Improving the Quality of Alpine Precipitation Observations:

Testing of a low-cost, energy efficient, and physically robust 24 GHz radar in extreme conditions at the Mount Washington Observatory

MOXXI 2019
New York University

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University of Colorado, Boulder
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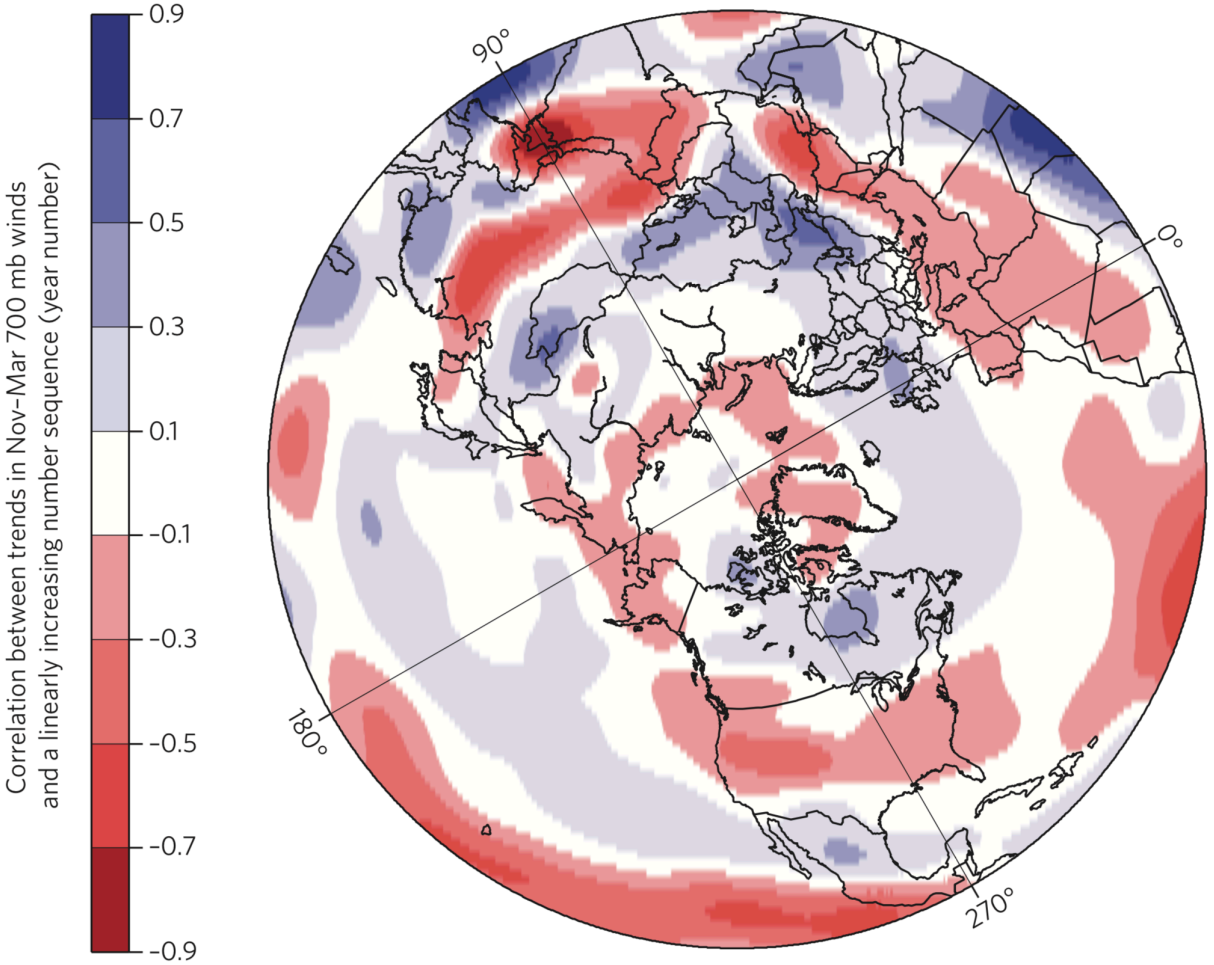
Motivation:

Michael Dettinger, 2014. Impacts in the third dimension. Nature Geoscience



- 700 mb winds have decreased (or increased) between 1950 and 2012
- Does this translate into a reduction in orographic enhancement of precipitation?
- We don't know because of the sparse network of alpine observations

Motivation:

"The distribution of ground-based stations is highly biased toward lower elevations, providing inadequate representation of mountain geography resulting in increased model error"

- *Filling the Data Gaps in Mountain Climate Observatories* Strachan et al. 2016

Motivation:

Royal Basin in Olympic National Park

Motivation:

Mountains as Water Towers

In the Western US, mountain catchments contribute up to 75% of surface and groundwater supplies

IPCC 2007

Photo Credit: Remko Tanis

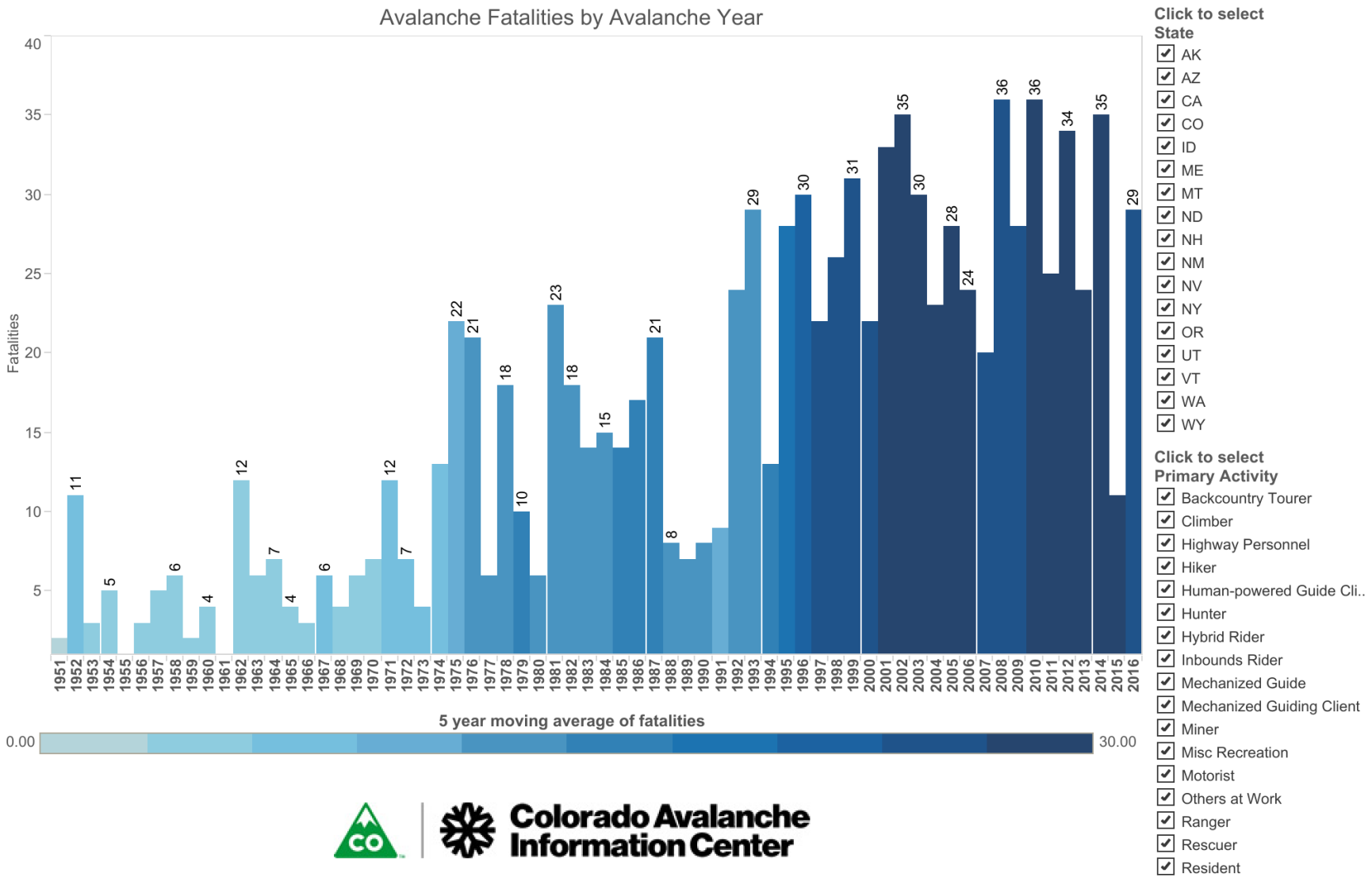
Motivation:

Avalanche Forecasting

Photo Credit: unofficialnetworks.com

Motivation:

Avalanche Forecasting



CO | Colorado Avalanche Information Center

The Problem:

Mountains are Remote

Challenges: Instrument deployment, maintenance, power, data transfer

The Problem:

Wind Induced Errors

FIG. 17. Mapping of airflow around a gauge orifice in laminar wind tunnel flow.

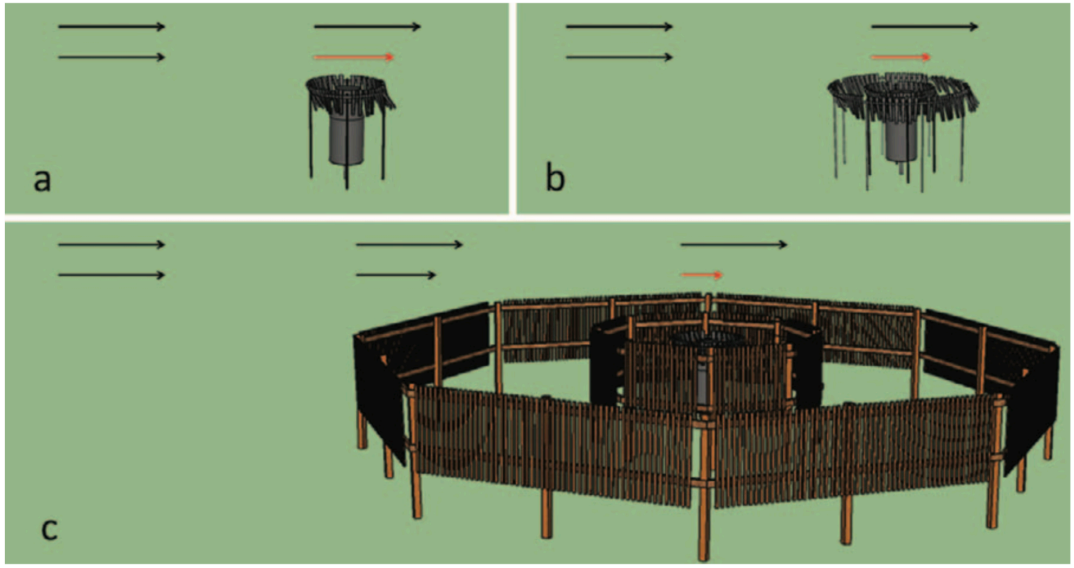


FIG. 16. Airflow past precipitation gauges shielded by (a) single Alter, (b) double Alter, and (c) DFIR shields. Wind vectors are based on sonic anemometer measurements in Fig. 13. Top row of vectors represent free-stream wind speeds, and vectors immediately above the gauge (red) represent wind speeds measured at the gauge inlet.

Rasmussen et al. 2012. How well are we measuring snow?

Potential Solution:

Vertically Pointed Radar

Lufft WS100

- 24 GHz (1.25 cm) Doppler Radar
  - Accumulation
  - Intensity
  - Particle Counts
  - Drop Size Distribution
  - Precipitation Type
- Potential to distinguish blowing from falling snow
- Wind errors associated with particle size estimation
  - Doppler derived fall speeds
  - Correct with turbulence (3-D wind) data?
- Lufft WS100
  - Low power (~ 10 Watts)
  - Integrated heater
  - Physically robust
  - Relatively low cost (~ $1200)

Potential Solution:

Vertically Pointed Radar

METEK Micro Rain Radar

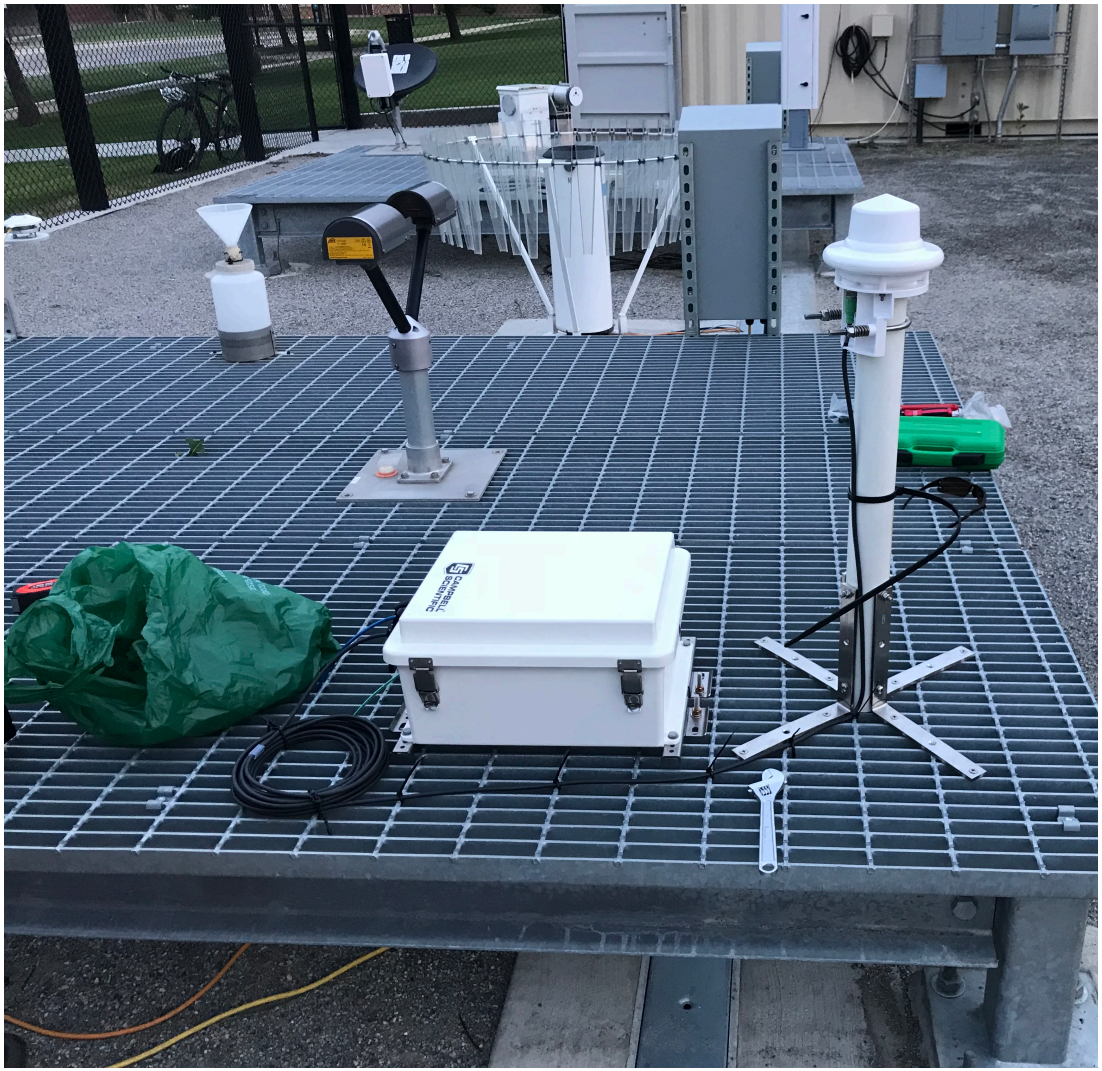
METEK Micro Rain Radar

- Antenna heating
- 30 Range Gates
- Raw reflectivity and doppler spectrum

- Higher Power (~25 Watts)
- High Cost (~$20,000)
- Not suitable for high wind environments

Lufft WS100:

Testing and Calibration at Boulder Skywatch Observatory



Instrumentation:

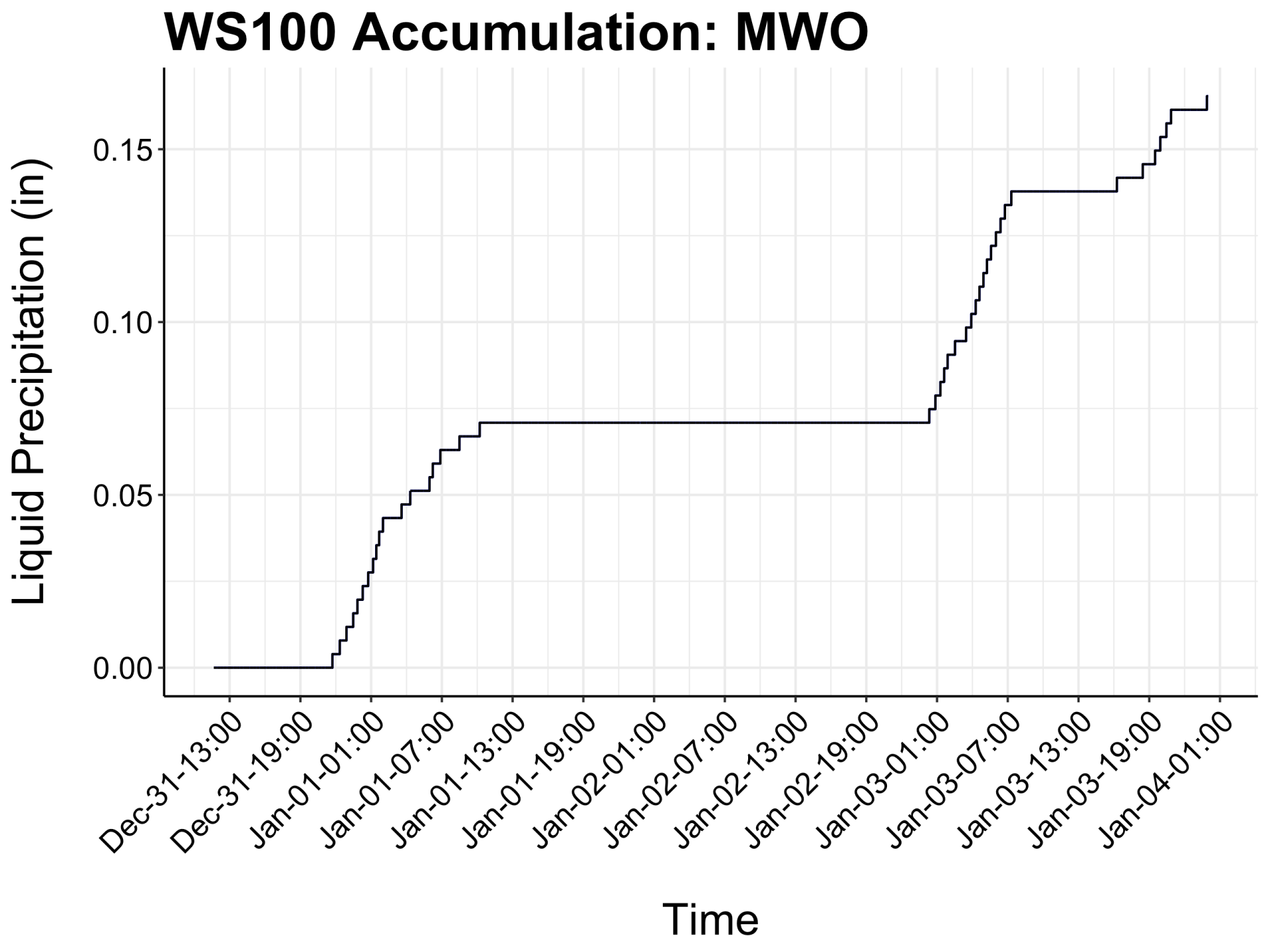
- ETI Rain Gauge
- Parsivel Disdrometer
- Micro Rain Radar
- Vaisala Ceilometer
- Wind Cube Lidar

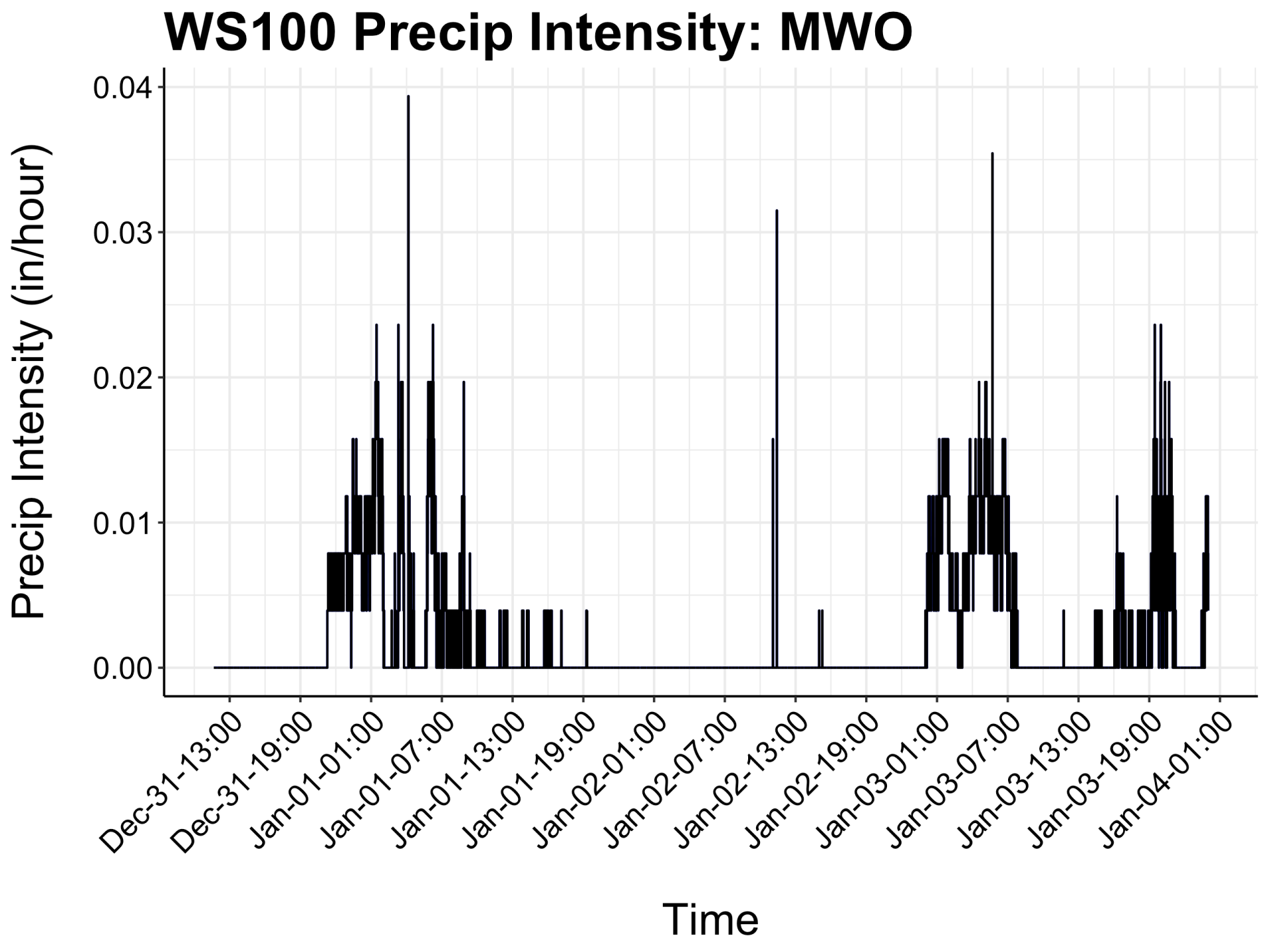
http://skywatch.colorado.edu

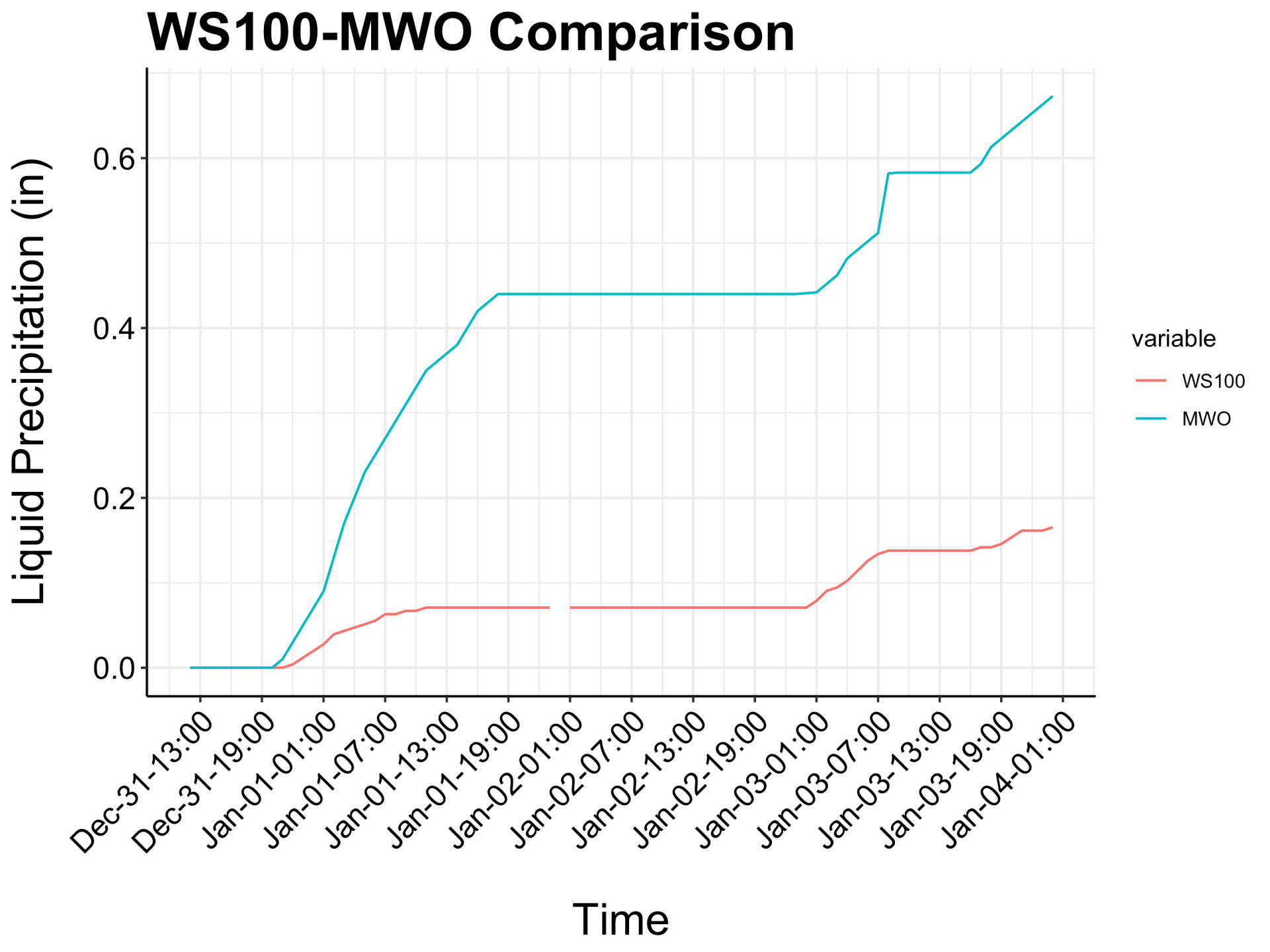
Lufft WS100:

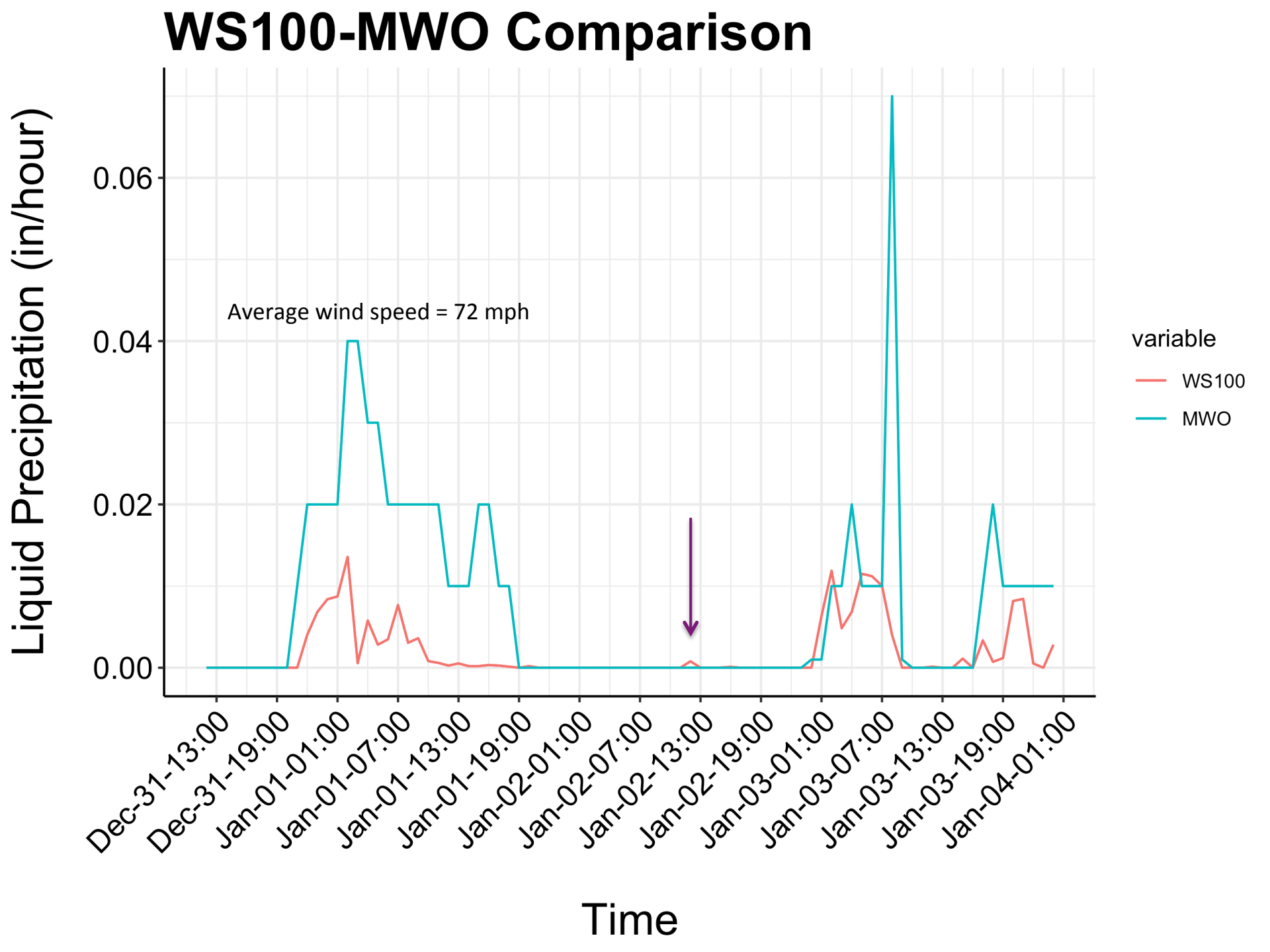
Testing and Calibration at Mount Washington Observatory

Operational at MWO from December 31, 2018 to January 8, 2019


WS100 Accumulation: MWO
Liquid Precipitation (in)
0.15
0.10
0.05
0.00
Dec-31-13:00
Dec-31-19:00
Jan-01-01:00
Jan-01-07:00
Jan-01-13:00
Jan-01-19:00
Jan-02-01:00
Jan-02-07:00
Jan-02-13:00
Jan-02-19:00
Jan-03-01:00
Jan-03-07:00
Jan-03-13:00
Jan-03-19:00
Jan-04-01:00
Time


WS100 Precip Intensity: MWO
Precip Intensity (in/hour)
0.04
0.03
0.02
0.01
0.00
Dec-31-13:00
Dec-31-19:00
Jan-01-01:00
Jan-01-07:00
Jan-01-13:00
Jan-01-19:00
Jan-02-01:00
Jan-02-07:00
Jan-02-13:00
Jan-02-19:00
Jan-03-01:00
Jan-03-07:00
Jan-03-13:00
Jan-03-19:00
Jan-04-01:00
Time


WS100-MWO Comparison
Liquid Precipitation (in)
0.0
0.2
0.4
0.6
Dec-31-13:00
Dec-31-19:00
Jan-01-01:00
Jan-01-07:00
Jan-01-13:00
Jan-01-19:00
Jan-02-01:00
Jan-02-07:00
Jan-02-13:00
Jan-02-19:00
Jan-03-01:00
Jan-03-07:00
Jan-03-13:00
Jan-03-19:00
Jan-04-01:00
Time
variable
WS100
MWO


WS100-MWO Comparison
Liquid Precipitation (in/hour)
0.06
0.04
0.02
0.00
Average wind speed = 72 mph
variable
WS100
MWO
Dec-31-13:00
Dec-31-19:00
Jan-01-01:00
Jan-01-07:00
Jan-01-13:00
Jan-01-19:00
Jan-02-01:00
Jan-02-07:00
Jan-02-13:00
Jan-02-19:00
Jan-03-01:00
Jan-03-07:00
Jan-03-13:00
Jan-03-19:00
Jan-04-01:00
Time

What is the truth?

Rime Ice

Rime Ice

Rime Ice

Next Steps

Is the Lufft WS100 or similar radar instrumentation suitable for a network of alpine observations?

- Develop calibration from Skywatch testing
- Determine the influence of wind
  - Obtain raw reflectivity and doppler data from WS100
  - Correct doppler derived fall velocities
- Compare MWO data with regional radar
- Install and test on Niwot Ridge, CO

Funding

CUAHSI

universities allied for water research

www.cuahsi.org

MWOBS

MOUNT WASHINGTON

OBSERVATORY