Lake-effect Electrification and Lightning (Project LEE*) – A “Shocking” SUNY Oswego Project

Scott Steiger and Thomas White

*LEE Project sponsored by the National Science Foundation

Scientists: Scott Steiger, SUNY Oswego,
E. Bruning, V. Chmielewski, G. Stano, J. Trostel, L. Boggs, J. Losego, Y. Wang,
K. Calhoun, D. Kennedy, T. Lang, C. Schultz, S. Waugh, K. Kosiba, J. Wurman

Photo: K. Jesmonth, IOP3

One of the most exciting phenomena for us mets…

- https://youtu.be/PdRWGMyeSYY

- Swear Word Warning (an “SWW” occasionally occurs in Steiger videos) for video to the right…

Lightning Primer

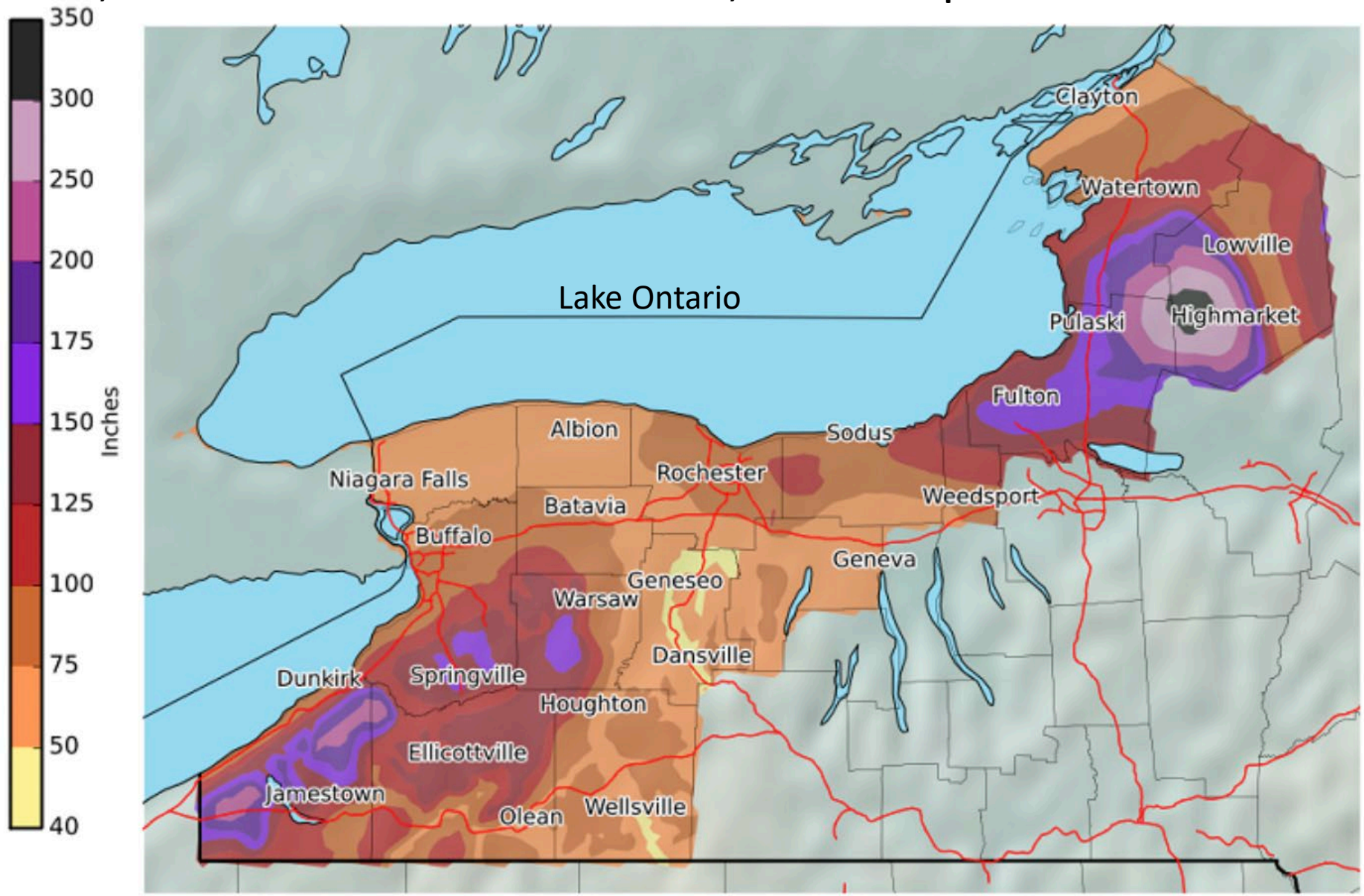
10 km,
Typical height of thunderstorm top

- Cloud electric fields: *Charge separation*
  - Ingredients: Graupel, ice crystals, and supercooled water in the presence of strong vertical motions
  - Transfer of charge between *colliding* graupel (is heavy, sinks) and ice crystals (light, lofted): graupel negatively charged, ice crystals positively charged

NWS Buffalo, NY

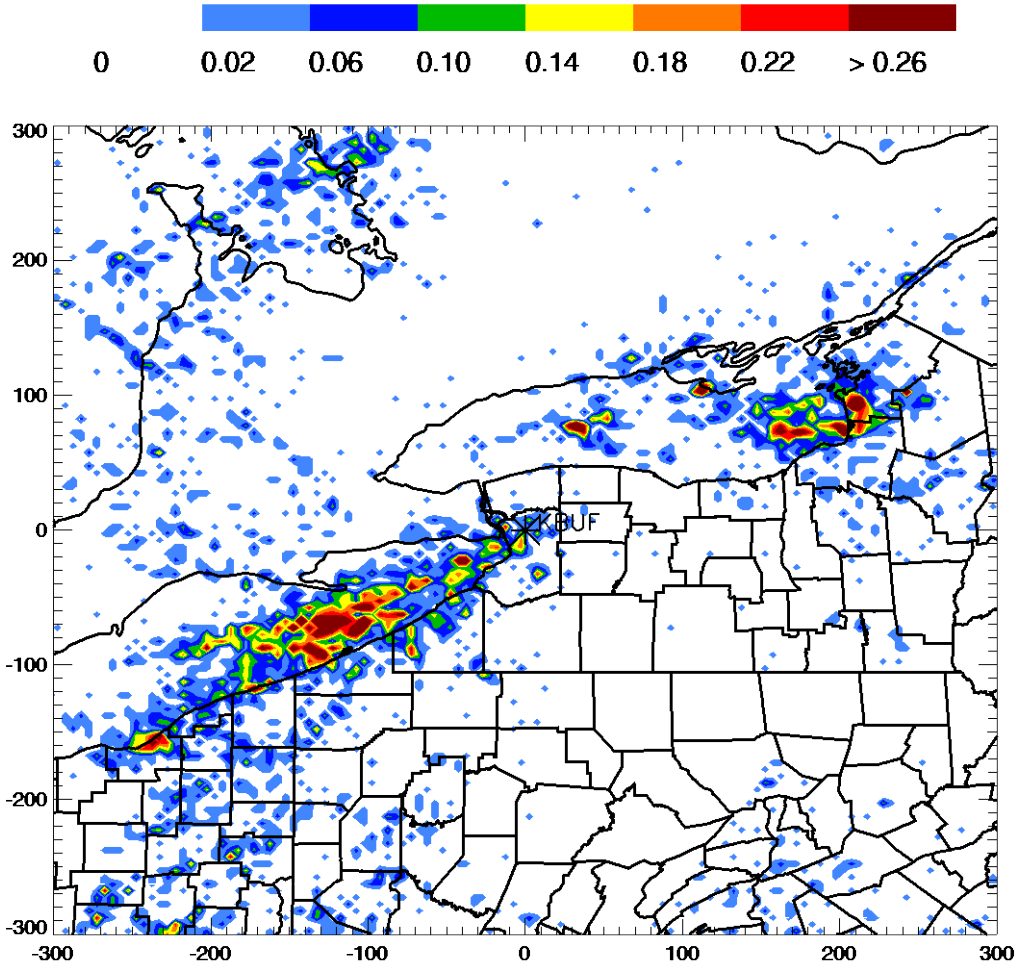
Average Annual Snowfall

Why LEE? Dependable, area-focused lab for winter electrification, easier to sample low clouds



Previous Research: LE (lake-effect) Lightning "Hot Spots"

1995-2007,
flashes km^{-2}



Steiger et al. (2009): Just CG during lake-effect

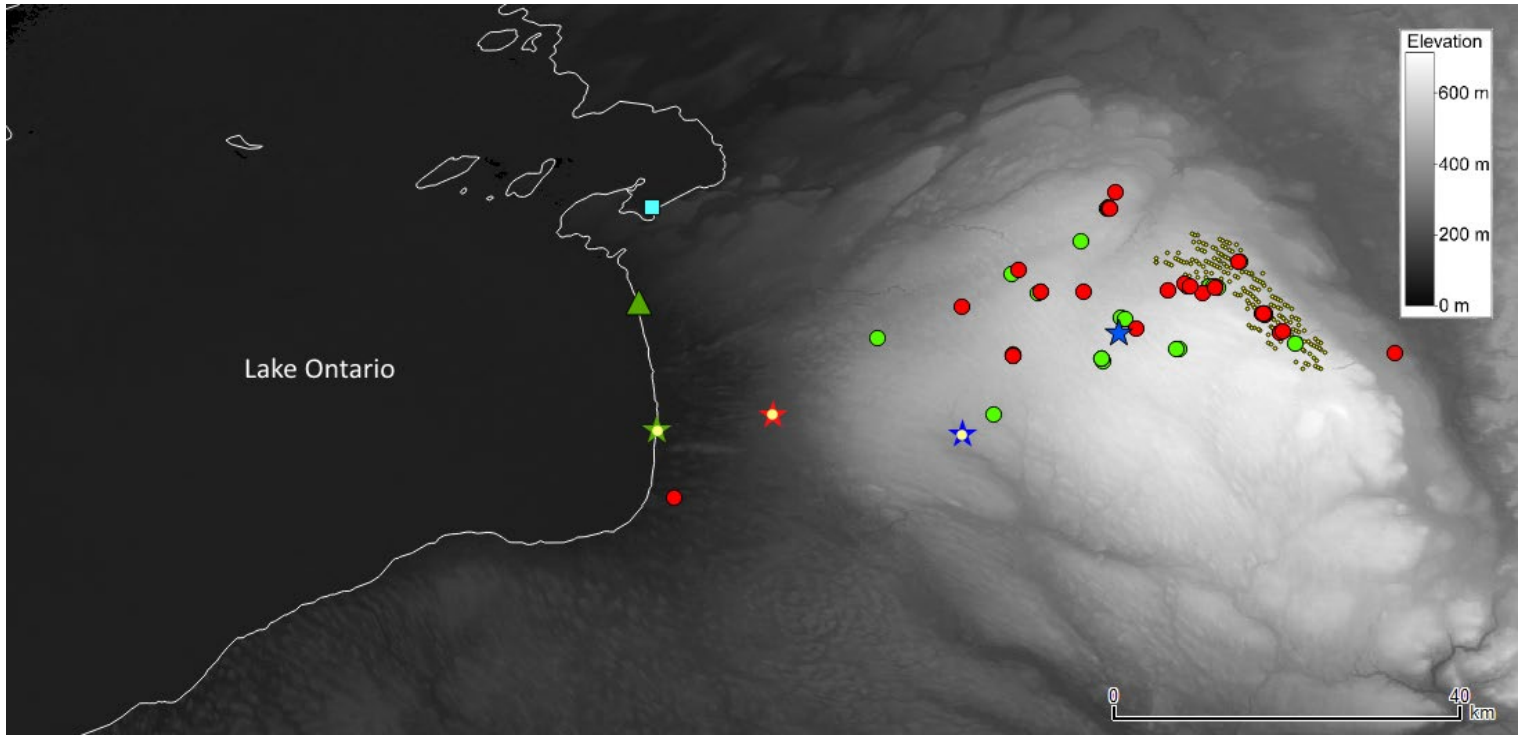
~5 events/season Lake Ontario (Letcher & Steiger 2010)

Max. 10s of flashes over several hours of an event (Moore & Orville 1990, Steiger et al. 2018)

Note: IC = Intracloud, CG = cloud-to-ground lightning

OWLeS Project (2013-14) hypothesis *not* well-supported

- "Lightning occurs in regions of stronger updraft and significant riming within the band." (see Steiger et al. 2018)

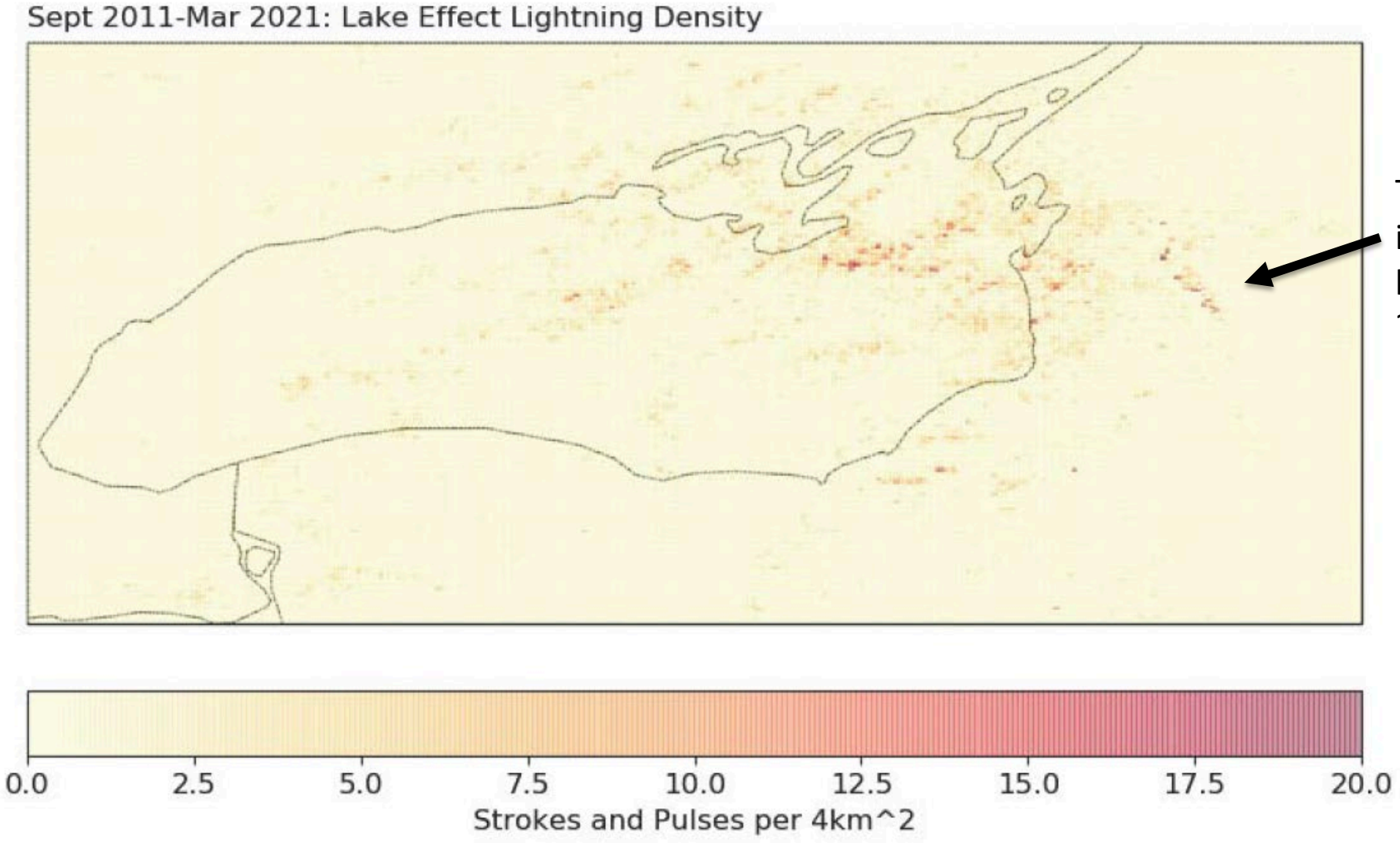


7 Jan 2014;

Green (CG stroke),
Red (IC pulse),
Yellow (turbines)

Steiger et al. (2018)

Updated LE lightning density



National Lightning Detection Network (NLDN) data

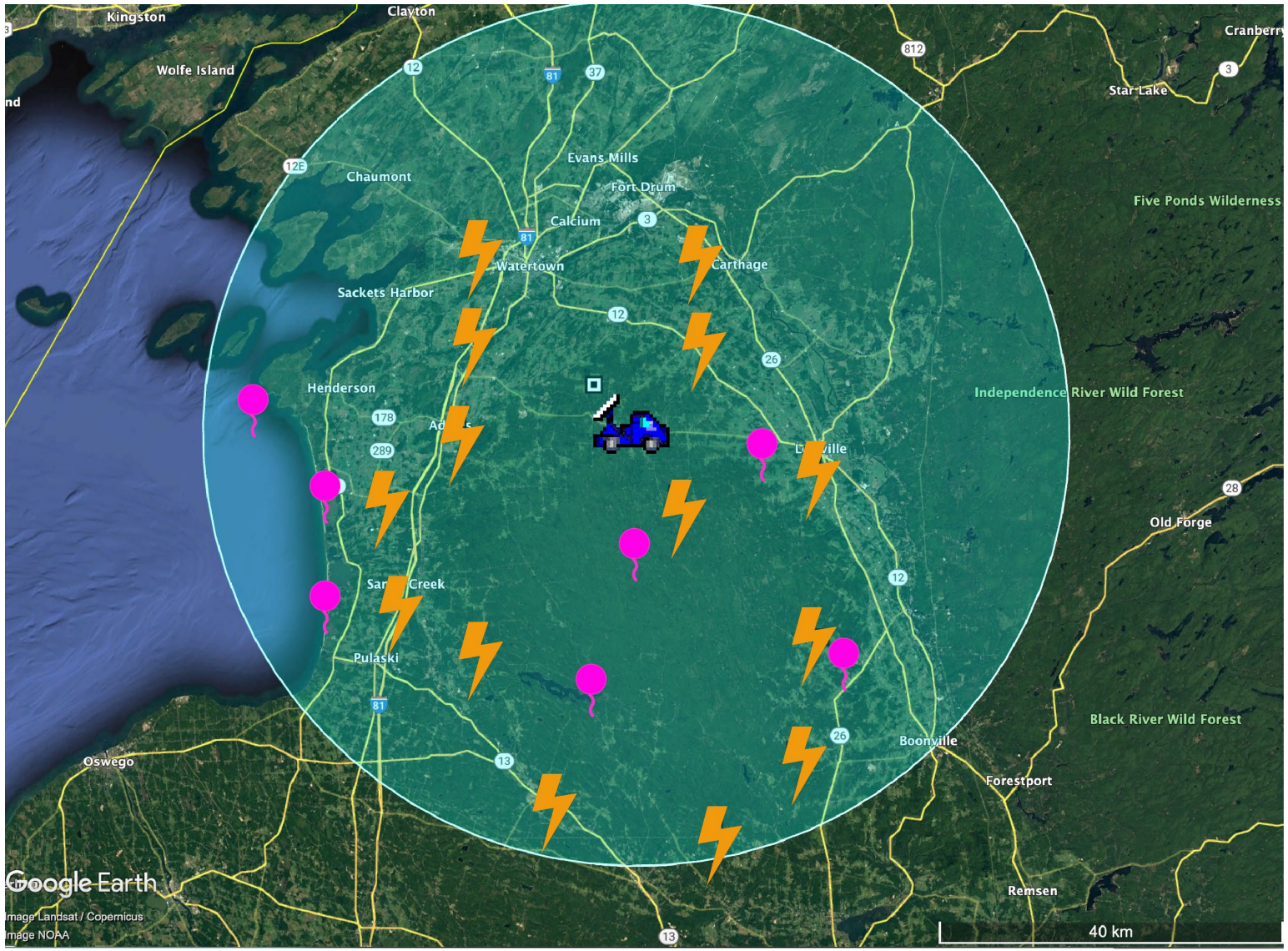
LEE Objectives

- For the first time, to document the electrical charge structure of lake-effect snow storms (surface-based convection to stratiform precipitation process), relate to hydrometeor (e.g., supercooled water, snow flakes) populations.
- Improve the understanding of turbine-initiated lightning (~300 Tug turbines over 100 m tall!). This kind of lightning more likely during winter?
- Compare LEE findings with those from sea-effect (Japan), cyclone (e.g., Project IMPACTS) electrification studies.
- Determine flash sizes and energies of lake-effect lightning.
- Electrification modeling (e.g., WRF-elect)
- Overlap with IMPACTS Project, involve many undergraduates (22)

LEE Facilities & potential set-up

Bolts=LMA sensors, Balloons=sondes (inc. EFMs and PASIV), DOW truck

Georgia Tech and NSSL LMAs



DOW: Wurman et al. (2021)

Environmental sonde Oswego

Lightning Mapping Array (LMA) stations: before & after snow

Portable LMAs as in Bruning et al. (2016)

Pulaski High School installation (Georgia Tech)

Students had to clean and facility managers did repairs on LMAs during LEE.

Photo: V. Salinas, U.Oklahoma; Greig, NY (NSSL unit)

DOW in the snow!

Photos: E. Caldon, 1 Feb 2023

Let’s go do some field work (at night?)!

Soundings

Vertical profiles of temperature, humidity, wind, electric field [new generation of Winn and Byerley (1975) EFM], particles (PASIV; Waugh et al. 2015)

Student teams also collected surface snow measurements at DOW and sonde locations

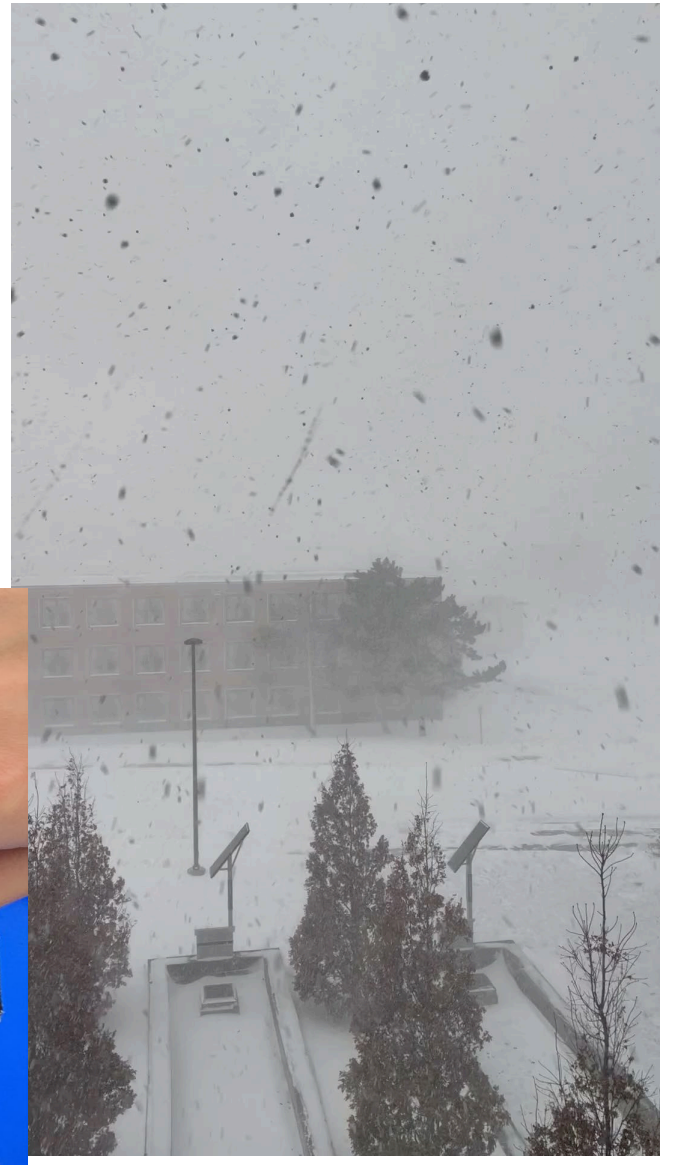
(This image not from LEE)

LEE issues: popped balloons (cold, large graupel), sondes landings in tough spots, PASIV supply chain issues

Photo by Liam Todd (SUNY Oswego), IOP5

Soundings cont.

Almost severe–sized graupel!
IOP3: 20 Nov 2022.
Wind-blown large graupel
popped balloons we think.



Successfully launched 13 EFM (Electric Field Meter) and 2 PASIV (particle imager) sondes during the project!

Environmental sounding issue: Oh the wind!

EFM/PASIV sounding issues

Up in the trees!

Photo source: WhatsApp Chat?

Popping balloon solution: keep launch tube dry and warm

EFM/PASIV sonde issues cont.

Warning: swear word! (SWW)

IOP10: 1 Feb 2023

Recovering sondes in deep snow!

Slept in the office some nights…

I only live a 15 min walk from home, but some nights I forecasted until midnight and then had to give the DOW team a briefing by 4 am…

Weather not cooperating for a time…

November gave us “Super Bowl” events, then mid-December was active into Christmas,

Then a whole lotta …

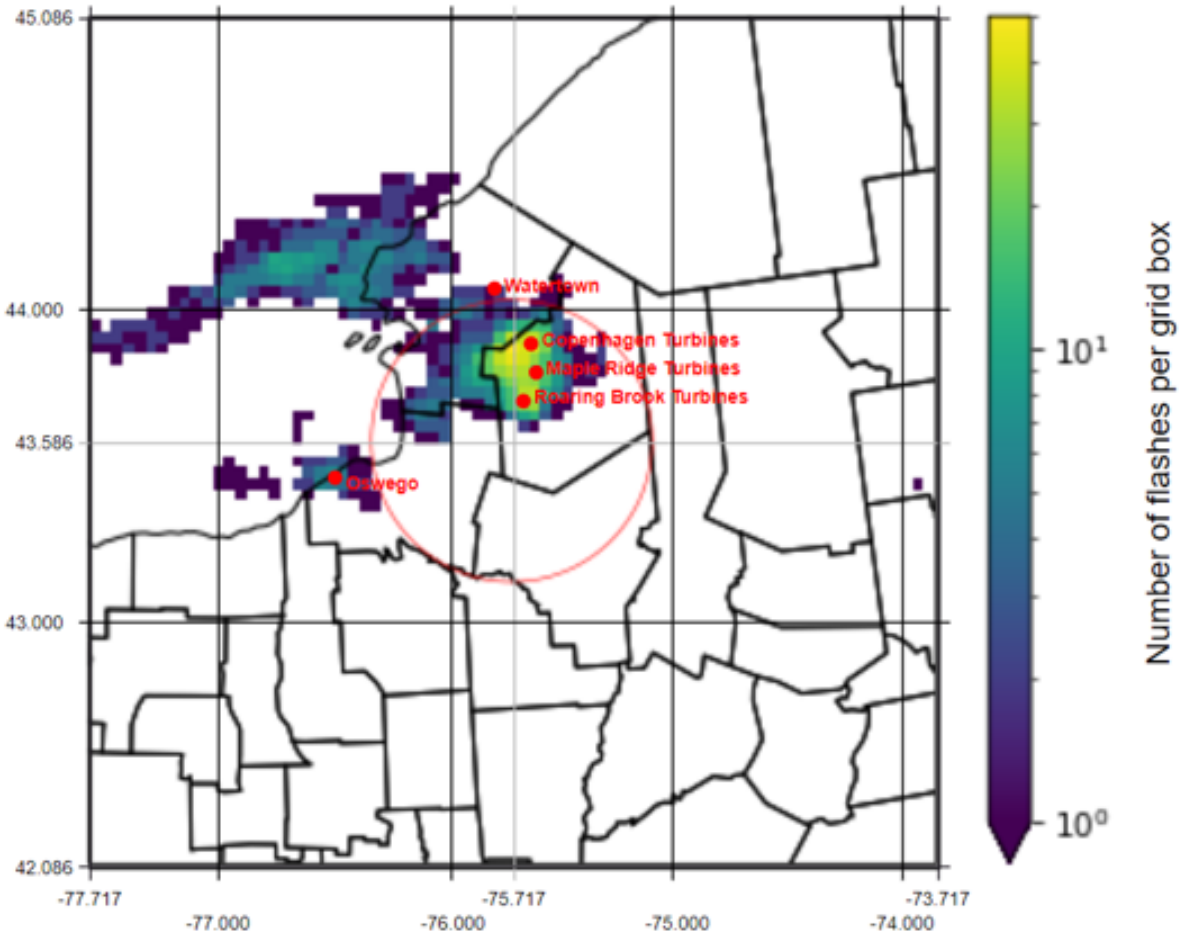
When Buffalo, NY got hit hard, so did Watertown!

Safety key!

IOP10: 1 Feb 2023

Overview of LEE results

- 11 Intensive Observation Periods (IOPs, 3 with lightning) + 8 other non-IOPs with lightning and frozen precipitation
- 239 total LMA flashes Nov - Feb
- Maximum flash rate: 26/hr (IOP3)
- 34% of flashes initiated within 300m of towers (10% within 100m)
- IOP3: 60% of lightning within 300m!
- Last IOP (11) with lightning 2-3 Feb 2023 (lake band – arctic front); several flashes noted without LMA data?

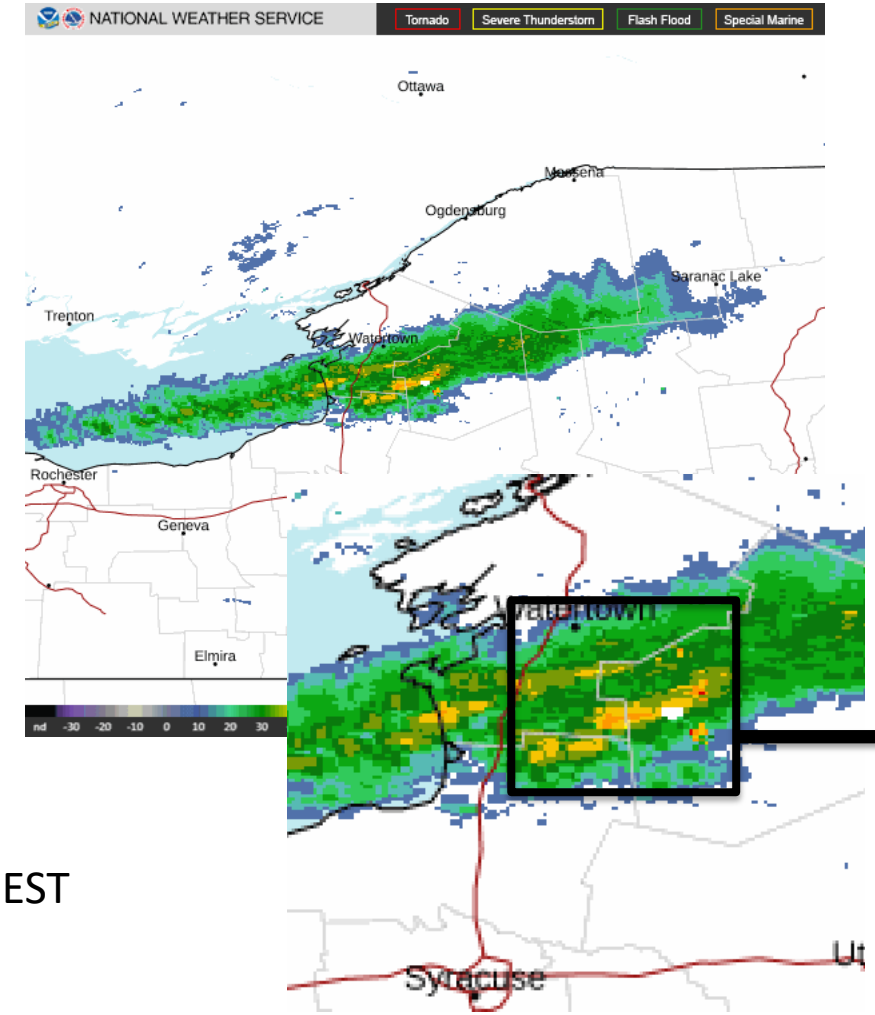


LMA FED for all events Nov ‘22 – Feb ‘23, grid box 4 km (239 flashes)

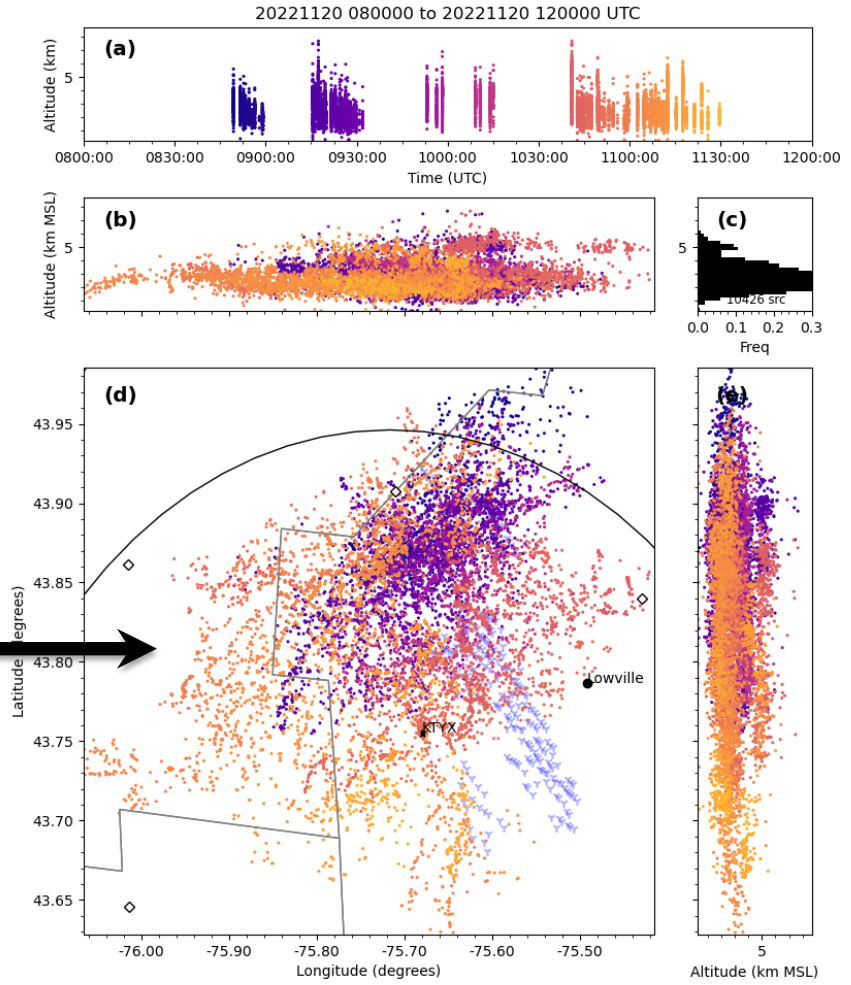
Prelim. Analysis: 20 Nov 2022

KTYX radar 1041Z, lower right zoomed-in; Lake band slowly moved South 08-12Z

Note 08Z = 3 am EST



Lightning 08-12Z: 5 lightning episodes

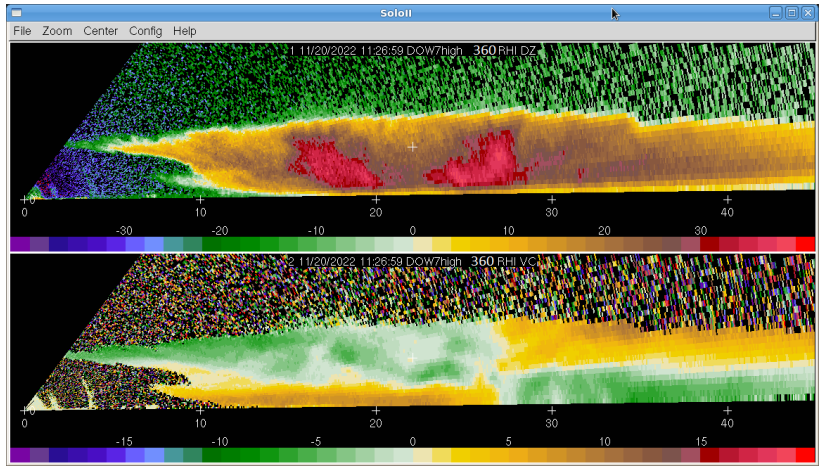


z MSL

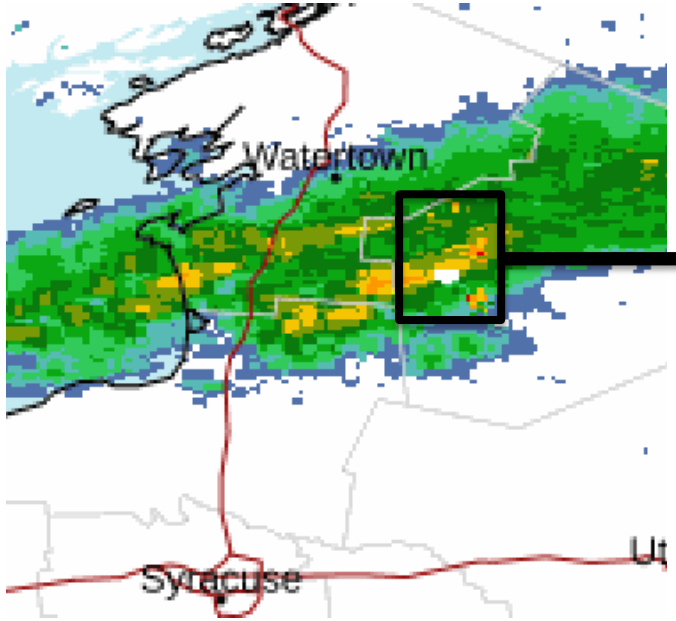
Think of each dot as a “piece” of lightning

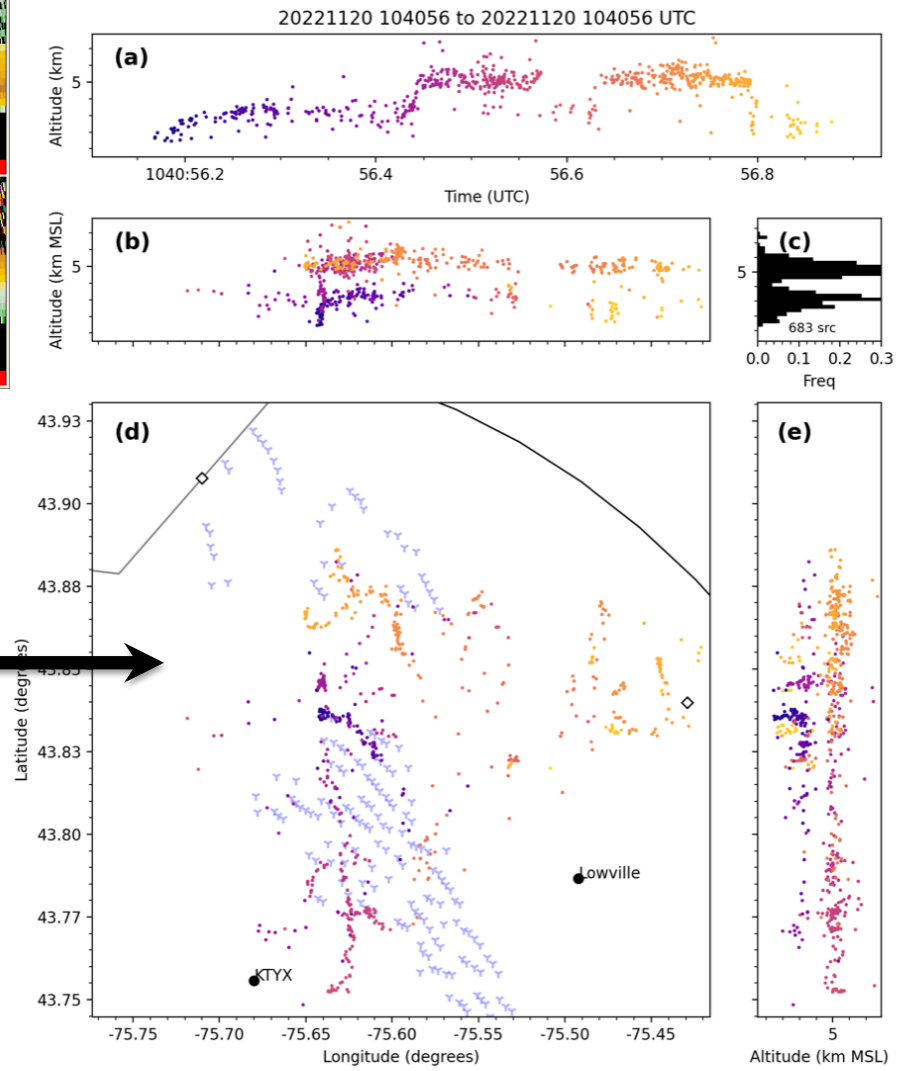
IOP 3 cont.: Single flash

1127Z DOW, Storm depth ~5 km ARL. Image provided by P. Robinson.



KTYX 1041Z





Bi-level behavior as in Schultz et al. (2018) thundersnow study

IOP3 cont.: 21Z

LMA points (white, see right) over DOW dBZ for flash hitting Oswego stack (below photo. From K. Jesmonth, SUNY Oswego, 2052Z)

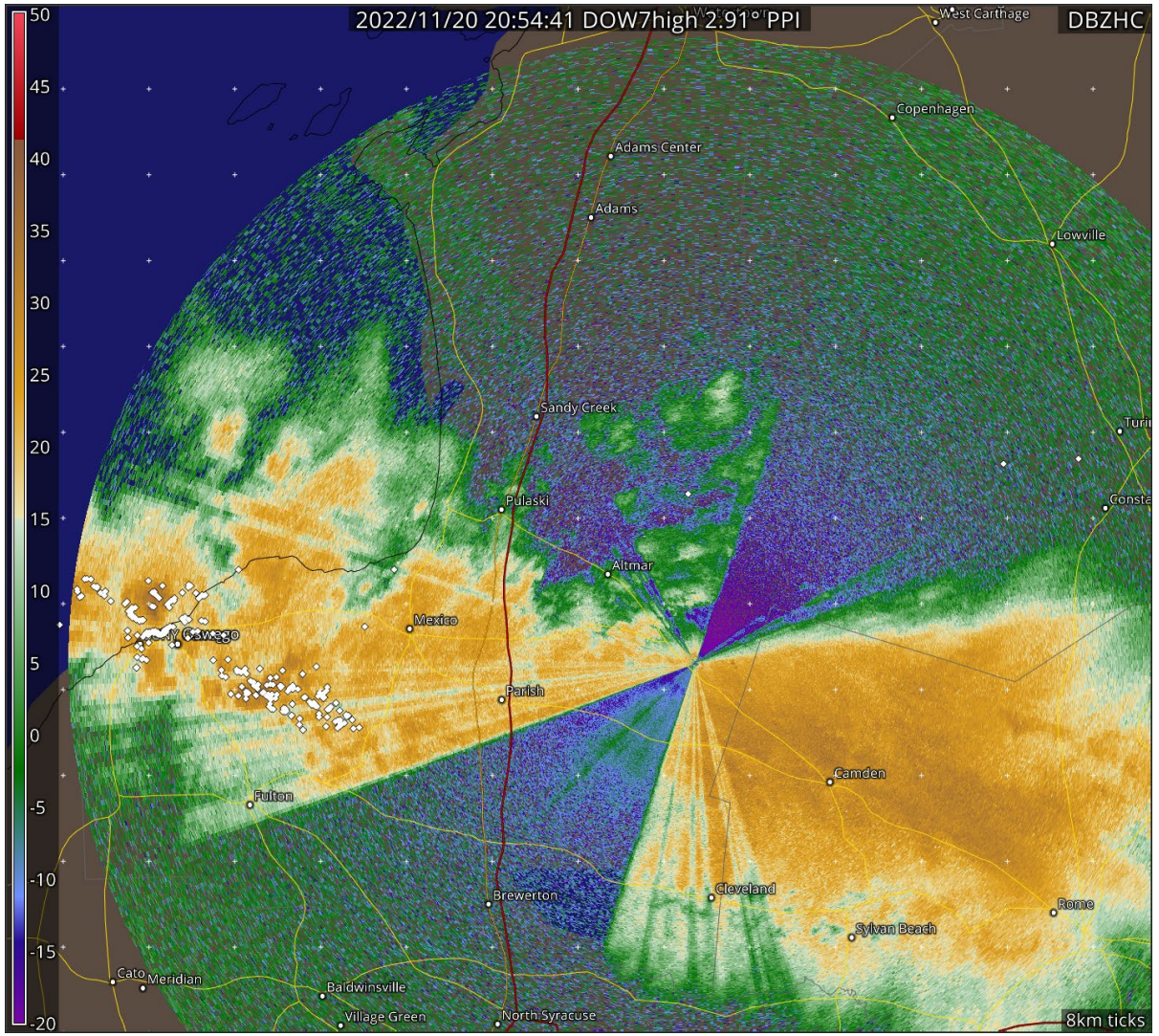


Image courtesy of Trevor White (U. Illinois)

Huge Graupel IOP3!

Photo: Jake Rumowicz, SUNY Oswego

0.75” diameter

Conclusions

- 11 IOPs (3 with lightning); 7 planned IOPs, 3 w/ lightning
- Captured great LMA data during intense lake-effect rain events September 2022 (flooding rains in Oswego, NY)
- Follow us on Twitter @nsf_lee
- Project website: https://www.eol.ucar.edu/field_projects/lee

- References available upon request (scott.steiger@Oswego.edu)
- Thank you to NSF: AGS Grant 2212177, and to all who collected the data, including 22 awesome Oswego undergrads!

Video of lake-effect lightning flash strike to Oswego stack 2052Z 20 Nov 2022

Video captured by K. Jesmonth