Environment and Climate Change Canada Environnement et Changement climatique Canada

Measuring Solid Precipitation in Canada: Lessons Learned from SPICE (and beyond)

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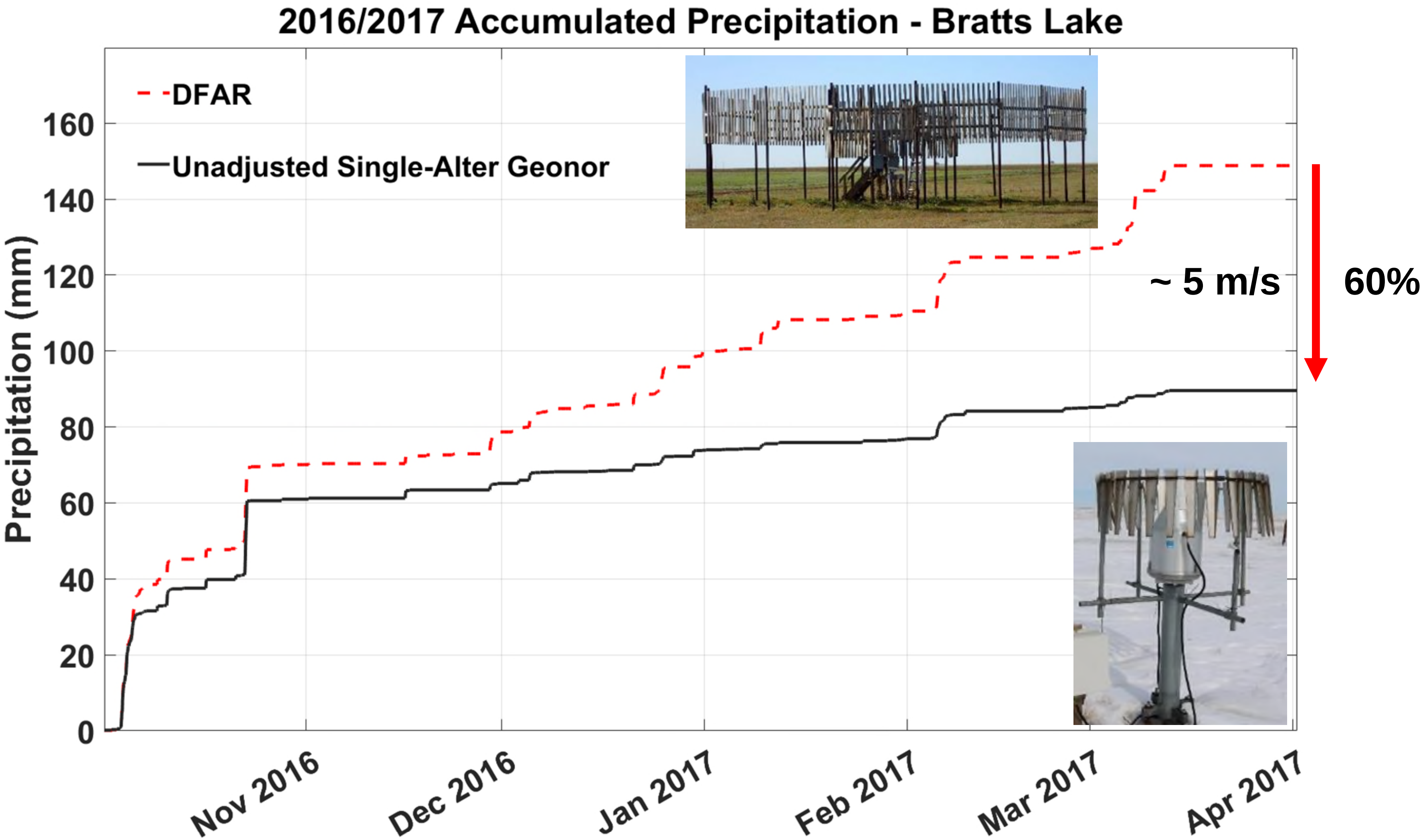
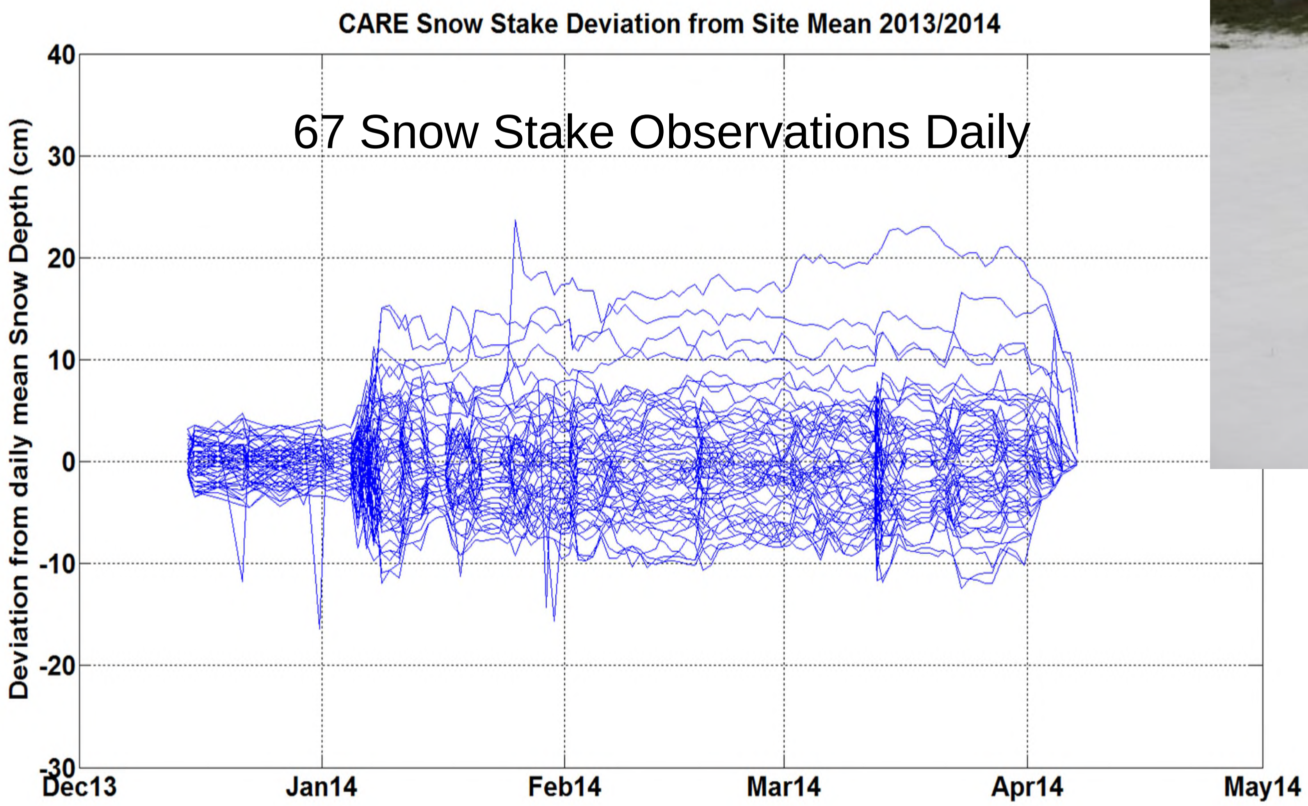
INTRODUCTION

- The in situ measurement of solid precipitation remains one of the most difficult meteorological measurements to make with any known level of accuracy and precision
- Observer effect theory: the mere observation of a phenomenon inevitably changes that phenomenon
- Systematic bias in the gauge measurement of solid precipitation due to wind can be **100%**
- Some aspects of the WMO guidelines for establishing meteorological sites are fundamentally flawed for accurate in situ solid precipitation measurement: exposure is not our friend!



2016/2017 Accumulated Precipitation - Bratts Lake
DFAR
Unadjusted Single-Alter Geonor
Precipitation (mm)
0
20
40
60
80
100
120
140
160
Nov 2016
Dec 2016
Jan 2017
Feb 2017
Mar 2017
Apr 2017
~ 5 m/s
60%

Spatial variability in snow depth



Sensor siting is important!

WMO SOLID PRECIPITATION INTER-COMPARISON EXPERIMENT (SPICE)

- **Objective:** to provide guidance on the performance and use of automated methods for the measurement of solid precipitation and snow on the ground

- 2 field seasons: **2013/2014** and **2014/2015**
- 16 countries hosting a total of 20 field sites
- > 200 sensors under test
- 1429 p. report, 15+ publications

Legend

1.	Caribou Creek, Saskatchewan, Canada	11.	Haukeliseter, Norway
2.	Bratt's Lake, Saskatchewan, Canada	12.	FMI/Sodankylä Arctic Research Centre, Finland
3.	Marshall Site, Colorado, USA	13.	Valdai, State Hydrological Institute, Russia
4.	CARE, Ontario, Canada	14.	Voljskaya Observatory, Gorodec, Russia
5.	Tapado AWS, Región de Coquimbo, Chile	15.	Pyramid Observatory, Nepal
6.	Formigal, Spain	16.	Gochang, Korea
7.	Col de Porte, France	17.	Joetsu, Japan
8.	Weissfluhjoch, Davos, Switzerland	18.	Rikubetu, Hokkaido, Japan
9.	Forni Glacier, Italy	19.	Guthega Dam, New South Wales, Australia
10.	Hala Gasienicowa Station, Poland	20.	Mueller Hut Weather Station, New Zealand

https://library.wmo.int/index.php?lvl=notice_display&id=20742

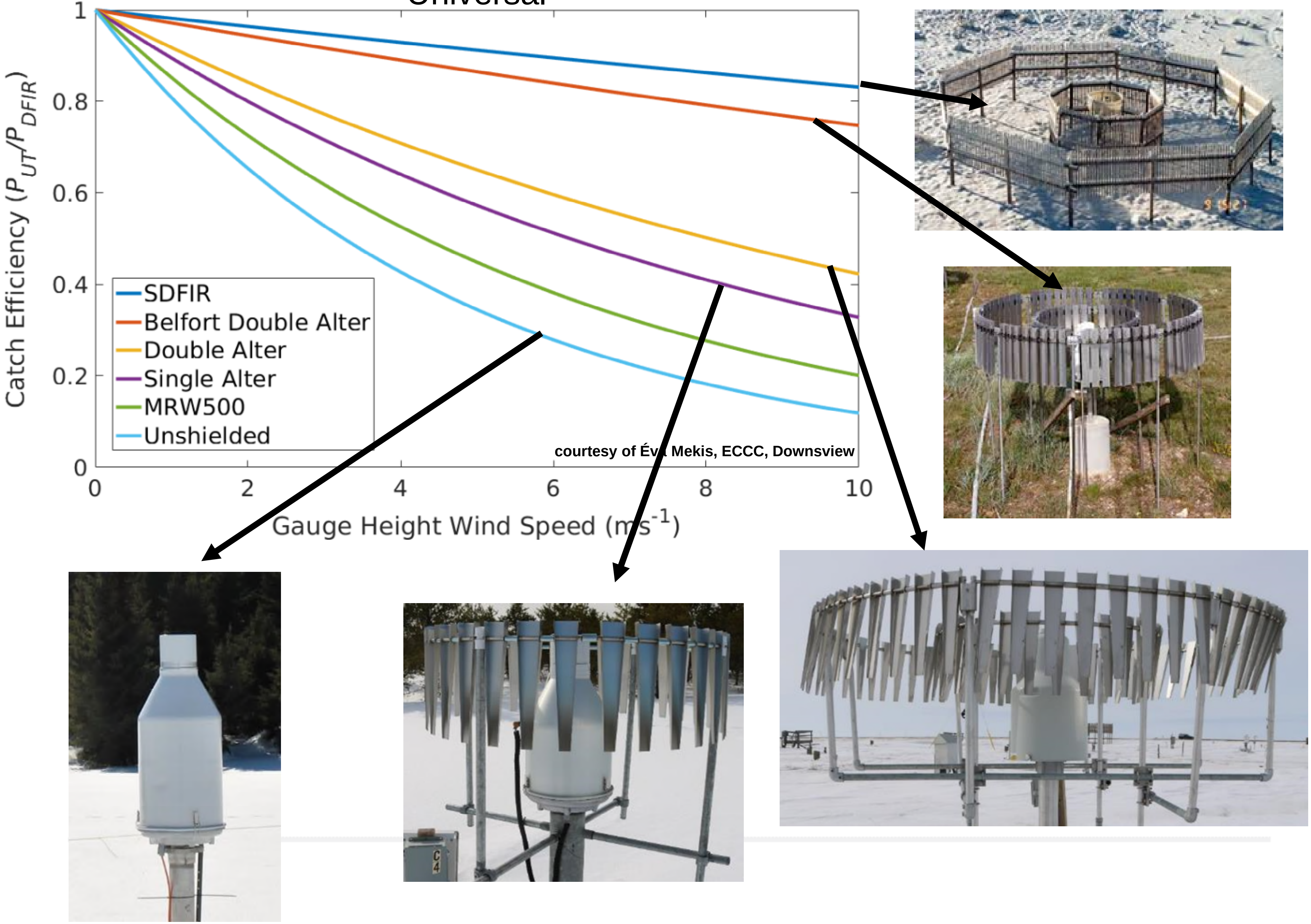
SPICE REFERENCE MEASUREMENTS

Double Fence Automated Reference (DFAR)

Graduated Snow Stakes

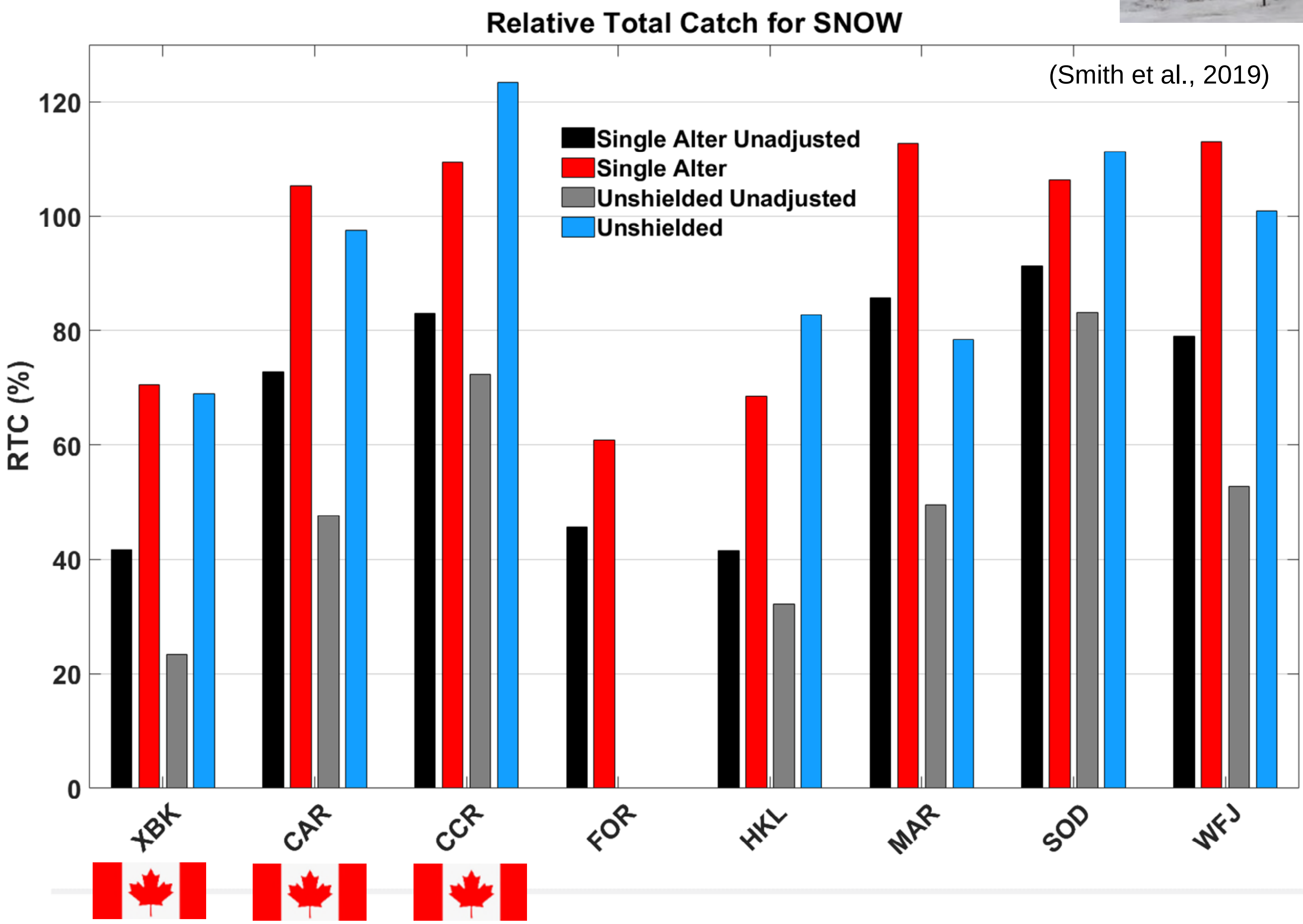
Snow Course

Gauge Catch Efficiency vs. Wind Speed
“Universal”



Post-SPICE Transfer Function Evaluation

2015/2016 & 2016/2017

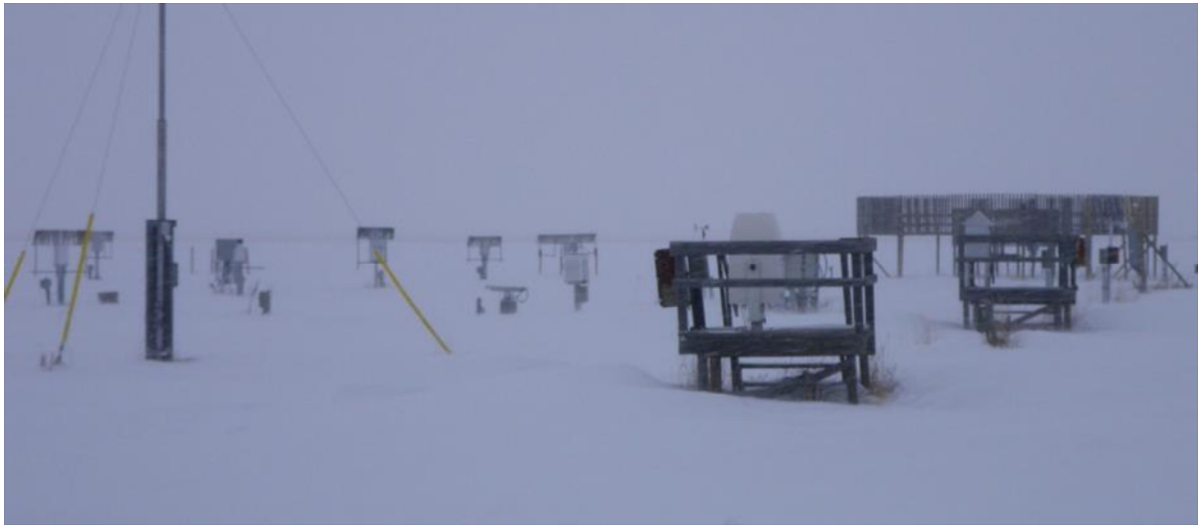


DFAR

Single Alter

Unshielded

Why are the SPICE transfer function so terrible on the Canadian Prairies?

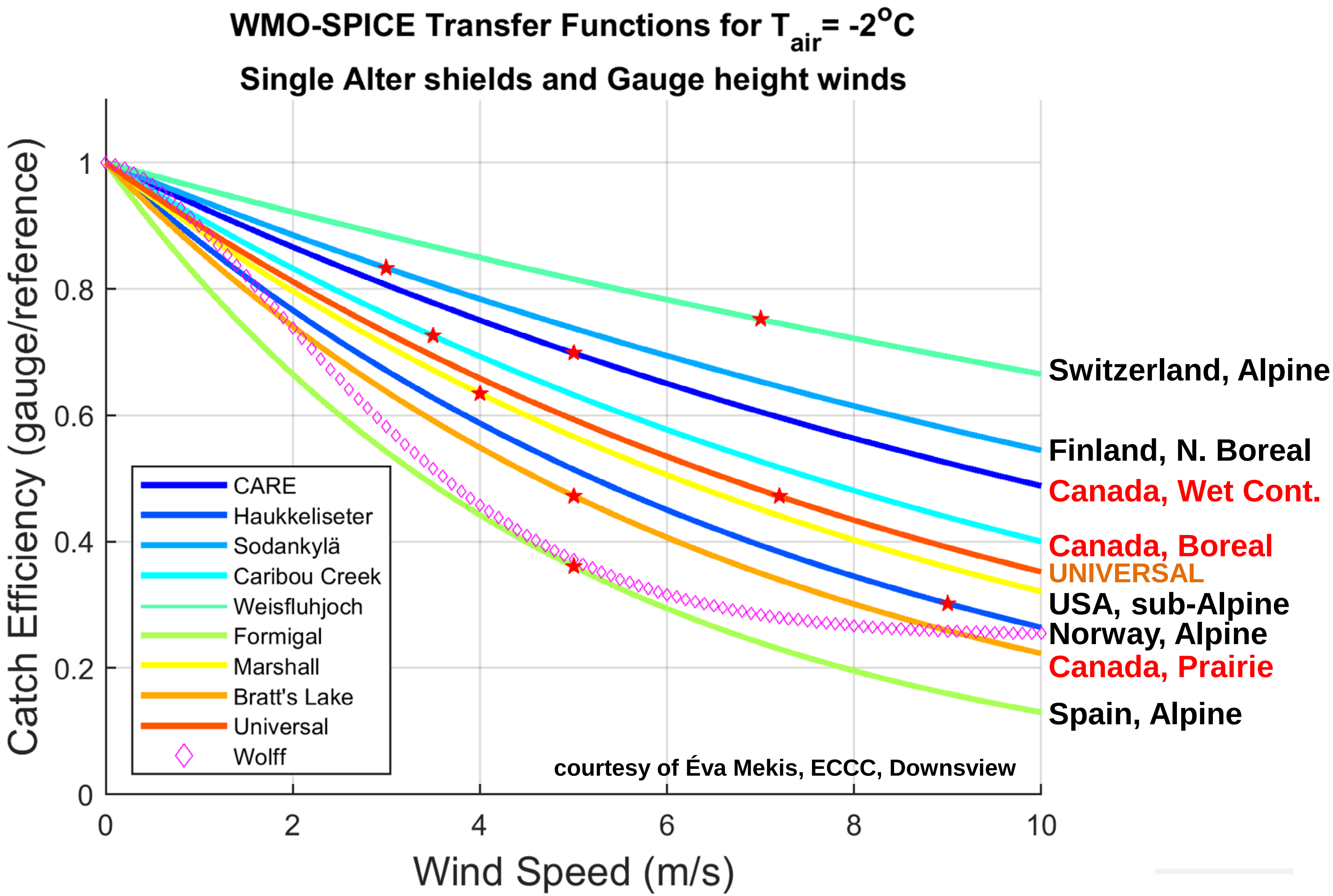


During the 2015/2016 & 2016/2017 winters at Bratt's Lake:

- DFAR measured 498 30-min snow events > **0 mm**

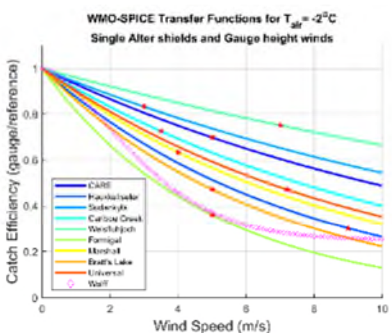
- Single Alter Geonor measured **0 mm** for 285 of those events
  - ➢ **14%** of the total precipitation recorded by the DFAR

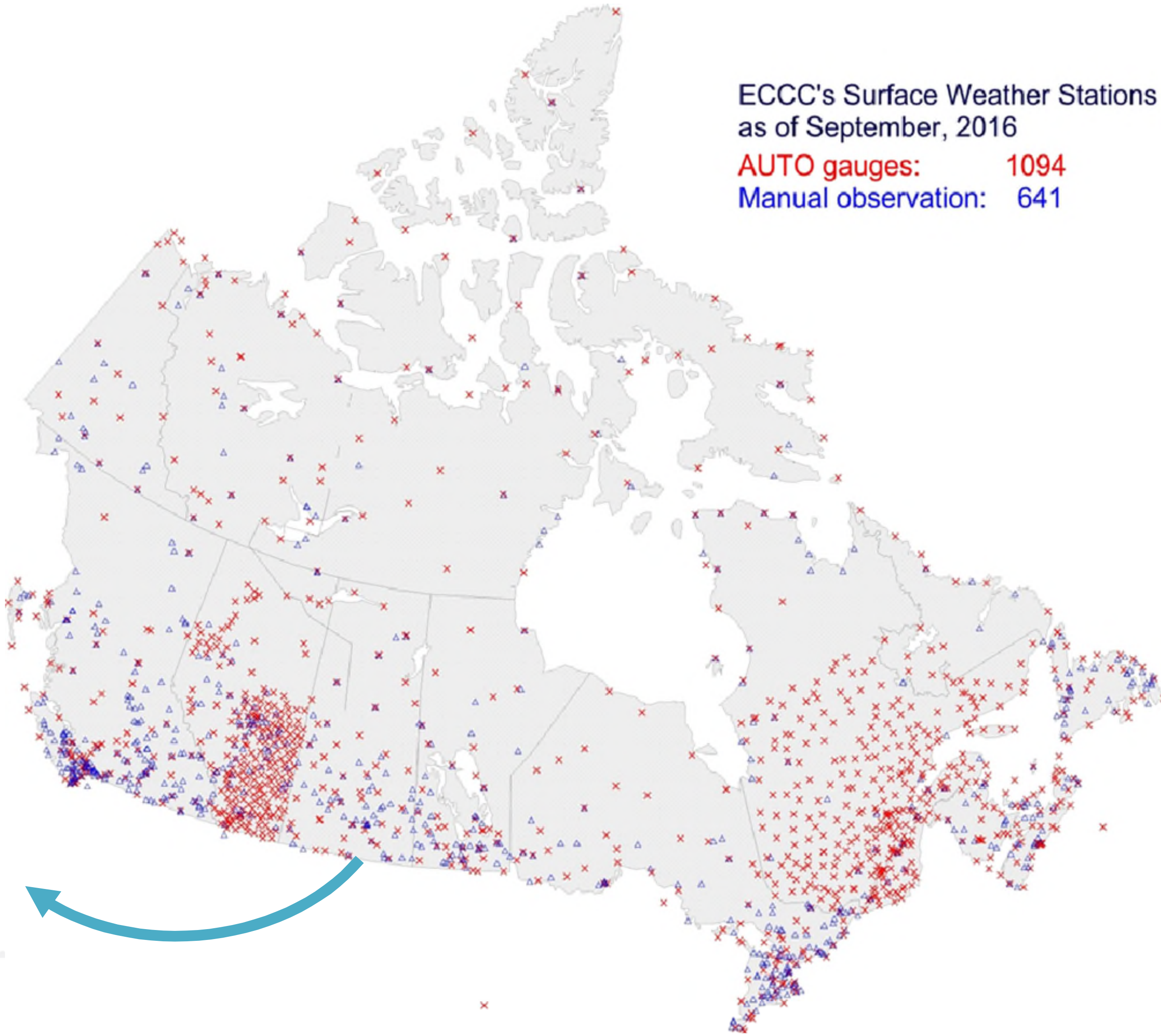
- Unshielded Geonor measured **0 mm** for 376 of those events
  - ➢ **24%** of the total precipitation recorded by the DFAR
- The transfer function performance is irrelevant…**you can't adjust 0!**



WMO-SPICE Transfer Functions for T_{air} = -2°C
Single Alter shields and Gauge height winds
Catch Efficiency (gauge/reference)
Wind Speed (m/s)
0
0.2
0.4
0.6
0.8
1
0
2
4
6
8
10
CARE
Haukkeliseter
Sodankylä
Caribou Creek
Weisfluhjoch
Formigal
Marshall
Bratt's Lake
Universal
Wolff
Switzerland, Alpine
Finland, N. Boreal
Canada, Wet Cont.
Canada, Boreal
UNIVERSAL
USA, sub-Alpine
Norway, Alpine
Canada, Prairie
Spain, Alpine
courtesy of Éva Mekis, ECCC, Downsview

THE ENVIRONMENT AND CLIMATE CHANGE CANADA WEATHER STATIONS





- Required metadata
- Precipitation typing
- Assessment ??

SPICE Snow Depth Sensor Evaluation

Ultrasonic

Laser

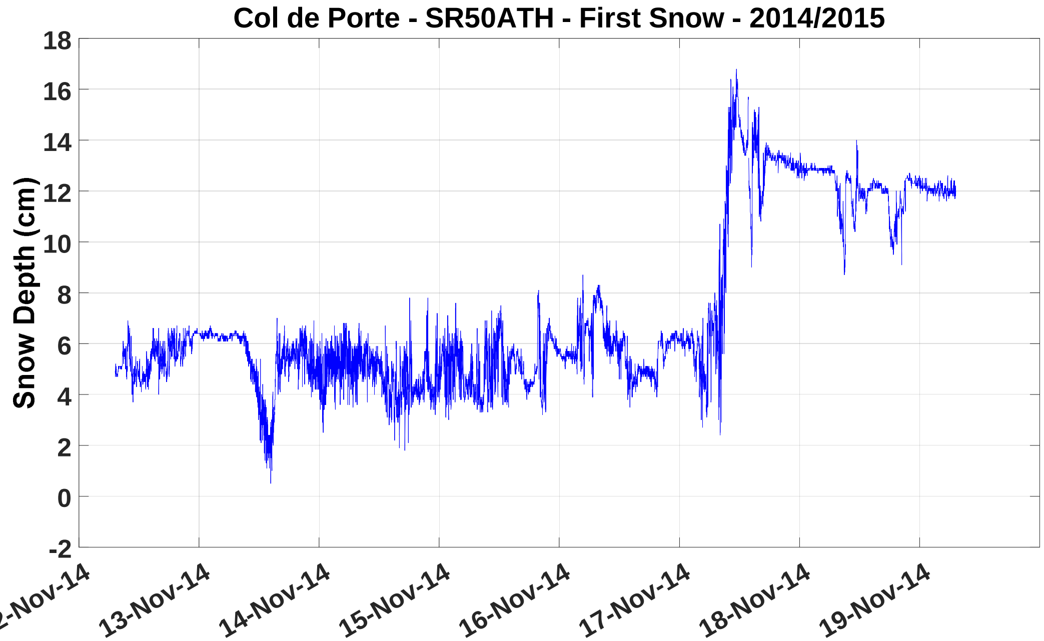
Pros:
- Less $$
- Requires less power

Cons:
- Lower accuracy and precision
- Requires a temperature measurement → source of error and noise
- Needs a flat reflective surface
- Measures the distance to the highest object in the target area

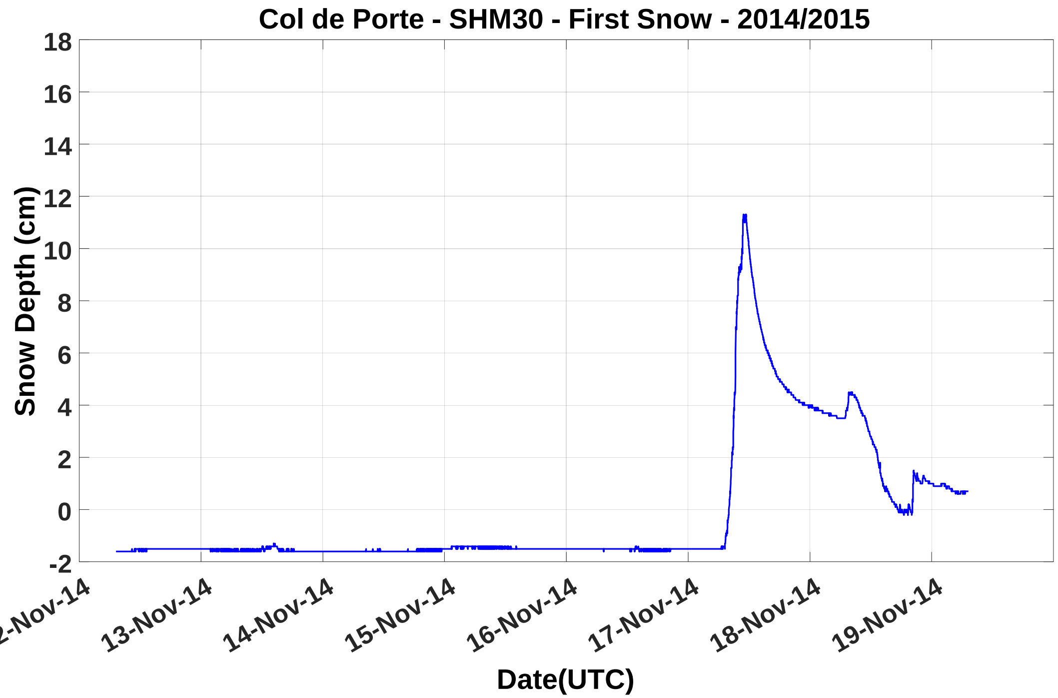
Pros:
- Higher accuracy and precision
- No temperature correction
- Surface target is less important
- Can provide instant snow yes/no

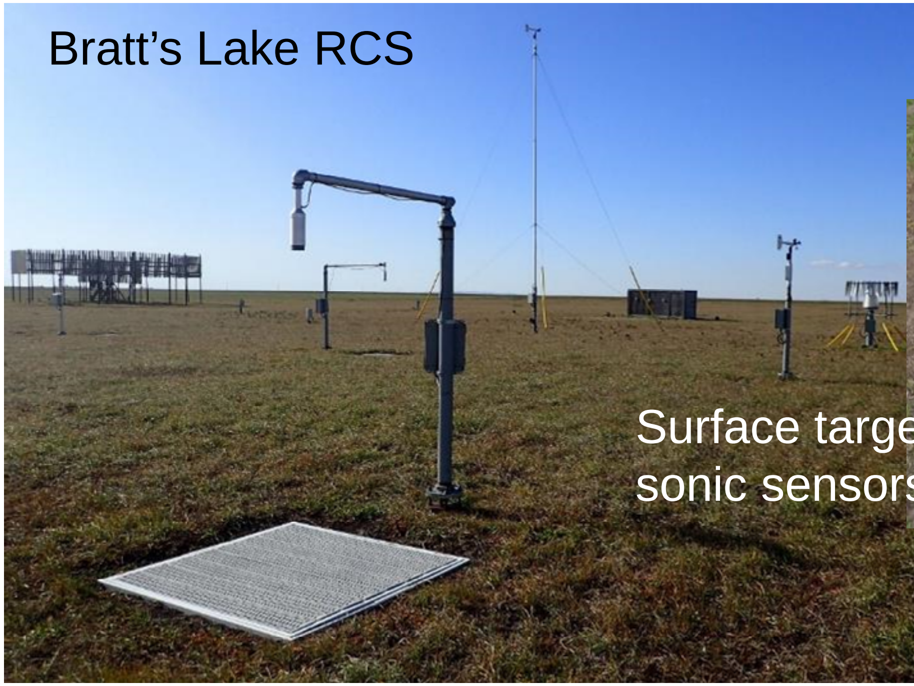
Cons:
- More $$
- Requires more power

➢ **Both sensors provide a point measurement of snow depth and don't account for spatial variability**



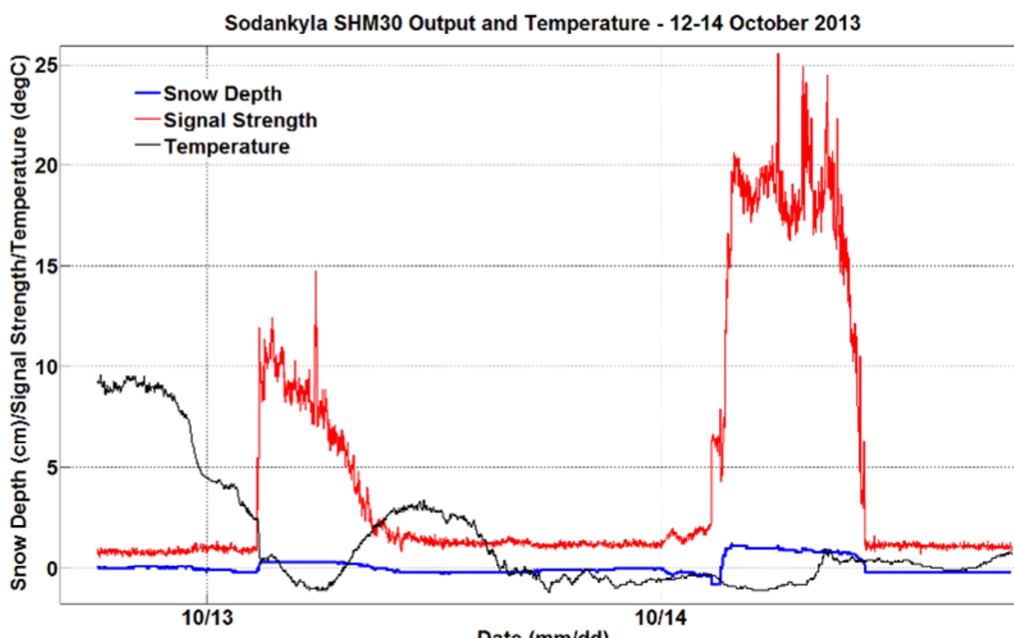
Base Target
Mown Grass





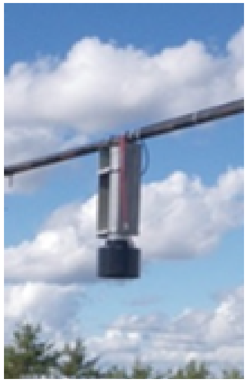
Surface target for sonic sensors

Laser sensors can use optical response to determine the presence of snow under the sensor



SPICE SWE Sensor Evaluation

Passive Gamma



Pros:

- Relatively large footprint
- Easy above ground installation
- Not influenced by infrastructure
- No maintenance required

Cons:

- $$
- Long (24 hr) integration period
- Sensitive to pre-freeze-up soil moisture changes
- Seems to be sensitive to infiltration during melt

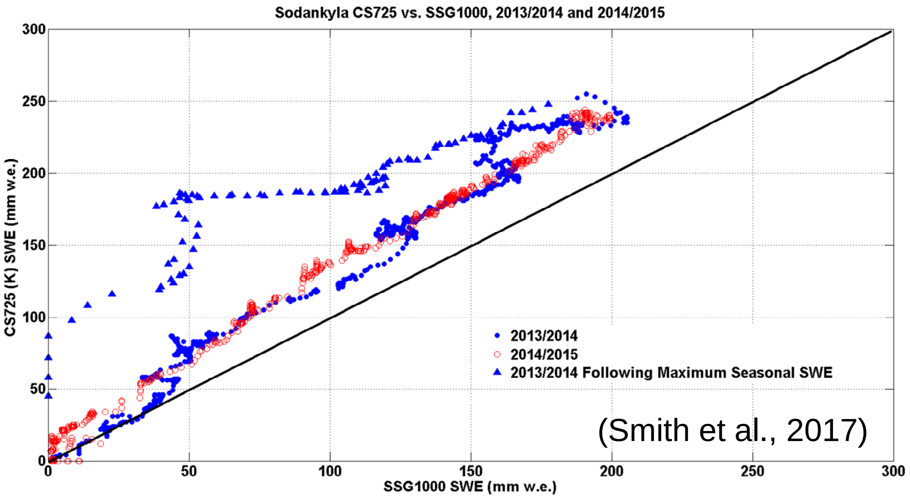
Snow Scales

Pros:

- Higher precision, higher frequency
- Direct measurement of snow mass

Cons:

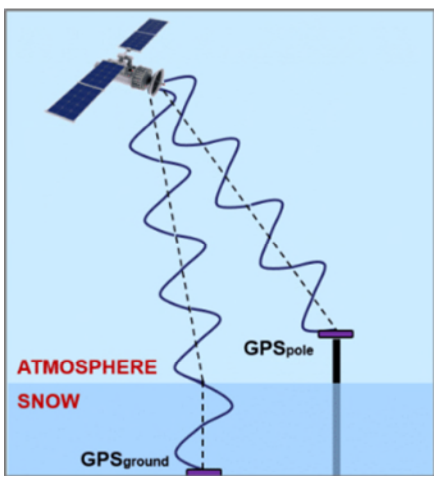
- Harder to install, more maintenance
- Snow “bridging”



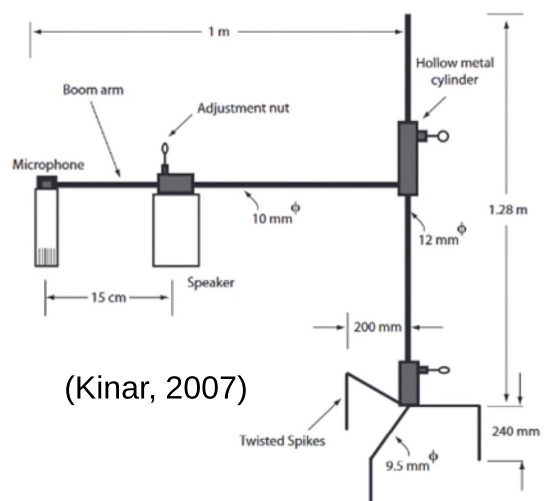
Emerging Technology: SWE Sensors

GNSS/GPS Dual Receiver

(Appel et al., 2019)



System for Acoustic Sensing of Snow

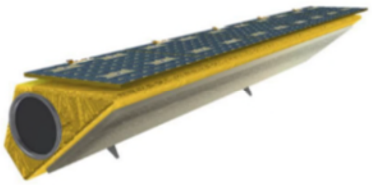


(Kinar, 2007)

Analysis of reflected acoustic waves to derive:

- Depth
- Density
- Liquid water content
- Temperature

New opportunities in remote sensing of snow



- ECCC has identified the need for moderate resolution (250-500 m) information on seasonal snow mass to fill observation gaps
- Canadian Space Agency (CSA) engaged to develop a new satellite mission → Single-aperature, dual frequency Ku-band (17.2/13.5 GHz) radar developed by AIRBUS
- Ku-band maximizes SWE retrieval capabilities and snow microstructure characteristics
- 500 km swath, complete coverage of Canada every 5 days
- Phase 0 science activities in progress

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CSA ASC

WILFRID LAURIER UNIVERSITY

UNIVERSITY OF MASSACHUSETTS MIRSL MICROWAVE REMOTE SENSING LABORATORY

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MSC Surface Network Renewal & the Precipitation Round Table (PRT)

Overall Objectives of the PRT:

- Coordinate the precipitation initiative and activities across ECCC
- Identify current issues / gaps and to discuss potential improvements
- Advise MSC toward a renewed surface network
- Make the information accessible for all

The activities are divided into 3 themes:

1. Instrumentation (ground-based observations) – with focus on sensors
   - requirements (elements, networks) *[what; where]*
   - recommendations regarding surface-based precipitation sensors *[how]*
2. Integration – Radar, Space-based and Surface Networks
   - what space-based measurements can provide for surface precipitation
3. Precipitation Data Analysis and Management – with focus on data quality
   - clarify end-to-end precipitation-related data and metadata management (data collection, processing, algorithms, archiving, distribution) and data analysis procedures (QA/QC)

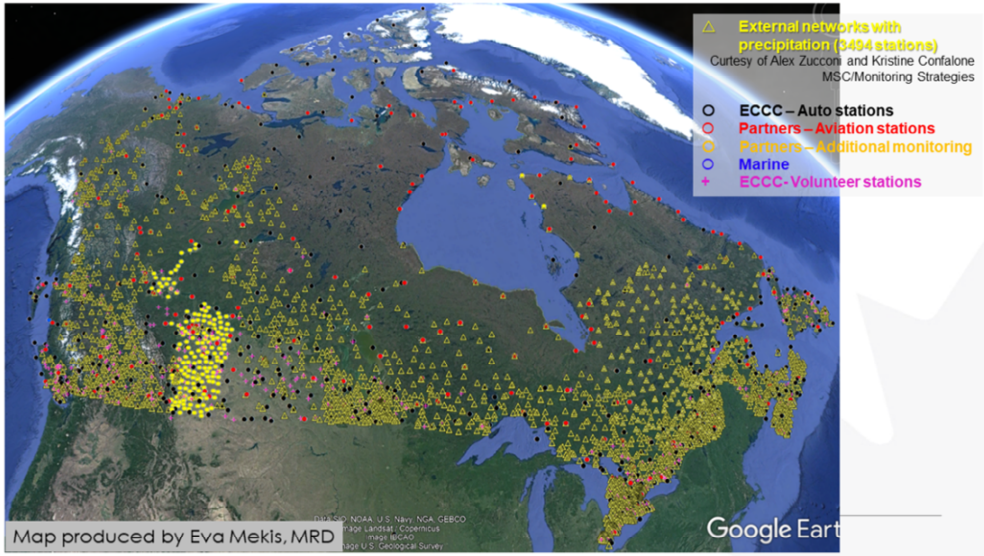
Precipitation elements (scope):

- Precipitation amount
- Precipitation rate
- Precipitation type (rain, snow, mixed)
- Light precipitation (formally called Trace)
- Snowfall
- Snow depth
- Snow on the Ground (SOG)
- Blowing snow
- Snow Water Equivalent (SWE)
- Snow extent
- Albedo/radiation
- Weather type elements (freezing rain, ice crystal,….)
- Fog

- MSC planned upgrade of 150 ECCC network stations from Geonor single Alter to Pluvio^2 Double Alter
- 40 new sites with Pluvio^2 Double Alter
- ~50 completed since 2016 → **Metadata!**

ECCC Solid Precipitation Data (in situ)

- Adjusted & Homogenized Canadian Climate Data (AHCCD)
  - 12/24 hour snow ruler depth measurements (**fewer every year**) converted to total precipitation amount based on snowfall density climatologies
  - Probably the best historical product: monthly and (cold) seasonal totals more reliable than short term amounts, not many intercomparisons (e.g. with DFAR)
  - Updated to the end of 2017
- Archived automated (RCS) gauge data
  - Not adjusted for wind bias in the public archive
  - ECCC (CRD) is publishing an adjusted gauge data set but the adjustment is based on a pre-SPICE transfer function (Wolff et al., 2015) that is likely resulting in over-adjustments
  - Updates have been discussed but are not imminent
- CaPA (https://weather.gc.ca/analysis/index_e.html#APCP)
  - Blended/gridded product but does not assimilate solid precipitation measurements when wind speeds > 2 m/s
  - Improvements under development
- Collaborative networks
  - Increasing opportunities (e.g. CoCoRaHS)
  - Unknown data quality



Thank You

Questions?