Environment and Climate Change Canada | Environnement et Changement climatique Canada

# AUTOMATED IN SITU MEASUREMENT OF SOLID PRECIPITATION AND SNOW COVER: LESSONS LEARNED DURING WMO-SPICE AND BEYOND

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**WMO SOLID PRECIPITATION INTERCOMPARISON EXPERIMENT (WMO-SPICE) 2012-2015**

EUMeTrain Snow Event Week, 8 Feb 2021

Canada

# INTRODUCTION

- The measurement of solid precipitation (and snow cover) is still one of the most difficult meteorological variables to make with any known degree of uncertainty
- Observer effect theory: the mere observation of a phenomenon inevitably changes that phenomenon → Precipitation gauges modify the measurement environment

➢ There are a multitude of advantages to automation but technology often tends to increase the sources of uncertainty (e.g. proprietary algorithms/firmware, signal noise, sampling errors, and increasing technical complexity)

## Measurements:

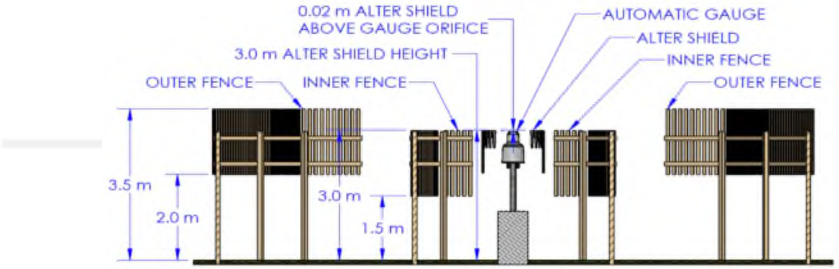
**Solid Precipitation** → Gauges and shielding, bias due to wind and transfer functions, non-catchment instruments and emerging technologies

**Snow Depth** → Sensors, surface targets and infrastructure, siting

**Snow Water Equivalent** → Sensors, emerging technologies

# 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 20 field sites
- 27 sensor types, > 270 total sensors tested
- 1429 p. report (WMO library) , 20+ 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 |

# SOLID PRECIPITATION

**OTT Pluvio$^2$ ***

**Geonor T-200B***

**MPS TRwS**

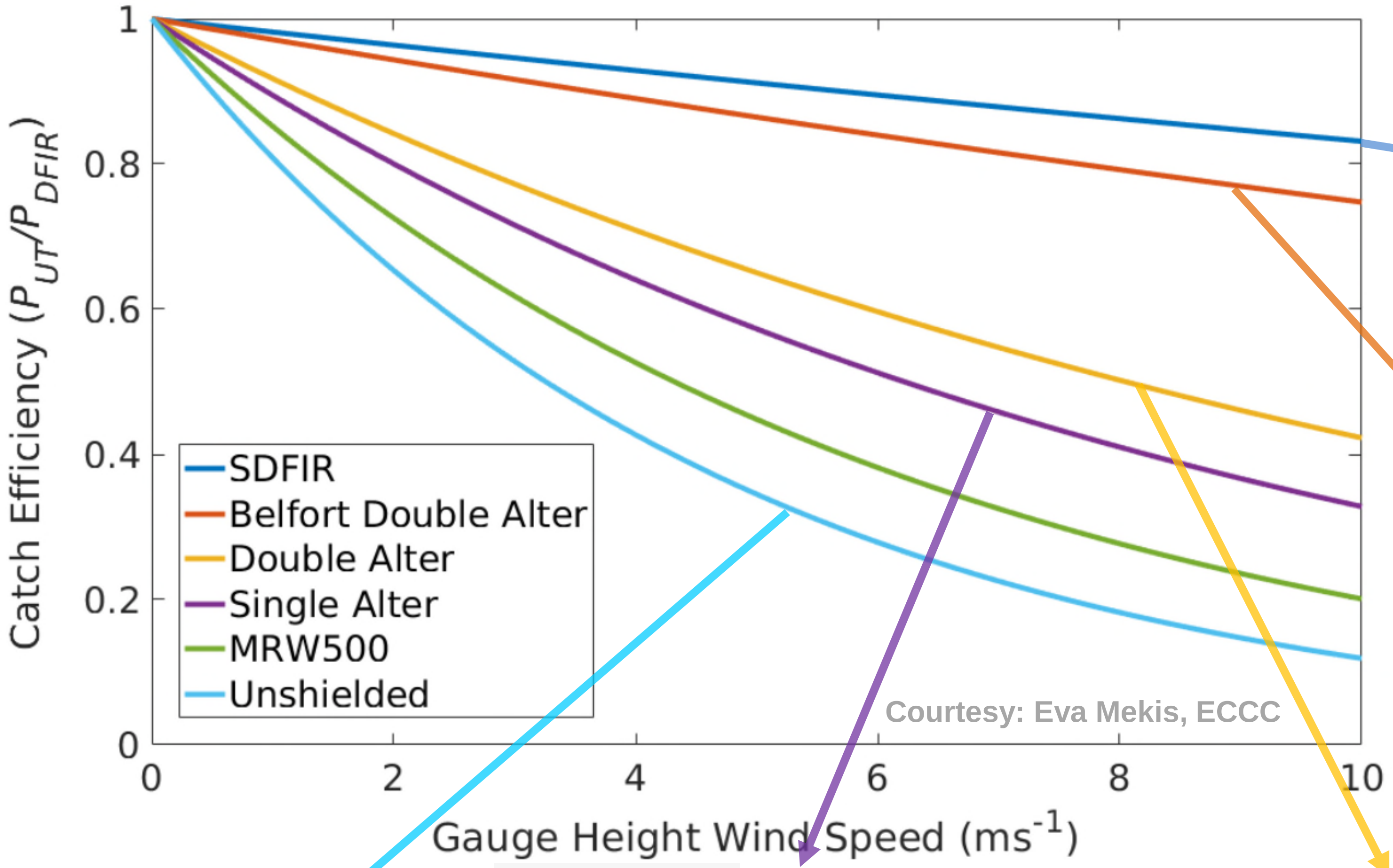

- Systematic bias in the gauge measurement of solid precipitation due to wind can be **100%**!
- Instrument profile has an impact on under-catch but the shield configuration is more important
- There can be issues with heated tipping buckets due to melt lag, potential chimney effects and significant evaporation

**Meteoservis MR3H-FC***

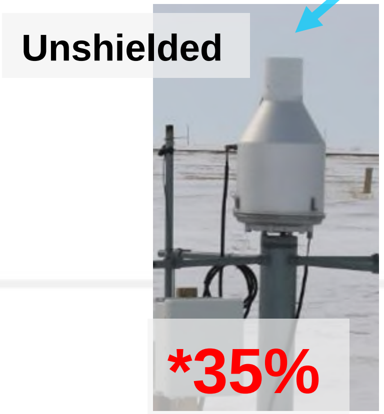

**Lambrecht rain[e]H3**

*** instrument tested during SPICE**

# Gauge Catch Efficiency of Solid Precipitation vs. Wind Speed





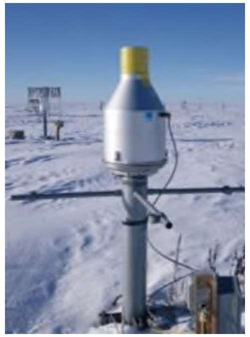



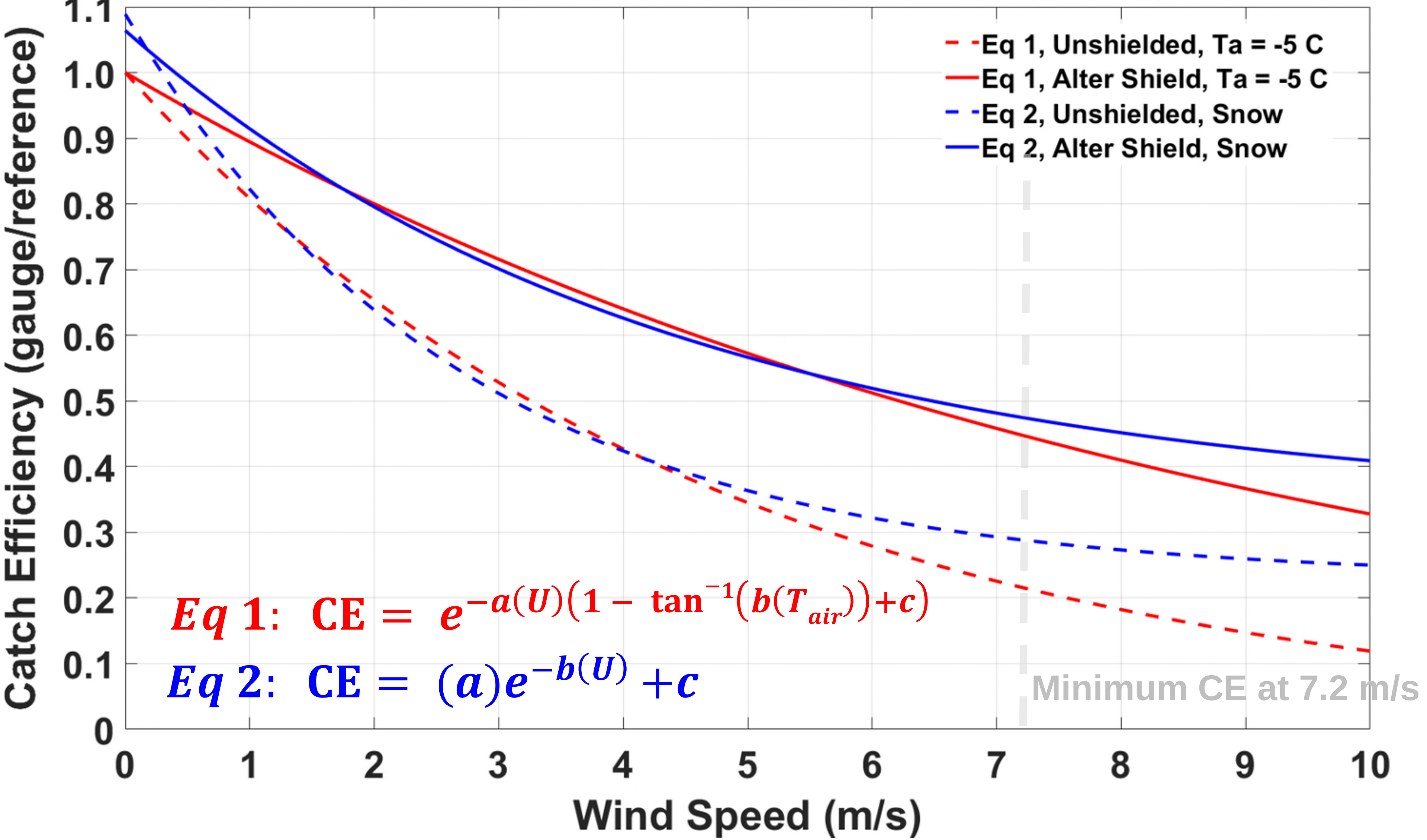



* ~ CE at 5 m/s compared to DFAR

“universal”

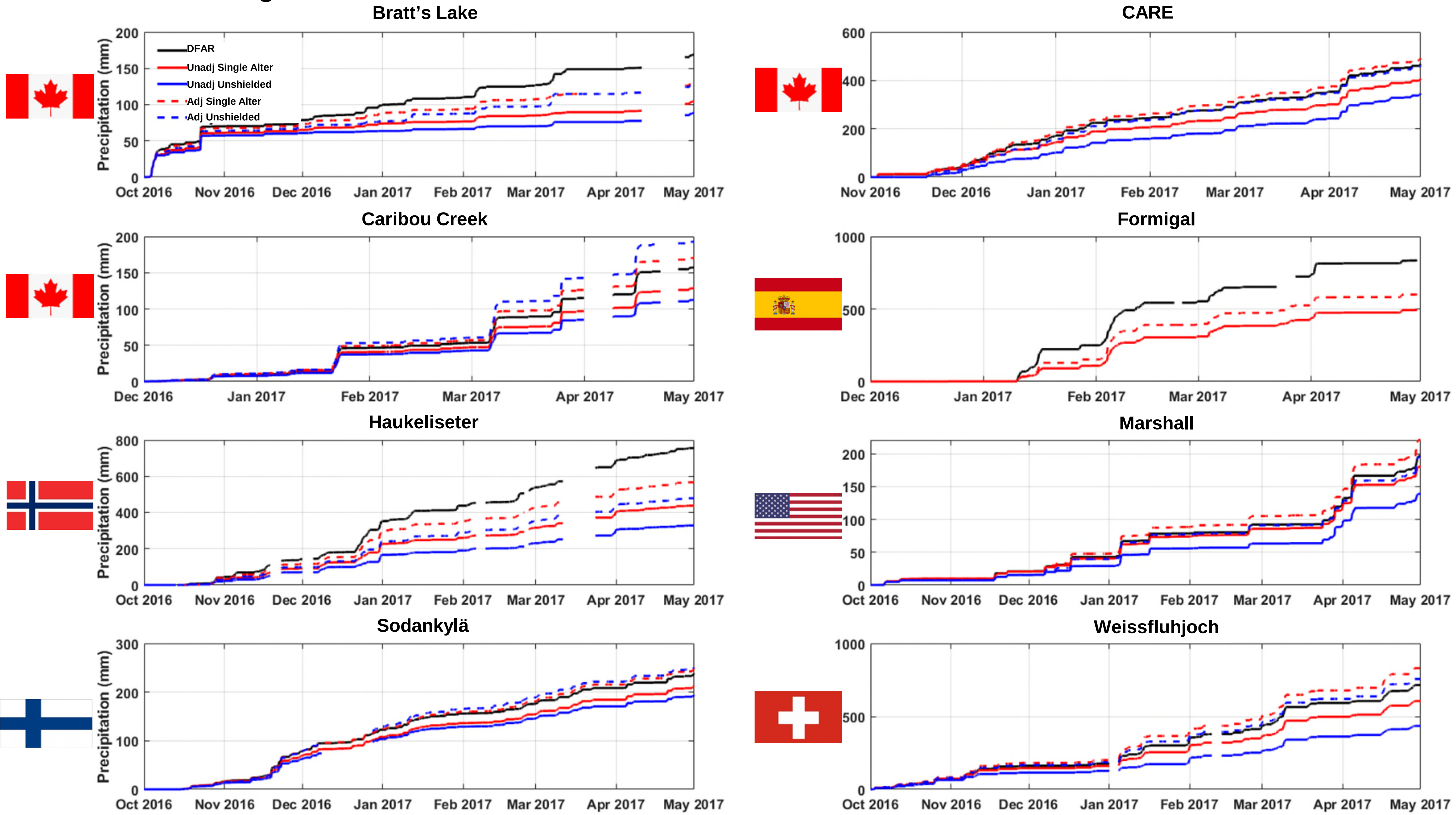
# WMO-SPICE Transfer Functions using Gauge Height Wind



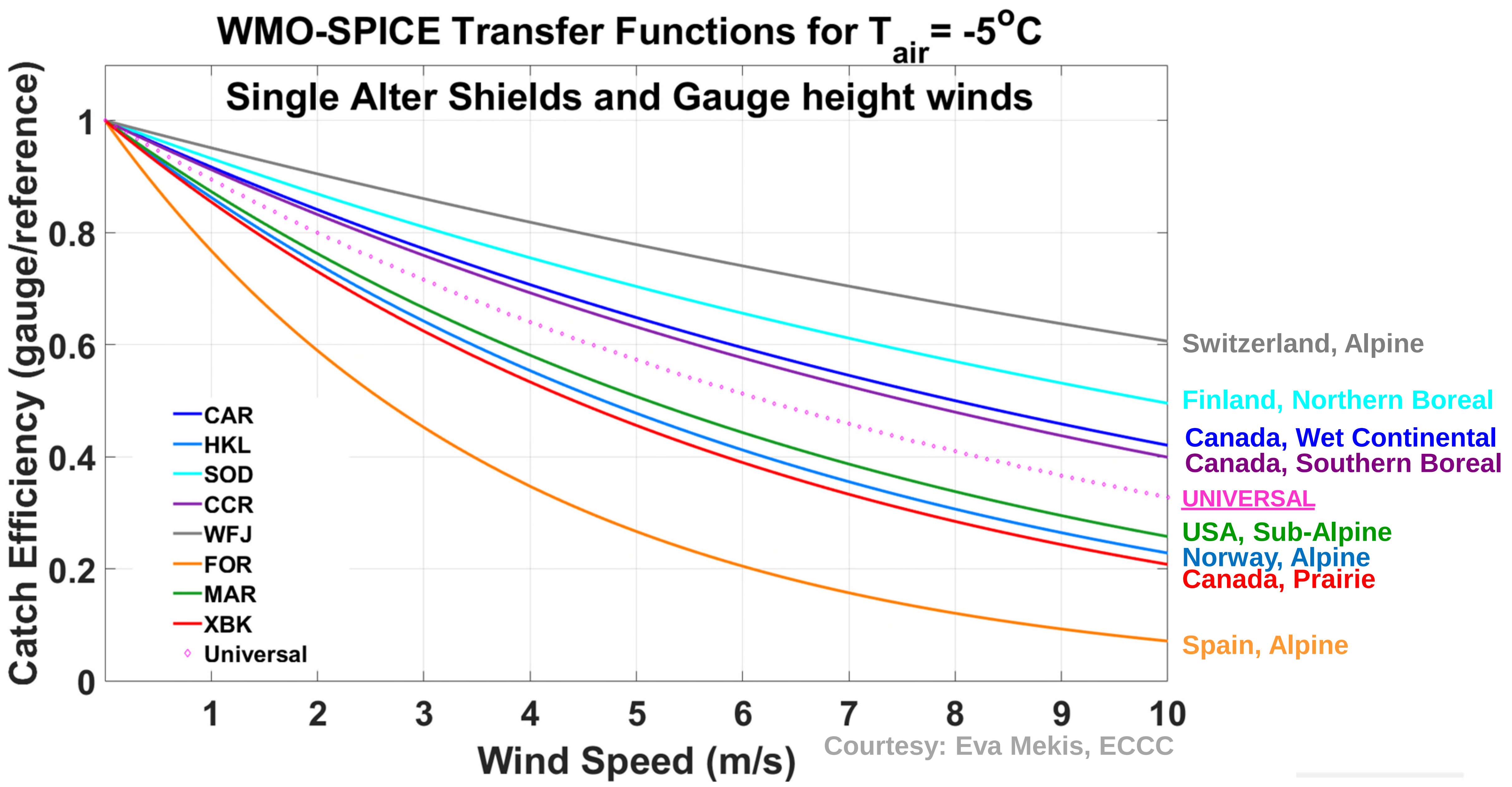



Kochendorfer, J., et al.: Analysis of single-Alter-shielded and unshielded measurements of mixed and solid precipitation from WMO-SPICE, Hydrol. Earth Syst. Sci., 21, 3525-3542, https://doi.org/10.5194/hess-21-3525-2017, 2017.

# Testing SPICE “Universal” Transfer Functions on 2016/2017 Accumulated Time Series

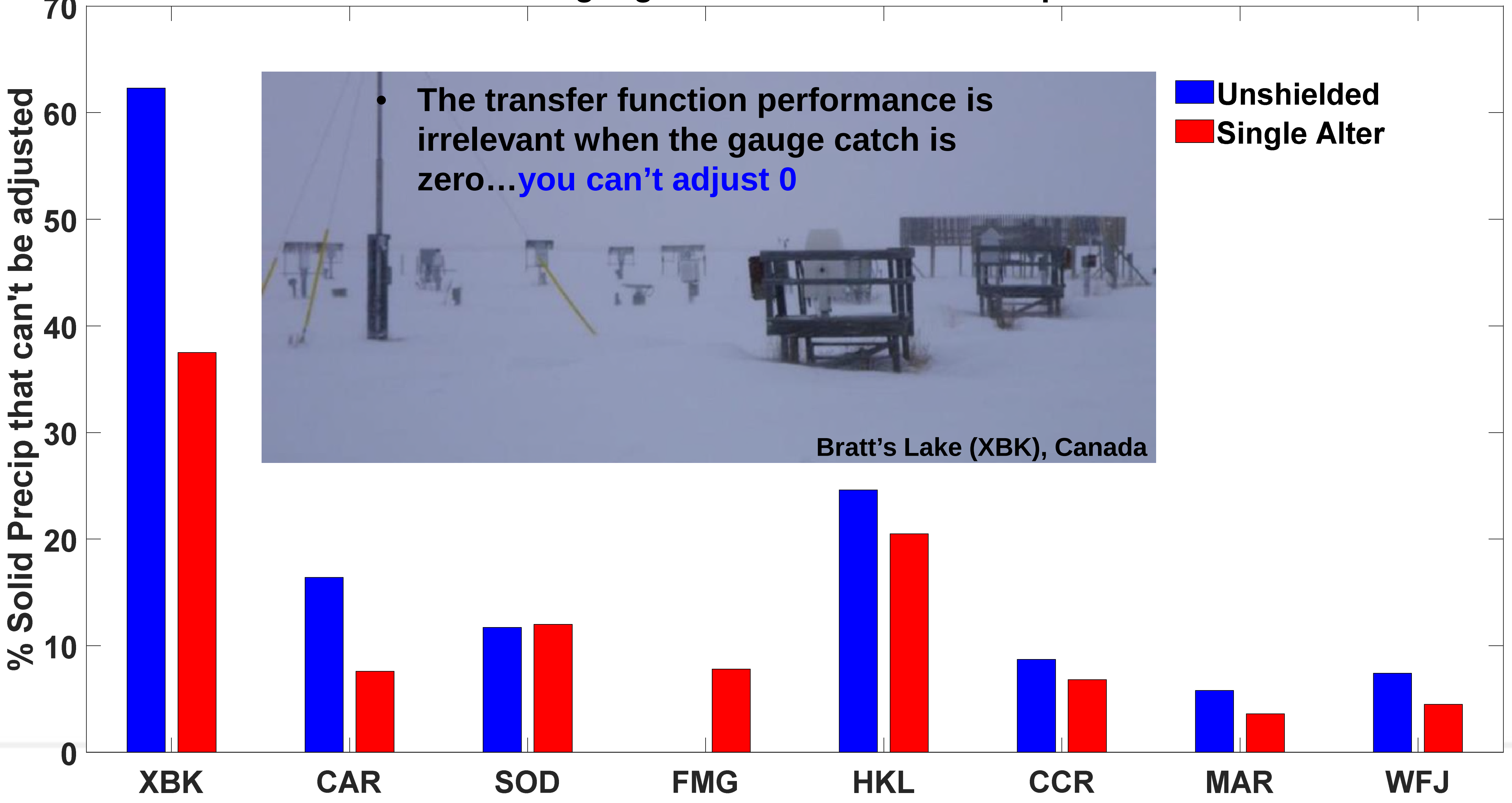



Smith et al. (2020)


WMO-SPICE Transfer Functions for $T_{air}$ = -5°C
Single Alter Shields and Gauge height winds
Catch Efficiency (gauge/reference)
1
0.8
0.6
0.4
0.2
0
CAR
HKL
SOD
CCR
WFJ
FOR
MAR
XBK
Universal
1
2
3
4
5
6
7
8
9
10
Wind Speed (m/s)
Switzerland, Alpine
Finland, Northern Boreal
Canada, Wet Continental
Canada, Southern Boreal
UNIVERSAL
USA, Sub-Alpine
Norway, Alpine
Canada, Prairie
Spain, Alpine
Courtesy: Eva Mekis, ECCC

# Why the large under-adjustment at cold and windy sites?

**Percentage of total DFAR Solid Precipitation when the non-DFAR gauge measures 0 for 30-min periods**




- The transfer function performance is irrelevant when the gauge catch is zero…you can’t adjust 0

# Emerging Technologies for measuring Solid Precipitation

Lufft WS100
24GHz Doppler radar

ECCC POSS
Polarized X-band Doppler radar (not commercially available)

Vaisala FD71P
Forward scatter laser visibility and present weather

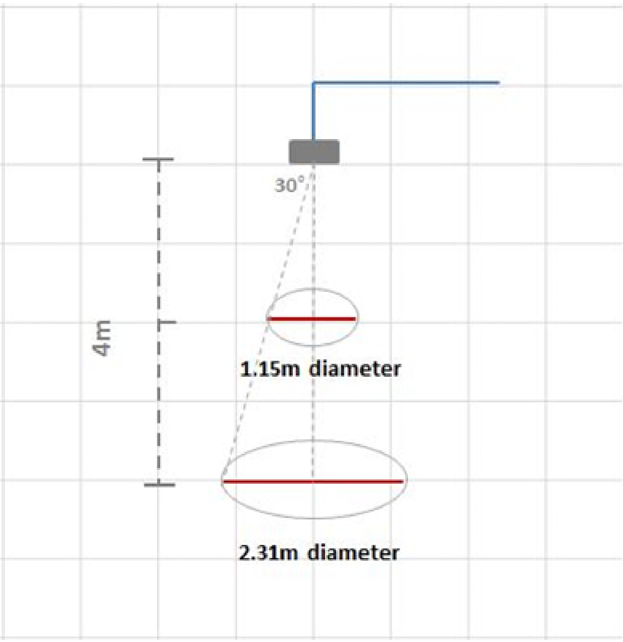
OTT Parsivel²
Laser disdrometer

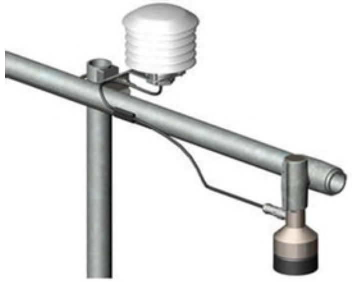
Thies CLIMA
Laser disdrometer

- Doppler radar, light extinction, light scattering
- Are not subject to the same aerodynamic under-catch as accumulating gauges
- Considerations: power requirements, proprietary processing algorithms, unattended operation
- SPICE: seasonal accumulations are less biased than short term event based accumulations: issues with estimating the density of snowfall → not recommended for event measurement
- Ancillary observation for light event detection, precipitation typing and partitioning, enhanced quality control for accumulating gauges
- **Hydrometeor fall velocity**: high correlation between fall velocity and gauge catch efficiency → developing, refining, and real-time application of transfer functions for adjusting under-catch

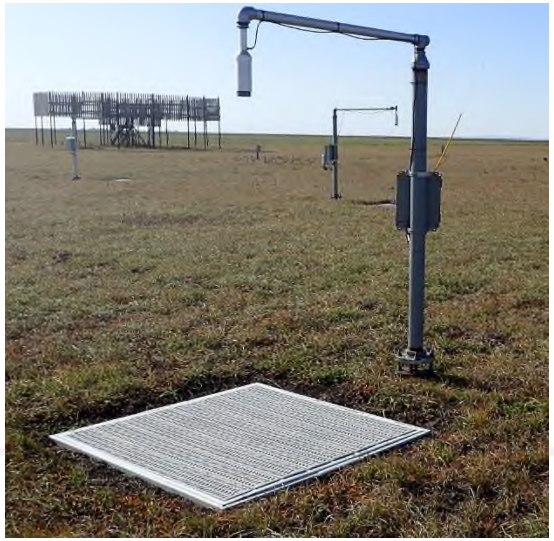
# SNOW DEPTH

## Ultrasonic

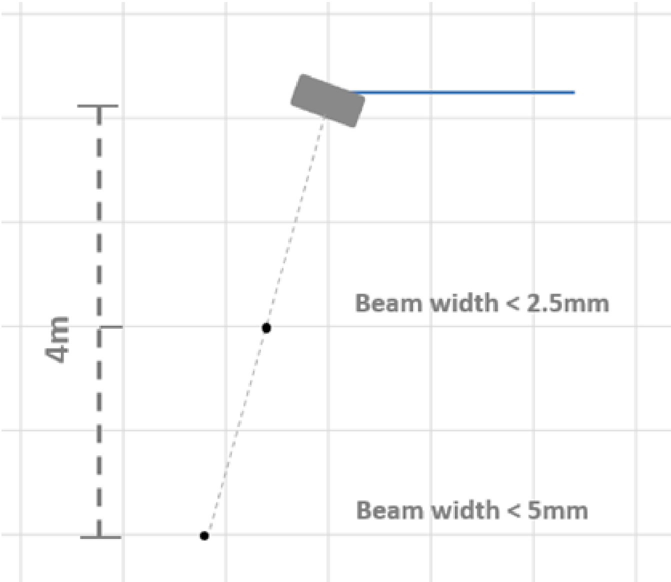


Range: 0.5 to 10 m
Accuracy: ± 1-2 cm
Resolution: 0.25 mm

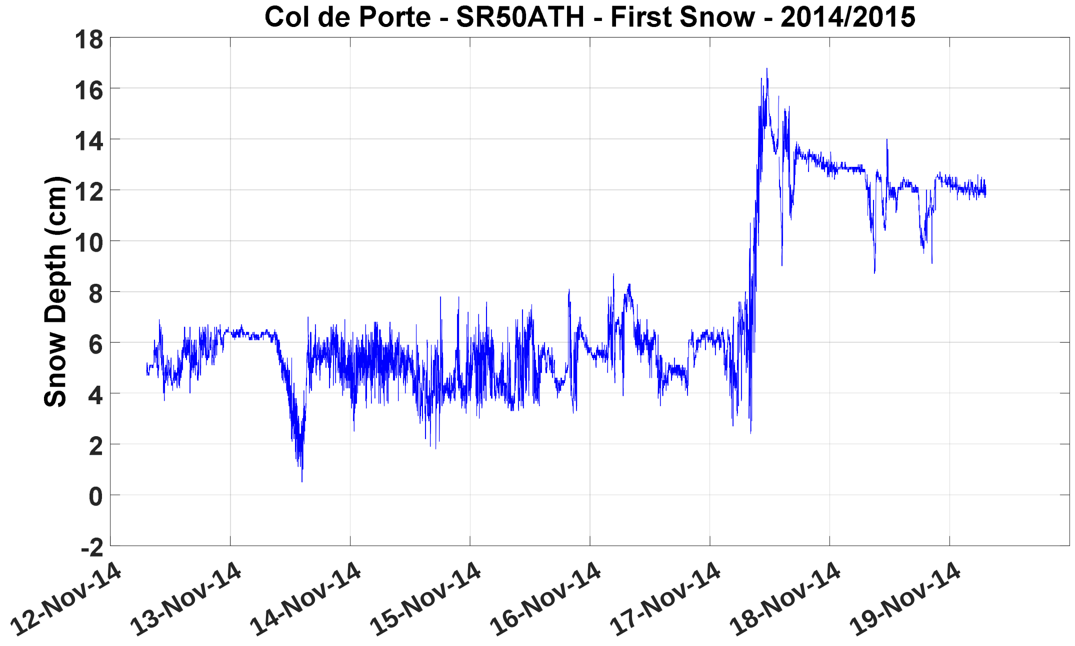


## Laser



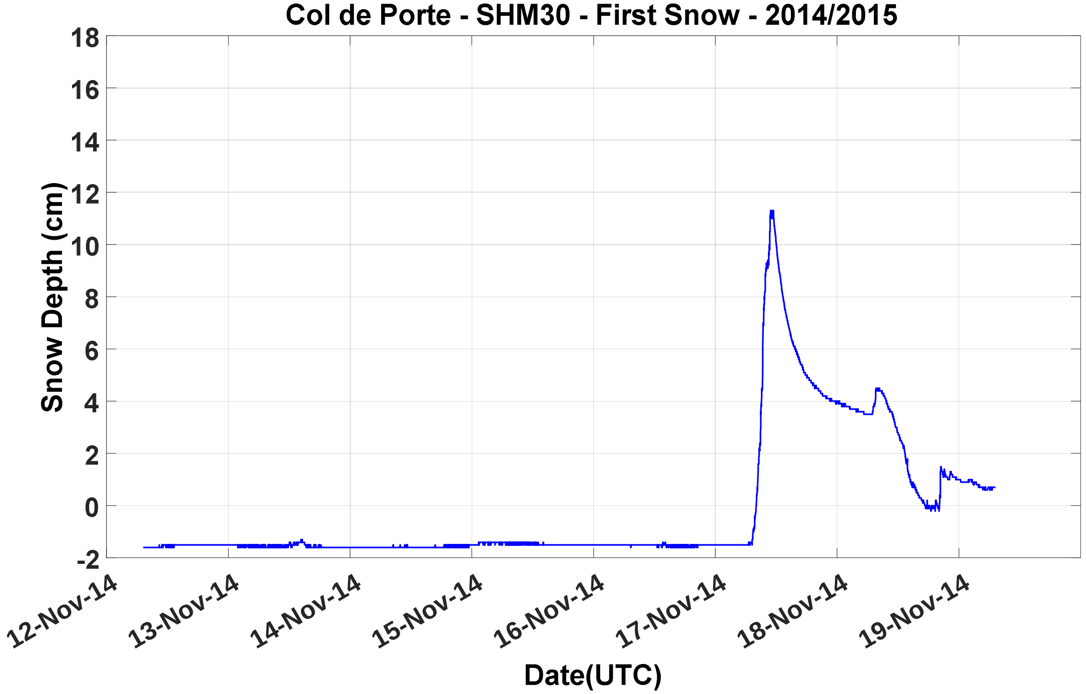

Range: 0 to 10 m
Accuracy: ± 0.5 cm
Resolution: 0.10 mm

**Ultrasonic**




# Base Target:
# Mown Grass

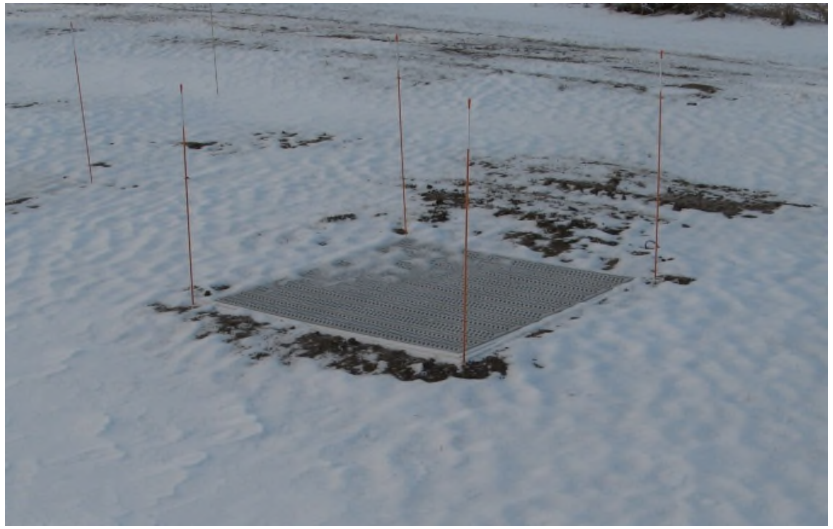
**Laser**




**3 m tower at Col de Porte, France**

# Instrument and Infrastructure Design: Surface Targets

## Grey Textured Plastic




## Green Artificial Turf

Nitu et al. (2018)

# Instrument and Infrastructure Design: Mounts and Heating

Unheated sensor, unheated horizontal boom

Heated sensor, unheated horizontal boom

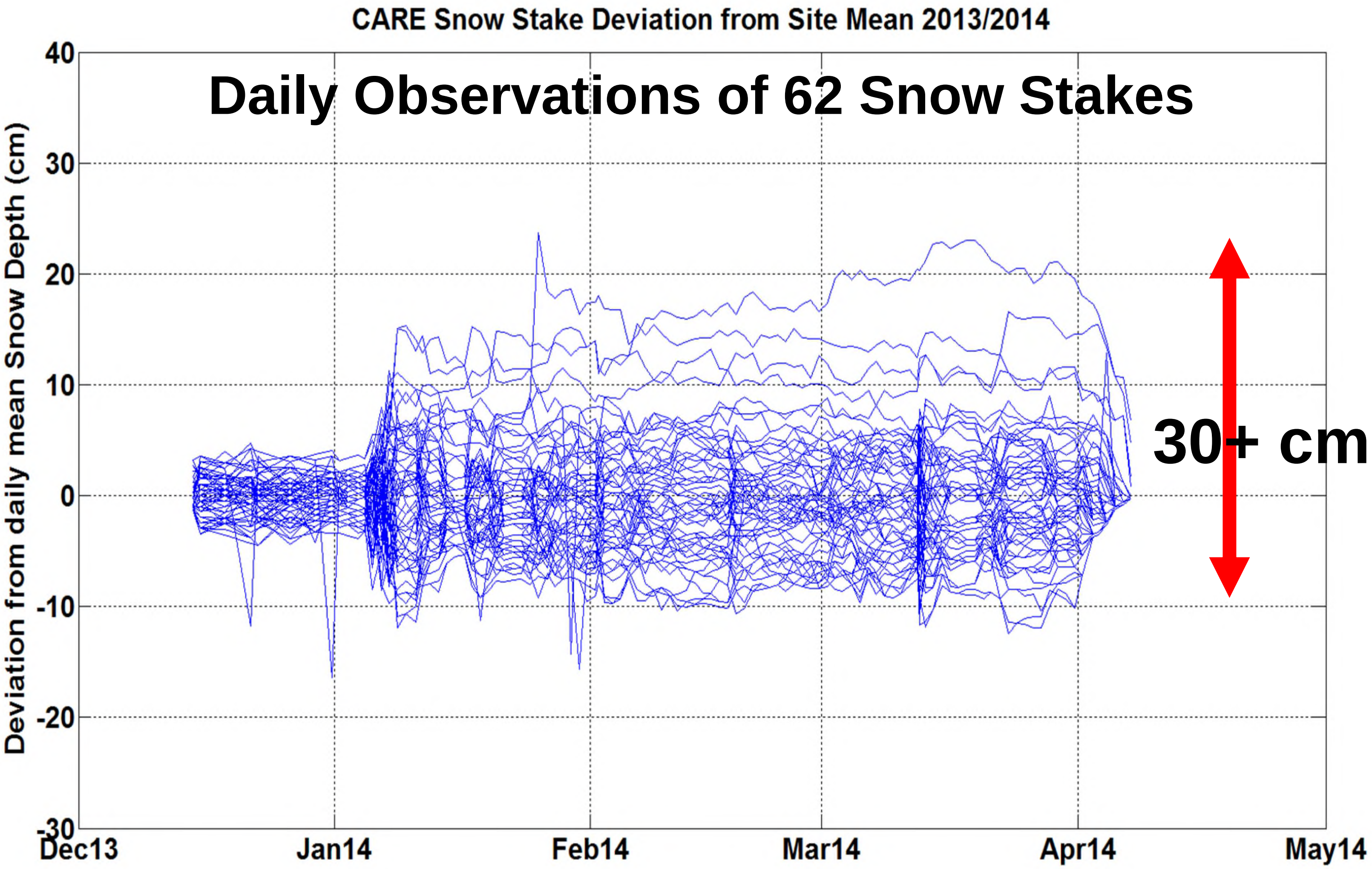
Unheated sensor, heated angled boom

Heated sensor, heated angled boom



Nitu et al. (2018)

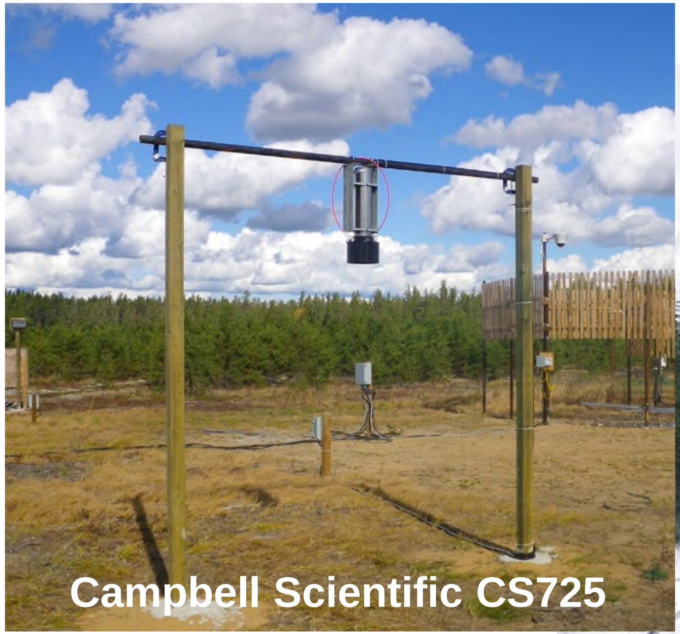
# Instrument Siting




**Sensor siting is important!**

# SNOW WATER EQUIVALENT (SWE)

## 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 (calibration)
- Seems to be sensitive to meltwater infiltration during melt

## Snow Scales or Pillows


**Pros:**

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

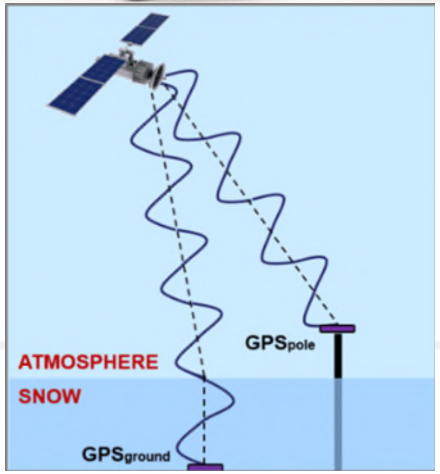
**Cons:**

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

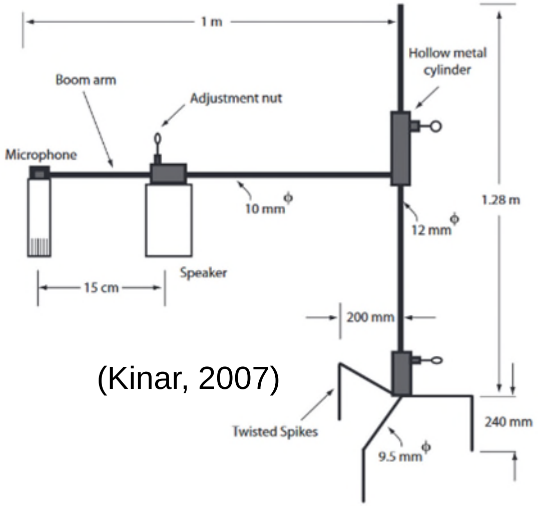
# Emerging Technologies

## GNSS/GPS Dual Receiver

(Appel et al., 2019)




## Acoustic Sensing of Snow

(Kinar, 2007)

Analysis of reflected acoustic waves to derive:

- Depth
- Density
- Liquid water content
- Temperature


Caribou Creek, Canada


Formigal, Spain


Weissfluhjoch, Switzerland


Bratt's Lake, Canada


Sodankylä, Finland


CARE, Canada


Haukeliseter, Norway


Marshall, USA

# *Thank You*