GOESR3 Final Report

Reporting Period: July 2017 – June 2020 (full 3-year period)

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Team Members: Heidinger/Wagner/Wanzong/Mateling/Bellon/Langlieb/Ritzman/Walter/Beachler

Project Title: An Enhanced Lake-Effect Snow Nowcasting Tool Using Synergistic GOES-R, NEXRAD, and Ground-Based Snowfall Microphysics Observations
Project Number: 408

Executive Summary

We have developed an enhanced Lake-Effect Snow (LES) nowcasting tool using products from the current GOES-16 observations for aiding in forecasts in the Marquette, Michigan region. This product is in development with National Weather Service (NWS) offices in the Great Lakes Region and aims to improve forecasts of LES events through cultivating better estimates of radar and satellite derived snow accumulations. We are working with the Marquette, Michigan (MQT) NWS Weather Forecasting Office (WFO) to assess LES events from the 2018-2019 and 2019-2020 winter seasons. We are also working with MQT WFO to test and implement the GOES-16 LES nowcasting tool during the 2020-2021 winter season and relay to us feedback on how the product performs as well as ways to improve the interface for aiding in forecasting.

Final Year Milestones (FY19) and Project Deliverables

We have completed the NEXRAD snow accumulation assessment of the LES events identified for the 2017-2018, 2018-2019, 2019-2020 winter seasons. We examined the relationship between the near-surface NEXRAD reflectivity and the Precipitation Imaging Package (PIP) derived snow rates and compared these for both synoptically-forced snow and LES events (see Fig. 1). We found that LES events have a distinct reflectivity (Z) to snow rate (S) relation versus those snow events not influenced by Lake Superior. This analysis aided in better constraints on LES event Z to S relations that were incorporated into the GOES-16 LES nowcasting product. We also assessed the variation of the PIP-derived snow density during lake-effect events, as the snow to liquid ratios (SLR) is highly variable. We plan to use these observations to recommend SLR ratios based on environmental conditions.

Additionally, we examined the GOES-16 derived cloud liquid water path (CLWP) during key LES events. As illustrated in Fig. 2, the spatial structure of the LES bands can be seen both in the GOES-16 CLWP and the NEXRAD reflectivity. This relationship was further developed and refined by examining key LES events from the 2017-2018, 2018-2019, and 2019-2020 winter seasons. We produced plots of CLWP and three available channels from GOES-16 for all winter precipitation events, which helped guide the joint GOES16 CLWP and NEXRAD snow rate analyses. These figures are also being automatically generated as GOES-16 data becomes available (every 5 minutes), and stored on local UW servers. The relationship between the GOES-16 CLWP and the NEXRAD/PIP adjusted snow rates (in liquid water equivalent – LWE) are shown as a two-dimensional histogram in Fig. 3. The fits to the composited data illustrate an exponential relationship between the CLWP and snow LWE rate. This fit was then applied to all available GOES-16 data for the past seasons.

Figure 4 illustrates an example of the GOES-16 LES nowcasting products for a LES event in January 2018. The top panel of Fig. 4 shows the GOES-16-derived LWE snow rate, while the bottom panel shows the geometric snow rate assuming a SLR of 10:1. These figures demonstrate the LES

nowcasting products that have been produced for past winter seasons and will be automatically created for the 2020-2021 winter season. We have constructed an automated system that receives the GOES-16 cloud products as they are produced in real time. The GOES-16 CLWP is then converted to GOES-16-derived snow LWE and geometric snow rates using the previously described empirical relationships. These figures (similar to those in Fig. 4) are generated and sent to a website hosted at UW/SSEC.

Discussion of operational transition readiness for any project outcomes

Dr. Pettersen and Ms. Mateling are working on the website with Mr. Bellon of SSEC. This website will go live on November 1, 2020 to deploy to the MQT NWS WFO the GOES-16-derived snow rate maps for the 2020-2021 winter season. The team is working with colleagues at the MQT NWS (Mr. Nick Langlieb, SOO, and Ms. Jacki Ritzman, Meteorologist) to refine a quality end-user product for the NWS MQT to implement. This product has GOES-derived LWE amounts (in mm hr-1), as well as several geometric accumulation rates (in hr-1) based on different SLRs (10:1, 20:1, 40:1). Drs. Pettersen and Kulie will continue to work with Mr. Langlieb and forecasters from the NWS MQT office to assess the lake-effect nowcasting tool for key LES events from past seasons. Drs. Pettersen, Kulie, and Wagner are preparing manuscripts related to the GOES-16 LES nowcasting performance and the Z to S NEXRAD assessment.

Additional Information

1. Interaction with operational partners –

- Drs. Pettersen and Kulie visited the NWS MQT WFO in September and November 2017 to preform instrument maintenance, data backups, and deploy several Pluvios and one Parsivel.
- Dr. Kulie visited the NWS Marquette, MI office in spring, 2018 to preform data backups, and undeploy several Pluvios.
- Drs. Pettersen, Kulie, and Ms. Mateling travelled to the NWS MQT WFO in October and November 2018 to work with their colleagues to both update and maintain the enhanced snow observation site at the office (MRR, PIP, Parsivel, Pluvio) and re-deploy a Pluvio network to quantify spatial variability of snowfall accumulation.
- Dr. Pettersen and Ms. Mateling travelled to the NWS MQT WFO in May 2019 to talk with the new SOO (Mr. Langlieb) and undeploy instruments for the summer season.
- Drs. Pettersen and Kulie and Ms. Mateling travelled to the NWS MQT office twice: Once to attend and present at the "Winter Weather Workshop" in October of 2019. And once in November of 2019 to work with their colleagues to both update and maintain the enhanced snow observation site at the office (MRR, PIP, Parsivel, Pluvio) and re-deploy a Pluvio network to quantify spatial variability of snowfall accumulation for a third season.
- Dr. Pettersen travelled to the NWS MQT WFO in January 2020 to check on winter deployments, calibrate and QC the PIP and MRR, and talk with the SOO and forecasters about the GOES-16 LES nowcasting tool.

2. Conference/workshop participation –

- Dr. Pettersen presented work at the AMS-Radars conference in Chicago, IL in August 2017 (Title: Enhancing our Understanding of Deep versus Shallow Snowfall Microphysics with Ground-Based Observations).
- Dr. Kulie presented work at the AMS Annual Meeting in Austin, TX in January 2018 (Title: Profiling Radar and Snow Microphysical Properties from Extended Ground Observations in the Upper Great Lakes)

- Dr. Pettersen gave an overview of the Marquette, MI enhanced LES snow instrumentation and project for the NOAA GLRCT monthly call in February 2018.
- Dr. Pettersen gave an overview of the Marquette, MI enhanced LES snow instrumentation and project for the NOAA GLRCT annual meeting in May 2018.
- Dr. Pettersen gave a presentation on the 4 winters of data from the enhanced observation suite at NWS MQT at the AMS Cloud Physics meeting in Vancouver, BC in July 2018. (Title: A Composite Analysis of Snowfall Modes from Four Winter Seasons in Marquette, Michigan)
- Dr. Pettersen was invited to give a presentation at the NWS MQT winter preparedness workshop in October 2018 (Title: Enhancing our Understanding of Snowfall Modes with Ground-Based Observations)
- Dr. Kulie presented PIP a snowfall regime-dependent particle size distribution analysis at the NASA Precipitation Measurement Missions Science Team Meeting in October 2018
- Ms. Mateling presented a poster at the analysis at the NASA Precipitation Measurement Missions Science Team Meeting in October 2018 on the variability of LES accumulation in the MQT region.
- The team presented work at the Marquette, Michigan NWS WFO "Winter Weather Workshop" in October 2019. Dr. Pettersen talked about the "Lake-Effect Nowcasting Tool" and on snow density variability as a function on snow type. Ms. Mateling showed her analysis on the spatial variation of snow accumulation in the Marquette region.
- Dr. Pettersen presented a poster at the 2019 American Geophysical Union Annual meeting titled "A composite Analysis of Snowfall Modes from Four Winter Seasons in Marquette, Michigan"
- Dr. Kulie presented a talk at the NSSL Satellite QPE Workshop in January 2020. On "GOES Product Development: Lake-Effect Snow Quantitative Precipitation Estimation (QPE)"

3. Outside project publicity –

- Local Marquette TV News coverage of Pluvio deployment (NASA-funded) in conjunction with the NOAA work at the Marquette, MI NWS office in February 2018
- The Lake-Effect Nowcasting Tool research and development was highlighted in the 2019 NOAA Science report (https://nrc.noaa.gov/Council-Products/NOAA-Science- Report – see page 14).
- The MQT snow JAMC manuscript was summarized and highlighted in a UW/SSEC News piece (https://www.ssec.wisc.edu/news/articles/12497/)

4. Journal articles –

- Pettersen, C., Kulie, M.S., Bliven, L.F, Merrelli, A.J., Petersen, W.A., Wagner, T.J., Wolff, D.B., and Wood, N.B.: A composite analysis of snowfall modes from four winter seasons in Marquette, Michigan, JAMC, 2020, doi: 10.1175/JAMC-D-19-0099.1.
- Pettersen, C., Bliven, L.F., von Lerber, A., Wood, N.B., Kulie, M.S., Mateling, M.E., Moisseev, D.N., Munchak, S.J., Petersen, W.A. and Wolff, D.B., 2020. The Precipitation Imaging Package: Assessment of Microphysical and Bulk Characteristics of Snow. Atmosphere, 11(8), p.785.
- Kulie, M.S., Pettersen, C., et al.: Upper Great Lakes Snowfall: Lessons Learned from a Multi-Sensor Snowfall Observatory, BAMS, *in review*
- Bliven, L., Pettersen, C., Kulie, M.S., et al.: The Precipitation Imaging Package: Precipitation Phase Discrimination. Atmosphere, *submitted*
- Kulie, M.S., Pettersen, C., Wagner, T.J., and Mateling, M.E.: Leveraging GOES-16 cloud properties towards improved characterization of lake-effect snow, JTech, *in preparation*
- Wagner, T.J., Kulie, M.S., and Pettersen, C.: Exploring relations of NEXRAD Z to S for different snow regimes using ground-based observations, JTech, *in preparation*

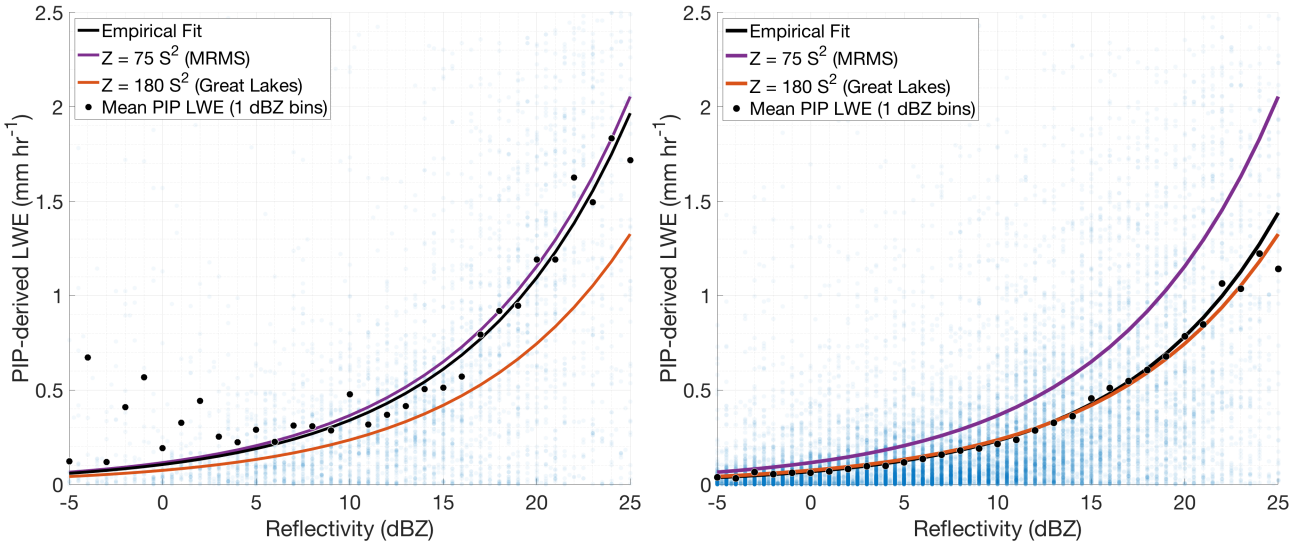

Figure 1: PIP-derived snow rates as a function of NEXRAD reflectivity for synoptically driven snow (80 independent events; left panel) and LES (230 independent events; right panel). An empirically determined Z to S relationship is shown in black, the MRMS in purple, and Great Lakes in orange.

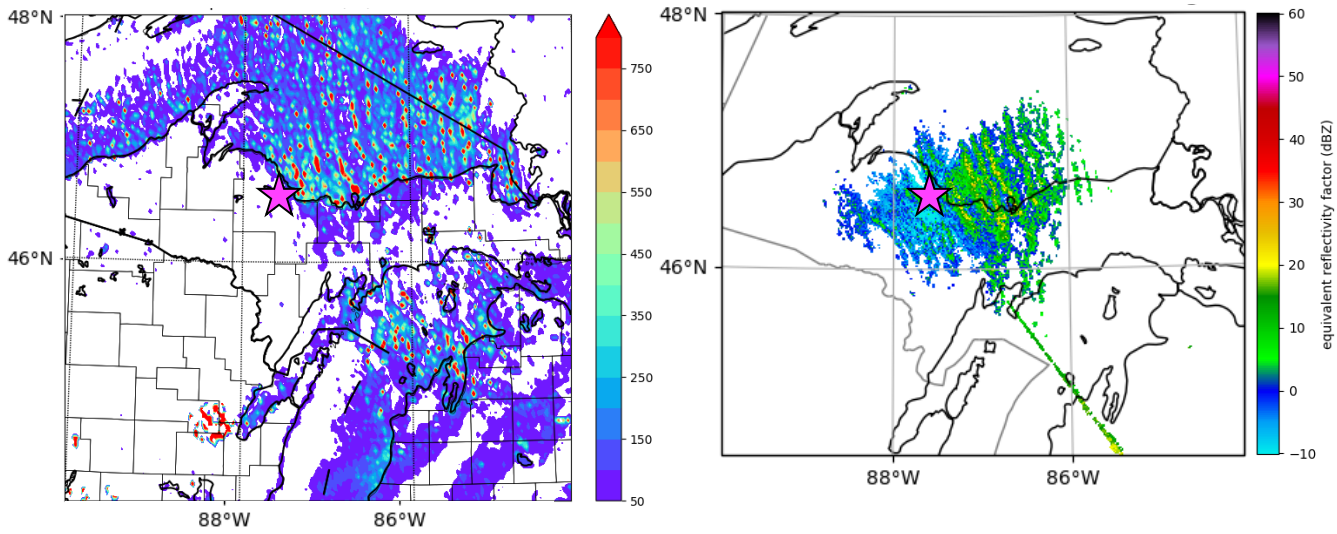

Figure 2: LeS event from 3 January 2018 with GOES-16 CLWP illustrated in the left panel and NEXRAD reflectivity shown in the right panel.

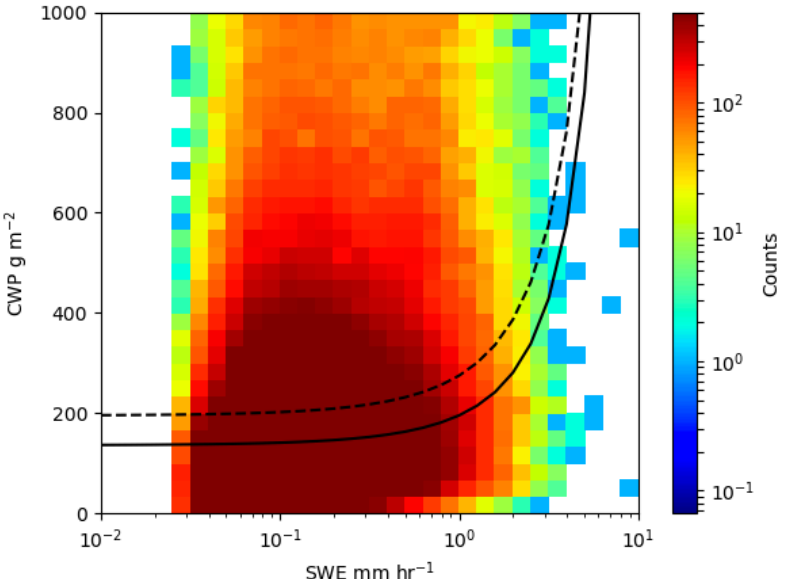

Figure 3: Two-dimensional histogram of GOES-16 derived CLWP and NEXRAD/PIP produced snow rates (LWE) for all the LES events over the 2018-2019 and 2019-2020 seasons. The solid black line is the fit using the median CLWP for each bin while the dashed black line used the mean CLWP. The median CLWP fit was used for the GOES-16 snow rate product.

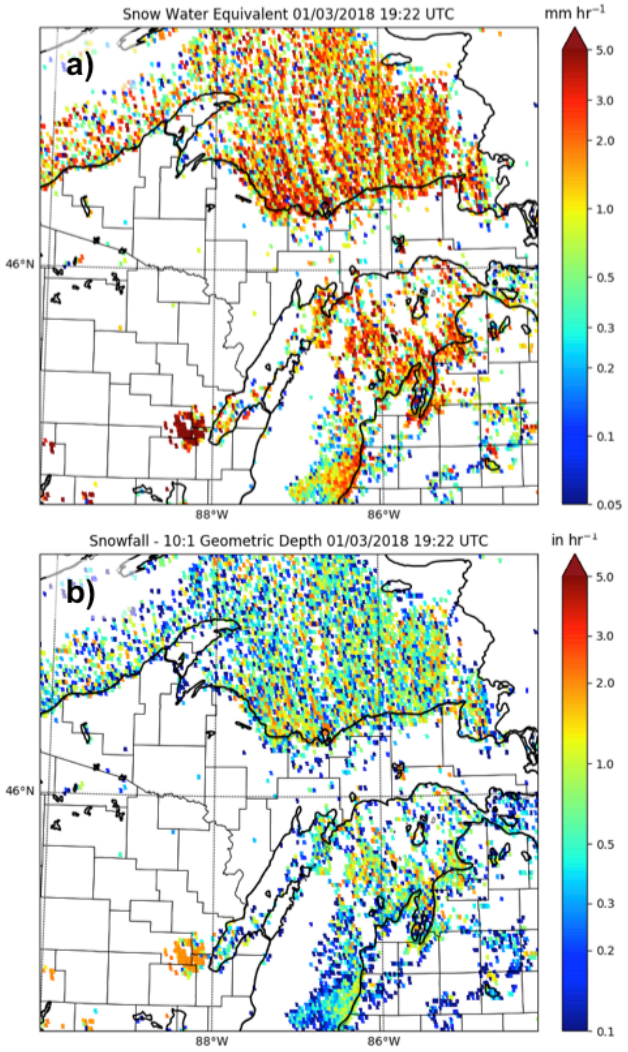

Figure 4: LES event from 3 January 2018 with GOES-16 derived: a) snow rate (LWE), b) 10:1 SLR