Forecasting Lake-Effect Snow in the Great Lakes Using NASA Satellite Data

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Introduction

- Lake-Effect Snow is common in the Great Lakes region during fall and winter
- Models are sensitive to initial conditions, particularly Great Lake Surface Temperatures (GLSTs) (Leins et al. 2010)
- The NASA Short-term Prediction Research and Transition (SPoRT) Center created a GLST composite that uses infrared estimates of GLSTs from the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on Terra and Aqua satellites, and other satellite data
- Current forecast models use the Real-Time Global Sea Surface Temperature (RTG SST) product, at a coarser resolution than the SPoRT GLST
- Sensitivities to Great Lake temperatures are explored for one lake-effect storm comparing model forecasts using RTG and GLST products

Lake-effect Storm Echinacea

- Favorable synoptic conditions (Niziol 1987) include (Figure 1a):
  - Large absolute temperature differences between lake surface and 850 hPa leading to instability forcing the development of precipitation
  - Wind orientation creates long fetch over Lake Erie and Lake Ontario
  - Minimal wind shear between the surface and 700 hPa winds facilitates organized snow bands, especially downwind of Lakes Erie and Ontario
- Areas downwind of Lake Erie and Ontario affected the most (Figure 1b)
  - These lakes will be the focus of analysis for this case study
  - Storm total snowfall ranged from 8-18 inches off of Lake Ontario and 10-12 inches off of Lake Erie

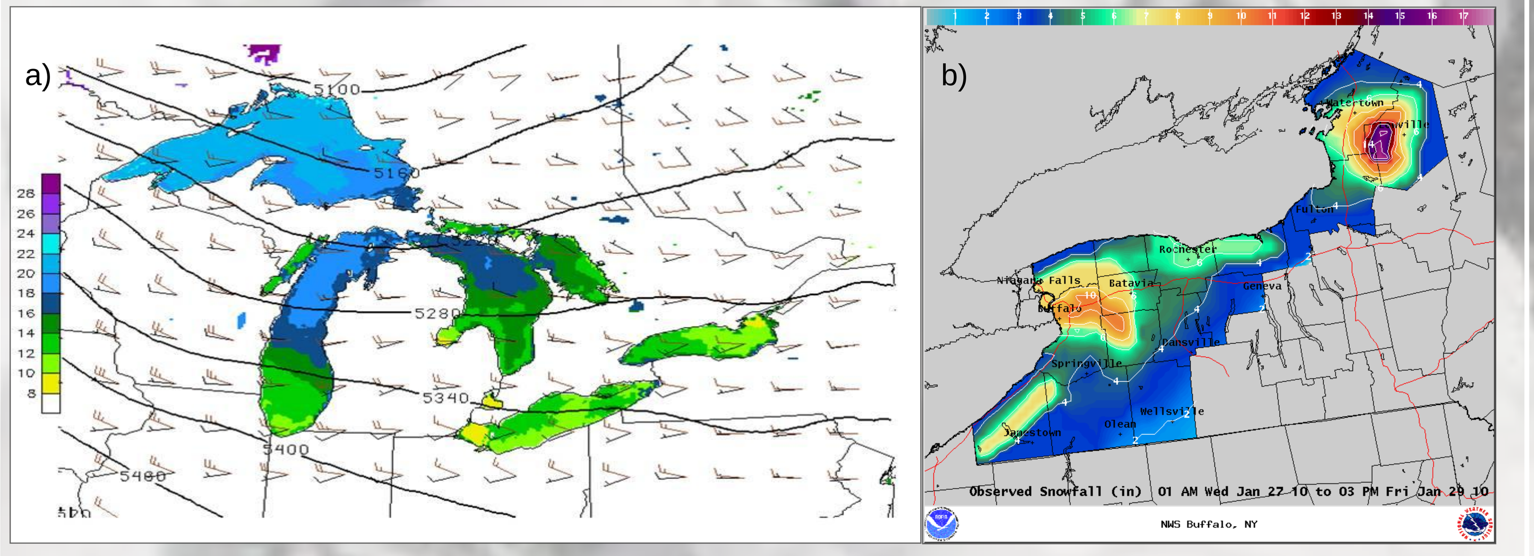

Figure 1: Lake-effect storm Echinacea formed on 27 January and dissipated on 29 January 2010
a) Synoptic conditions shown with 500 hPa heights (black contours), 10 m winds (black barbs), 700 hPa winds (brown barbs), and absolute temperature difference between lake surface and 850 hPa (color fill)
b) Storm total snowfall (inches). Graphic courtesy of National Weather Service in Buffalo, NY

Methodology

- Create two forecasts using the Weather Research and Forecasting model Environmental Modeling System (WRF-EMS) used by forecasters
- Create a control forecast using the RTG product, which is currently used in models, and an experimental forecast using the GLST product
- The same WRF-EMS configuration was used in the comparison of RTG and GLST forecasts (Table 1)

Table 1 – Model parameterizations used in case study

Parameter	Physics Package
Vertical Levels	45
Physics Schemes selected	No Cumulus Parameterization
Microphysics	New Thompson Graupel Scheme
Planetary Boundary Layer	Mellor-Yamada-Janjic-NAM operational scheme
Land Surface Physics	Noah Land Surface Model-Unified NCEP/NCAR/AFWA scheme
Long and Short Wave Radiation	Rapid radiative transfer scheme

- The NASA SPoRT GLST product is a composite of MODIS and other satellite observations with the Great Lakes Environmental Research (GLERL) ice mask
- Data processing described in Figure 2

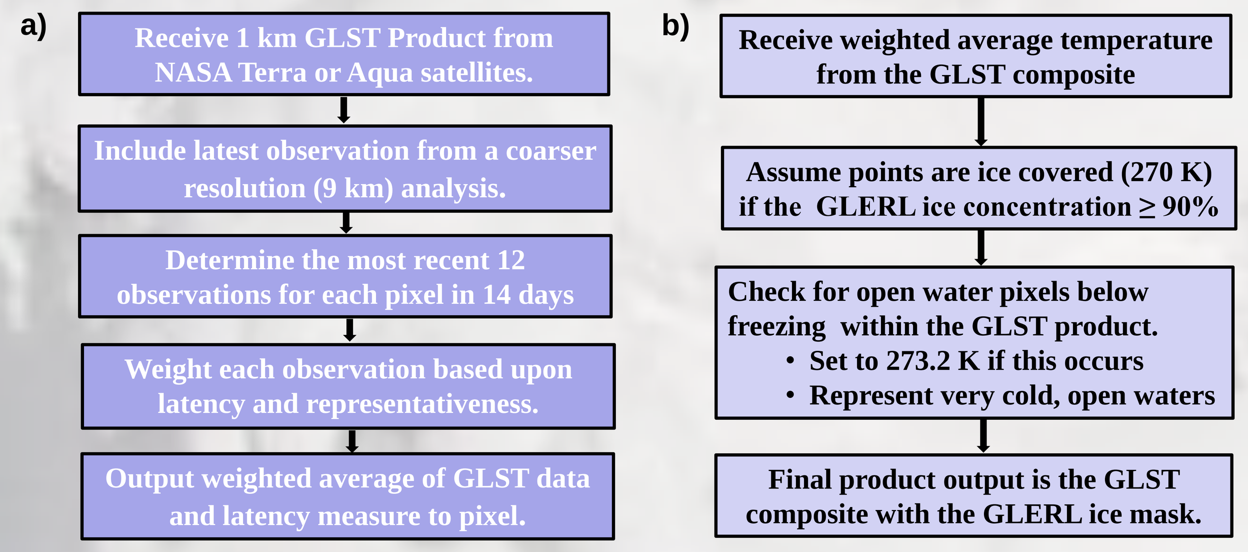

Figure 2a): Description of satellite data and how it is weighted. Data latency is a way to weigh the data and give newest data more weight **Figure 2b):** Description of how the ice mask is produced in the SPoRT GLST product

Model Initial Conditions

- NASA SPoRT GLST provides 1 km high-resolution data available 4 times a day
- Ice masks created using the NOAA GLERL data
  - Smaller ice mask in GLST product using GLERL data
  - RTG uses measurements of 273.15K (0°C) for ice (Figure 3a)
- Temperature for open water from RTG SST and NASA GLST with RTG ice mask were compared (Figure 3b)
  - The RTG ice mask was used in both to provide a comparison with equal points

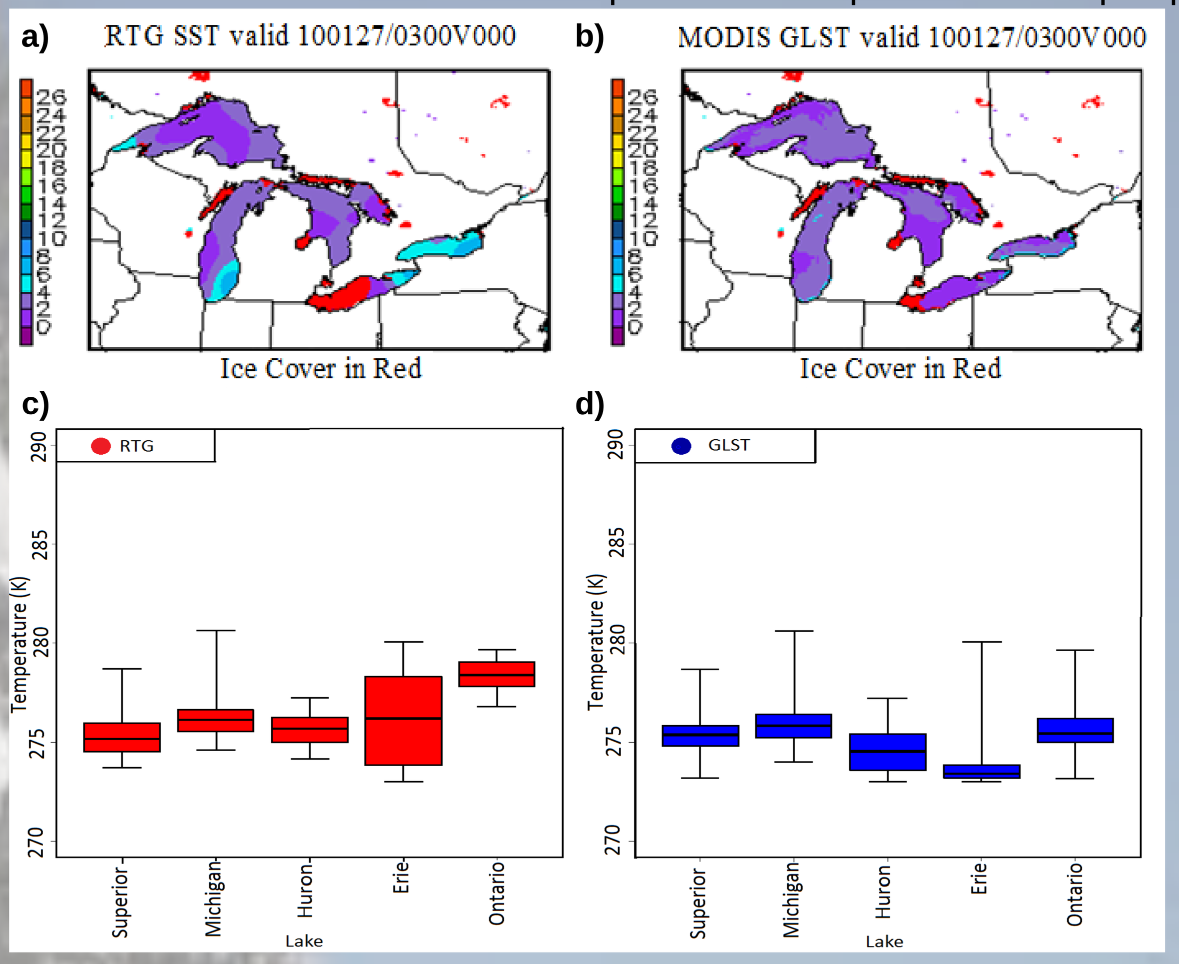

Figure 3: Comparison of the a) RTG SST and the b) SPoRT GLST temperatures and ice masks on 03 Z January 27, prior to lake-effect storm Echinacea c) box and whisker plot of lake surface temperatures using open water points from RTG SST d) as in c), but for the SPoRT GLST assuming equal water points

Differences in Latent Heat Fluxes

- Latent heat release can contribute to intensification of convective circulation, convergence and precipitation (Kristovich and Laird 2002)
  - Studies suggest changes are linear, and not affected much by local temperature spikes (Gerbush et al. 2007)
  - Latent heat fluxes generally decreased in GLST forecast (Figure 4)
  - Used Lake Ontario for heat flux comparisons because lake was ice-free in both model forecasts, allowing equal points for comparison

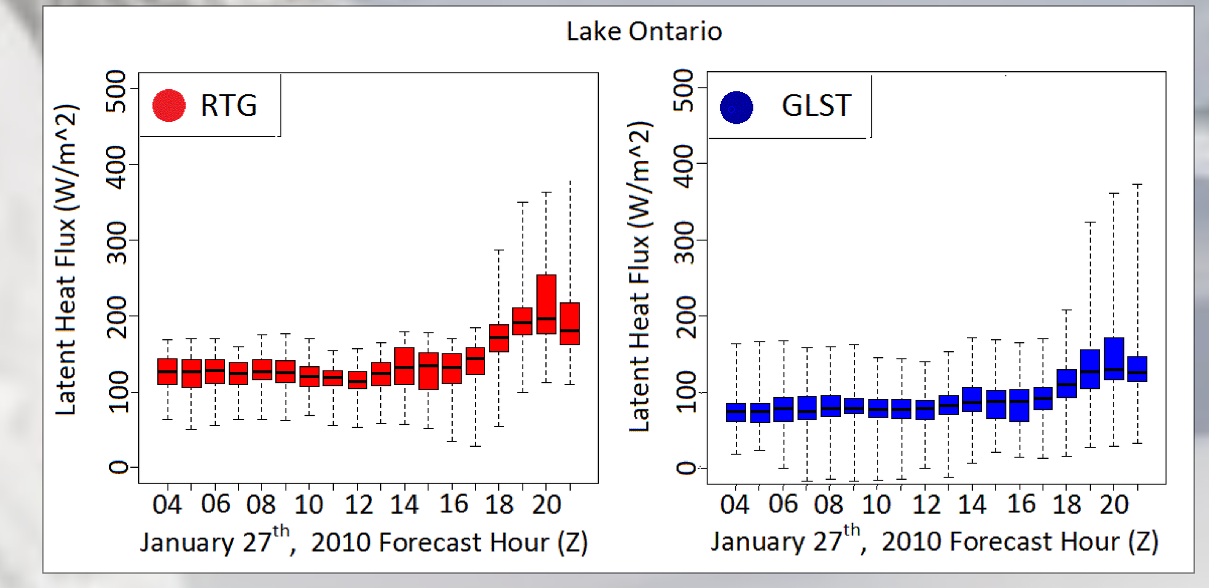

Figure 4: Latent Heat measurements using Lake Ontario open water points from RTG and GLST products Measurements taken from forecast hours 04 Z to 21 Z on January 27

Differences in Sensible Heat Fluxes

- Sensible heat can contribute to lake-land temperature differences, thermally driven circulations, convergence, and precipitation (Kristovich and Laird 2002)
  - Studies suggest changes are non-linear, leading to large changes in temperature spikes (Gerbush et al. 2007)
  - Sensible heat fluxes generally decreased in the GLST forecast (Figure 5)

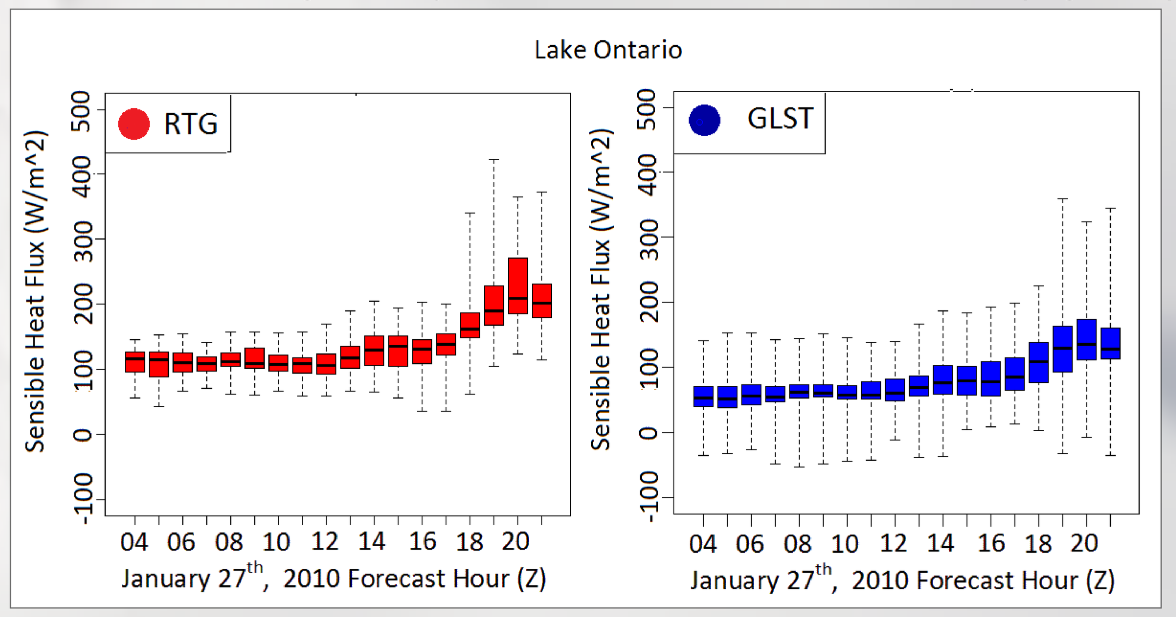

Figure 5: Sensible Heat measurements using Lake Ontario open water points from RTG and GLST products. Measurements taken from forecast hours 04 Z to 21 Z on January 27

Precipitation Forecast

- Storm total precipitation from the RTG and GLST forecasts were compared to NCEP Stage IV radar estimates and surface gauge reports
  - Stage IV is a good indicator of location of precipitation
- Both models predicted precipitation south of actual location shown by Stage IV
- GLST forecast produced lower precipitation amounts, but more coverage over Lake Erie

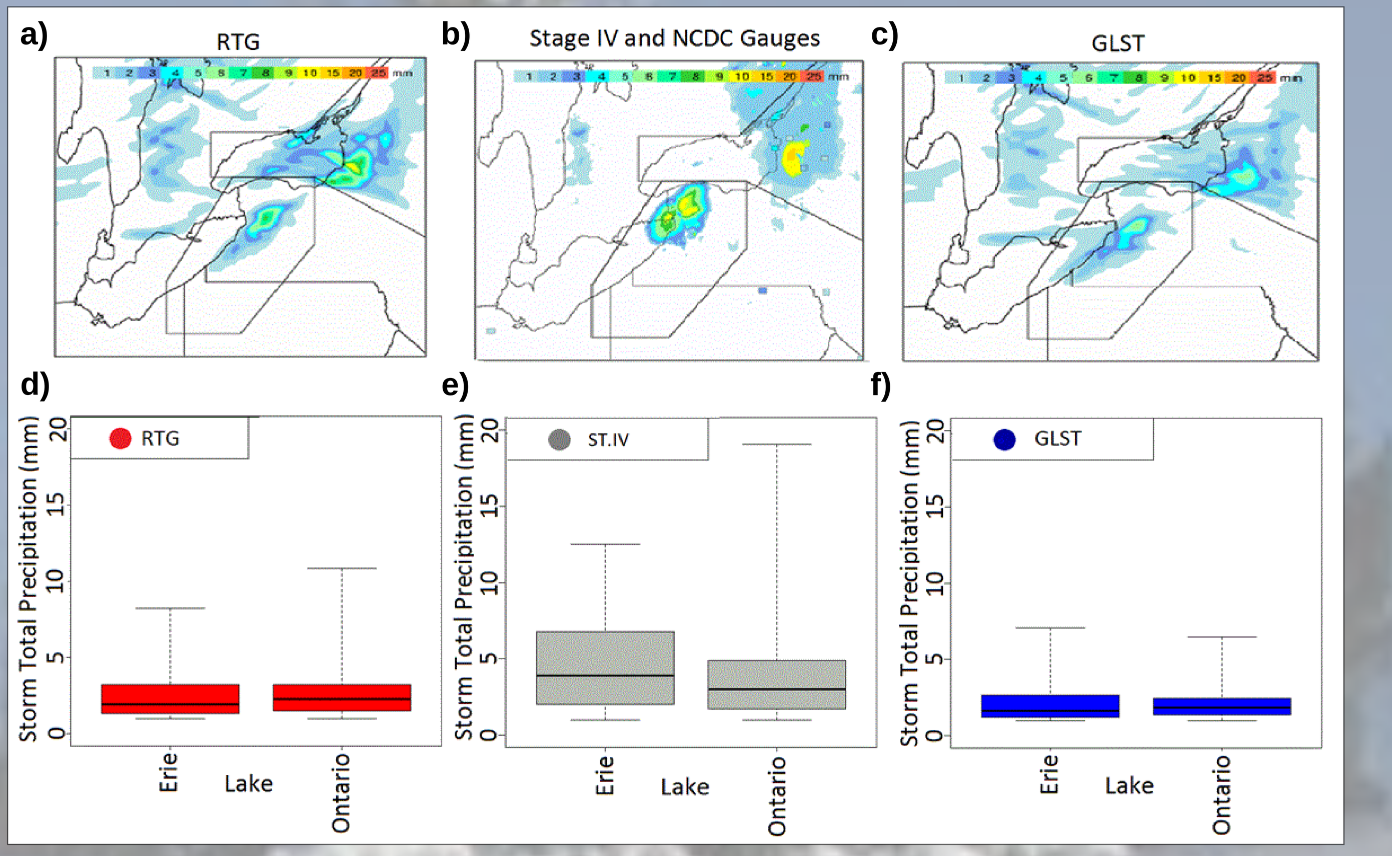

Figure 6: Comparison of predicted and observed precipitation a) Liquid equivalent precipitation (mm) accumulated through 21 Z on 27 January 2010 as predicted by the RTG forecast b) as in a) but based upon NCEP Stage IV analysis and gauge reports c) as in a) but for the GLST forecast d-f) box and whiskers plots of storm total precipitation for points within lake-effect precipitation boundaries shown in figure 6a

Conclusions

- The NASA SPoRT GLST product shows:
  - Significantly less ice cover over Lake Erie from the GLERL mask
  - Generally cooler temperatures for Lake Erie and Lake Ontario
  - Smaller latent and sensible heat fluxes over Lake Ontario
  - Storm total precipitation was generally decreased
- Over the Great Lakes comparison against Stage IV shows that RTG and GLST predicted the precipitation slightly south of where it occurred (Figure 6)
- This project provided more insight on model sensitivities to temperature and ice cover in forecasting precipitation

Future Work

- More case studies will be analyzed comparing the products
- Optimal Interpolation (OI) will also be developed in future case studies
  - OI is expected to provide a smoother gradient which will take into account points nearby, creating a product with more accurate forecasts
- The National Weather Service will explore how to use the product in local forecasts

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