Validation of Bin Microphysics in a Large Eddy Simulation for the 30 January 2012 Lake Effect Snow case during GCPEx

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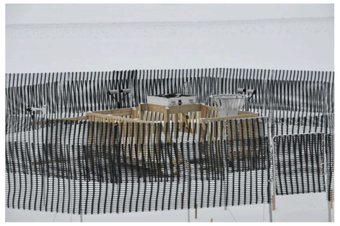
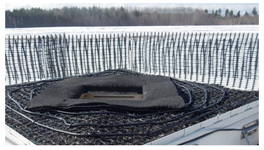
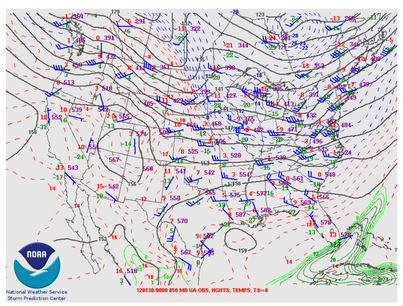
Introduction

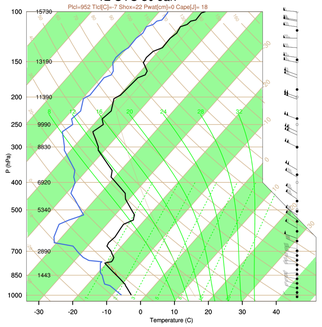
- GCPEx had many advanced *in situ* and remote sensing observations for ground validation and microphysical studies
- Focus on the 30 January 2012 lake effect snowfall event around the Huronia site
- Proposal goal: Use 2DVD, PVI, scanning radar, POSS, MRR, etc. for comparisons to WRF bin microphysics simulations





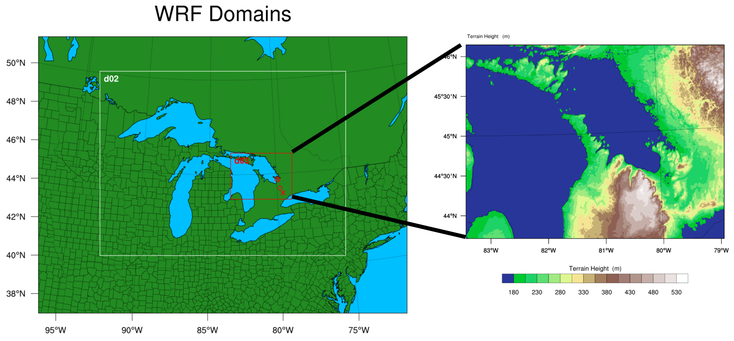
Synoptic Overview





- Lake-effect precipitation
  - Cold air advection across Great Lakes with water ~2-4°C, 850 mb temps ~-15°C
  - CAPE in lowest 2 km given lake surface temperature, capped above ~2-2.5 km

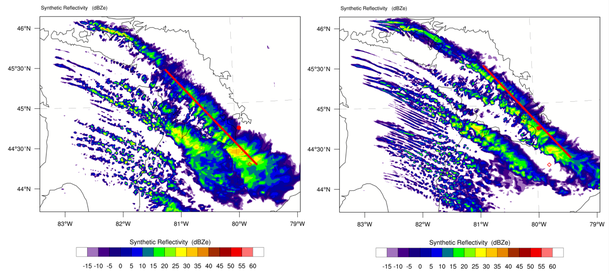
Model Configuration & Testing



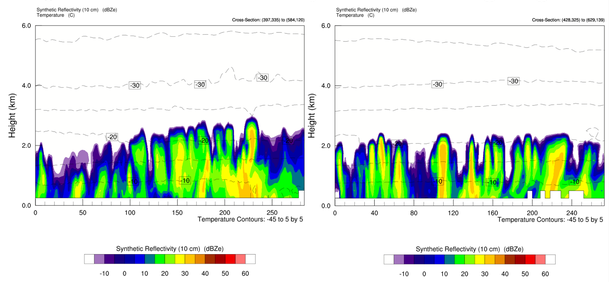
- Nested configuration: 4.5, 1.5, 0.5 km
- 500 m domain run with bin microphysics using 1-way nesting
- Initial testing focusing on ICs/BCs, PBL and surface scheme
- Using high-resolution NASA MUR SST product for lake temperature

Bulk Scheme Simulations

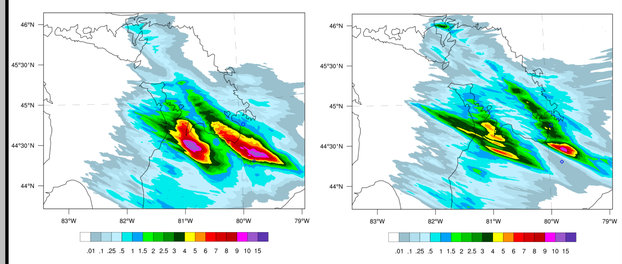
- Initial testing using RUC ICs/BCs, NASA MUR SSTs, Thompson microphysics
  - 500 m grid spacing simulation
  - LES "gray zone"
- Examine impact of PBL scheme
  - With and without MYNN2.5 PBL scheme
- LES simulation on left (no PBL), with PBL on right



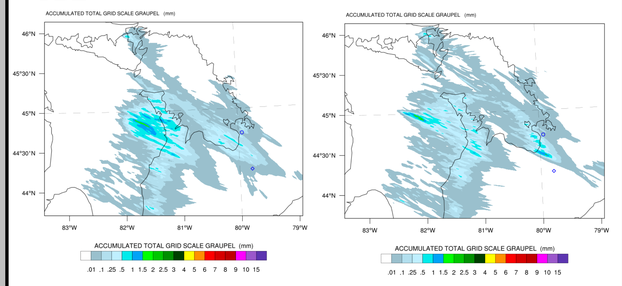
- Low-level simulated reflectivity (above), cross-section (below) along red lines
- Both simulations have broadly similar structure: Cellular nature of bands, shallow spatial extent with rapid increase in reflectivity with decreasing height



- However, PBL simulation may be less cellular with less spatial coverage



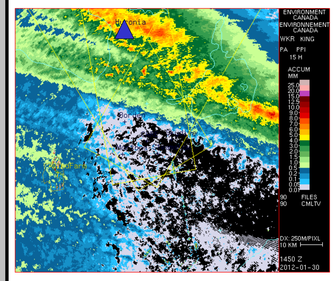
- Total liquid accumulation (top) and total graupel liquid equivalent (bottom)
- LES has more precipitation and graupel than with PBL



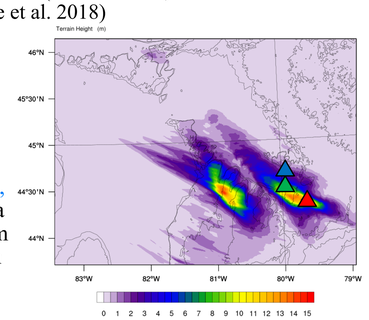
- More intense cellular updrafts (not shown)
- Generate more condensate, more precipitation
- More physically correct, but worse hindcast

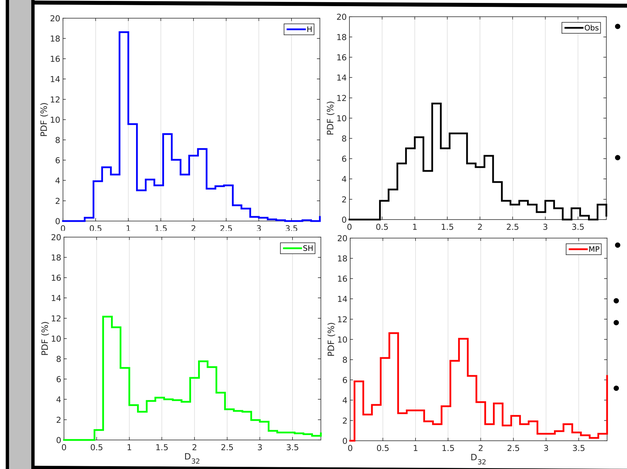
Bin Scheme – Observation Comparisons

- University of Pecs and NCAR Bin microphysics scheme (UPNB)
  - Mixed-phase bin microphysics (2 moments) based on the method of moments (Tzivion et al., 1986)
  - Liquid drops, pristine ice crystals, snowflakes, and graupel particles. Snow density varies between 100 and 900 kg/m^3; graupel density varies between 450 and 800 kg/m^3. Riming ratio on snowflake is prognosed to determined when snow is converted into graupel. More details can be found in (Geresdi 1998; Rasmussen et al. 2002; Xue et al. 2010, 2012; Geresdi et al. 2014; Sarkadi et al. 2016, and Xue et al. 2018)

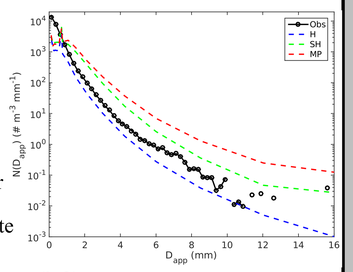


- Storm accumulation map
- Obs (left), bin simulation (right)
- Huronia site is blue triangle in panels
- Simulation overestimates total liquid accumulation (1-4 mm, ~10-50%)
- For model-Huronia site comparisons: Triangles on right panel: 1) Huronia (H, blue, less than obs); 2) South of Huronia (SH, green, similar to obs); 3) Maximum model Precipitation (MP, red, more than obs)
- Basis for aggregated comparisons



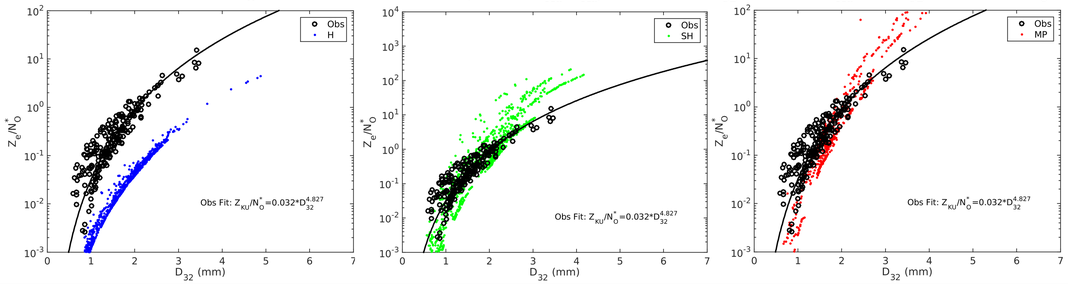


- 2DVD storm averaged PSD (right) - Shape is non-exponential; gamma with negative μ
- Bin scheme reproduces PSD shape and number well for D>1mm
- 2DVD not accurate for smaller sizes



- Storm D_{32} histograms (left)
- Obs has peak frequency near 1.5 mm, large spectral width with tail of large D_{32} (large aggregates). SVI images show alternating periods of graupel and aggregates
- Model also has large spectral width, but has bimodal distribution at all locations
  - Aggregates at larger D_{32}, graupel and/or ice at small D_{32}? Issue with species conversion?

- Below are scattering simulations of Z_e/ N_o^* vs D_{32}, where observed Z_e is at Ku-band assuming oblate spheroid with an axis ratio=0.8. Particle density is based on Bohm's method and fall speed from 2DVD. Note that $N_o^*=IWC/D_{32}^3$ for snow (Syzrmer and Zawadzki; Field et al.). The coefficient of Z_e-SR relation is approximately proportional to $[N_o^*]^{-0.5}$. Model Z_e is based on Rayleigh scattering, spherical shape and fixed density.
- Agreement with obs is reasonable at the SH and MP locations for D_{32}<2mm. At larger D_{32}, Rayleigh Z_e from the model is larger than T-matrix at Ku-band.
- Goal is to use dual-wavelength ratio from D3R radar (DWR=Z_{Ku}/Z_{Ka}) to estimate D_{32}, then use Z_{Ku} and D_{32} to estimate N_o^*.



Conclusions

- Successful LES-scale lake effect simulations
  - LES (without PBL scheme) produces realistic event at 500 m grid spacing
- Bin microphysics reasonable, key differences identified:
  - Total liquid accumulation overestimated
  - Storm averaged PSDs match well for aggregates; possibly underestimate small particles
  - D_{32} has bimodal distribution not in obs
  - Model produces similar Z_e/ N_o^* vs D_{32}

Next Steps

- Manuscript on bulk microphysics simulations
- Bin simulation sensitivity analysis focused on key uncertain parameters, diffusional growth, collection efficiency
  - Further quantitative comparisons to observations

Acknowledgments

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