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Sensitivity of Lake-Effect Snowfall to Lake Ice Cover in the Great Lakes Region

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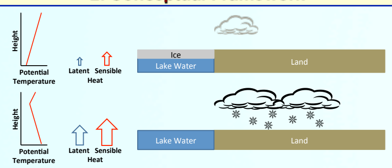
1. INTRODUCTION

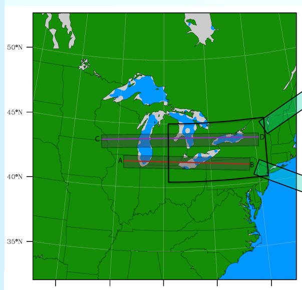
- Lake-effect snow in the Great Lakes region forms during cold air outbreaks, and is primarily caused by destabilization of the boundary layer as cold air is advected over relatively warm water
- Lake ice has been shown to significantly reduce latent and sensible heat fluxes from the lake surface, reducing convection and precipitation downwind of the lake (Gerbush et al. 2008)
- The overall occurrence of lake-effect snow in the Great Lakes increased over all lakes during the 1990's, consistent with lake surface temperature increases (Burnett et al. 2003)
- Studies have predicted an increase in lake surface temperature by 2.5 to 7 degrees Celsius by 2100 (Trumpickas et al. 2009)
- This study examines the impact of varying ice cover and lake surface temperatures on precipitation amounts and structure of lake-effect snow in the Great Lakes region, using a 2009 case study simulated with the Weather Research and Forecasting (WRF) model

2. Conceptual Framework



3. WRF MODEL AND TEST CASE SCENARIOS

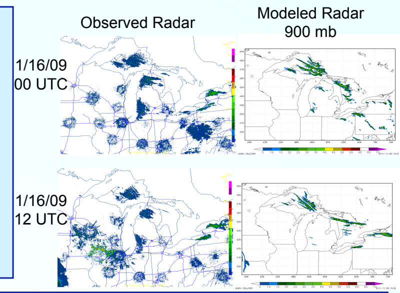
- 3km horizontal grid spacing with 35 vertical layers with 1km, 69 vertical layer nest over Lakes Erie and Ontario
- Initial and boundary conditions obtained from three-hourly North American Regional Reanalysis (NARR) dataset
- 60 hour run initialized at 1200 UTC 14 January 2009 ending at 0000 UTC 17 January 2009



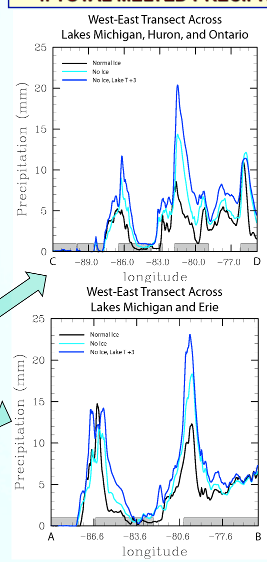
- Four simulations:
  - Control: Uses NARR-observed ice cover (gray shading) and lake temperatures
  - Complete Ice: Lake surface temperatures > 265 K (the average ice temperature in NARR) were set to 265 K to simulate complete ice coverage
  - No Ice: Lake surface temperatures < 273.15 K were set to 273.2 K
  - LST3K: Lakes were assumed to be ice free and temperatures were uniformly increased by 3 K

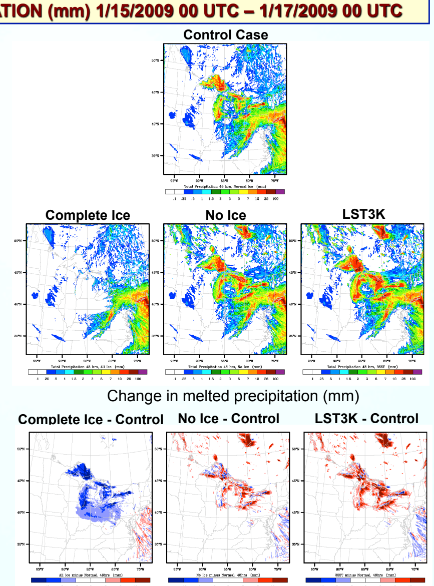
3. MODEL VALIDATION

- Model predicts the formation and relative radar intensity of lake-effect snow over the Great Lakes region
- Several shoreline bands are resolved downwind of Lakes Superior and Michigan, with a mid-lake band over Lake Ontario
- Small discrepancies exist in the placement of the bands due to minor errors in wind direction
- At 3km horizontal resolution, the model is not able to explicitly resolve fine scale shoreline lake-effect snow bands due to typical band width of 4-6 km (Liu et al. 2004).



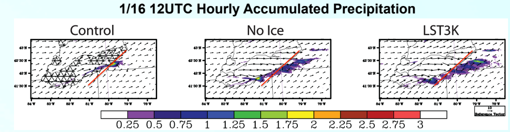
4. TOTAL MELTED PRECIPITATION (mm) 1/15/2009 00 UTC – 1/17/2009 00 UTC



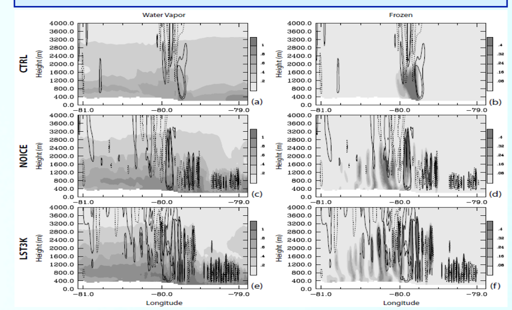


- Transition from the control to no ice case increases precipitation downwind of all of the Great Lakes, with the most significant increases downwind of Lake Ontario
- Transects show further inland propagation of snowfall with changes from control to no ice and LST3K cases
- Intensity of snowfall increase with changing lake properties

5. 1km RESOLUTION PRECIPATION AND MIXING RATIO



- Removal of ice leads to widespread development of shoreline bands
- Increases in lake surface temperature increases the intensity of the bands.



- Above transects are of water vapor and frozen mass (snow, ice, and graupel) mixing ratio (grey shading, g/kg) and vertical velocity (outlines) along red line in the above figure.
- As lake temperature increases, the cloud top height increases as the width decreases. Vertical velocity intensity shows minimal change.

6. CONCLUSIONS

- Reduction in ice coverage and increases in lake surface temperature increase precipitation amount and intensity
- Downwind propagation of lake-effect snow increases with changes in ice coverage and lake temperature for short over water fetches
- Changes in lake surface properties can narrow and deepen of each snow band with greater areal coverage of higher concentrations of water vapor.

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