Project Title Page
Proposal for a Partners Project

Title: COMET Partners Proposal: Understanding the Interaction between Short-Wave Troughs and Lake-effect Snow Events

Date: 7 February 2019

Signatures for University
University Name: _Hobart and William Smith_
Address: _______300 Pulteney St. _____
__Geneva, NY 14456______________

Principal Investigator
Name (typed): Nicholas Metz
Telephone number: 315-781-3819
FAX number: 315-781-3860
Address: _300 Pulteney St._______
___Geneva, NY 14456____________
Email: nmetz@hws.edu

University Official (usually dept. chair)
Name (typed): David Kendrick
Title: Geoscience Dept Chair
Telephone number: 315-781-3929
FAX number: 315-781-3860

University Official (contract sent to)
Name (typed): Roberta Truscello
Title: Director of Sponsored Programs
Address: _300 Pulteney St._____
___Geneva, NY 14456__
Telephone number: 315-781-3754
FAX number:
Email: truscello@hws.edu

Signatures for NWS
NWS Office:____________________
Address:______________________

Principal Investigator
Name (typed): Jared Klein
Telephone number:
FAX number:
Email:

MIC/HIC
Name (typed):
Telephone number:
FAX number:

SSD Chief
Name (typed):

Regional Director
Name (typed):

SUMMARY OF BUDGET REQUEST:

COMET FUNDS: Year 1__14941_______

NWS FUNDS: FY 1__5000____ FY 2________

Partners Project Title Page
Proposal for a Partners Project

Title: COMET Partners Proposal: Understanding the Interaction between Short-Wave Troughs and Lake-effect Snow Events

Date: 7 February 2019

Signatures for University
University Name: _Hobart and William Smith_
Address:_______300 Pulteney St. ____
__Geneva, NY 14456_______________

____
Principal Investigator
Name (typed): Nicholas Metz
Telephone number: 315-781-3819
FAX number: 315-781-3860
Address: _300 Pulteney St.________
___Geneva, NY 14456_____________
Email: nmetz@hws.edu

____
University Official (usually dept. chair)
Name (typed): David Kendrick
Title: Geoscience Dept Chair
Telephone number: 315-781-3929
FAX number: 315-781-3860

____
University Official (contract sent to)
Name (typed): Roberta Truscello
Title: Director of Sponsored Programs
Address: _300 Pulteney St._____
___Geneva, NY 14456__
Telephone number: 315-781-3754
FAX number:
Email: truscello@hws.edu

Signatures for NWS
NWS Office: Binghamton, NY
Address: 32 Dawes Drive
Johnson City, NY 13790

Jared Klein
Principal Investigator
Name (typed): Jared Klein
Telephone number: (607) 770-9531 ext. 224
FAX number: (607) 798-6624
Email: Jared.Klein@noaa.gov

Douglas A. Butts
MIC/HIC
Name (typed): Douglas Butts
Telephone number: (607) 770-9531 ext. 222
FAX number: (607) 798-6624

____
SSD Chief
Name (typed):

____
Regional Director
Name (typed):

SUMMARY OF BUDGET REQUEST:

COMET FUNDS: Year 1________

NWS FUNDS: FY 1________ FY 2________

Partners Project Title Page
Proposal for a Partners Project

Title: COMET Partners Proposal: Understanding the Interaction between Short-Wave Troughs and Lake-effect Snow Events

Date: 7 February 2019

Signatures for University
University Name: _Hobart and William Smith_
Address:_______300 Pulteney St. ____
__Geneva, NY 14456_______________

____
Principal Investigator
Name (typed): Nicholas Metz
Telephone number: 315-781-3819
FAX number: 315-781-3860
Address: _300 Pulteney St.________
___Geneva, NY 14456_____________
Email: nmetz@hws.edu

____
University Official (usually dept. chair)
Name (typed): David Kendrick
Title: Geoscience Dept Chair
Telephone number: 315-781-3929
FAX number: 315-781-3860

____
University Official (contract sent to)
Name (typed): Roberta Truscello
Title: Director of Sponsored Programs
Address: _300 Pulteney St._____
___Geneva, NY 14456__
Telephone number: 315-781-3754
FAX number:
Email: truscello@hws.edu

Signatures for NWS
NWS Office: Binghamton
Address: 32 Dawes Drive
Johnson City, NY 13790

____
Principal Investigator
Name (typed): Jared Klein
Telephone number:
FAX number:
Email:

____
MIC/HIC
Name (typed):
Telephone number:
FAX number:

____
SSD Chief
Name: Kenneth W. Johnson

____
Regional Director
Name: Jason P. Tuell

SUMMARY OF BUDGET REQUEST:

COMET FUNDS: Year 1_________

NWS FUNDS: FY 1________ FY 2________

NWS Checklist for Submitting a COMET Outreach Proposal

Actions Before Proposal is Submitted to COMET	**YES**	**NO**	**DATE**
1. Did NWS office staff and university staff meet to discuss and form outline and scope of project?	X		
2. Did NWS office consult Scientific Services Division (SSD) staff?	X		
3. Was Statement of Work and budget formulated as a team effort between university and NWS staffs?	X		
4. Was proposal submitted to SSD for review?	X		2/7/19
5. Did SSD forward copies of proposals dealing with WSR-88D data to Radar Operations Center (ROC), Applications Branch Chief for review?		n/a	
6. Did SSD forward copies of proposals dealing with hydrometeorology to the Senior Scientist of OHD for review?		n/a	
7. Did SSD review the data request for project to ensure its scope and criticality for proposal?	X		
8. Is all data for the project being ordered by NWS offices through the National Climatic Data Center's (NCDC) Research Customer Service Group free of charge?	X		
9. Does budget include publication charges and travel costs for NWS employees to present results at scientific conferences?	X		
10.Does budget separate NWS costs into fiscal year costs and university costs into calendar year costs?			
11.Does proposal include a separate justification for university hardware purchases which are usually not funded by the COMET Outreach Program?		n/a	
12. Have the following people signed off on the proposal cover sheet: - MIC/HIC? - SSD Chief? - Regional Director?	X		
13. Is a letter of endorsement signed by regional director attached?	X		

NWS Checklist for Submitting a COMET Outreach Proposal

Actions after Endorsement by NWS	YES	NO	DATE
1. University submits proposal to the COMET Program.	X		
2. Proposal acknowledgment letter sent by the COMET Program to submitting university with copies to SSDs and NWS office.			
3. COMET review of proposal (internal review for Partners Project proposals and formal review for Cooperative Project proposals).			
4. The COMET Program sends acceptance, rejection, or modification letters to university with copies to SSD, NWS office, and OST12.			
5. The COMET Program allocates funds for university.			
6. OST12 obligates funds for NWS offices.			
7. SSD/NWS office orders data from NCDC.			
8. NWS office or SSD calls OST12 for accounting code for expenses.			
9. NWS office sends copies of all travel vouchers and expense records to OST12.			
10. NWS office or SSD sends copies of publication page charge forms to OST12.			
11. NWS office keeps SSD informed of progress on the project and any results or benefits derived from the project.			

COLLEGES AND UNIVERSITIES RATE AGREEMENT

EIN: 16-0743040

ORGANIZATION:
Hobart and William Smith Colleges
337 Pulteney Street
Geneva, NY 14456

DATE:01/20/2017

FILING REF.: The preceding agreement was dated 03/04/2014

The rates approved in this agreement are for use on grants, contracts and other agreements with the Federal Government, subject to the conditions in Section III.

SECTION I: Facilities And Administrative Cost Rates

RATE TYPES: FIXED FINAL PROV. (PROVISIONAL) PRED. (PREDETERMINED)

	EFFECTIVE PERIOD				
TYPE	**FROM**	**TO**	**RATE(%)**	**LOCATION**	**APPLICABLE TO**
PRED.	06/01/2017	05/31/2021	70.00	On-Campus	All Programs
PRED.	06/01/2017	05/31/2021	21.00	Off-Campus	All Programs
PROV.	06/01/2021	Until Amended	70.00	On-Campus	All Programs
PROV.	06/01/2021	Until Amended	21.00	Off-Campus	All Programs

*BASE

Direct salaries and wages excluding all fringe benefits.

SECTION II: SPECIAL REMARKS

TREATMENT OF FRINGE BENEFITS:

Fringe benefits applicable to direct salaries and wages are treated as direct costs.

TREATMENT OF PAID ABSENCES

Vacation, holiday, sick leave pay and other paid absences are included in salaries and wages and are claimed on grants, contracts and other agreements as part of the normal cost for salaries and wages. Separate claims are not made for the cost of these paid absences.

OFF-CAMPUS DEFINITION: For all activities performed in facilities not owned by the institution and to which rent is directly allocated to the project(s), the off-campus rate will apply. Actual costs will be apportioned between on-campus and off-campus components. Each portion will bear the appropriate rate.

Equipment means an article of nonexpendable, tangible personal property having a useful life of more than one year, and an acquisition cost of $5,000 or more per unit.

Your next proposal based on actual costs for the fiscal year ending 05/31/2020 is due in our office by 11/30/2020.

SECTION III: GENERAL

A. LIMITATIONS:

The rates in this Agreement are subject to any statutory or administrative limitations and apply to a given grant, contract or other agreement only to the extent that funds are available. Acceptance of the rates is subject to the following conditions: (1) Only costs incurred by the organization were included in its facilities and administrative cost pools as finally accepted: such costs are legal obligations of the organization and are allowable under the governing cost principles; (2) The same costs that have been treated as facilities and administrative costs are not claimed as direct costs; (3) Similar types of costs have been accorded consistent accounting treatment; and (4) The information provided by the organization which was used to establish the rates is not later found to be materially incomplete or inaccurate by the Federal Government. In such situations the rate(s) would be subject to renegotiation at the discretion of the Federal Government.

B. ACCOUNTING CHANGES:

This Agreement is based on the accounting system purported by the organization to be in effect during the Agreement period. Changes to the method of accounting for costs which affect the amount of reimbursement resulting from the use of this Agreement require prior approval of the authorized representative of the cognizant agency. Such changes include, but are not limited to, changes in the charging of a particular type of cost from facilities and administrative to direct. Failure to obtain approval may result in cost disallowances.

C. FIXED RATES:

If a fixed rate is in this Agreement, it is based on an estimate of the costs for the period covered by the rate. When the actual costs for this period are determined, an adjustment will be made to a rate of a future year(s) to compensate for the difference between the costs used to establish the fixed rate and actual costs.

D. USE BY OTHER FEDERAL AGENCIES:

The rates in this Agreement were approved in accordance with the authority in Title 2 of the Code of Federal Regulations, Part 200 (2 CFR 200), and should be applied to grants, contracts and other agreements covered by 2 CFR 200, subject to any limitations in A above. The organization may provide copies of the Agreement to other Federal Agencies to give them early notification of the Agreement.

E. OTHER:

If any Federal contract, grant or other agreement is reimbursing facilities and administrative costs by a means other than the approved rate(s) in this Agreement, the organization should (1) credit such costs to the affected programs, and (2) apply the approved rate(s) to the appropriate base to identify the proper amount of facilities and administrative costs allocable to these programs.

BY THE INSTITUTION:

Hobart and William Smith Colleges

(INSTITUTION)

Carolee White

(SIGNATURE)

Carolee E. White

(NAME)

VP for Finance

(TITLE)

Jan 20, 2017

(DATE)

ON BEHALF OF THE FEDERAL GOVERNMENT:

DEPARTMENT OF HEALTH AND HUMAN SERVICES

(AGENCY)

Darryl W. Mayes -A

Digitally signed by Darryl W. Mayes -A
DN: c=US, o=U.S. Government, ou=HHS, ou=PSC, ou=People, 0.9.2342.19200300.100.1.1=2000131669, cn=Darryl W. Mayes -A
Date: 2017.01.30 09:31:50 -05'00'

(SIGNATURE)

Darryl W. Mayes

(NAME)

Deputy Director, Cost Allocation Services

(TITLE)

1/20/2017

(DATE) 1207

HHS REPRESENTATIVE: Ryan McCarthy

Telephone: (212) 264-2069

Budget

	COMET Funds	NWS Contributions
	HWS	BGM
University Senior Personnel		
1. Dr. Nicholas Metz	0	NA
Other University Personnel		
1. Undergraduate Research Assistant (11 weeks total work; 8 summer, 3 academic year)	$5,575	NA
Fringe Benefits on University Personnel	$363	NA
Total Salaries + Fringe Benefits	$5938	NA
NWS Personnel		
1. Co-PI	NA	50 hrs (Klein)
2. NWSFO Forecasters	NA	50 hrs
3. Student Volunteers	NA	100 hrs
Travel		
1. Research Travel	$400	
2. Conference Travel	$4,000	$2,000
Total Travel	$4,400	
Other Direct Costs		
1. Materials & Supplies	$0	NA
2. Publication Costs (put in the NWS column if a co-author will be an NWS employee)	$0	$3,000
3. Other Data	$0	
4. NWS Computers & Related Hardware	NA	
5. Other (see budget justification)	$700	
Total Other Direct Costs	$700	
Indirect Costs		NA
1. Indirect Cost Rate	70%	
2. Applied to which items?	Total Salaries	
Total Indirect Costs	$3,903	NA
Total Costs (Direct + Indirect)	$14,941	$5,000

COMET Proposal BUDGET JUSTIFICATION

Personnel:

- ❖ Funds are requested for the equivalent of 10.5 weeks of student research on this grant to aid with research analyses and to provide a meaningful research experience for an undergraduate student. This student research time will occur during the summer of 2019 (8 weeks) and the fall semester of the 2019–2020 academic year (3 weeks). The student will be paid $525 dollars per week for the 8 weeks during the summer of 2019 ($4200 total) and $13.75 per hour for the 3 weeks of research time (100 hours over the semester) at HWS during the fall of 2019 ($1375 total).

- ❖ Fringe Benefits are calculated at a rate of 8.65% for summer student salary only. Academic year student salary is not eligible for fringe benefits.

Travel:

- ❖ Funds are requested to cover HWS travel costs associated with the presentation of research results by Dr. Metz and the HWS research assistant at a national conference (e.g., the AMS Annual Meeting, AMS Conference on Mesoscale Processes, the AMS Conference on Weather Analysis and Forecasting, the NWA Annual Meeting) and a local conference (e.g., NROW, the Northeastern Storm Conference) at an average cost of $2000 per participant. This estimate includes costs for travel, lodging, and conference registration for both conferences ($4000 total).

- ❖ Requested HWS travel funds will also be used to offset the costs for Dr. Metz and the research student to travel to the Binghamton NWSFO five times. These trips will take place once prior to the beginning of summer research in 2019, three times during the summer of 2019, and once during the fall of 2019 to share results of ongoing research with forecasters so this information can be directly integrated into the forecasting of lake-effect snow. Furthermore, these trips will allow Dr. Metz to receive forecaster feedback that helps to guide future grant-related research. ($400 total).

- ❖ **Funds are requested for the NWSFO to present the research results during at least one conference or workshop. These funds would support travel to either one national conference or two regional conferences (e.g., GLOWM, Northeast Storm Conference, NROW).**

Other Direct Costs:

- ❖ Funds are requested to cover housing costs on the HWS campus for one undergraduate student during the summer portion of the research (8 weeks at HWS). The housing costs are $87.50 per week.

- ❖ **Funds are requested for the NWSFO to cover publication costs of a scientific journal article.**

Indirect Costs / F&A

- Indirect costs for HWS are calculated using 70% of Total Salary and Wages.

COMET Partners Proposal:
Understanding the Interaction between Short-Wave Troughs and Lake-Effect Snow Events

Project Summary: This proposed research is a collaboration between the National Weather Service Forecast Office (NWSFO) at Binghamton and Hobart and William Smith Colleges (HWS). We propose to utilize multiple operational observational products, including GOES-16, along with numerical model analysis to improve forecaster understanding of the impacts of mesoscale upper-level short-wave troughs on lake-effect snow bands off of Lake Ontario.

Proposed Start Date: 15 April 2019; Project Duration: 1 year; Proposed Budget: $14,941

Project Overview:

Lake-effect snowstorms produce prolific snowfall on the shores of the Great Lakes and present a severe hazard to public safety, as they can be challenging events to forecast. These snowstorms are mesoscale convective precipitation events that typically develop downwind of warm water bodies, such as the Great Lakes. They affect a narrow area of land (sometimes only 10–20-km across) with heavy snowfall. The necessary conditions for these types of storms include a temperature decrease of 13°C from the water to 850 hPa, minimal wind shear throughout the unstable layer, an elevated inversion, low-level convergence, and a sufficient fetch over the lake (Niziol et al. 1995). The relatively warm lake waters create positive lapse rates through 850 hPa or higher allowing a conditionally unstable environment to develop in the lower troposphere (Niziol et al. 1995). This convective instability leads to convective bands that can produce significant, localized snow accumulation while having small liquid-water equivalents (Lackmann 2001).

Lake-effect snow is typically thought of as a lower-troposphere mesoscale feature, with less attention paid to upper-level features that may interact with the snow bands. During a typical cold season, numerous short-wave troughs pass through the Great Lakes region (Metz et al. 2019). These short waves tend to move in the same direction as the synoptic-scale flow, incorporating “air motion with dimensions of cyclonic scale, as distinguished from a long wave” (Glickmann 2000). While short-wave troughs reside in the middle and upper levels of the atmosphere, they have important consequences for weather at the surface. Differential cyclonic vorticity advection (CVA) found ahead of short-wave troughs provides forcing for ascent and can lead to atmospheric destabilization (e.g., Jiusto et al. 1970; Niziol et al. 1995; Holton and Hakim 2013). For example, the passage of a short-wave trough and its attendant CVA over a lake-effect snow system can cause the lake boundary layer to deepen as the inversion heights rise (Jiusto et al. 1970; Niziol et al. 1995). With an increase in the inversion height, instability often increases over the lake and lake-effect convection can intensify quickly, causing larger snowfall totals than initially expected (Niziol et al. 1995). While the impacts of these short-wave troughs on lake-effect snow events have only received limited attention in the literature (e.g., Metz et al. 2019), these features can potentially result in a substantial change in lake-effect snow band character. Figure 1a shows a lake-effect snow band off of Lake Ontario at 0300 UTC 7 January 2014. Only 3-h later, this snow band increased in intensity and inland extent, dropped southward and even took on cyclonic curvature (Fig. 1b). This change in band character occurred in advance of a sharp upper-level short-wave trough that began to cross Lake Ontario as the lake-effect band character changed substantially (Fig. 1c). It is clear from this example that the approach of an upper-level short-wave trough likely contributes to the change in band character in a short period of time and poses a potential forecast challenge.

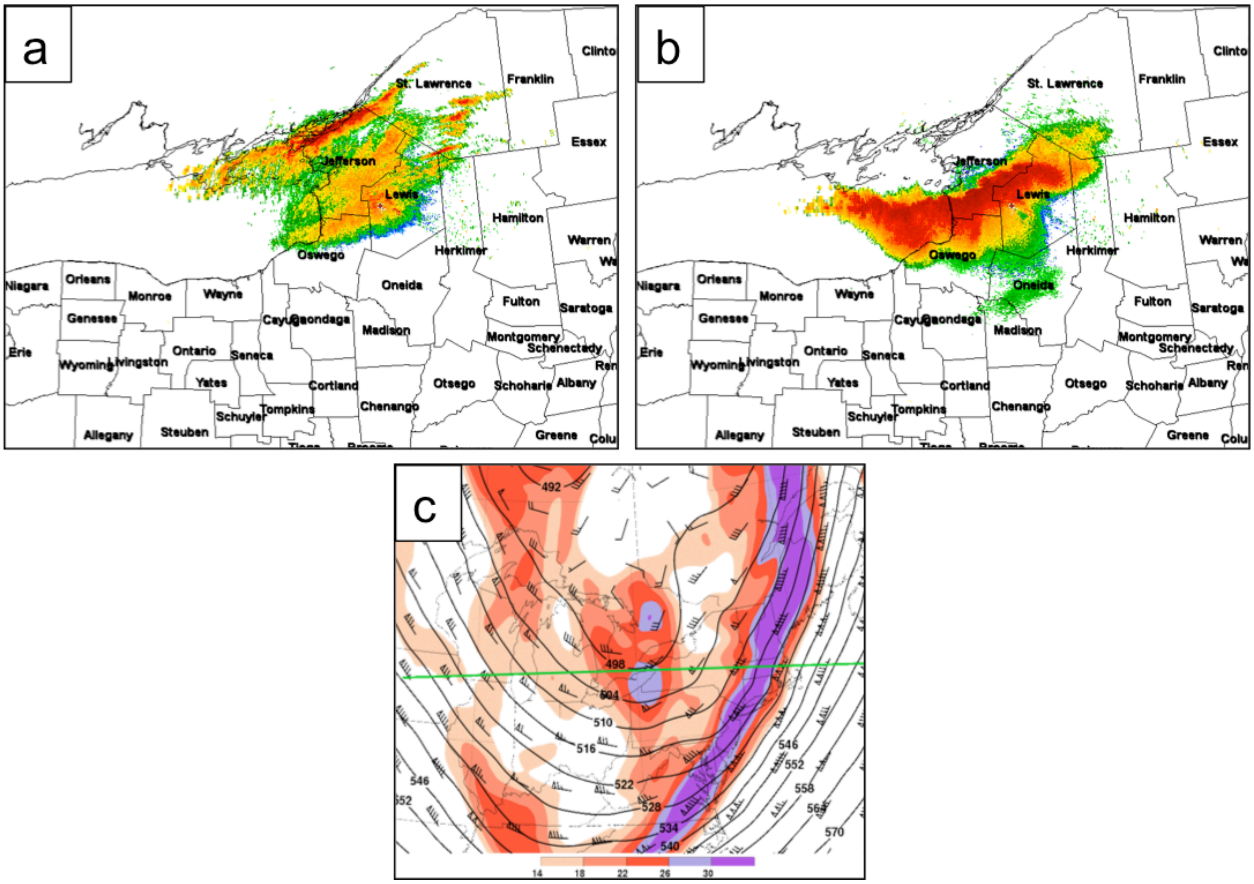

Figure 1. Radar reflectivity from Montague, NY in dBZ at (a) 0300 UTC 7 January 2014 and (b) 0600 UTC 7 January 2014 and (c) 500-hPa heights (black lines in dam), 500-hPa absolute vorticity (shaded according to color bar in ×10^{-5} s^{-1}), and 500-hPa wind (barbs in knots) for 0600 UTC 7 January 2014. The red shading in (a) and (b) indicates 35 dBZ reflectivity. The green line in (c) indicates the cross-section line for Fig. 3.

Metz et al. (2019) examined a seven-year climatology of cool-season short-wave troughs in the Great Lakes region and identified how often they crossed a Great Lake coincident with an ongoing lake-effect cloud band. This climatology revealed that 607 troughs moved through the Great Lakes region over these cold seasons, almost one every other day. Of these 607 short-wave troughs, 380 of them passed over a Great Lake concurrent with an ongoing lake-effect band. In particular, 275 of these troughs crossed Lake Ontario as an ongoing lake-effect band was present. While this study examined the frequency of these type of concurrent events, it did not investigate the changes in band character as each short-wave trough passed overhead.

Our primary goal with this proposed research is to investigate the ability of archived meteorological data, including GOES-16, to improve forecasts of lake-effect snow bands that occur as an upper-level short-wave trough passes overhead. Satellite imagery, and particularly water-vapor imagery, is often utilized by operational forecasters to identify the location and progression of short-wave troughs. Specifically, we will focus on bands off of Lake Ontario as these events have the greatest impact on the NWSFO at Binghamton. These forecasters are tasked with providing forecasts that lessen the impact of winter storms on the population of central New York. In that regard, they produce forecasts of lake-effect snow that are highly detailed in location, timing, and intensity. Forecasters have long understood that the passage of short-wave troughs over the Great Lakes can have significant impacts on the evolution of lake-effect snow. However anticipating the precise impacts of these short-wave troughs on lake-effect snow location, timing, and intensity continues to be a challenge. Experience indicates that passage of these troughs almost always leads to some kind of change in lake-effect snow morphology. However several different evolutions have been observed, making highly accurate predictions difficult. For example, sometimes the passage of a short wave results in a weakening of pre-existing snow bands, while at other times bands appear to strengthen. Sometimes bands will undergo a shift in location or orientation with the passage of a short wave, while at other times these changes fail to occur. The effects of short-wave troughs on lake-effect snow appear to be related to environmental factors such as flow direction, moisture, stability, and short-wave trough character, however no rigorous work has been done to confirm this hypothesis. Based on these observations, it appears that classifying short-wave troughs based on the environment in which they are embedded, and relating that environment to how troughs impact lake-effect snow bands, may be a promising avenue for increased understanding of these systems, which will ultimately lead to better forecasts. The introduction of high resolution modeling to operational forecasting during the past few years also appears to have promise for improved forecasts. However the utility of these model forecasts during scenarios involving short-wave trough passages has not been closely examined. The results from this project should benefit the forecasters at the NWSFO at Binghamton along with other NWSFOs in the Great Lakes region.

Project Objectives: We propose two primary research objectives in order to understand how short-wave troughs impact lake-effect snow bands off of Lake Ontario. The first objective involves utilizing a climatology of short-wave troughs in the Great Lakes region, while our second objective involves examining operational GOES-16 imagery in an attempt to document short-wave trough impacts on lake-effect snow bands for recent winters and the winter of 2019-2020 in real time. Both objectives aim to improve analysis and forecasting of lake-effect snow band morphology.

1. Climatological and Case-Study Analysis of Short-Wave Trough Impacts on Lake Ontario Lake-Effect Snow Bands: This proposed research will address questions such as: *What types of interactions occur between short-wave troughs and lake-effect snow bands? How do these interactions change based on the character of the short-wave trough (i.e., trough depth, sharpness, direction of motion, location relative to Lake Ontario)? How do the short-wave troughs impact the near-lake environment? How predictable are the interactions between short-wave troughs and lake-effect snow bands?* This proposed research aims to improve the forecasts of lake effect snow bands during periods when short-wave troughs cross the Great Lakes region. Our proposed climatological analysis will cover a 7-winter period (2007/08–2013/14) and will focus on short-wave troughs that move in the vicinity of Lake Ontario on days when a lake-effect band is also present (e.g., Metz et al. 2019).

A recently created 7-cold season climatology of short-wave troughs in the Great Lakes region will serve as the starting point for this research objective (Metz et al. 2019). During this seven-winter period, a total of 607 short-wave troughs were found to occur in the Great Lakes region. These troughs were counted for the database if they were present for six consecutive hours within the Great Lakes region and had: (1) visible curvature in the 500-hPa wind and height fields, (2) a 500-hPa vorticity maximum of at least 18×10^{-5} s^{-1} within the curvature, and (3) a curvature width of less than 1500 km (in line with short-wave trough size definition in Tuttle and Davis 2013). After reviewing data from several years, short-wave troughs were binned into five categories based primarily on the direction of movement. These five classes were Type W: movement from the west (between 247.5°–292.5°) Type NW: movement from the northwest (between 292.5°–337.5°), Type SW: movement from the southwest between (202.5°–247.5°), Type LWT: movement rounding the base of a long-wave trough (typically changing motion direction throughout lifecycle), and Type COL: cut-off lows. While cutoff lows are not typically classified as short-wave troughs, some of these lows met the classification criteria and thus received their own category. A typical year in the climatology featured anywhere between ~80 and 120 short-wave troughs passing through the Great Lakes region (Fig. 2). Further, Metz et al. (2019) identified 275 of these short-wave troughs that crossed Lake Ontario simultaneous to an ongoing lake-effect cloud band. A first step will be to extend this climatology to include the most recent cold seasons as well.

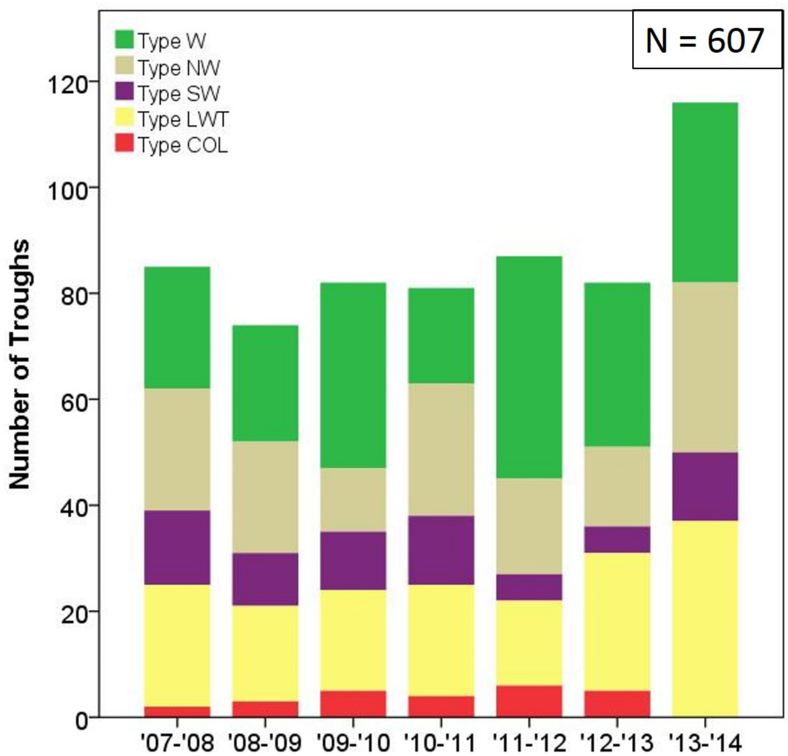

Figure 2. The total number of cold season short-wave troughs during each year stacked by type.

We plan to utilize archived model grids, GOES satellite imagery, WSR-88D radar, soundings, surface and snowfall observations, and other archived data to examine the environmental conditions associated with each of these lake-effect events and the manner with which each short-wave trough altered the near-lake environment and the snow band itself. We hope to further classify these short-wave troughs based on the environment in which they are embedded (e.g., stability, moisture, short-wave trough character). For example, experience at the NWSFO at Binghamton suggests that the depth of the short-wave trough may have a direct impact on the change in character of a lake-effect snow band. One potential way to determine this depth is to examine cross-sections of potential vorticity as shown in Figure 3.

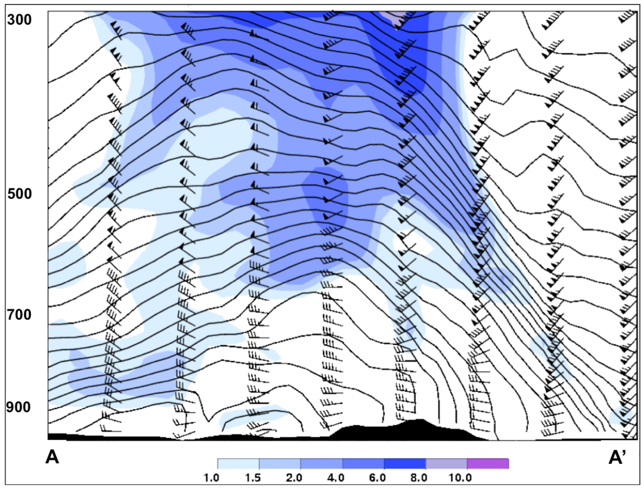

Figure 3. Cross section of potential vorticity (shaded according to the color bar in PVU), potential temperature (black lines in K), and winds barbs (in knots) through the short-wave trough shown in Figure 1c.

In this example the 2 PVU surface (e.g., Lackmann and Bosart 1995) from the 0600 UTC 7 January 2014 short-wave trough (Fig. 1c), extends downward to almost 650 hPa (Fig. 3). The 2 PVU surface is often considered the dynamic tropopause and as such is a good level to examine to determine the depth of short-wave troughs. In a similar fashion, other environmental conditions such as the low-level moisture and stability over and downstream of Lake Ontario will also be cataloged for each lake-effect snow event, while the morphology changes of each band will also be recorded (e.g., intensity, inland extent, organization type).

Forecasters and a student intern at the NWSFO at Binghamton will examine representative archived case studies and utilize a variety of mesoscale model data to further investigate these interactions. These forecasters typically begin examination of modeling in the lake-effect snow forecasting process by looking at a combination of low-resolution (12–13 km) operational models such as the NAM, GFS, and RAP. These models provide a general idea on the environment in which the lake-effect snow will be embedded, including whether any significant short waves will be moving across the area. Based on the expected environment, forecasters can use pattern recognition to develop expectations for an upcoming event. These expectations can then be refined by using higher-resolution models. Examples of higher resolution models at their disposal include the HRRR model, the 3-km NAM CONUS nest, NCEP generated WRF high-resolution window runs, High-resolution Ensemble Forecasts (HREF), and a locally produced 4-km WRF run. These models are compared with expectations from pattern recognition and the lower-resolution runs to produce a final forecast. One goal of this model examination will be to determine the precise impacts of each short-wave trough on the near-lake environment and band character and how well each model did at forecasting these interactions. For example, figure 4 shows a sounding comparison during the 7 January 2014 lake-effect snow event (Figs. 1a,b).

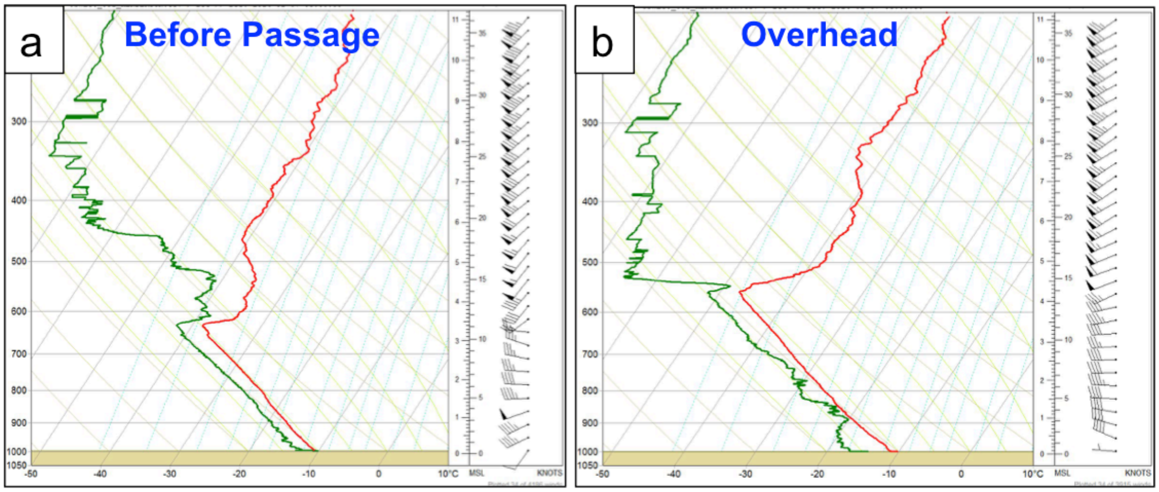

Figure 4. Soundings taken immediately to the east of Lake Ontario at (a) 0500 UTC 7 January 2014 and (b) 0800 UTC 7 January 2014.

This event occurred during the Ontario Winter Lake-effect Systems (OWLeS) Field Project (Kristovich et al. 2017) so there were high temporal resolution research soundings during the event. This sounding comparison shows that at 0500 UTC 7 January 2014, when the shortwave-trough was just to the west of the eastern Lake Ontario shoreline, the environmental inversion was around 625 hPa (Fig. 4a). Just 3-h later as the trough moved overhead, the inversion height raised to ~550 hPa (Fig. 4b) consistent with the band strengthening (Figs. 1a,b). The model data may provide important information at a high temporal resolution about environmental changes such as those shown in figure 4 and how these environmental changes related to changes in lake-effect band morphology.

2. Examination of GOES 16 Products: This proposed research will aim to address the following questions. *How useful is GOES-16 for forecasting lake-effect snow? How well does GOES-16 detect short-wave troughs? Can GOES-16 be used to predict lake-effect band morphology changes as short-wave troughs approach Lake Ontario? Can the results from research objective 1 be used to inform best practices when utilizing GOES-16 imagery?* Forecasters at the NWSFO at Binghamton already examine operational satellite data while forecasting lake-effect snow events. For this project, forecasters would pay particular attention to the utility of this imagery in identifying short-wave troughs and examining their interaction with lake-effect snow events. A goal of this objective is to increase forecaster awareness of new GOES-16 products for lake-effect snow forecasting, particularly when short-wave troughs are near Lake Ontario.

For this research, we plan to examine water-vapor imagery, along with visible and infrared imagery for a variety of lake-effect snow cases that occurred during recent winters and use this to inform a real-time examination of events during the winter of 2019–2020. The combination of all three water vapor channels on GOES-16 will provide insight on the vertical structure of short-wave troughs with each lake-effect snow event. High temporal and spatial resolution satellite data will likely be helpful in diagnosing the stability and moisture associated with each short-wave trough by looking at the development of clouds and snow showers upstream from good radar coverage areas over Lake Huron and central Lake Ontario. Further, this data will be useful in identifying shifts in snow-band orientation upstream from Lake Ontario, possibility portending future snow band changes over Lake Ontario. Finally, satellite data will help identify changes in the inland extent of bands, given radar-data coverage issues for lake-effect snow, which tends to be a relatively shallow phenomenon. Since the final few years examined in research objective one will overlap with years when the GOES-16 was in service, these results can be combined with lessons learned from GOES-16 imagery to better inform forecasters when lake-effect events occur.

Project Tasks:

1. HWS 2019 Undergraduate Summer Research Program: These COMET funds will provide an opportunity for an undergraduate student to be hired to work as a part of the HWS 2019 summer research program. This program is an eight-week research experience where the student will work as a part of a larger group of students conducting research with Dr. Metz and Dr. Neil Laird. This student will utilize the already compiled climatology of short-wave troughs to document how the lake-effect band morphology and the near-lake environment changes as troughs of differing character approach and subsequently depart the Lake Ontario region. Dr. Metz had the opportunity to participate in undergraduate research and has made every effort to include undergraduate students in his research since he was hired at HWS in 2011. Over the past eight summers, Dr. Metz has worked with ~40 undergraduate students on various projects. All past research projects undertaken by Dr. Metz and his research students have contributed to furthering grant-funded research and this work has been presented at numerous regional and national conferences including the AMS Conference on Mesoscale Processes, the AMS Conference on Weather and Forecasting, the AMS Student Conference, the AMS Conference on Climate Variability, and the Northeastern Storm Conference. Furthermore, much of this work has contributed to publications that have appeared in *Monthly Weather Review, Weather and Forecasting, The International Journal of Climatology, and The Journal of Applied Meteorology and Climatology.* This particular student research participant is in a unique situation because the student will be able to travel to NWSFO Binghamton multiple times during the summer to work directly with forecasters. This arrangement will allow for rapid and repeated sharing of results between Dr. Metz, the student, and the NWSFO at Binghamton and allow for COMET project research to be more closely conducted with forecasters at the NWSFO at Binghamton.

2. NWSFO Binghamton 2019-20 Winter Weather Workshop: The NWSFO Office in Binghamton hosts a winter weather workshop at their office during each November. Dr. Metz will visit NWSFO Binghamton during this workshop and provide an overview of the research project to all forecasters at the office. By November, a good portion of the research will have been completed. This meeting will allow for immediate incorporation of relevant research products into the forecasting process at the NWSFO at Binghamton.

3. NWSFO Forecaster Participation: During the winter of 2019-20, forecasters at NWSFO Binghamton will be asked to complete a short questionnaire each time they are faced with a case of an interaction between a short-wave trough and a lake-effect snow event. These questionnaires will act as a real-time assessment of the forecasting for these events. Examples of questions that will likely be included in these questionnaires include: *What operational products did you utilize in forecasting this lake-effect event? What insight did satellite imagery provide into the short-wave trough? In what ways was the satellite imagery helpful in understanding the changes in band character as the short-wave trough approached the Lake Ontario region?* These questionaries' will be collected and summarized throughout the winter season and used to further inform the research process.

Furthermore, the NWSFO at Binghamton forecasters will help identify particularly difficult to forecast events so that in-depth case studies can be examined to aid in the forecasting of real-time events.

4. HWS Students Researchers during 2019-20 School Year: Student research on this project will continue beyond the summer of 2019 to aid Dr. Metz and NWSFO forecasters in conducting in-depth case studies of data archived in real-time during the winter of 2019-20. One student will be hired as a student researcher under this COMET grant in the fall of 2019, while an additional student will work with Dr. Metz during the spring of 2020 for credit by registering for an Independent Study. These additional student workers will help place the lake-effect data and questionnaires collected during the winter of 2019-20 into the context of the climatological work created during the HWS summer research program in the summer of 2019.

5. NWSFO Summer Student Intern: During the summer of 2019, one of the NWSFO Binghamton Student Interns will aid NWSFO forecasters in identifying and cataloging difficult to forecast events. This student will help SOO Klein put together the in-depth case studies mentioned under number 3 above.

Project Schedule:

Time Period	Task
May 2019	Meeting of HWS and NWSFO personnel to discuss and plan for COMET proposal.
Summer/Fall 2019	Dr. Metz and HWS student collaborate to examine multiple year climatology of short-wave trough interactions with lake-effect snow events off of Lake Ontario to determine spectrum of changes to the environment and bands.
Summer/Fall 2019	NWSFO Binghamton personnel and student intern identify historical case studies of short-wave trough interactions and use satellite and other related datasets to understand how each event unfolds
November 2019	Attend the NSWFO Binghamton Winter Weather Workshop to discuss research results. Forecaster questionnaire for the 2019/2020 winter will be introduced and discussed.
Winter 2019/2020	NWSFO Binghamton forecasters will identify case studies in real time where short-wave troughs impact lake-effect snow bands off of Lake Ontario. For each case they will fill out questionnaire and archive GOES-16 satellite data and numerical forecasts. These cases will be explored in the context of the climatology and historical case studies by HWS students and Dr. Metz.
Fall 2019/ Winter 2020	Presentation of research results at Northeast Regional Operational Workshop, Great Lakes Operational Workshop, AMS Conference of Weather Analysis and Forecasting, Northeastern Storm Conference.
Spring 2020	Synthesize research results and prepare a scientific journal article describing important findings.

Expected Benefits:

- **Develop a further awareness of how GOES-16 products can benefit in the forecasting process of lake-effect snow events.**
- **Develop a more complete understanding of the impacts of short-wave trough passages on the character of lake-effect snow bands over a variety of atmospheric conditions.**
- **Further develop and expand collaboration between the NWSFO at Binghamton and HWS**
- **Train student researchers in the research process and the importance of transferring research results into the operational setting.**

References:

Glickman, T.S., *American Meteorlogical Society Glossary of Meteorology,* Allen Press, 2nd edition, 2000.

Holton, J. R., and G. J. Hakim, 2013: *An Introduction to Dynamic Meteorology.* 5th ed. Academic Press, 532pp.

Jiusto, J. E., D. A. Paine, and M. L. Kaplan, 1970: Great Lakes snowstorms. Part 2: Synoptic and climatological aspects. State University of New York at Albany Report ESSA E22-49-70, 58 pp.

Kristovich, D. A. R., R. D. Clark, J. Frame, B. Geerts, K. R. Knupp, K. A. Kosiba, N. D. Metz, J. Minder, T. D. Sikora, W. J. Steenburgh, S. M. Steiger, J. Wurman, and G. S. Young, 2017: The Ontario winter lake-effect systems (OWLeS) field campaign: Scientific and educational adventures to further our knowledge and prediction of lake-effect storms. *Bull. Amer. Meteor. Soc.,***98,** 315–332.

Lackmann, G. M., 2001: Analysis of a surprise western New York snowstorm. *Wea. Forecasting,* **16**, 99–116.

--------------, and L. F. Bosart, 1995: Postlandfall tropical cyclone reintensification in a weakly baroclinic environment: A case study of hurricane David (September 1979). *Mon. Wea. Rev.,* **123,** 3268–3291.

Laird, N. F., N. D. Metz, L. Gaudet, C. Grasmick, L. Higgins, C. Loeser, and D. A. Zeilinsky, 2017: Climatology of cold season lake-effect cloud bands for the North American Great Lakes. *Int J. Climatol.* **37,** 2111–2121.

Metz, N. D., Z. A. Bruick, P.K. Capute, E. W. Ott, M. M. Neureuter, and M. Sessa, 2019: An investigation of short-wave troughs in the Great Lakes region and their concurrence with lake-effect snow. *J. Appl. Meteor. Climatol.,* in press.

Niziol, T. A., W. R. Snyder, and J. S. Waldstreicher, 1995: Winter weather forecasting throughout the eastern United States. Part IV: Lake-effect snow. *Wea. Forecasting,* **10,** 61-77.

Tuttle, J. D., and C. A. Davis, 2013: Modulation of the Diurnal Cycle of Warm-Season Precipitation by Short-Wave Troughs*. J. Atmos*. Sci., **70**, 1710–1726.

Wagenmaker, R., J. F. Weaver, and B. Connell, 1997: A satellite and sounding perspective of a sixty-three inch lake-effect snow event. *Nat. Wea. Digest*, **21**, 30-42.

BIOGRAPHICAL SKETCH

Nicholas D. Metz

Department of Geoscience	Tel:	315-781-3615
Hobart & William Smith Colleges	Fax:	315-781-3860
Geneva, NY 14456	Email:	nmetz@hws.edu

a. Professional Preparation:

Valparaiso University	Meteorology	2004	B.S.
University at Albany	Atmospheric Sciences	2008	M.S.
University at Albany	Atmospheric Sciences	2011	Ph.D.

b. Appointments:

2017-present	*Associate Professor*, Department of Geoscience, Hobart and William Smith Colleges, Geneva, New York
2011-2017	*Assistant Professor*, Department of Geoscience, Hobart and William Smith Colleges, Geneva, New York
2010-2011	*Research Assistant,* Department of Atmospheric and Environmental Sciences, University at Albany, Albany, New York
2010	*Instructor,* Department of Atmospheric and Environmental Sciences, University at Albany, Albany, New York
2009-2010	*Teaching Assistant Instructor*, Department of Atmospheric and Environmental Sciences, University at Albany, Albany, New York
2007-2009	*Research Assistant,* Department of Atmospheric and Environmental Sciences, University at Albany, Albany, New York
2006	*Instructor,* Department of Atmospheric and Environmental Sciences, University at Albany, Albany, New York
2004-2007	*Teaching Assistant*, Department of Atmospheric and Environmental Sciences, University at Albany, Albany, New York
2003	*Research Experience for Undergraduates Research Assistant,* National Weather Center, National Severe Storm Laboratory and University at Oklahoma, Norman, OK
2002-2004	*Undergraduate Teaching Assistant,* Department of Meteorology, Valparaiso University, Valparaiso, IN

c. Recent Publications:

Metz, N. D., Z. A. Bruick, P.K. Capute, E. W. Ott, M. M. Neureuter, and M. Sessa, 2019: An investigation of short-wave troughs in the Great Lakes region and their concurrence with lake-effect snow. *J. Appl. Meteor. Climatol.,* in press.

Laird, N. F., N. D. Metz, L. Gaudet, C. Grasmick, L. Higgins, C. Loeser, and D. A. Zeilinsky, 2017: Climatology of cold season lake-effect cloud bands for the North American Great Lakes. *Int J. Climatol.* **37,** 2111–2121.

Crossett, C. C. and N. D. Metz, 2017: A climatological study of extreme cold surges along the African Highlands. *J. Appl. Meteor. Climatol.,* **56,** 1731–1738.

Cordeira, J. M., N. D. Metz**,** M. E. Howarth, and T. J. Galarneau Jr., 2017: Multiscale upstream and in-situ precursors to the elevated mixed layer and high-impact weather over the Midwest U.S. *Wea Forecasting,* **32,** 905–923.

Kristovich, D. A. R., R. D. Clark, J. Frame, B. Geerts, K. R. Knupp, K. A. Kosiba, N. D. Metz, J. Minder, T. D. Sikora, W. J. Steenburgh, S. M. Steiger, J. Wurman, and G. S. Young, 2017: The Ontario winter lake-effect systems (OWLeS) field campaign: Scientific and educational adventures to further our knowledge and prediction of lake-effect storms. *Bull. Amer. Meteor. Soc.,***98,** 315–332.

Bentley A. M. and N. D. Metz, 2016: Tropical transition of an unnamed, high-latitude, tropical cyclone over the eastern Pacific Ocean. *Mon. Wea. Rev.,* **144,** 713–736.

Metz N. D., H. M. Archambault, T. J. Galarneau Jr., A. F. Srock, and L. F. Bosart, 2013: A comparison of South American and African preferential pathways for extreme cold events. *Mon. Wea. Rev.,* **141,** 2066–2086.

Metz N. D. and L. F. Bosart, 2010: Derecho and MCS development, evolution, and multiscale interactions during 3–5 July 2003. *Mon. Wea. Rev.,* **138**, 3048–3070.

Metz N. D., D. M. Schultz, and R. H. Johns, 2004: Extratropical cyclones with multiple warm-front-like baroclinic zones and their relationship to severe convective storms. *Wea. Forecasting*., **19**, 907–926.

\

BIOGRAPHICAL SKETCH

Jared Klein
Science and Operations Officer
National Weather Service Forecast Office Binghamton, NY
E-mail: Jared.Klein@noaa.gov
Phone: (607) 770-9531 Ext.224

Professional Experience

Science and Operations Officer 2018–Present
Binghamton National Weather Service Forecast Office
Johnson City, New York

Senior Forecaster 2014–2018
Philadelphia National Weather Service Forecast Office
Mount Holly, New Jersey

Senior Forecaster 2013–2014
Washington D. C. National Weather Service Forecast Office
Sterling, Virginia

General Forecaster 2009–2013
Washington D. C. National Weather Service Forecast Office
Sterling, Virginia

Meteorologist Intern 2008
Washington D. C. National Weather Service Forecast Office
Sterling, Virginia

Jared has assisted or led office training and science programs during his NWS career. He has a strong interest in winter weather, gaining experience of forecasting complex, high-impact winter storms in the populated I-95 Mid- Atlantic region from Washington D.C. to Philadelphia. Serving as a winter weather subject matter expert for various local, regional and national projects, Jared has been a contributor in the development of the NWS Probabilistic Snowfall Experiment and NWS forecaster training for the NWS Advanced Warning Operations Winter Course. Jared has been engaged in research, training and program management associated with severe convective weather and heavy rainfall/flash flooding in the Mid Atlantic and Northeast U.S. He has also been involved in the Collaborative Science, Technology, and Applied Research (CSTAR) program as a collaborator/focal point for several research projects.

Education

M.S., Atmospheric Sciences, University at Albany, State University of New York, Albany, New York, 2007

B.S., Meteorology, Cook College-Rutgers, State University of New Jersey, New Brunswick, New Jersey, 2005.

Select Conference Presentations and Publications

Jurewicz, M.J., J.R. Klein, and D.A. Butts, 2018: Correlating trends in Flash Extent Density to tornadogenesis for supercells in northeast Pennsylvania. *19th Northeast Regional Operational Workshop*, Albany, New York.

Gaines, M.W., and J.R. Klein, 2017: Case study analysis of the July 24, 2017 high-impact flash flood event and EF-2 Tornado in Stevensville, Maryland. *18th Northeast Regional Operational Workshop*, Albany, New York.

Klein, J.R., 2016: The potential role of a sting jet during the 8 June 2016 severe thunderstorm event in the Mid- Atlantic region. *17th Northeast Regional Operational Workshop*, Albany, New York.

Zubrick, S., M.R. Kramar, J.R. Klein, and J.E. Lee, 2014: Characteristics of atypical damaging mesovortices in Quasi- Linear Convective Systems: science and warning challenges. *94th AMS Annual Meeting*, Atlanta, Georgia.

Showers, J., J.R. Klein, S.M. Zubrick and C. Strong, 2011: Climatology of tornadoes in the Baltimore-Washington area from 1950 to 2010. *36th Annual NWA Meeting*, Birmingham, Alabama.

Werner, N.D., S. Konarik and J.R. Klein, 2009: Analysis of flash flooding events in the Baltimore-Washington National Weather Service Forecast Office's county warning area. *34th Annual NWA Meeting*, Norfolk, Virginia.

Klein, J.R., 2007: Mesoscale precipitation structures accompanying landfalling and transitioning tropical cyclones over the Northeast United States. M.S. thesis, Dept. of Earth and Atmospheric Sciences, University at Albany, State University of New York, *139 pp*.