Numerical Simulation and Radar Analysis of a Lake-Effect Snow Event: What Goes on in Yonder Clouds?

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Research Questions

- Based on dual-polarization radar data, is there evidence of significant cloud liquid water in an early season lake-effect snow band?
- Using the WRF modeling system, do common cloud microphysical schemes produce the observed liquid water, ice and snow?
- Do numerical simulations depend strongly on the cloud microphysical scheme? What role do boundary layer (BL) schemes play?
- In general, does the WRF simulate this early season case well?

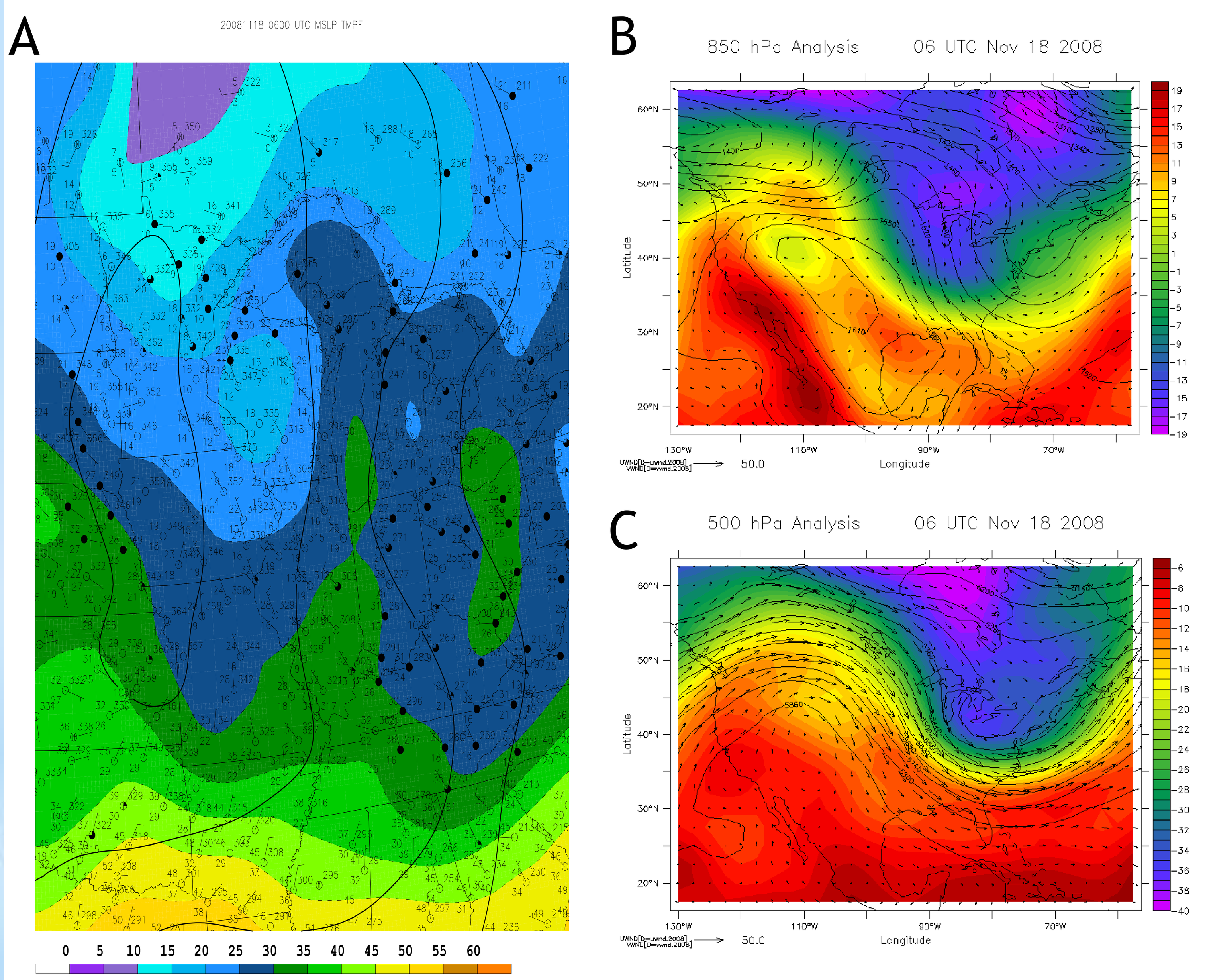

Fig. 1: (a) Surface, (b) 850 and (c) 500 hPa Analyses 00 UTC Nov 18 2008

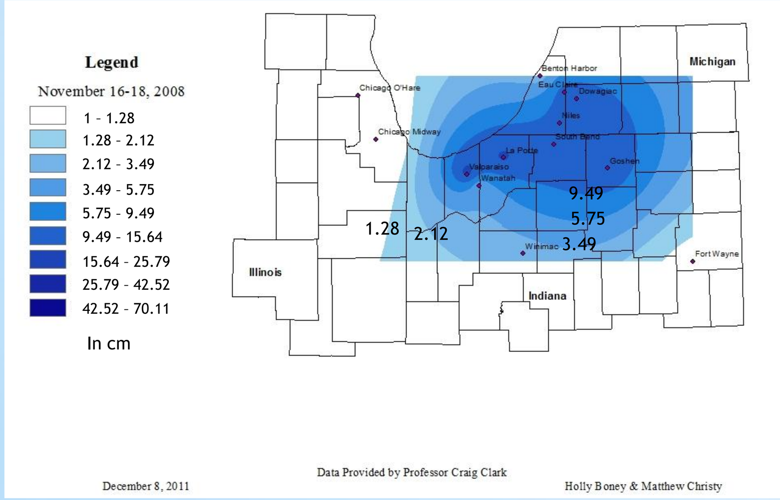

Fig. 2: Map of regional snowfall (cm) 16-18 Nov. 2008. The broad regional pattern occurs due to the combination of the earlier snow in southwest Michigan/north central Indiana and later snowfall in northwest Indiana.

WRF Settings

- Nested domain 12 km outer domain with 4 km inner domain
- GFS Initial/Boundary Conditions
- Microphysical Schemes
  - Lin, Ferrier, Goddard, Milbrandt, Morrison, NSSL2M, NSSL2MCCN, Thompson, SBUyLin, WSM5, WDM5, WDM6
- PBL Schemes
  - MYJ, MYNN2, YSU

The Test Case

- Event began with widespread wind-parallel bands in southwest Michigan on 17 November.
- With northerly flow overnight, morphology changed to a short-lived mid-lake band overnight.
- Maximum snowfall exceeded 16 cm in northwest Indiana.

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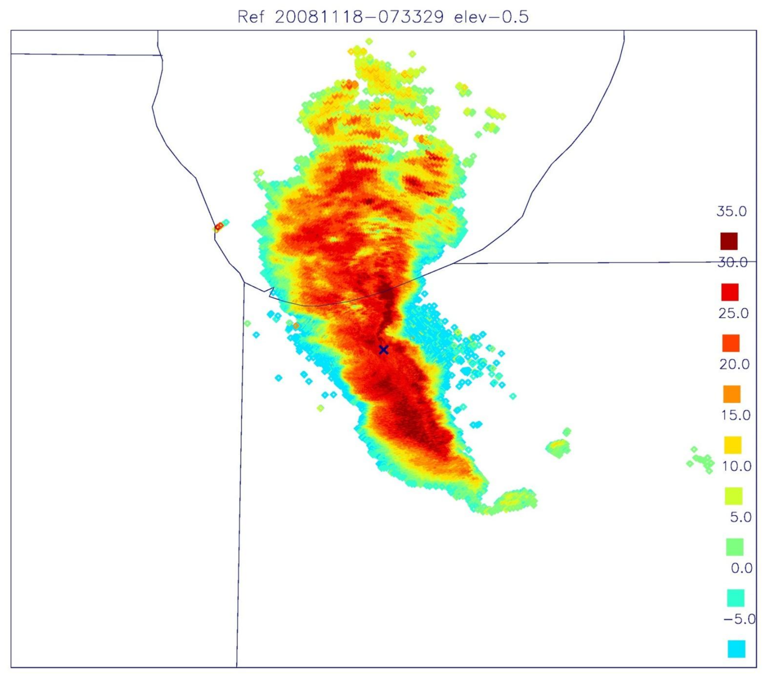

Fig. 3: Radar reflectivity (Z) from KVAL at 0733 UTC 18 Nov. 2008

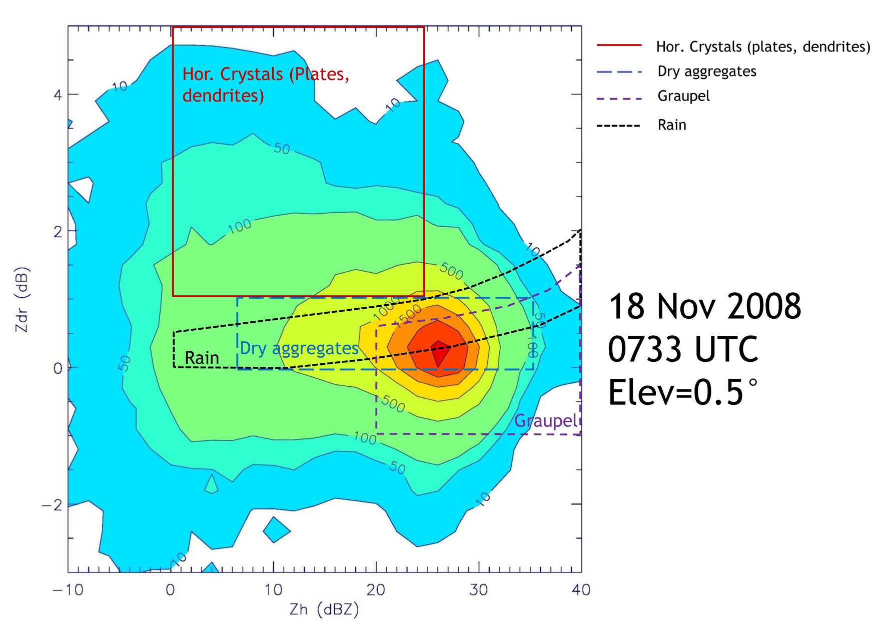

Fig. 4: Distribution of radar points in Z-Zdr space from KVAL at 0733 UTC 18 Nov. 2008

Radar Analysis

- KVAL perfectly captured the band of lake effect snow. This band was centered over the radar around 0730 UTC.
- Distribution of radar points in Z-Zdr space indicates a maximum with relatively high Zh and slightly positive Zdr, most likely due to the presence of both dry aggregates and graupel. The substantial number of points with high Zdr and low Zh indicate the presence of flat, horizontally aligned ice crystals, such as plates and dendrites.
- The hydrometeor classification algorithm identified ice crystals as the most prevalent hydrometeor at all altitudes. Below 1 km a significant number of points were identified as graupel and rain (mostly small drops).
  - The presence of rain and graupel (by definition a rimed particle) suggested by the radar data, supports the hypothesis that liquid water is present in the lower levels.
- For future events, more detailed microphysical information from our recently installed disdrometer, will measure precipitation size, fall speeds, and identify precipitation type.

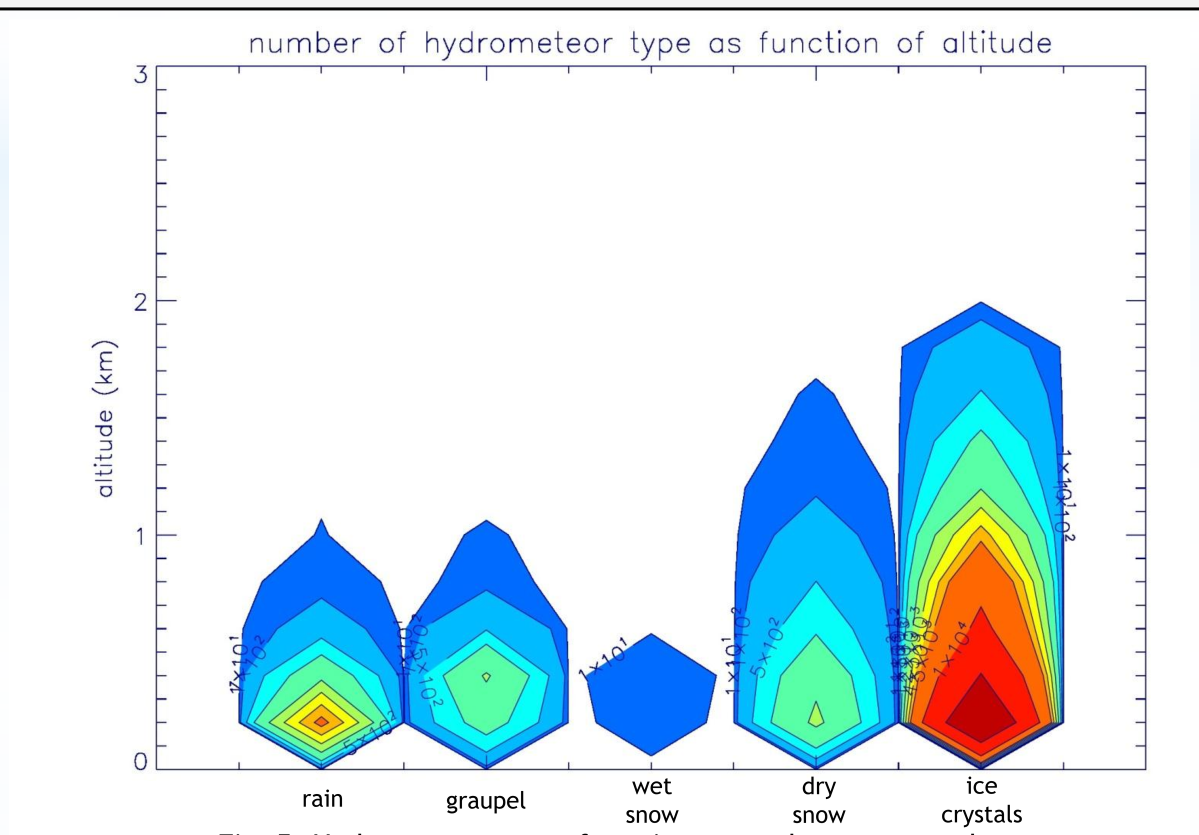

Fig. 5: Hydrometer counts for rain, graupel, wet snow, dry snow, and ice crystals from KVAL at 0733 UTC 18 Nov. 2008

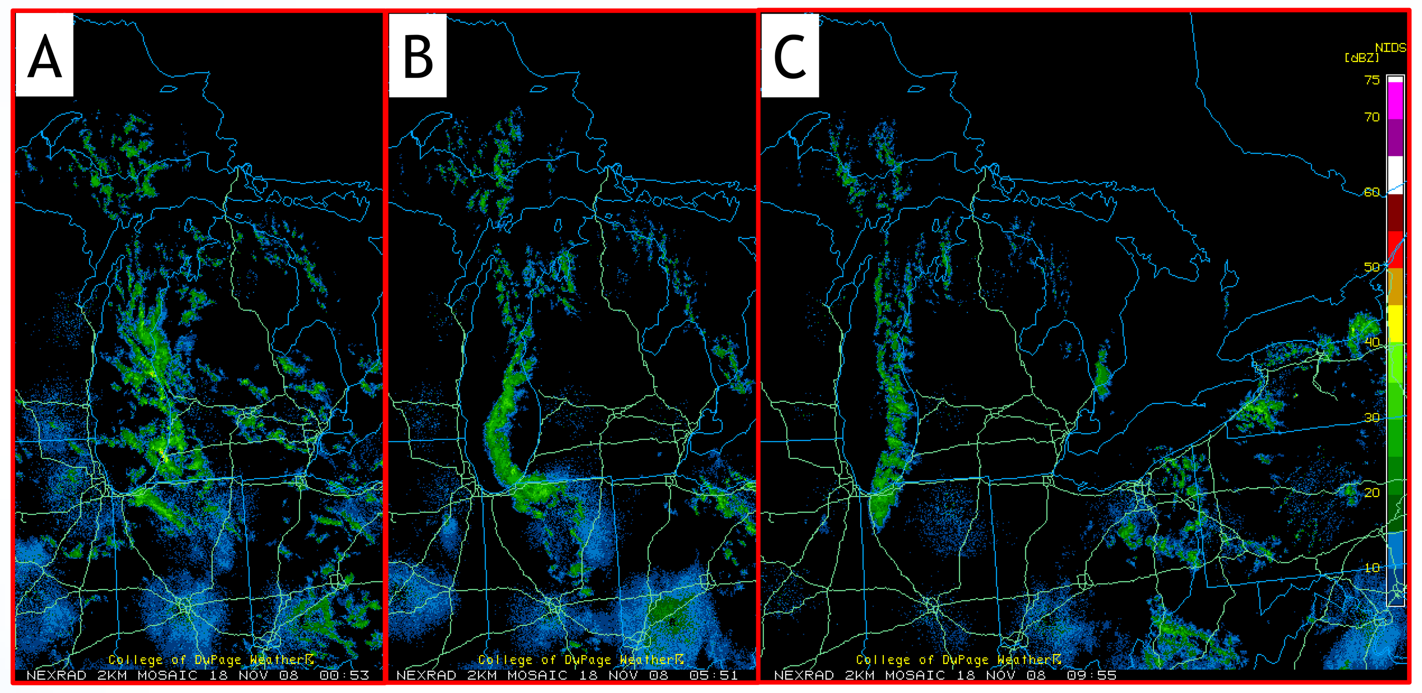

Fig. 6: Regional radar reflectivity throughout the event at (a) 0100, (b) 0600, and (c) 1000 UTC on 18 Nov. 2008

Model Simulations

- Simulations produce the significant mid-lake, lake-effect snow band in northwest Indiana, as well as antecedent wind-parallel bands in southwest Michigan.
- Most microphysical schemes produce cloud liquid water, snow, and ice.
- The lake-effect simulation is only slightly sensitive to the microphysics parameterization, so long as the scheme includes mixed phase processes.
- Simulations were not very sensitive to the selected boundary layer parameterization.
- Not all aspects of a land-breeze circulation are present with this mid-lake band, perhaps due to the event evolution and duration.

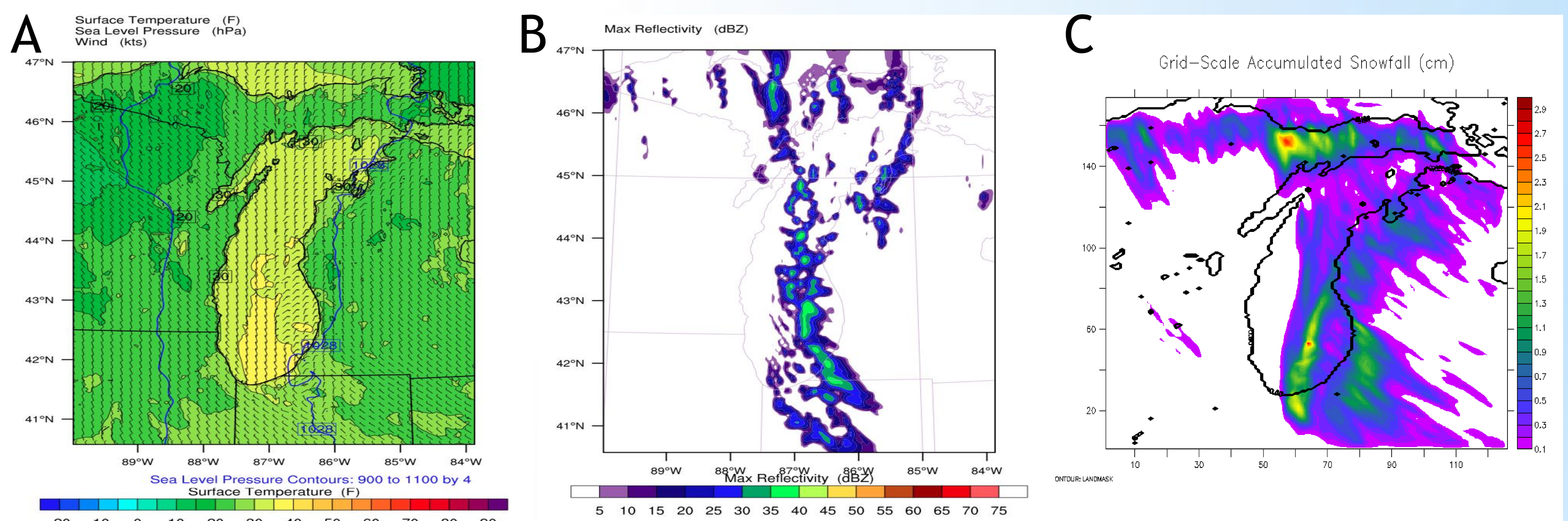

Fig. 7: WRF simulation with Goddard microphysics and MYJ boundary layer options:
(a) 06 UTC surface analysis, (b) simulated radar reflectivity, (c) and event-accumulated snowfall

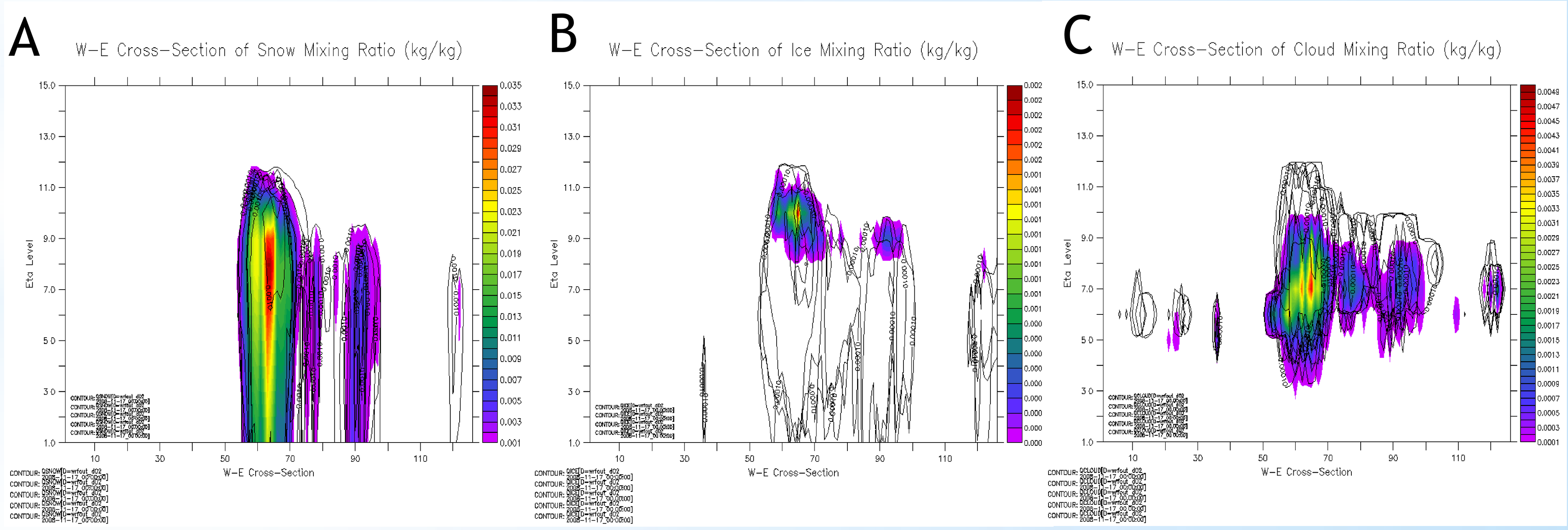

Fig. 8: W-E cross section of 10 UTC cloud properties, integrated with latitude across the lake for:
(a) snow mixing ratio, (b) ice mixing ratio, and (c) cloud water mixing ratio.

	Snow (kg/kg)	Ice (kg/kg)	Cloud Water (kg/kg)
Goddard	4.7	0.07	0.29
Lin	0.3	0.01	0.13
WSM5	2.4	0.67	0.03
Ferrier	2.4	-	0.21
Milbrandt	1.2	0.02	0.89
Morrison	2.4	0.02	0.63
SBUyLin	4.1	0.01	0.34
WDM5	2.4	0.58	0.03
WDM6	2.0	0.55	0.03
NSSL2M	0.9	0.06	0.55
NSSL2MCCN	0.8	0.03	0.52

Table 1. Domain 2 integrated 10 UTC Nov 18 hydrometeor mixing ratios.

	Precipitation (cm)	Snow (cm)	Graupel (cm)
Goddard	38.2	35.1	1.5
Lin	45.3	1.6	43.5
WSM5	43.9	42.6	-
Ferrier	39.5	-	-
Milbrandt	36.2	12.0	23.7
Morrison	34.3	-	-
SBUyLin	42.4	-	-
WDM5	37.6	36.6	-
WDM6	38.6	34.4	3.2
NSSL2M	30.6	17.3	12.3
NSSL2MCCN	30.2	13.6	15.5

Table 2. Domain 2 average grid-scale precipitation for 48 hour simulation.

Conclusions

- Analysis of radar data indicates the presence of liquid water, as well as graupel and snow.
- WRF simulations with mixed phase microphysical schemes indicate widely varying distributions of snow, ice, and liquid water mixing ratios.
- Lake-effect morphology and placement are not very sensitive to microphysical scheme and differences in hydrometeor characteristics.
- Mesocale circulation and BL growth are not very sensitive to microphysical schemes.
- While lake-effect cloud properties are varied and complex, overall model results are not very sensitive to microphysical details.