Environment and Climate Change Canada | Environnement et Changement climatique Canada

THE SOUTHERN ONTARIO LIDAR (SOLID) MESONET: IMPACTS ON AVIATION AND SEVERE WEATHER NOWCASTING



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Environment and Climate Change Canada's 50th anniversary
50e anniversaire d'Environnement et Changement climatique Canada
Meteorological Service of Canada's 150th anniversary
150e anniversaire du Service météorologique du Canada

Canada

AMS Annual Meeting – January 14, 2025

HIGH IMPACT WEATHER RESEARCH SECTION AT ECCC

Research Programs:

1. Radar
2. Aircraft
   - Policy – Regulatory
   - Weather-related aviation safety
3. Cloud Physics
4. Nowcasting and High-Impact Weather (HIW)

Research activities using next-gen and established observing technologies

- Development, testing, & evaluation of new technologies & their applications
- Radar, lidar, aircraft, satellite missions

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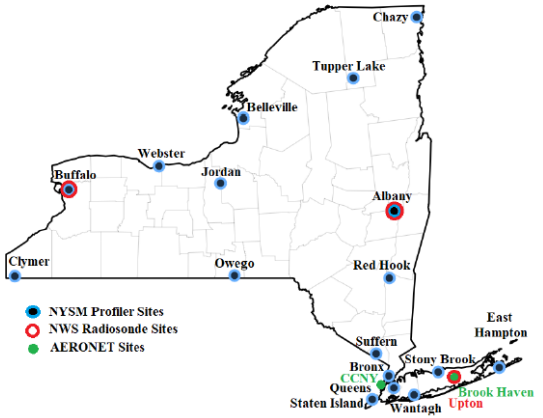
INVESTIGATING TECHNOLOGIES THAT CAN FILL GAPS IN THE CURRENT UPPER AIR NETWORK

- Need to reduce dependency on a single technology (radiosondes) by investigating the potential of implementing a mixed network
- **Objectives:**
  - Support identification, testing, and implementation of new commercial technologies, including impact analyses and bridge to operations
  - Recommend cost-effective integrated observing system which best serves Canadian needs
- Technologies under investigation for increased adoption:
  - AMDAR, GPSMet, Doppler lidar, water vapour lidar, radiometers
- Examples of other agencies deploying Doppler lidar Mesonets for nowcasting:

EU's COST action: PROBE[1]



New York State Mesonet[2]



[1]Cimini et al. (2020): "Towards the profiling of the atmospheric boundary layer at European scale—introducing the COST Action PROBE." Bull. Of Atmos. Sci. & Technol.
[2]Shrestha et al. (2022): "Evaluation of the New York State Mesonet Profiler Network Data." AMT

SOLID MESONET: IMPACT ASSESSMENT

Observations:

- 8 Doppler lidars are deployed around Toronto, including one at the Toronto Pearson Airport (CYYZ), forming a Mesonet. Observations are made, processed, & available in near-real time
- One DIAL (water vapour profiling) and MWR radiometer (Radiometrics) are also deployed

Study Period: November 2022 to ongoing

Operational Scopes / Areas of Responsibilities:

- OSPC-DOWNSVIEW (analyze observations from the entire Mesonet → **regional forecasters**)
- CMAC-EAST (analyze observations from the Doppler lidar at Pearson → **aviation forecasters**)

Study Parameters:

- Observations will be provided to operational forecasters continuously (every 10 minutes, 24/7) during the study period
- Compile case studies and provide qualitative feedback on the impact of Doppler lidar observations on the nowcast
- Collaboration with other governmental departments and federal agencies
- Near-real time product delivery to ECCC's internal data management system and NinJo display software for operational forecasters

Complementary Mesonets with Similar Instrumentation



Vertical wind profile available at centre of each circle every 10 minutes

Red = Halo

Green = Leosphere





Pearson Supersite (co-located with existing staffed observation station)

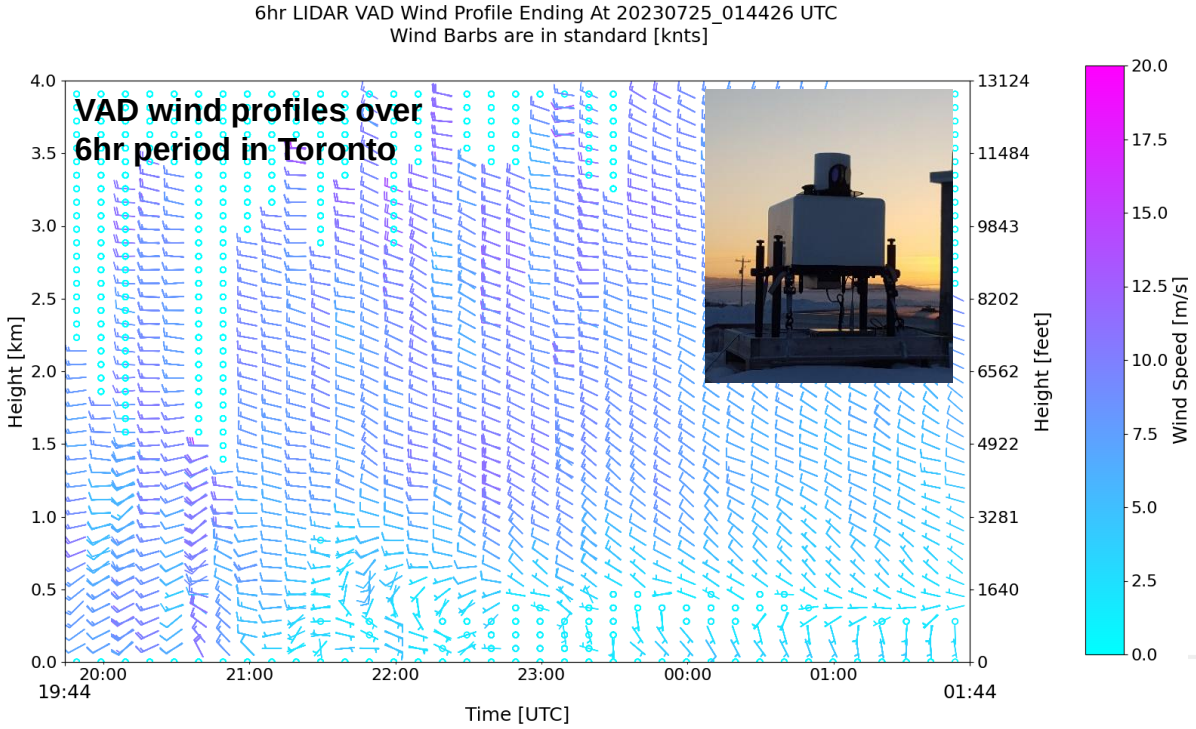
Proposed additional Lidar (Western U)

Cobden
Shawville
Killaloe
Eganville
Barry's Bay
Renfrew
Gatineau
Ottawa
Combermere
Calabogie
Mississippi Mills
Carleton Place
Kemptville
Port Carling
Bracebridge
Haliburton
Bancroft
Gravenhurst
Minden
Perth
Smiths Falls
Midland
Orillia
Wasaga Beach
Kawartha Lakes
Brockville
Marmora
Tweed
Barrie
Innisfil
Peterborough
Campbellford
Gananoque
Greater Napanee
Kingston
Clayton
Kincardine
Hanover
Belleville
Quinte West
Philadelphia
Newmarket
Brighton
Fort Drum
Prince Edward
Watertown
Cobourg
Markham
Vaughan
Brampton
Listowel
Fergus
Toronto
Lake Ontario
Mississauga
Milton
Oakville
Oswego
Kitchener
Stratford
Cambridge
Fulton
St. Marys
Hamilton
Niagara-on-the-Lake
Brockport
Lockport
Rochester
Baldwinsville
Cicero
St. Catharines
Niagara Falls
Henrietta
Syracuse
Oneida
Ingersoll
Welland
Batavia
London
Strathroy
Auburn

SOLID MESONET LIDARS

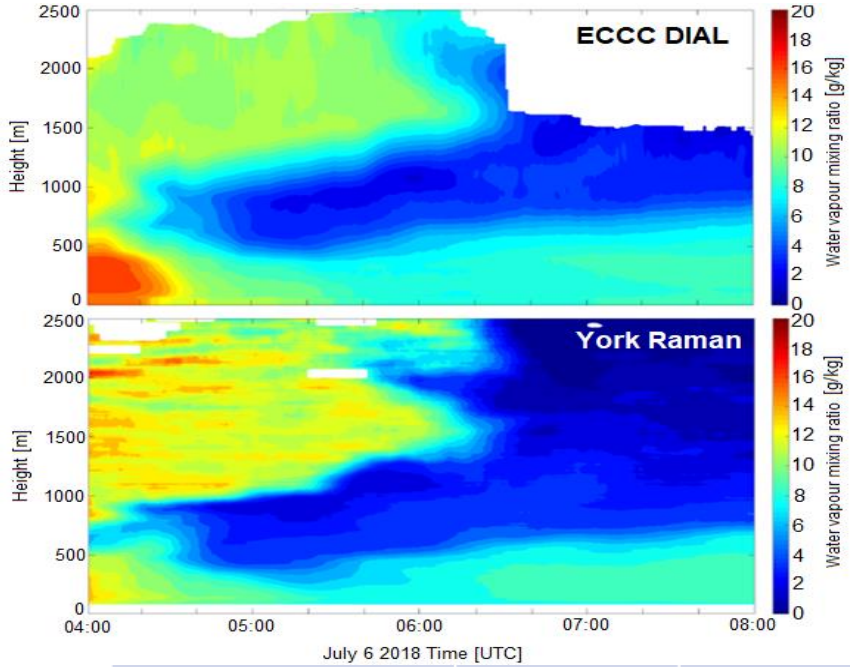
Doppler (wind) Lidar

- Mixed network design
  - 5 Halo Streamline XR+
  - 3 Leosphere 100S Windcube
- 24-hr PBL wind profiles every 3* m up to ~4 km
  - *Halo: overlapping range gates
- Scanning strategy established
  - PPI, 8-beam VAD, vertical stare



Vaisala DIAL Water Vapour Lidar

- 24-hr PBL water vapour profiles every ~100 m up to 3 km
- New commercial version deployed to Ottawa airport (fall 2024)
  - Co-located with a Halo lidar and a **Radiometrics MWR Radiometer**

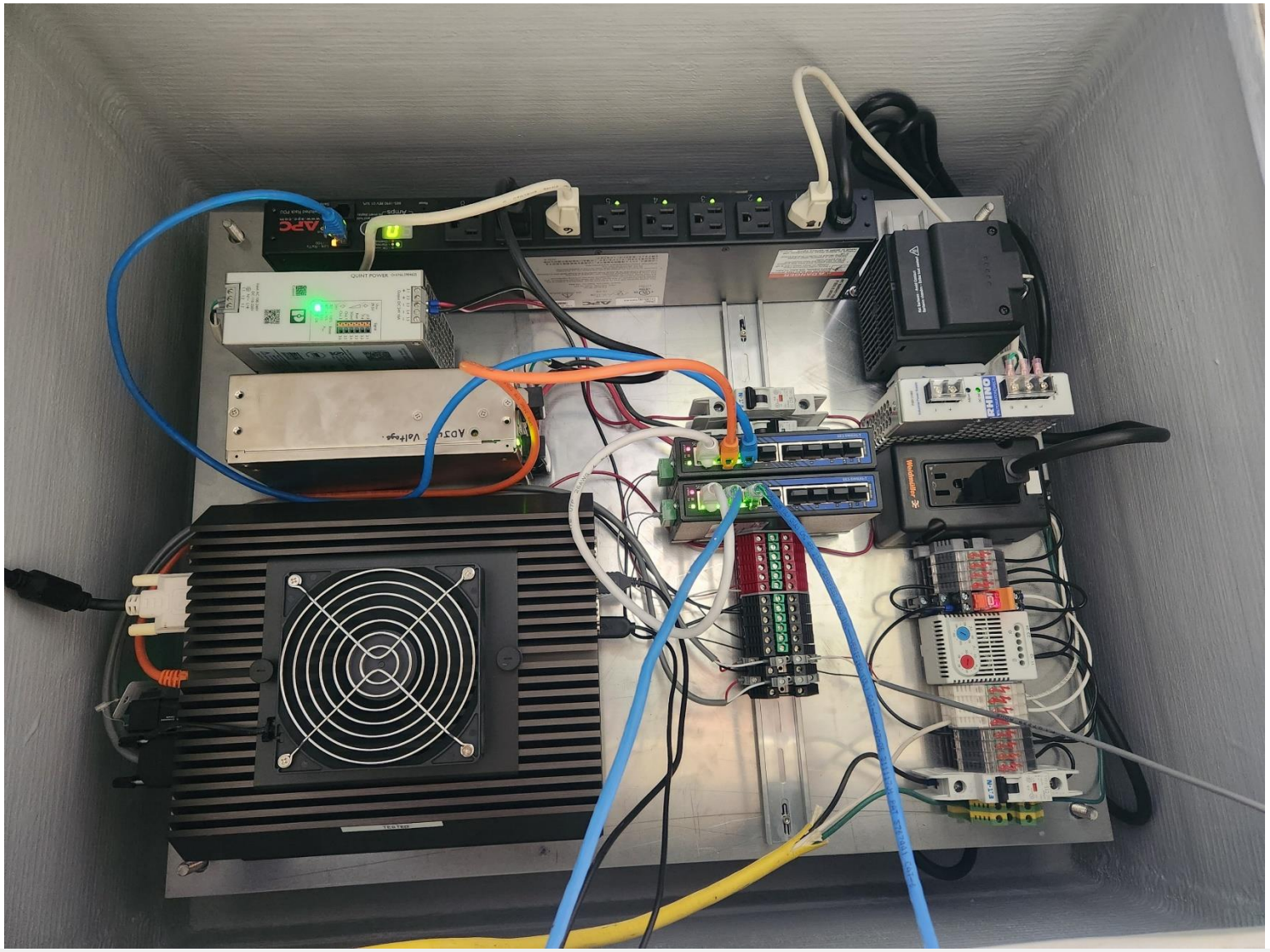




Results in Toronto using the pre-commercial version

Mariani et al. (2020): Toronto water vapour lidar intercomparison campaign. *Remote Sens.*

DATA COLLECTION SYSTEM



Visible:

- Network Power Switch/Bar
- Heater
- Multiple 24VDC P.S.
- 110VAC Duplex (For UPS)
- Breakers
- Terminal Blocks
- Thermostat
- Brick PC (Windows Data Acq.)
- Dual Network Switches

Under Base Plate

- UPS
- Cellular Modem

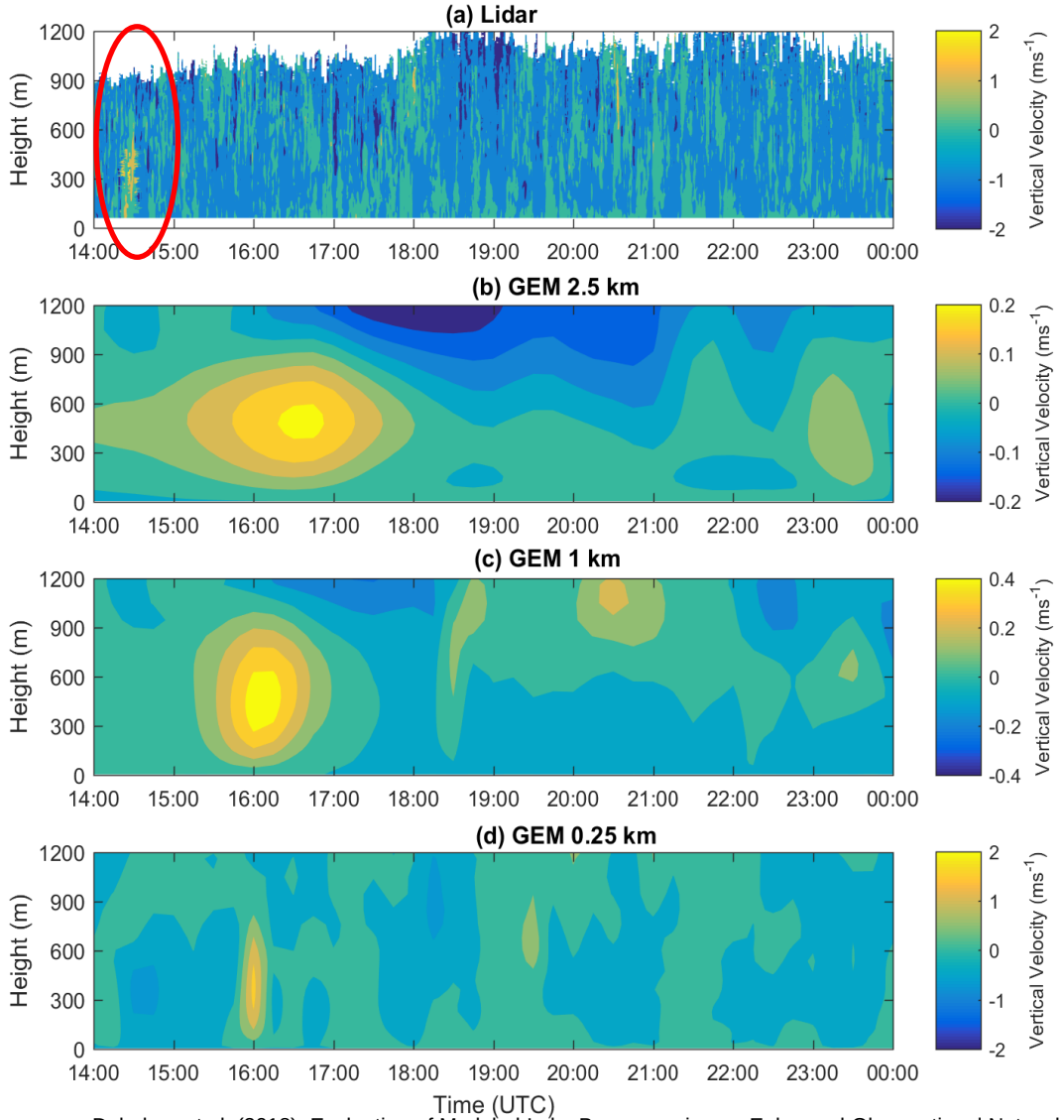
Not Shown: USB HDD

Data is processed and quality-controlled on-site, then FTP'd to ECCC servers for routing and near-real time display

DOPPLER LIDAR OBSERVATIONS: RELIABILITY

- 24/7 autonomous operation during all weather
  - >90% instrument uptime for 6 lidars 2015 - 2023
  - Two lidar failures in the past two months: aging hardware (10yrs)?
- Multi-year, multi-site comparisons indicate excellent agreement in the lidar's wind profile observations
  - Average bias against radiosonde < 0.27 m/s[1]
  - Comparisons against ECCC GEM had similar biases[1]
- Comparisons against radar confirm the ability to detect wind shears and stratified wind layers[2]
- Can detect and track fast-moving meteorological features such as the lake breeze front[3]
- Can detect low level jets, enhanced convection (w), cloud base height, and other features

Doppler lidar observation of the lake breeze front at Toronto Island

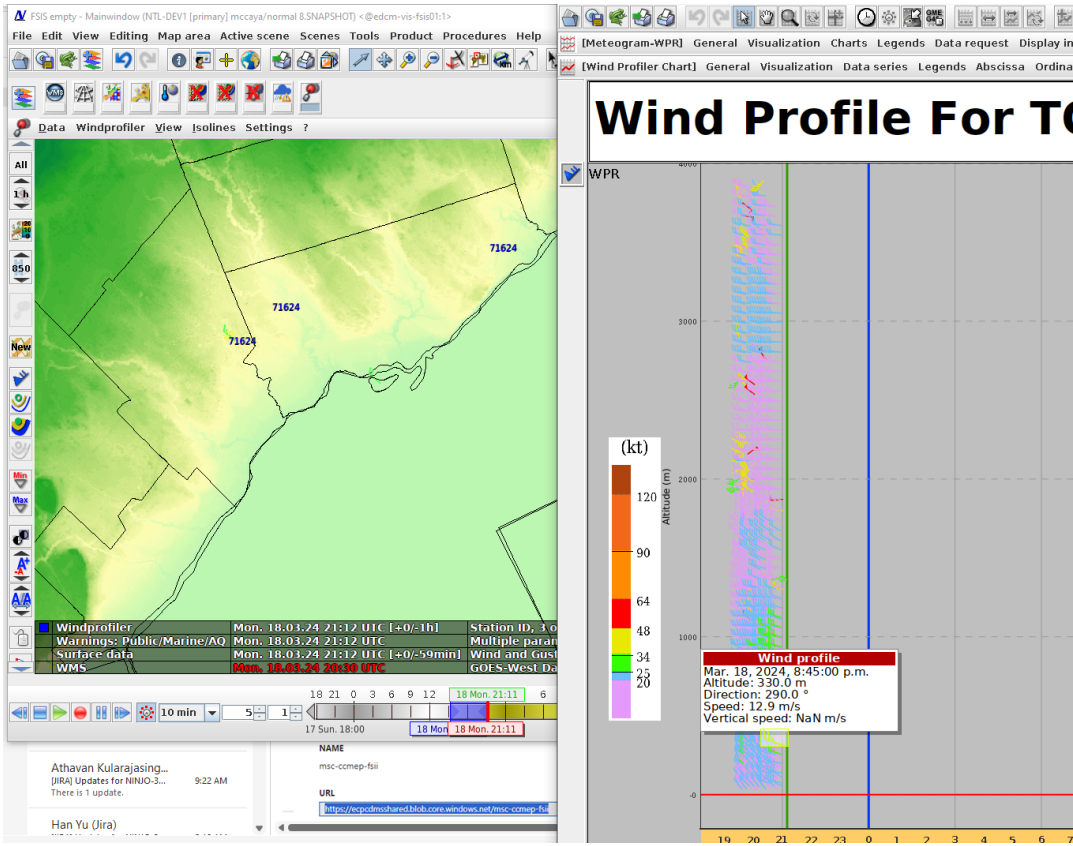


Dehghan et al. (2018): Evaluation of Modeled Lake Breezes using an Enhanced Observational Network in Southern Ontario: Case Studies *J. Appl. Met. and Clim.*

1: Mariani, Z.; Crawford, R.; Casati, B.; Lemay, F. (2020). A Multi-Year Evaluation of Doppler Lidar Wind-Profile Observations in the Arctic. Remote Sens. 2020, 12, 323. https://doi.org/10.3390/rs12020323
2: Mariani, Z., A. Dehghan, G. Gascon, P. Joe, D. Hudak, K. Strawbridge, and J. Corriveau: Multi-instrument observations of prolonged stratified wind layers at Iqaluit, Nunavut. Geophys. Res. Lett., 45 (3), 1654-1660.
3: Mariani, Z., A. Dehghan, D.M. Sills, and P. Joe: Observations of Lake Breeze Events during the Toronto 2015 Pan-American Games. Boundary-layer Meteor. (Open Access), 166(1), 113-135, DOI: 10.1007/s10546-017-0289-3.

FORECASTER FEEDBACK: MAIN TAKEAWAYS

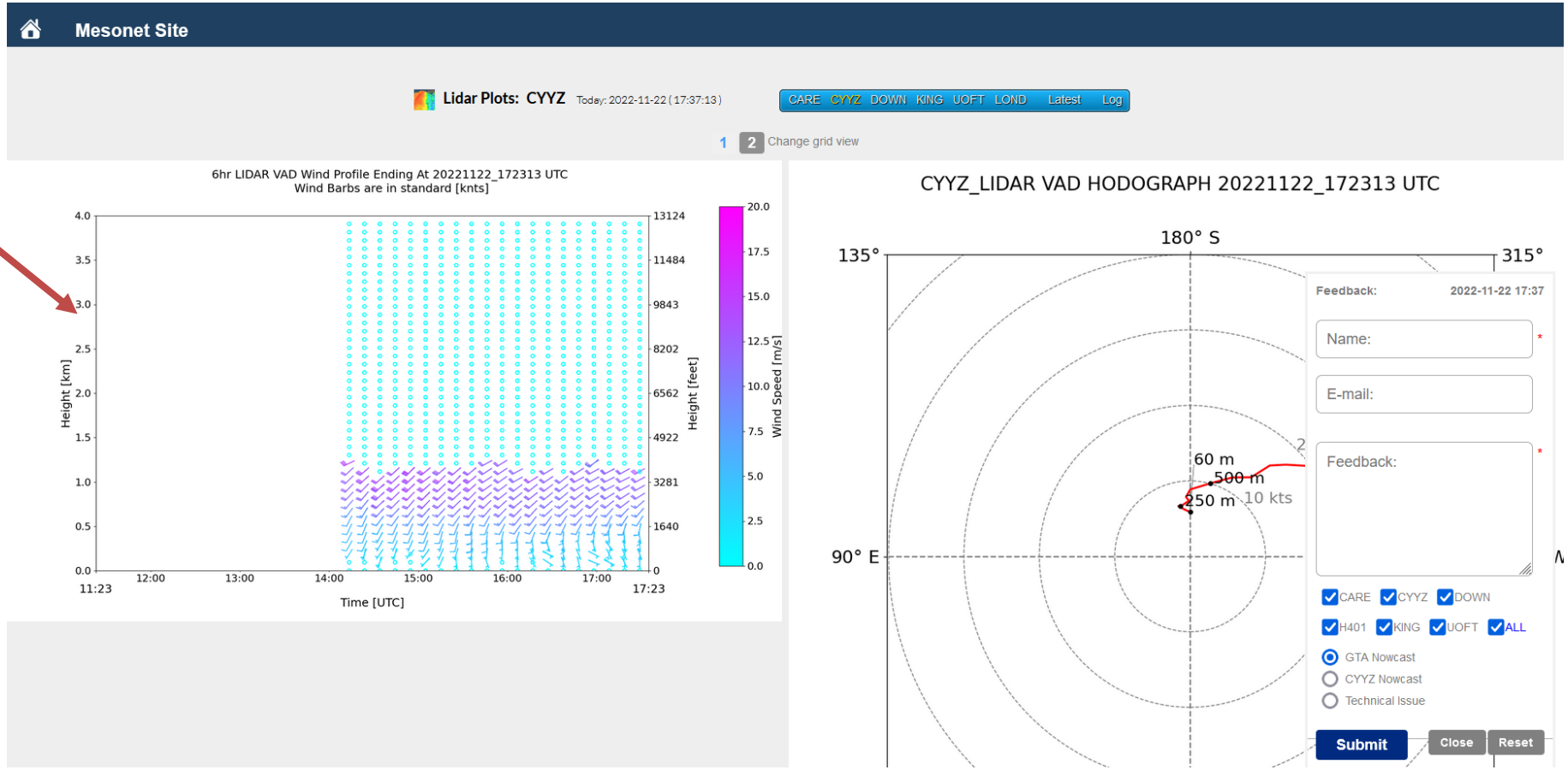
- Positive impact assessment thus far
  - Strong user uptake
  - Investigating potential nowcasting applications
- Primary benefit: aviation nowcasting
  - Increasing confidence in reporting upper air winds
  - Upper air wind data also sent to NavCanada and Pearson Airport Authority
  - Incident reporting and investigations
- Severe weather detection & tracking
  - Convective initiation
  - Storm track adjustments
  - Lake breezes
- Impact analysis ongoing for:
  - Gap-filling upper air observations (complement radiosondes)
  - Potential (?) for derecho and tornado events
    - Low-level shear underestimated by models during EF0 event Nov 11, 2024
  - Network design optimization



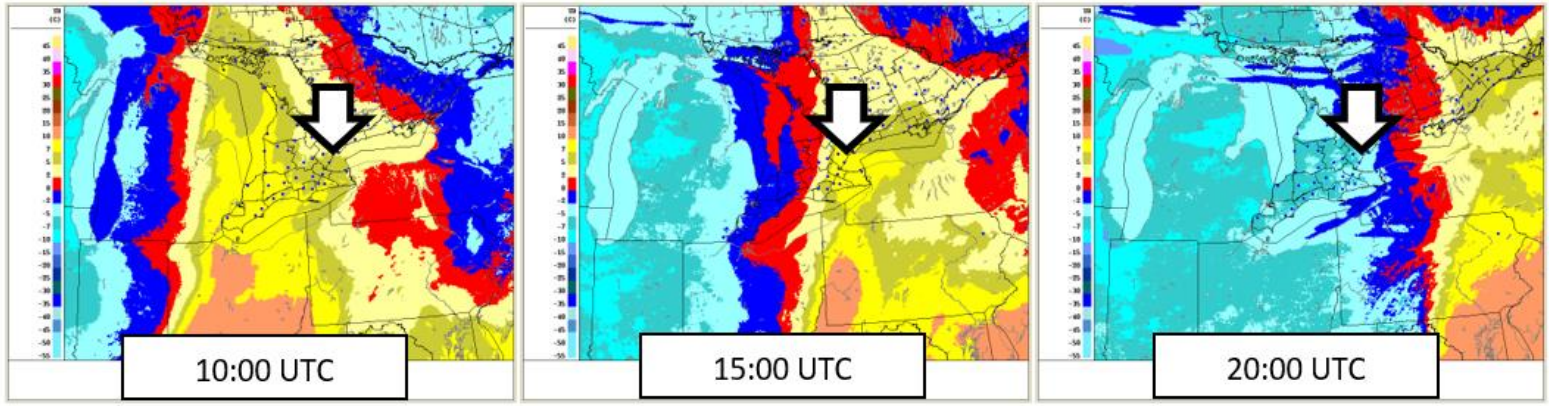
Example real-time wind barb display for operational forecasters on NinJo software

SOLID MESONET REAL-TIME DATA FEED

- Wind profile data is quality controlled & delivered to forecasters in real-time
- NinJo feed available
  - External webpage http://hiwr.ca/mesonet.php to view wind profiles in real-time
- New profile every 10 minutes
- Timelapse available
- Real-time products:
  - Vertical wind profile (u, v),
  - Vertical velocity (w),
  - Cloud base height,
  - Boundary layer height (PBLh)
- Also available: water vapour (from the DIAL) and thermodynamic profiling (from the radiometer)
  - Not yet available in Ninjo



NOWCASTING CASE STUDY 1: COLD FRONT



ages showing the movement of the cold front across Southern Ontario on
e arrows indicate the location of Toronto Pearson Airport. Retrieved from
e Change Canada. (2022). GEM forecast [Dataset].

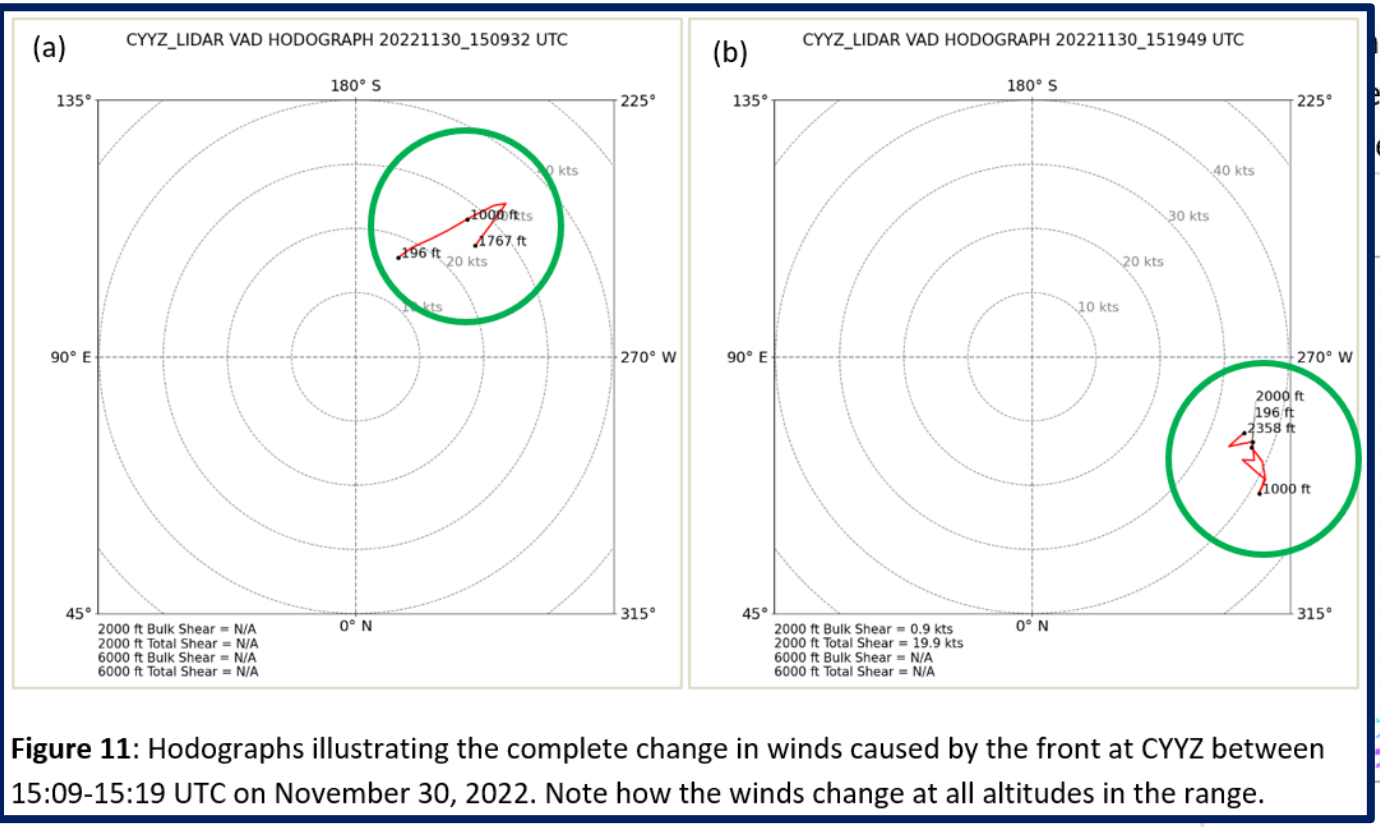


Figure 11: Hodographs illustrating the complete change in winds caused by the front at CYYZ between 15:09-15:19 UTC on November 30, 2022. Note how the winds change at all altitudes in the range.

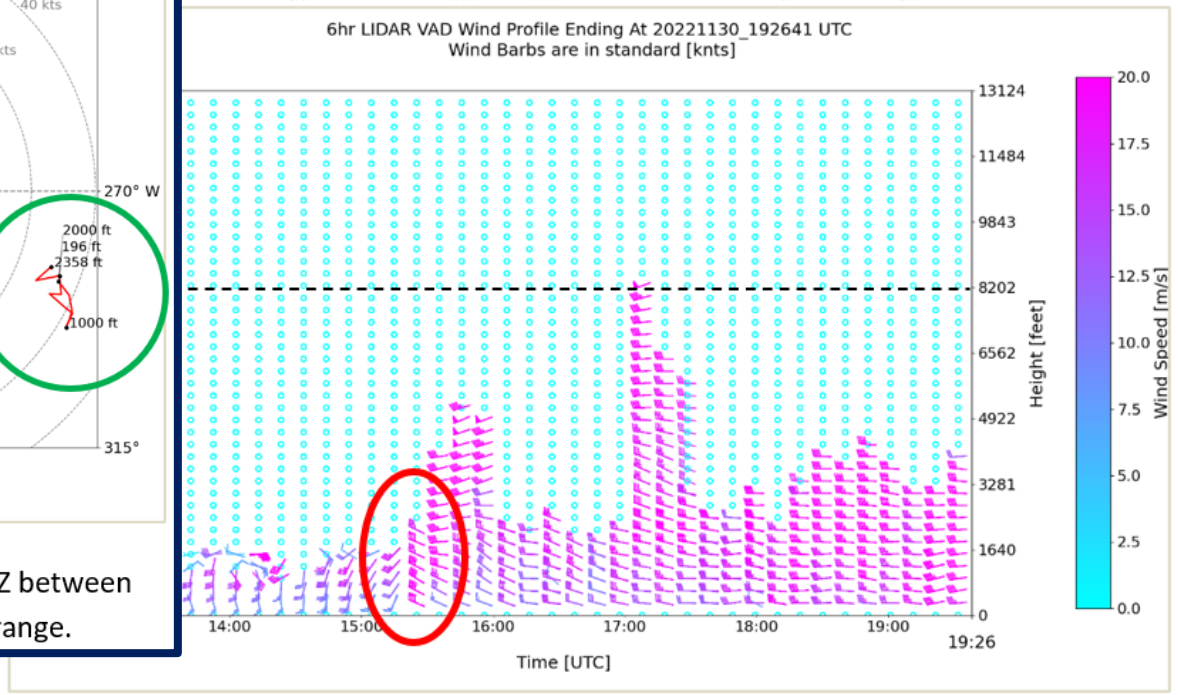


Figure 10: 6-hour VAD wind barb plot from 13:26-19:26 UTC on November 30, 2022 showing the abrupt change in wind speed and direction when the cold front passed the CYYZ site.

NOWCASTING CASE STUDY 2: HARD LANDING AT TORONTO PEARSON AIRPORT

- Cold frontal passage at th
  777 flight on Nov 13, 202
- Stronger, surprising NW v
  immediately prior to landi
- Peak in upwards motion a
  rapid switch to descent in
  (vertical velocity plot: blue
- **Mesonet is the only sou**
- Case is still under investig

NATIONAL POST

Wind shear whistleblower warns of dangerous landing conditions at Canadian airports

On a flight to Kamloops from Vancouver last year passengers who weren't strapped in tightly hit the ceiling. Some prayed, others screamed

Chris Lambie

Published Dec 30, 2024 • Last updated 1 week ago • 6 minute read

70 Comments



Investigators review the remains of the Air France plane which crashed on landing, at Pearson Airport in Toronto, on Aug. 3, 2005. PHOTO BY DAVID DUPREY /AP

NATIONAL POST

News / Canada

Air Canada flight narrowly avoids crash-landing at Toronto Pearson Airport

'I work on the ramp at Toronto Pearson and witnessed this. It truly looked like the plane had lost control,' read one comment on the video

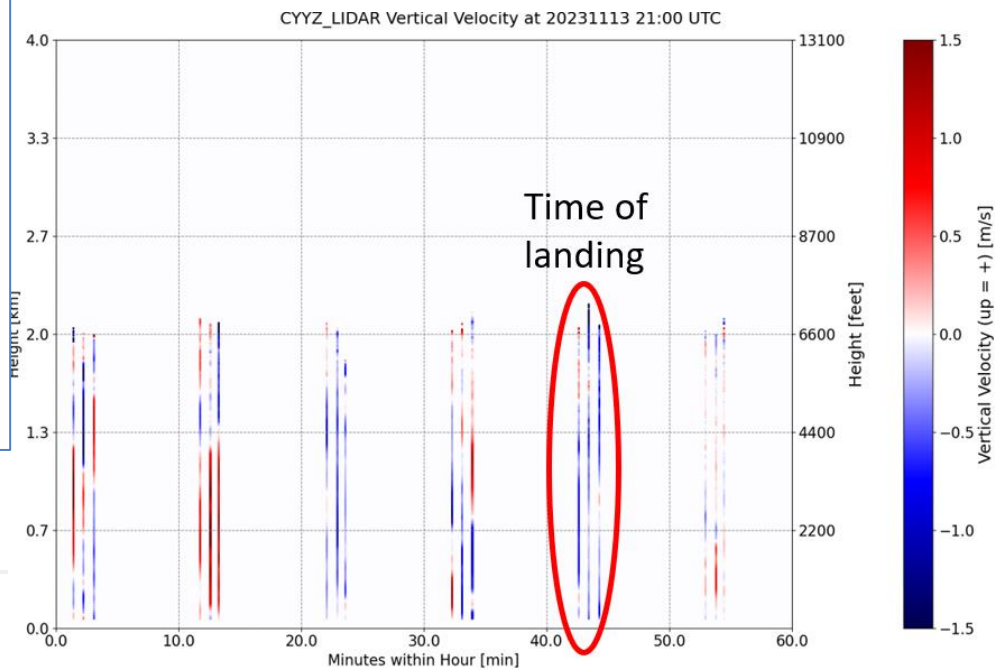
Lynn Chaya

Published Nov 15, 2023 • Last updated 5 days ago • 1 minute read

155 Comments



The viral video has nearly 115,000 views with aviation fans chiming in on the "very rare event," one commenter said. PHOTO BY WAKE TURBULENCE AVIATION/YOUTUBE



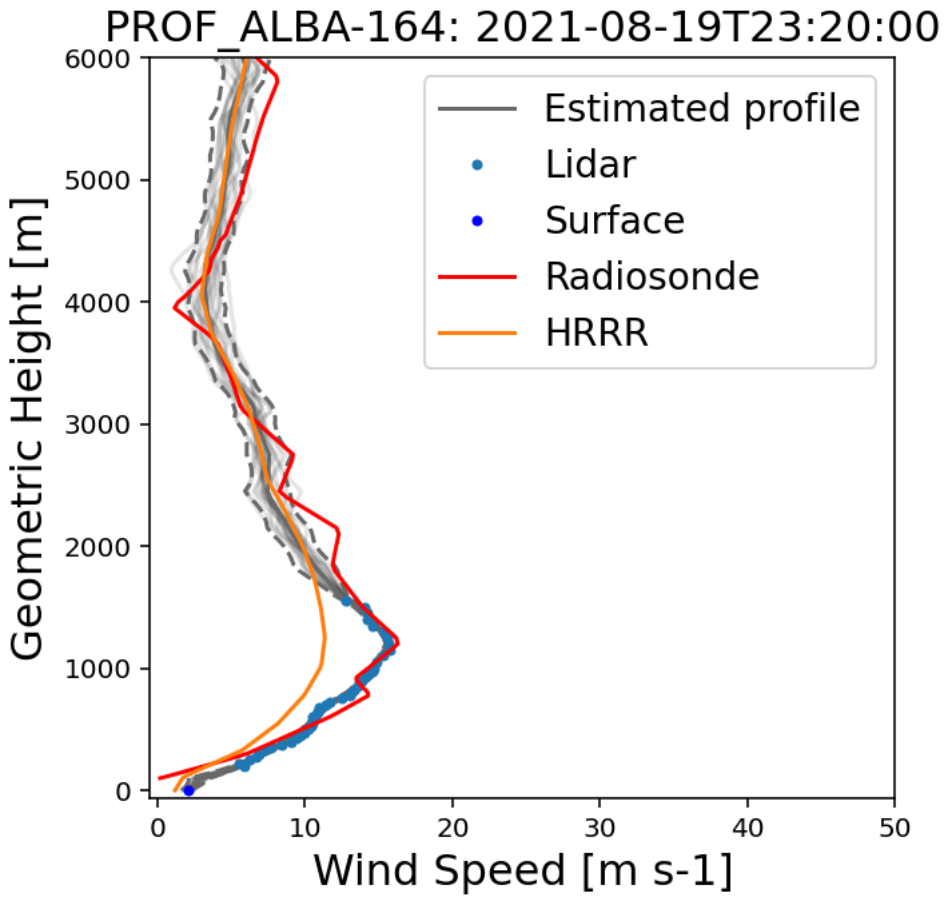
APPLICATION: ESTIMATION OF METEOROLOGICAL INDICES

Optimal estimation:

- Posterior mean and covariance given Doppler lidar wind profiles, surface observations and background model (HRRR)
- Can sample an ensemble of possible realizations
- Fill data gaps, allow computation of met. indices for the whole vertical range / grid
- Low latency, with higher temporal resolution than radiosondes
- Next step: full 3D estimation

Validation:

- Compare estimated profiles VS radiosondes
- Compare estimated profiles against held out observations
- Compare estimated profiles against ERA5 reanalysis



Example: 1-3 km mean wind speed

HRRR = 9.5 m/s

Radiosonde = 11.8 m/s

Optimal estimation = 10.5 ± 0.25 m/s

** Note: cherry-picked example for illustrative purpose*

Conclusions

- SOLID Mesonet provides 24/7 observations to operational forecasters from 8 Doppler lidars, one DIAL (water vapour profiling), and one radiometer (T, water vapour profiling)
- Data is openly available (archive or real-time, raw vs. products, all available)
- Focus has been on winds: demonstrated need for co-located thermodynamic profiling
- Positive impact assessment and user feedback from operational forecasters
- Additional applications:
  - Developing interpolated meteorological indices (SOLID+NYS Mesonet) on the grid for severe weather indices
  - SOLID Mesonet observations for air quality studies and modelling (e.g., **Study of Winter Air Pollution in Toronto, SWAPIT campaign, winter 2024**) → turbulence from Doppler lidar
  - Ottawa airport site → aircraft calibration/validation campaigns (e.g., the current **ESA EarthCARE** and **FORUM satellite ECALOT & WHAFFFERS cal/val campaigns**)
  - Data assimilation into NWP models: ongoing impact assessments

