Evaluation of Planetary Boundary Layer Schemes Within the Weather Research and Forecasting – ELEC Model during Project LEE

Thomas White, Dr. Yongang Wang, Dr. Scott Steiger
Department of Atmospheric and Geological Sciences, SUNY Oswego

Introduction

- Lake-effect snow (LES) is mesoscale process that develops over a lake due to the temperature difference between the surface of the water and upper air.
- The 2022-23 Lake-Effect Electrification (LEE) Project provides multiple datasets for in-situ and remote sensing measurements of LES that can be used to verify numerical weather prediction models, including the ability to simulate electrification.
- LES is known to produce CG (cloud-to-ground) and IC (intra-cloud) lightning that may be influenced by tall man-made objects, inflicting damage to property and hazardous to life.

Research Goal

- Determine the validity of simulated values compared to observations using the YSU (Hong et al. 2006), UW (Bretherton and Park 2009), and MYNN2 (Nakanishi and Niino 2009) Planetary Boundary Layer (PBL) schemes.

Methods

- Simulate Intensive Observation Period (IOP) 2 over the LEE domain (Fig. 1) using the Weather Research and Forecasting (WRF) model with the additional ELEC package.
  - Use YSU, UW, and MYNN2 PBL schemes
- Take latitude centered LLAP band measurements at -77.5, -76.5, -75.5 longitude between 0Z 18 Nov and 12Z 19 Nov 2022.
- Compute the mean, median, and standard deviation of composite reflectivity for KTYX radar and each model run output during the period.
- Compare observed soundings and radar data to model equivalent.

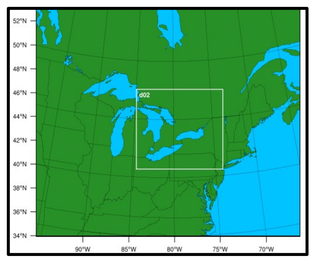

Fig. 1. Computational domains (outer and inner nest) of WRF simulation.

Table 1. WRF-ELEC initialization, electrification, and physics schemes.

Computational Domain	Refer to Fig. 1
Horizontal Resolution	9.0 km and 3.0 km
Planetary Boundary Layer (PBL)	YSU, UW, and MYNN2
Cumulus Parameterization	Grell-Freitas and N/A
Microphysics Parameterization	NSSL Two moment
Charging Type	Inductive and Non-Inductive
Lightning Discharge	3D discrete discharge
Boundary Conditions	Hourly ERA5 Reanalysis

Results

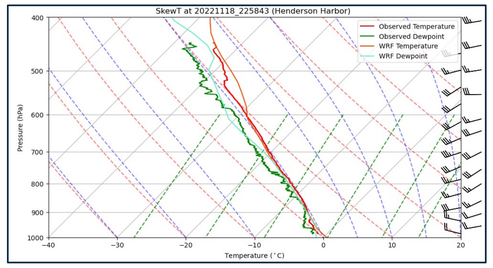

Fig 2. Sounding Comparison at Henderson, NY (see Fig. 3 for location) plotting T, Td, and wind barbs (WRF on right) valid near 0Z 19 Nov 2022 using YSU PBL scheme.

- Model sounding shows highly saturated 950-750 hPa layer (Fig. 2)
- Steep lapse rates in both simulation and observed throughout surface to 600 hPa
- Boundary layer (~750 hPa top) seen in observed sounding

Table 2. Total number of hours that best match observation for max, mean, median, and standard deviation of each model run between 0Z 18 Nov and 12Z 19 Nov.

	Hours Closest to Radar Observation			
	Max	Mean	Median	Standard Deviation
YSU	19	13	16	15
UW	6	9	8	6
MYNN2	12	15	14	16

- YSU run best matches observed radar maximum and median
- MYNN2 best matches observed radar mean and standard deviation; UW worst for all

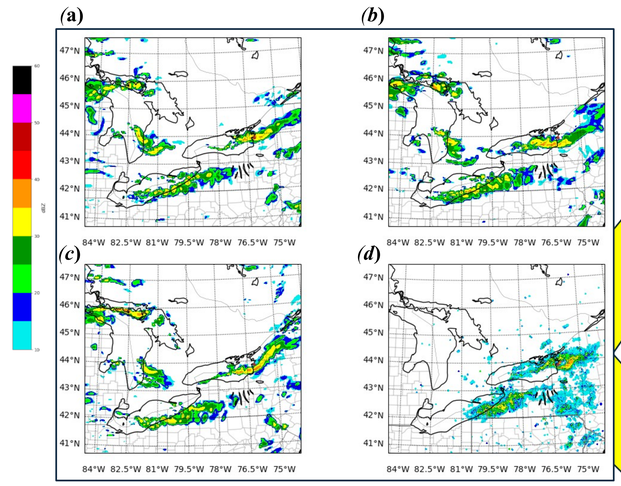

Fig 3. Map displaying composite reflectivity at 0Z 19 Nov 2022: a) WRF YSU, b) WRF UW, c) WRF MYNN2, d) KTYX, KBUF, KBGM radar. Red dot shows Henderson, NY

- YSU scheme shows best location of LLAP matched to radar observations (Fig. 3a, d)
- Convective cells >45 dBZ observed by radar not resolved in simulations

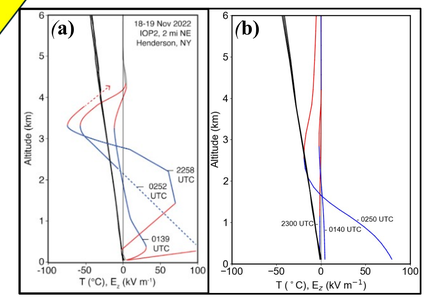

Fig. 4. a) Observed and b) simulated z component of the electric field at Henderson, NY for IOP2 at various times from 18 to 19 Nov 2022 using YSU PBL scheme. Also shown T and T_d both panels in black.

- WRF simulated E_z does not increase at the surface (Fig. 4)
- Only 0250Z shows reasonable E_z values compared to observations

- Highest electric field magnitude within greatest dBZ values (Fig. 5)
- Simulated CG flashes show greatest electric field magnitude near the surface
- Nearest LMA recorded flash occurred at 1551Z Nov 18

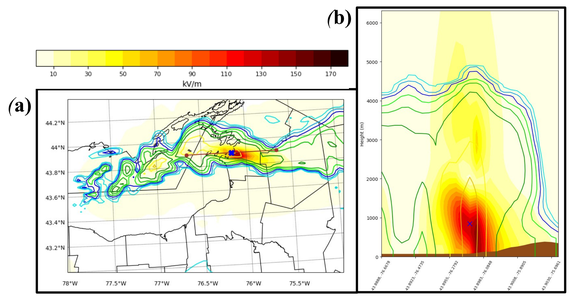

Fig 5. a) Plan View and b) vertical cross section of contour lines of composite reflectivity (dBZ) with color contours of the electric field magnitude (kV/m). Blue X indicated flash initiation point valid at 1355Z 18 Nov 2022 using YSU PBL scheme. Cross section location shown by red line in a) connected by two dots.

Conclusion

- The YSU PBL scheme shows the most accurate composite reflectivity values and LLAP band location throughout the entire IOP.
- The WRF model struggles to resolve convection, especially within narrow LES bands.
- Flash location, frequency, and time of occurrence are not well represented by the WRF-ELEC model as almost double the maximum of 16 simulated flashes (MYNN2) were observed by a lightning mapping array.
- UW PBL scheme does not handle electrification well, developing zero flashes.
- Flash initiation points are correlated to the regions of highest dBZ.

Acknowledgements

- Project LEE was funded by NSF grant number 2212177
- Dr. Ted Mansell and Dr. Sebastian Harkema for helping with WRF-ELEC configuration

References: