Added to Homework Assignment

- Work through following COMET module: Enroll. Complete quiz. Have quiz results emailed to me (john.horel@utah.edu)
- http://www.meted.ucar.edu/hydro/precip_est/part1_measurement/

- Precipitation: Total depth to which a flat, horizontal surface of known area would have been covered assuming no water loss by melting, runoff, or evaporation
- Precipitation rate: precipitation per unit time: $R = M_w/\rho_w$ [kg/(m^2 s) / kg/ m^3]

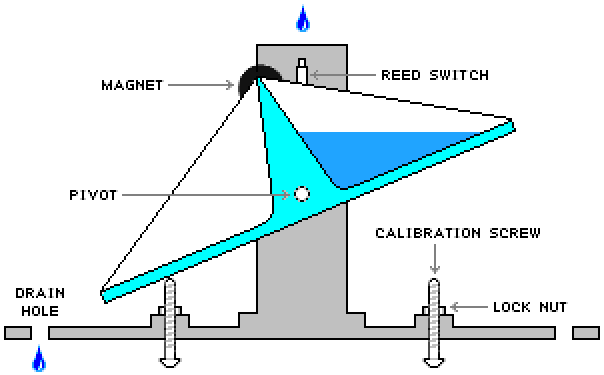
Manual Measurement

- CoCoRAHS training: http://www.cocorahs.org/Content.aspx?page=training_slideshows
- Measure precipitation at ~ fixed temporal intervals
- Inner measuring cylinder amplifies signal while reducing catch errors

Automated Sensors

Automated Sensors

- Volumetric: Tipping bucket
- Weighing
  - Pressure (Belfort,Noah)
  - Vibrating wire (Geonor)
- Others
  - Optical
  - Hot plate

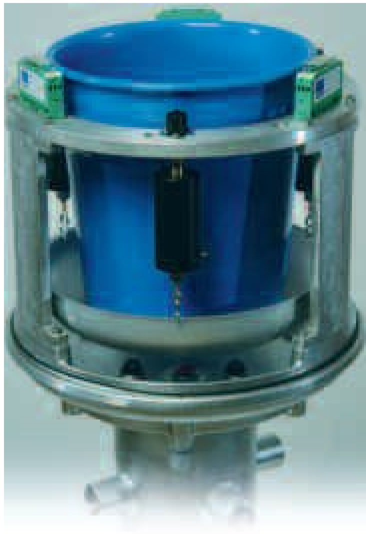


SNOTEL: Weighing Gauge and Snow Pillow

SNOTEL Snow Pillow

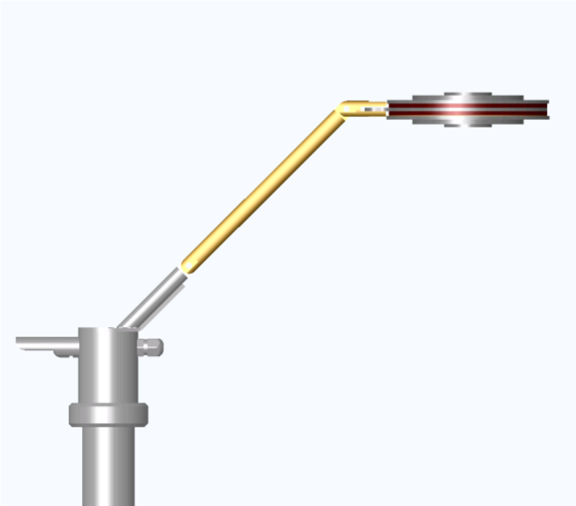
Vibrating Wire

- The precipitation collected in the container are weighed with a vibrating wire load sensor, which gives a frequency output.
- The frequency will be a function of the applied tension on the wire, i.e. from this, the amount of precipitation can be computed.
- The frequency is recorded as a square-shaped 0-5 V signal



Hot Plate sensor

- provides real time snow and liquid precipitation rates
- sensor head consists of two isolated plates warmed by electrical heaters.
- During storms, it measures the rate of rain or snow by how much power is needed to evaporate precipitation on the upper plate and keep its surface temperature constant.
- The second plate, positioned directly under the evaporating plate and heated to the same temperature as the top, is used to factor out cooling from the wind.



Snow Depth

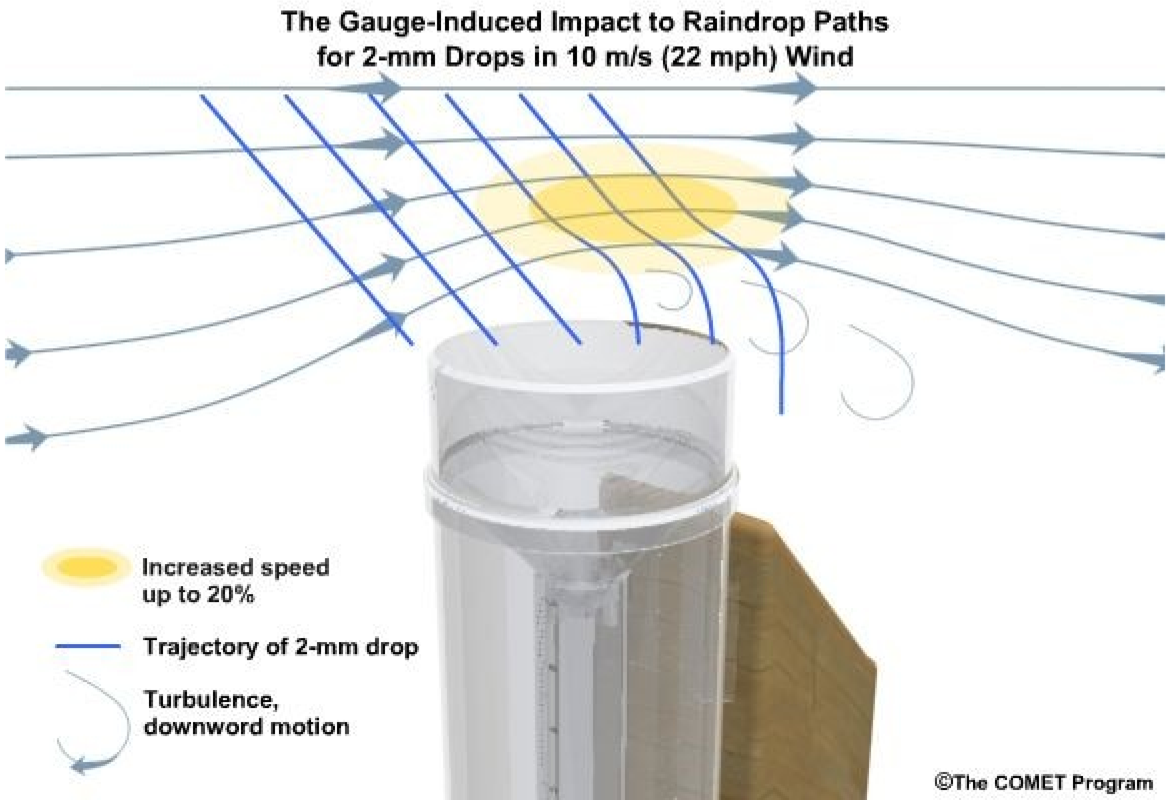
- The sensor measures the distance from the sensor to a target.
- The sensor works by measuring the time required for an ultrasonic pulse to travel to and from a target surface.
- An integrated temperature probe with solar radiation shield, provides an air temperature measurement for properly compensating the distance measured.
- An embedded microcontroller calculates a temperature compensated distance and performs error checking.
- Both distance and air temperature can be output as an analog signal between 0 to 2.5 Volts or 0 to 5 Volts.
- Accurate measurement of snow depth poses many difficult problems

Sources of Error

- Representativeness
  - Sampling errors can be + or –
- Wind
- Evaporation- dry gauge delays detection of onset
- Splash/capping/plugging/dew
- Tipping bucket underestimation at high rain rate
- Temperature sensitivity to weighing gauge
- Automating precipitation detection

Sources of Error

- Exposure
  - Turbulent flows lead to undercatch
  - Worse for snow vs. rain
  - Problems increase as wind speed increases



Rain

- Rule of thumb: 1% loss for every 1 mph increase in wind speed, or 2.2% for every 1 m/s increase
- Uncertainty associated with drop sizes & gauge location
- Best measurements in windy conditions:
  - Large drops
  - Gauge near the ground
  - Shielded gauges
- Poorest measurements
  - Small drops/drizzle drops
  - Elevated gauges

Wind Shield Type

- Double Fence Intercomparison Reference (DFIR)
- Single/Double Alter shields
- Natural shielding by trees

Climate Reference Network Station Wyoming for National-Level Climate Monitoring (Red Canyon Nature Conservancy, Wyoming)

New Historical Climatology Network Station for Regional-Level Climate Monitoring (Greenville, AL)


All Weather Precipitation Accumulation Gauge (AWPAG)
with Double-Structure Wind Shield
08/14/2008 18:12
NOAA

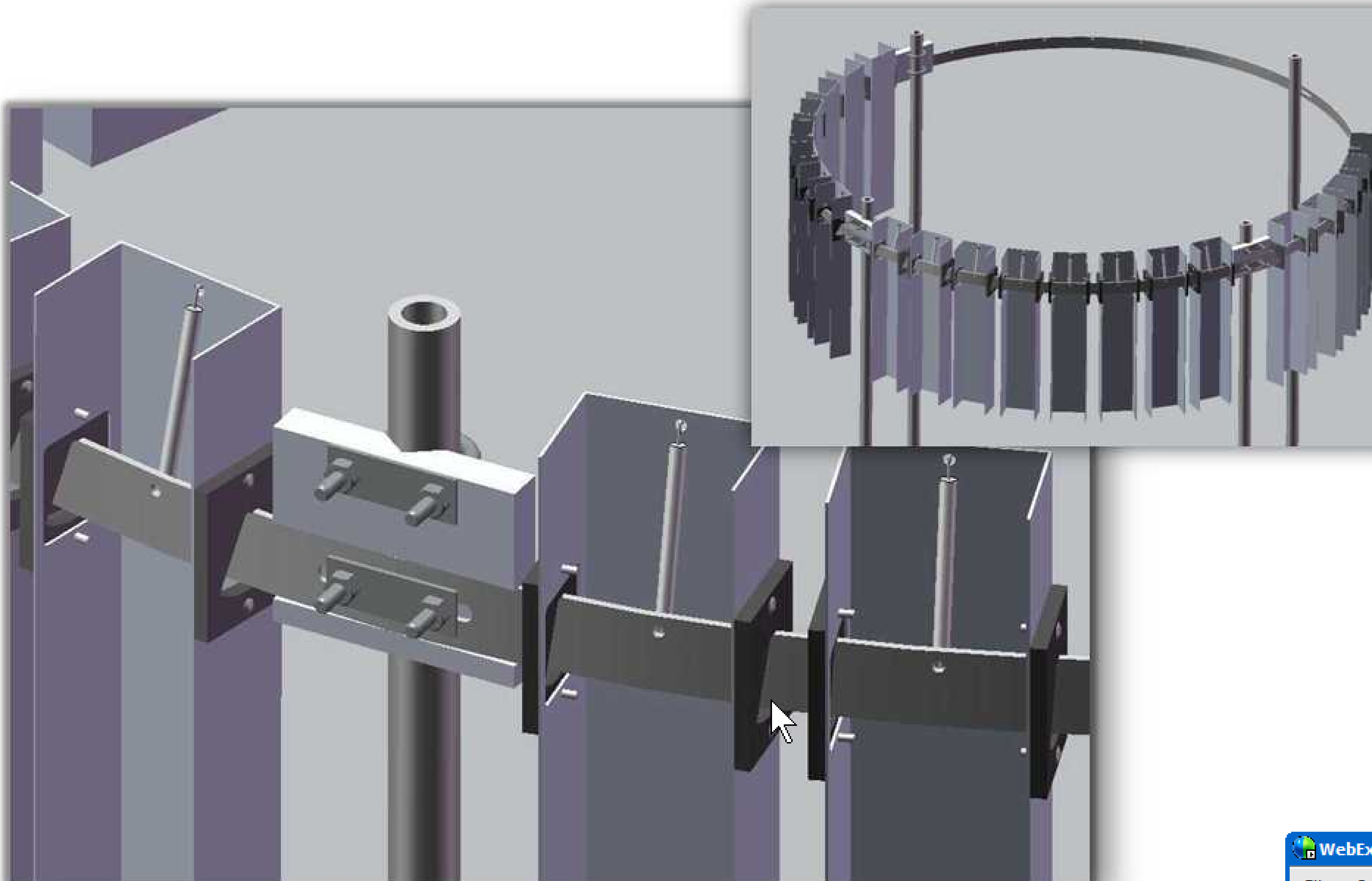
WebEx Player

Alter Shield in 20-30 kn Wind

WebEx

File Co

Belfort Shield Design



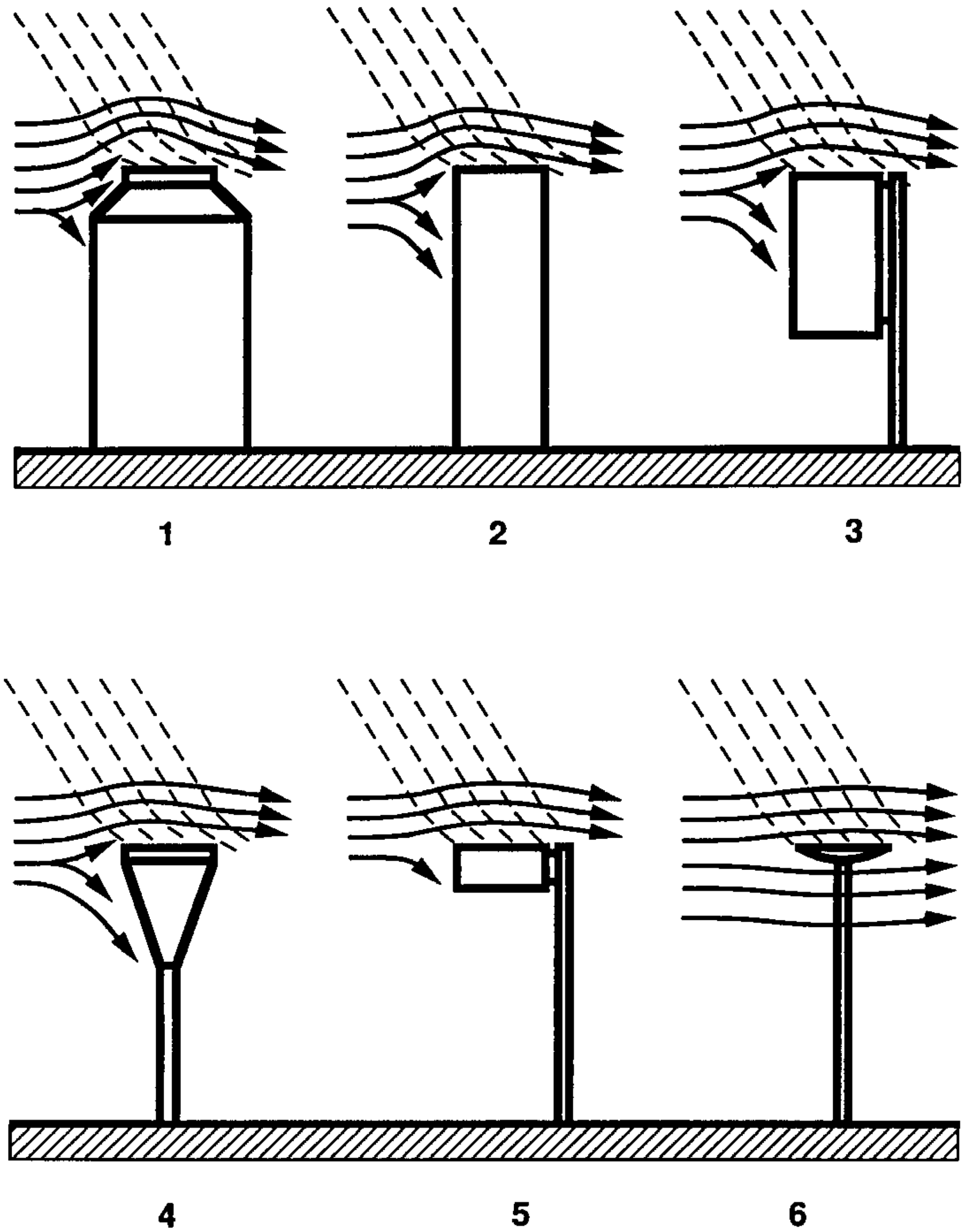
Impact of Shields

- Shielded gauges, on average, measure 20–70% more snow than unshielded gauges (Yang et al. 1999)
- The use of wind shields on precipitation gauges has introduced a significant discontinuity into precipitation records, particularly in cold and windy regions.
- This discontinuity is not constant and it varies with wind speed, temperature, and precipitation type.

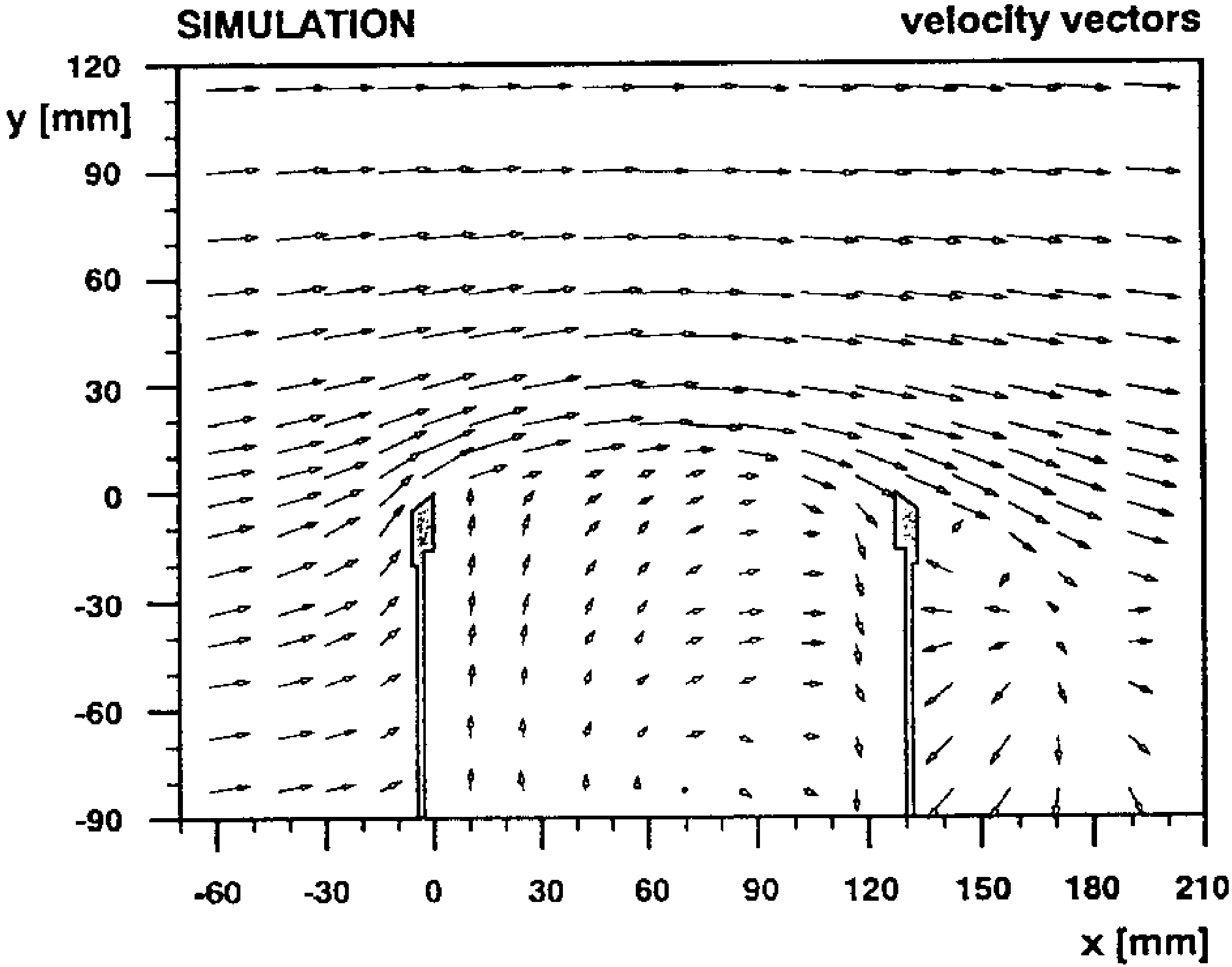
B.E. Goodison, P.Y.T. Louie, and D. Yang (1998)

Table 5. Summary of the Alter-Shielded Versus Unshielded Belfort Gauges at Five WMO Sites

Precipitation Type	Event Number, Day	Mean T_{max}, °C	Mean T_{min}, °C	Mean Wind at 3 m, m/s	DFIR	Belfort Gauge: Alter-Shielded	Belfort Gauge: Unshielded
				Danville			
Snow	153	−2.4	−11.6	1.4	894.8 mm 124.6%	860.4 mm 119.8%	717.9 mm 100.0%
Mixed	49	3.0	−6.5	1.2	827.3 mm 113.1%	827.8 mm 113.1%	731.6 mm 100.0%
Rain	30	5.2	−1.6	1.0	432.4 mm 105.7%	481.3 mm 117.6%	409.2 mm 100.0%
				Bismarck			
Snow	18	−2.9	−10.2	3.5	87.1= 744.4%	15.2 mm 129.9%	11.7 mm 100.0%
Mixed	14	−4.4	−9.8	3.2	58.7 mm 1276.1%	6.9 mm 150.0%	4.6 mm 100.0%
Rain	3	7.6	1.5	3.3	9.3 mm ...	n/a ...	n/a ...
				Reynolds Creek			
Snow	65	3.0	−6.0	2.2	141.1 mm 125.3%	142.7 mm 126.7%	112.6 mm 100.0%
Mixed	32	7.3	−3.1	3.5	117.6 mm 106.1%	121.0 mm 109.2%	110.8 mm 100.0%
Rain	41	9.3	−0.2	2.7	194.5 mm 105.1%	187.0 mm 101.1%	185.0 mm 100.0%



B.E. Goodison, P.Y.T. Louie, and D. Yang (1998)

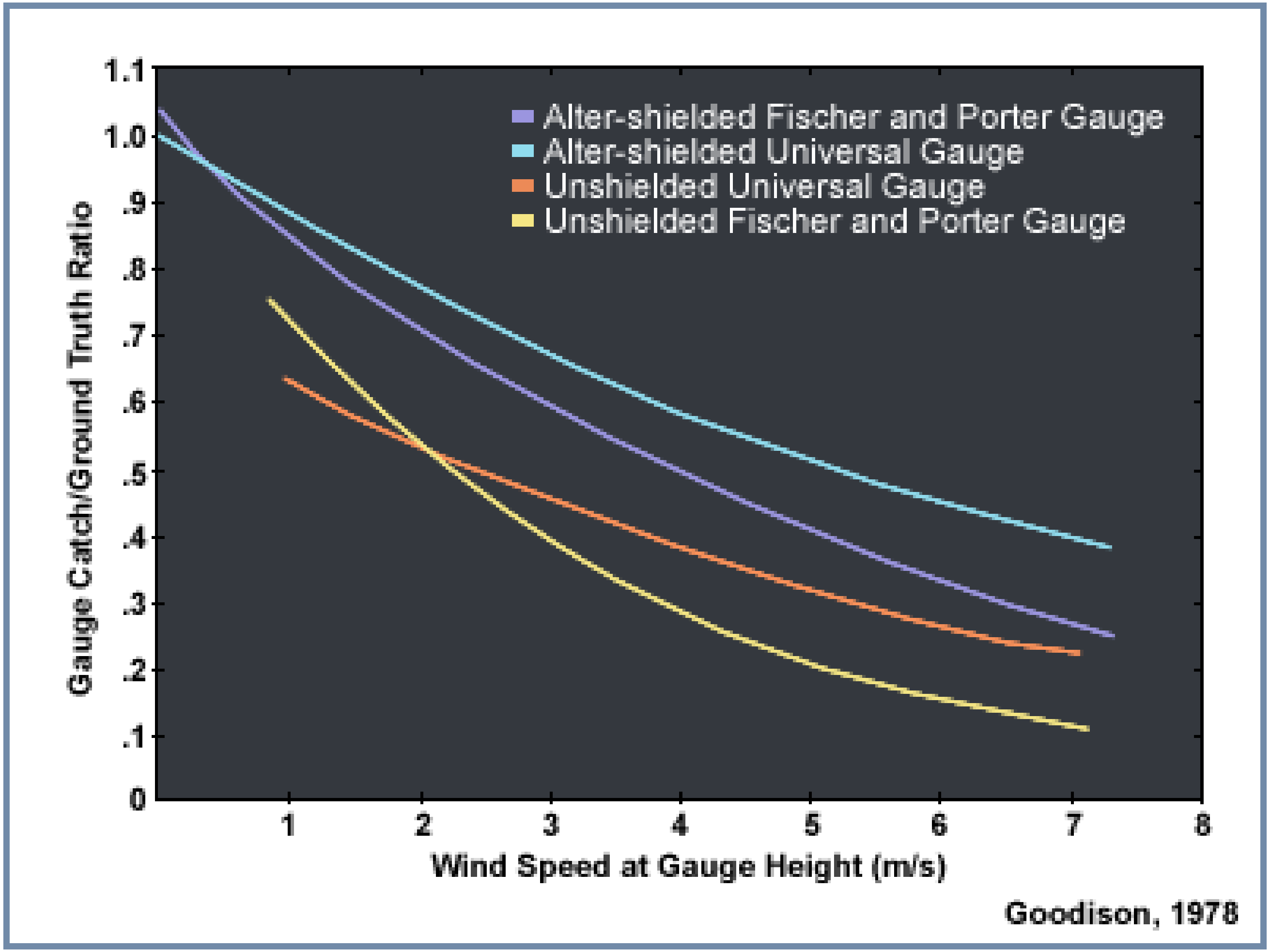


Nešpor, V. (1993)

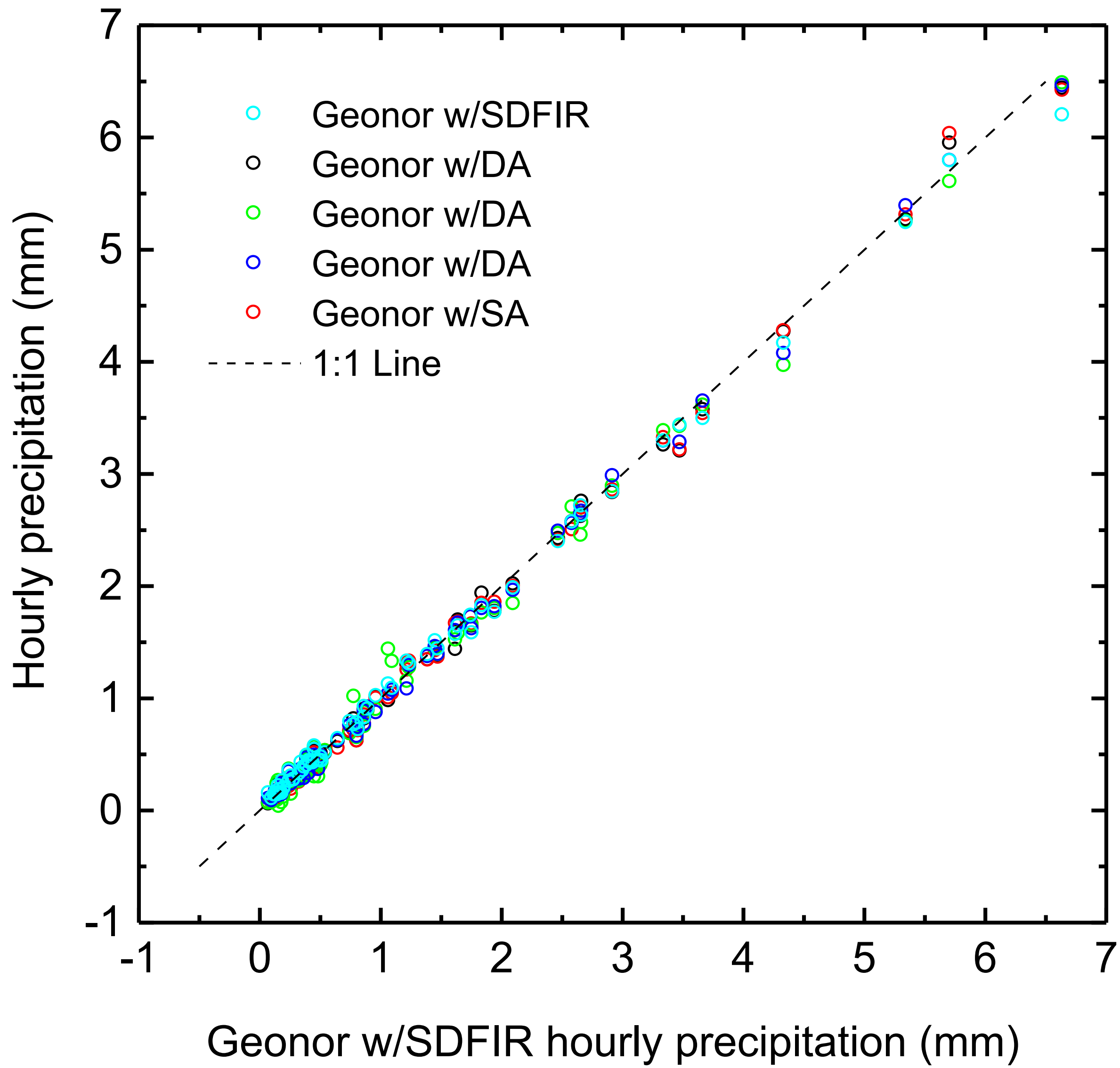

SEP 9 2009


DEC 14 2009

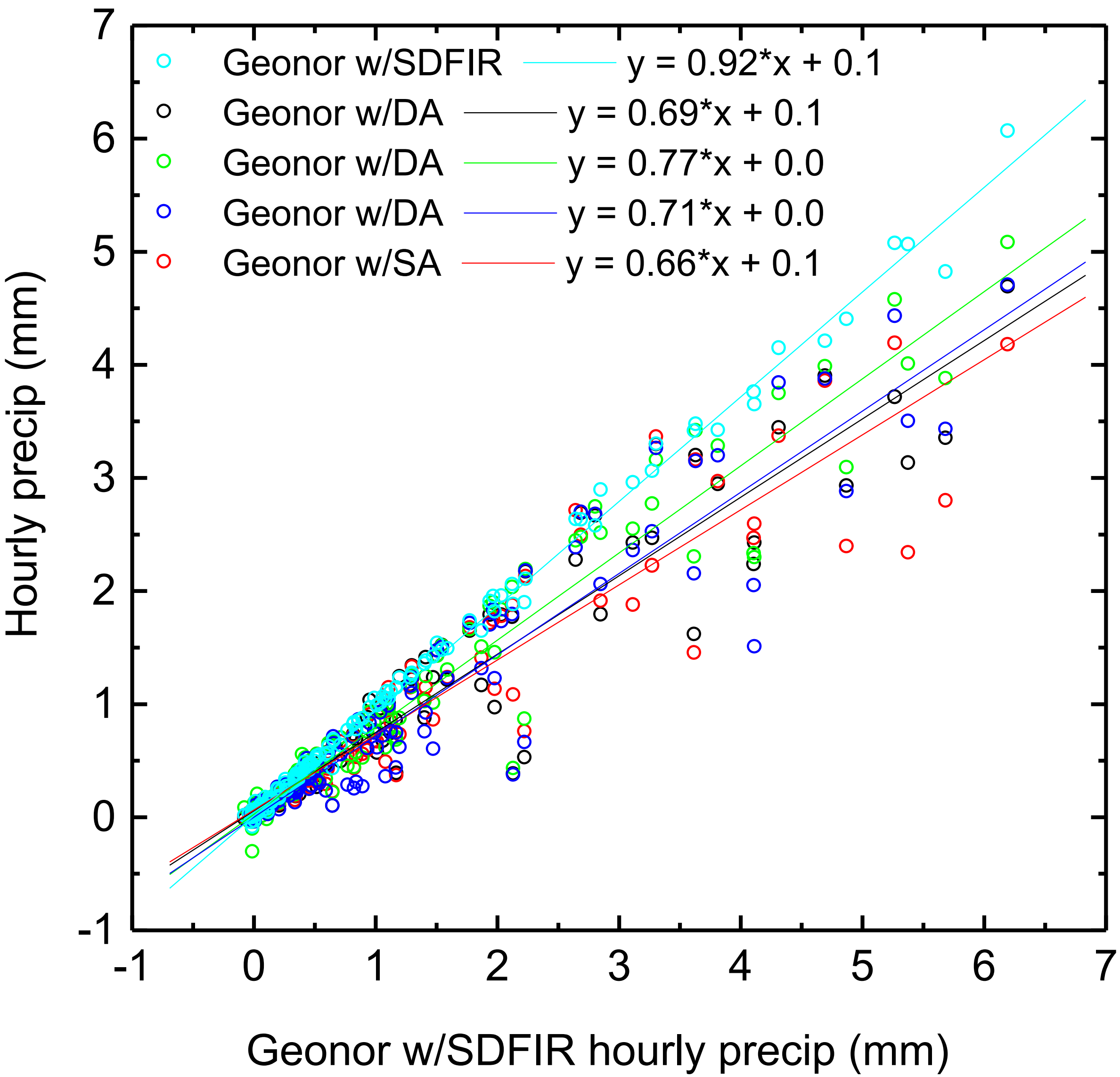

OCT 6 2009

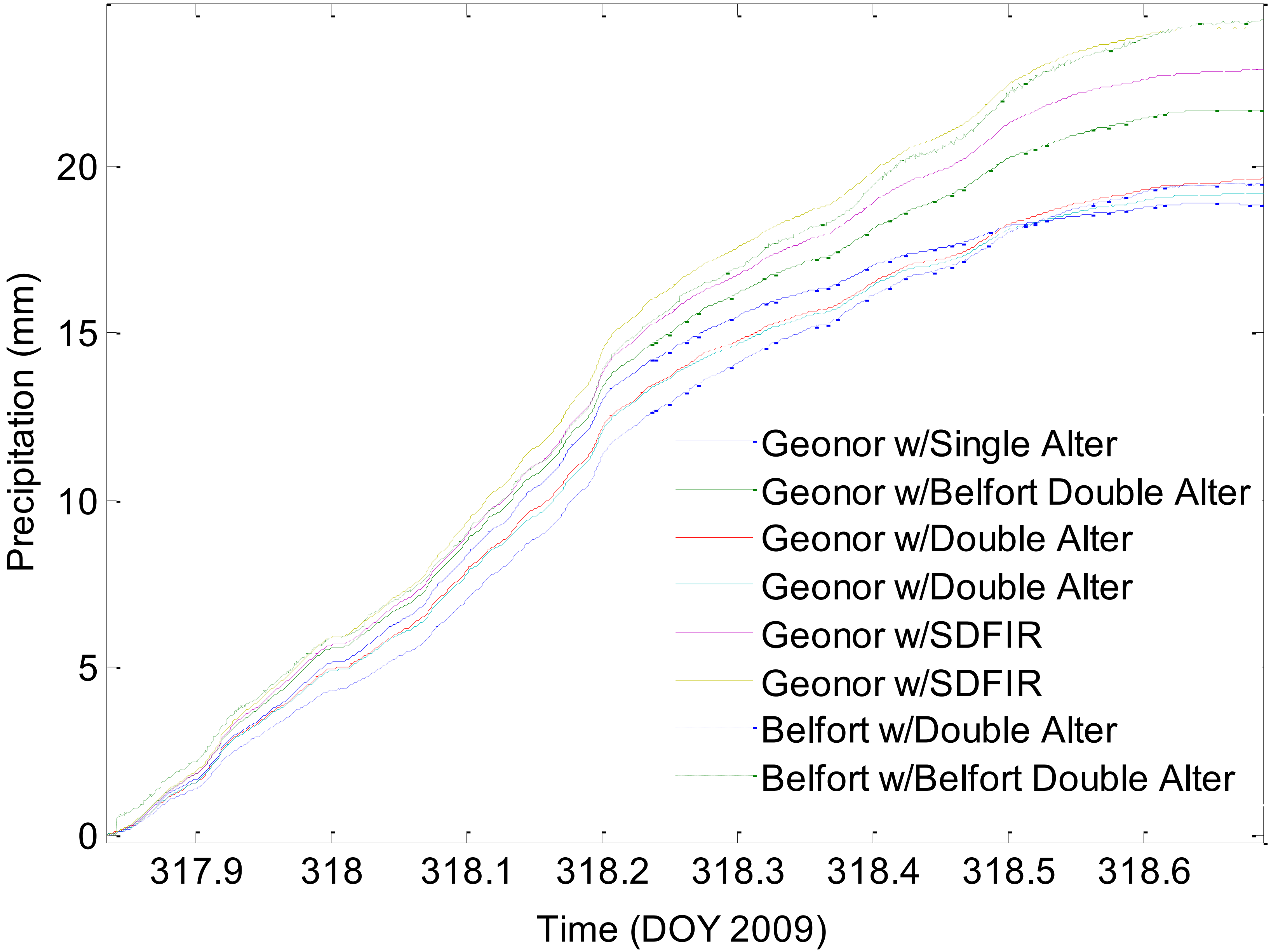

Alter-shielded Fischer and Porter Gauge
Alter-shielded Universal Gauge
Unshielded Universal Gauge
Unshielded Fischer and Porter Gauge
Gauge Catch/Ground Truth Ratio
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
1
2
3
4
5
6
7
8
Wind Speed at Gauge Height (m/s)
Goodison, 1978

Liquid Precipitation

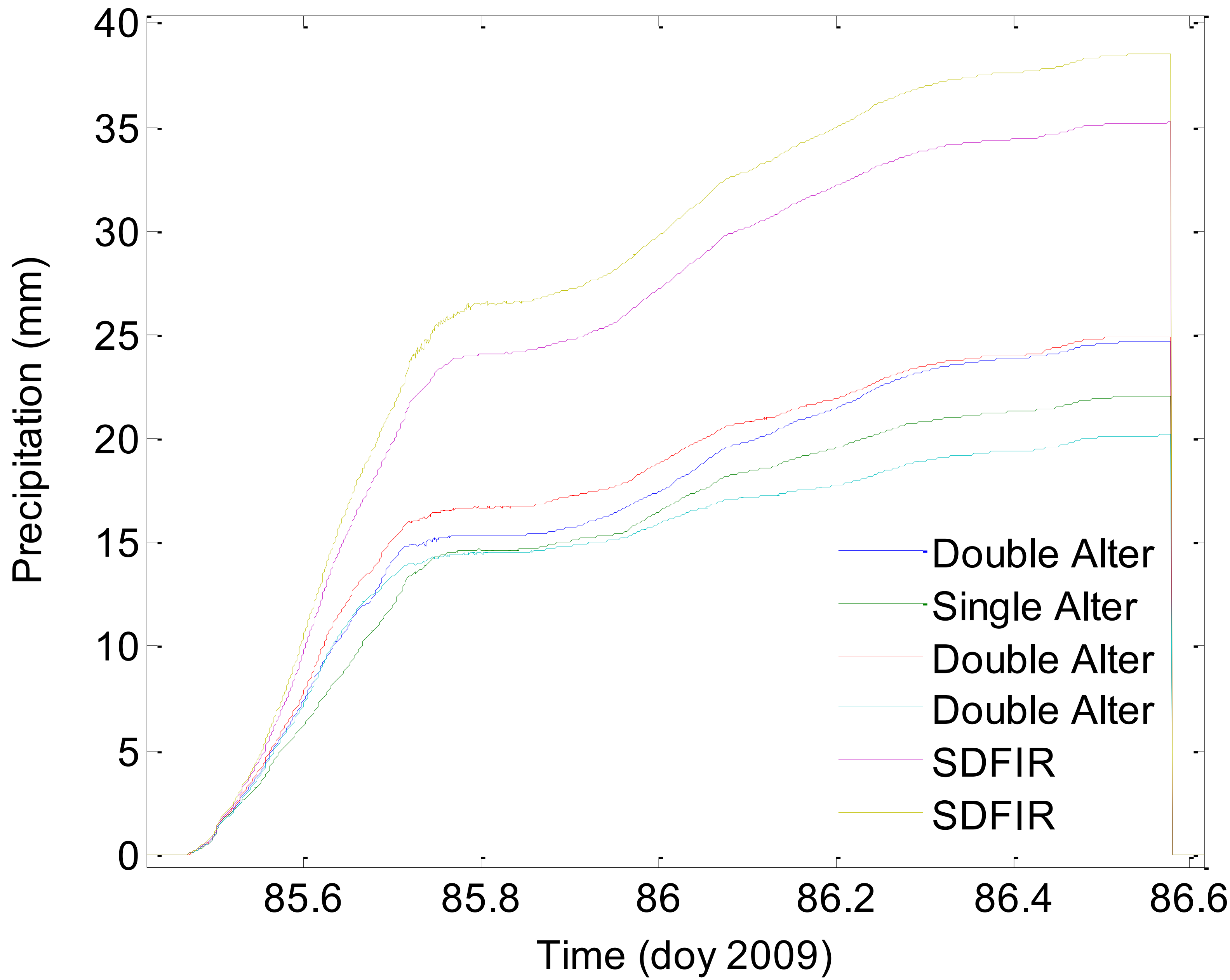


Solid Precipitation

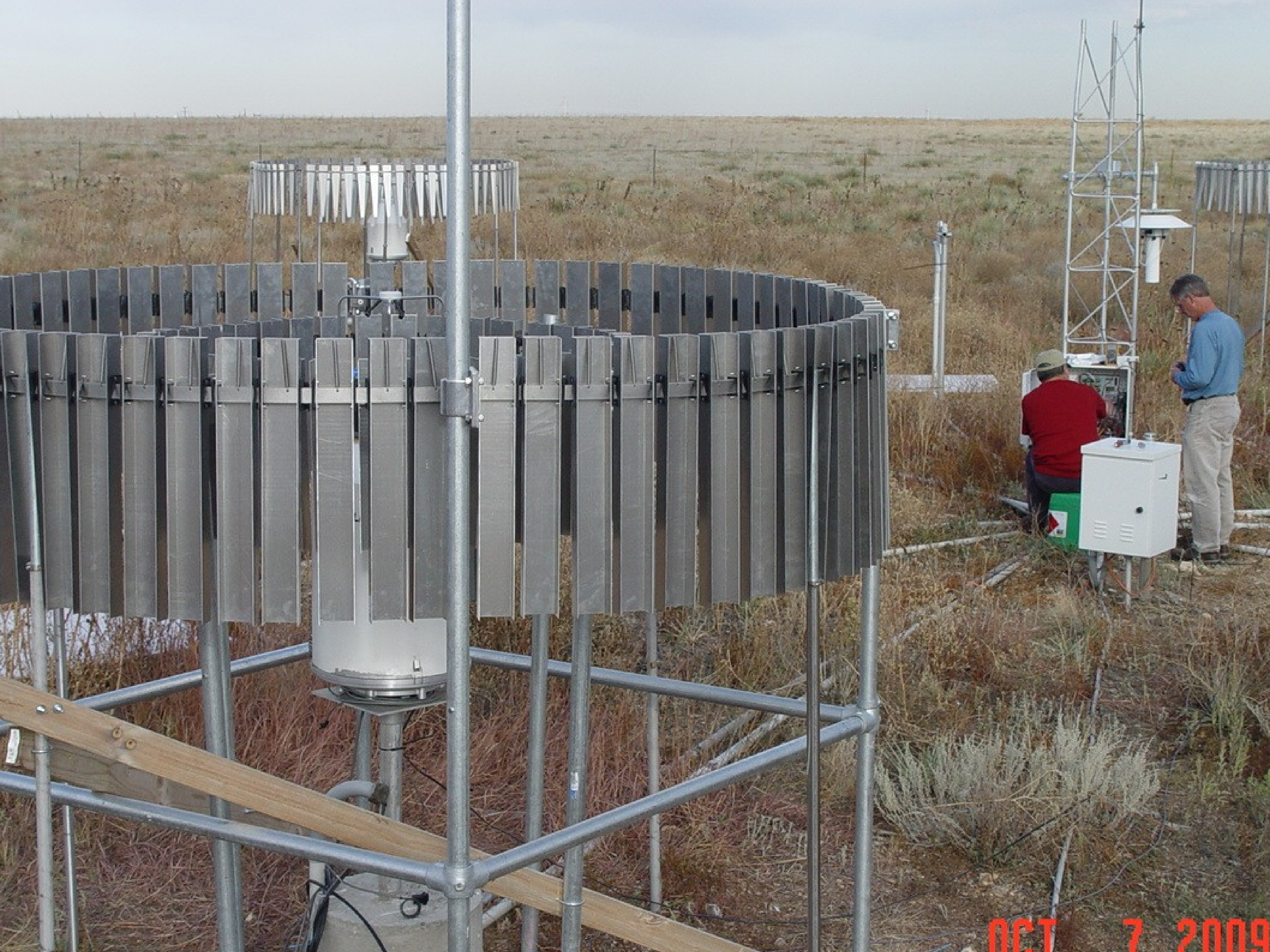




Precipitation (mm)
0
5
10
15
20
317.9
318
318.1
318.2
318.3
318.4
318.5
318.6
Time (DOY 2009)
Geonor w/Single Alter
Geonor w/Belfort Double Alter
Geonor w/Double Alter
Geonor w/Double Alter
Geonor w/SDFIR
Geonor w/SDFIR
Belfort w/Double Alter
Belfort w/Belfort Double Alter

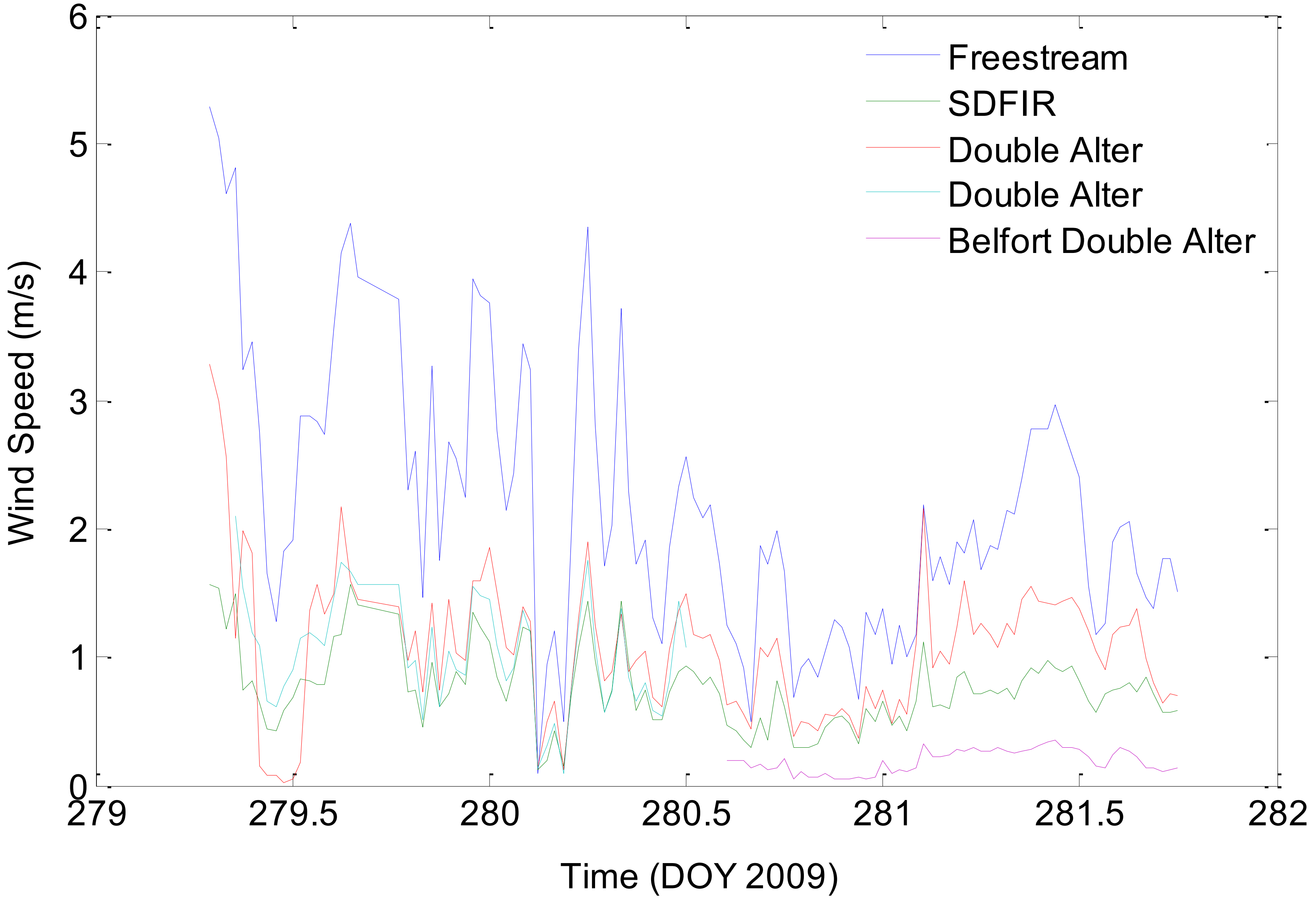


Precipitation (mm)
40
35
30
25
20
15
10
5
0
85.6
85.8
86
86.2
86.4
86.6
Time (doy 2009)
Double Alter
Single Alter
Double Alter
Double Alter
SDFIR
SDFIR


OCT 7 2009

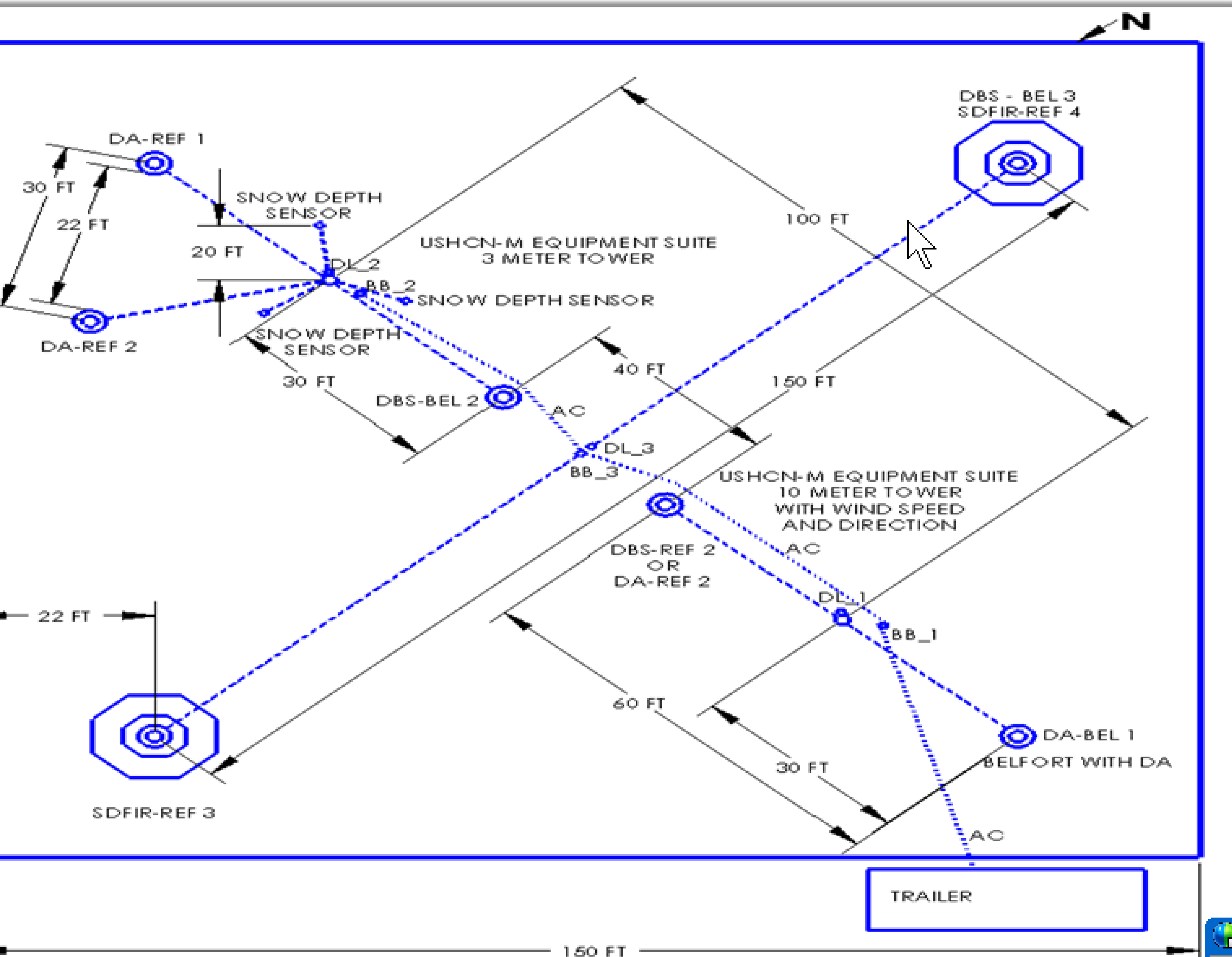

OCT 7 2009


OCT 7 2009



Freestream
SDFIR
Double Alter
Double Alter
Belfort Double Alter
Wind Speed (m/s)
Time (DOY 2009)
0
1
2
3
4
5
6
279
279.5
280
280.5
281
281.5
282

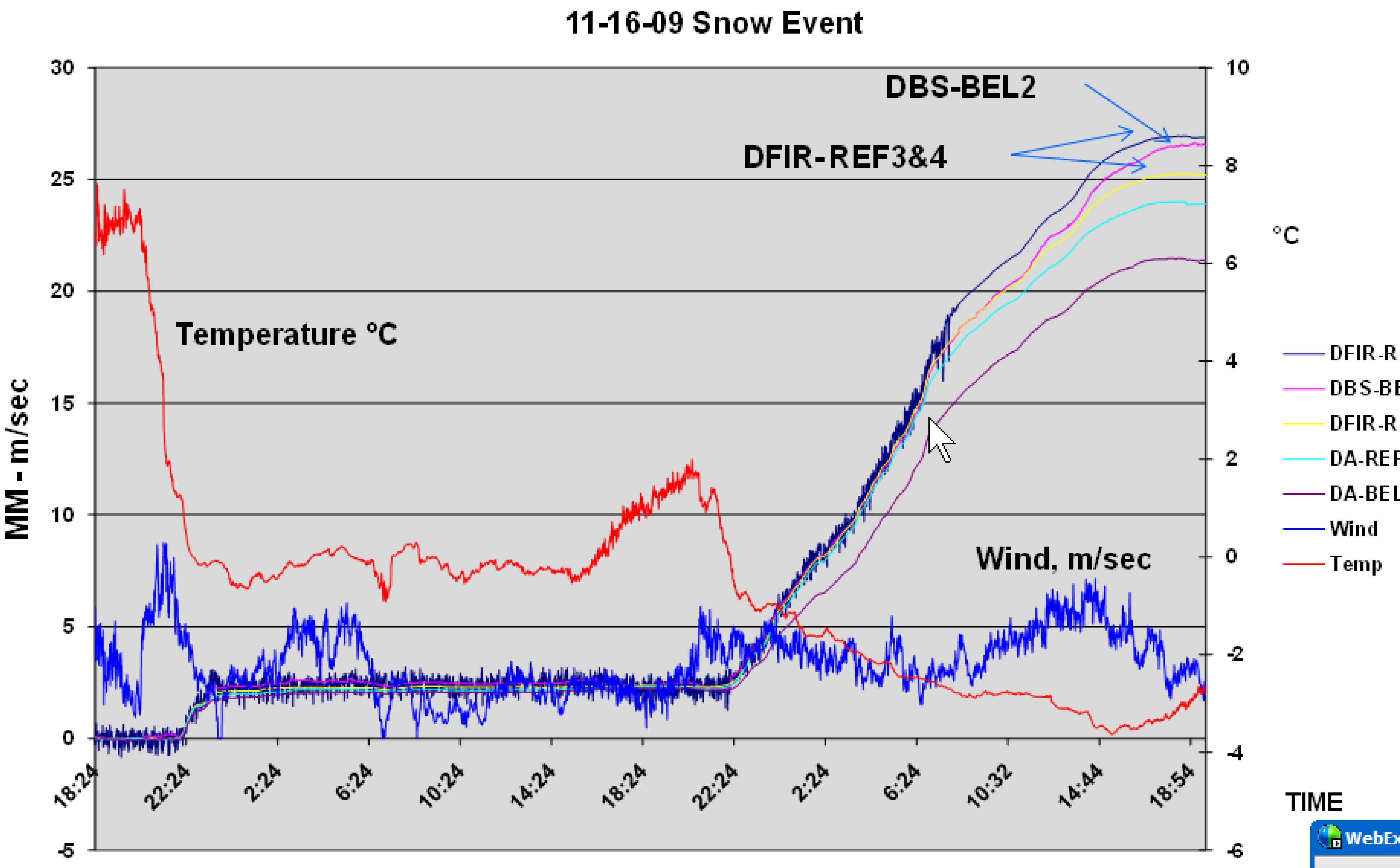
st Bed Marshall, CO



WebEx Player - paper165285_1

File Controls Help

November Snow Event



Rain Gauge QPE Key Points

- Gauge reports excellent for well-maintained, optimally located gauges in light winds
- Rain gauges do not necessarily provide good spatial resolution
- Significant underestimation error in strong winds
- Gauge undercatch affected by variability in wind and hydrometeors
- High wind: possibly greater inaccuracy in gauge data than in radar data (where good radar data)