Errors, biases, and corrections for weighing gauge precipitation measurements from WMO-SPICE

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[2]Environment Canada, Toronto, ON, Canada
[3]World Meteorological Organization, Geneva, Switzerland
[4]Norwegian Meteorological Institute, Oslo, Norway
[5]National Center for Atmospheric Research, Boulder, US
[6]Environment Canada, Dartmouth, Nova Scotia, Canada
[7]Meteoswiss, Payerne, Switzerland
[8]Environment Canada, Climate Research Division, Saskatoon, Canada
[9]Delegación Territorial de AEMET en Aragón, Zaragoza, Spain
[10]Finnish Meteorological Institute, Helsinki, Finland
[11]Kyungpook National University, Daegu, Korea

World
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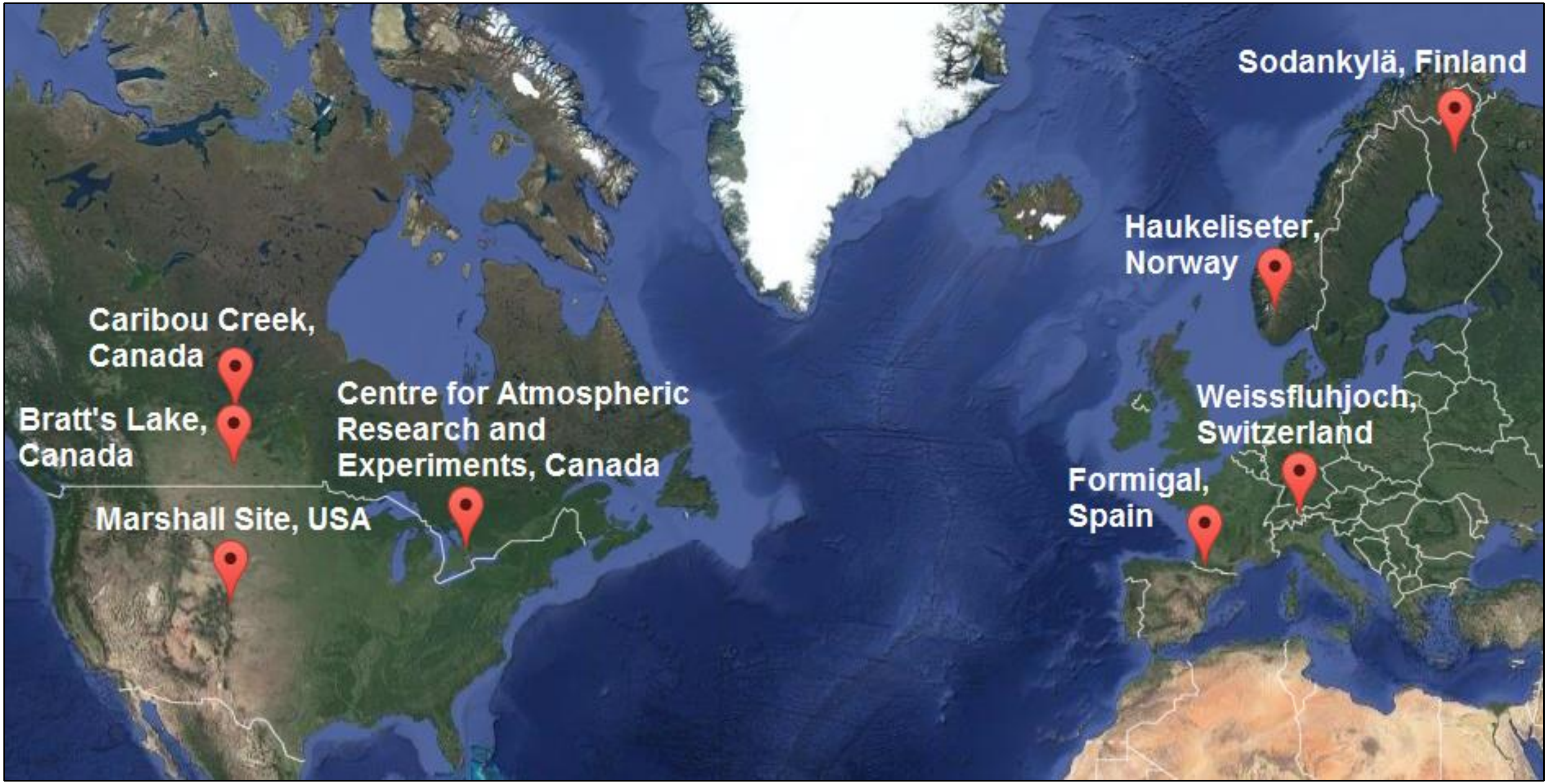
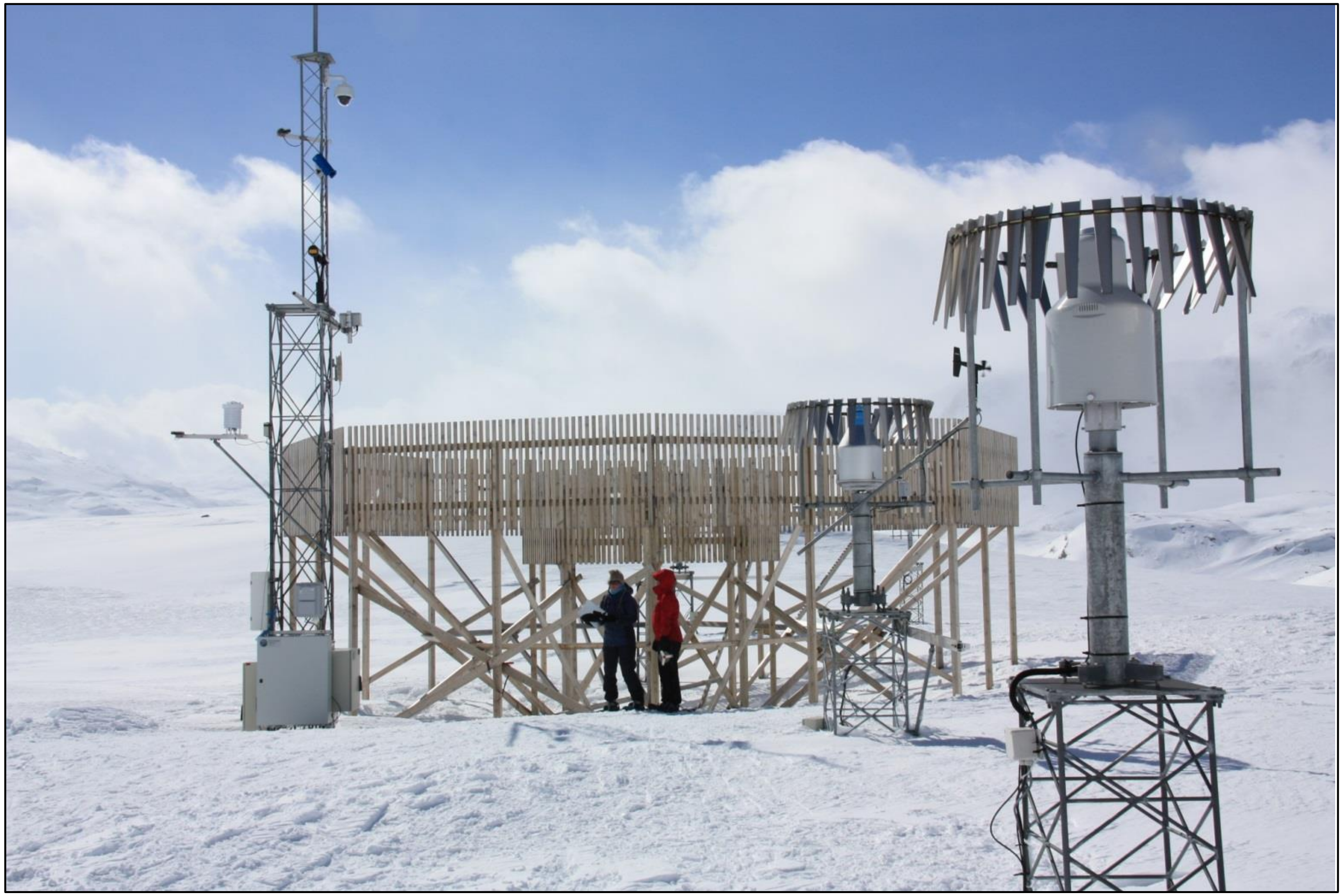
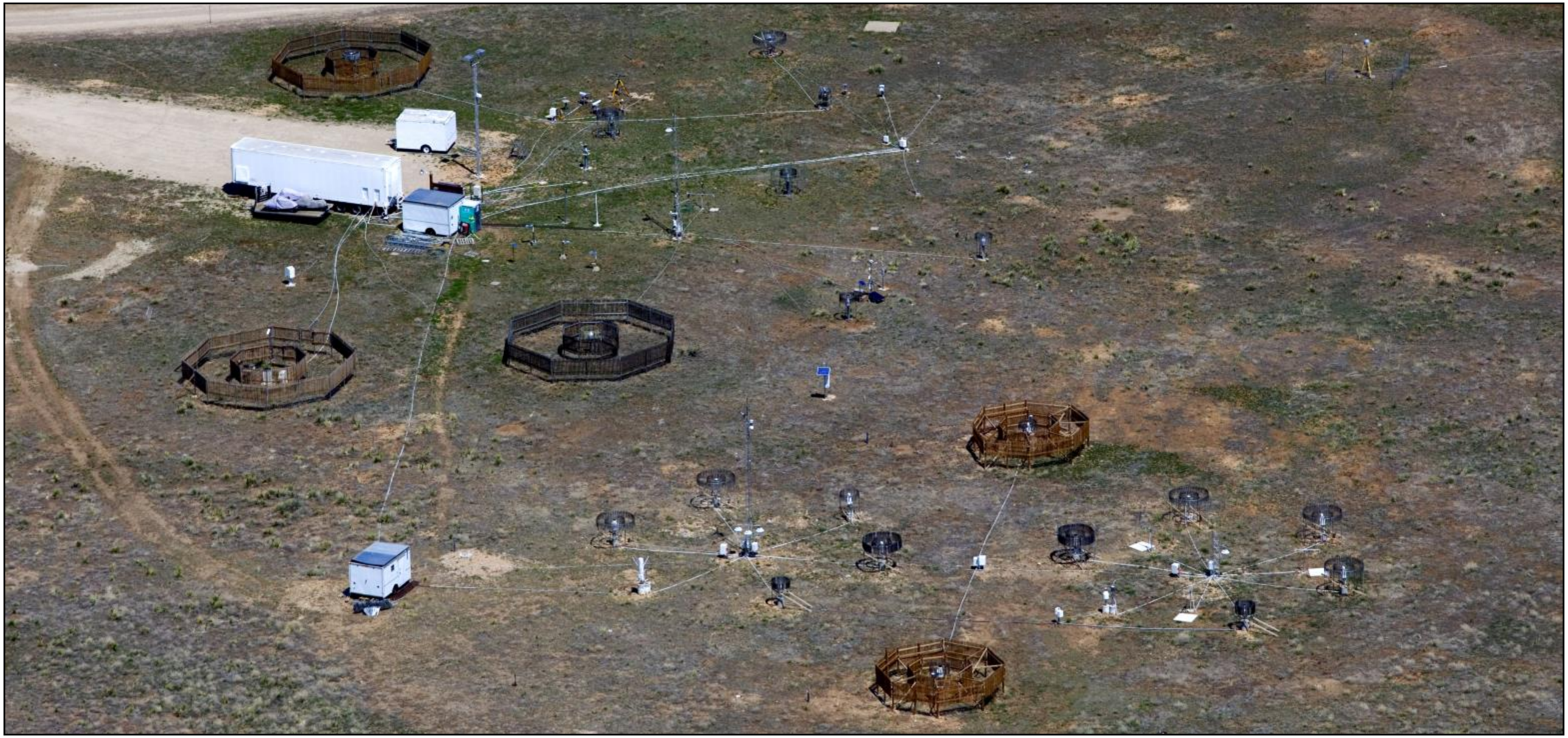
Site Locations


Sodankylä, Finland
Haukeliseter, Norway
Caribou Creek, Canada
Bratt's Lake, Canada
Centre for Atmospheric Research and Experiments, Canada
Weissfluhjoch, Switzerland
Formigal, Spain
Marshall Site, USA

An Example Testbed (Norway)

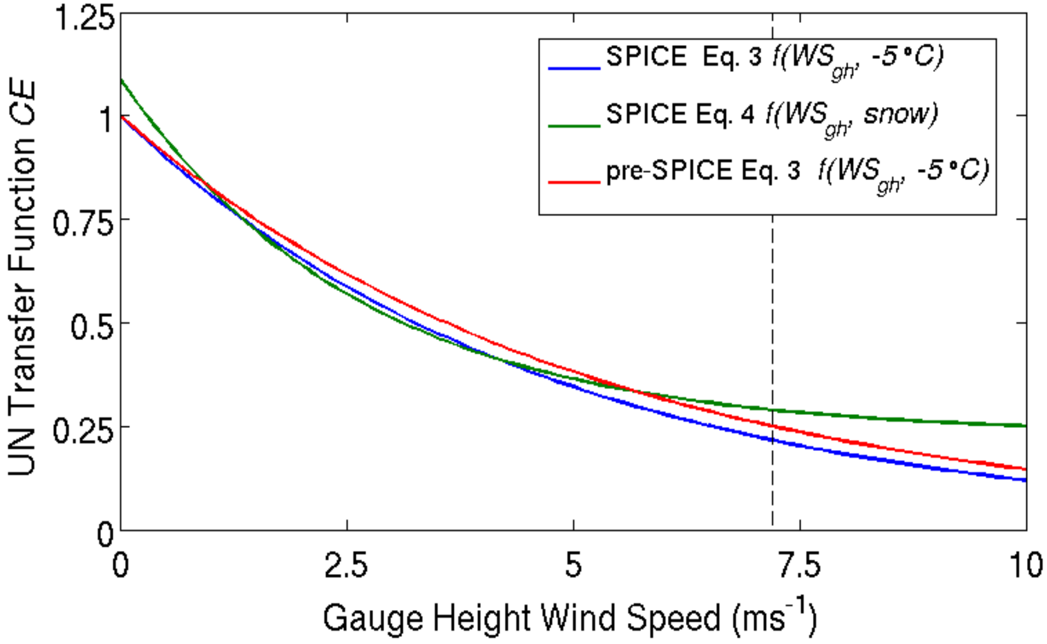


Another Example Testbed (USA)

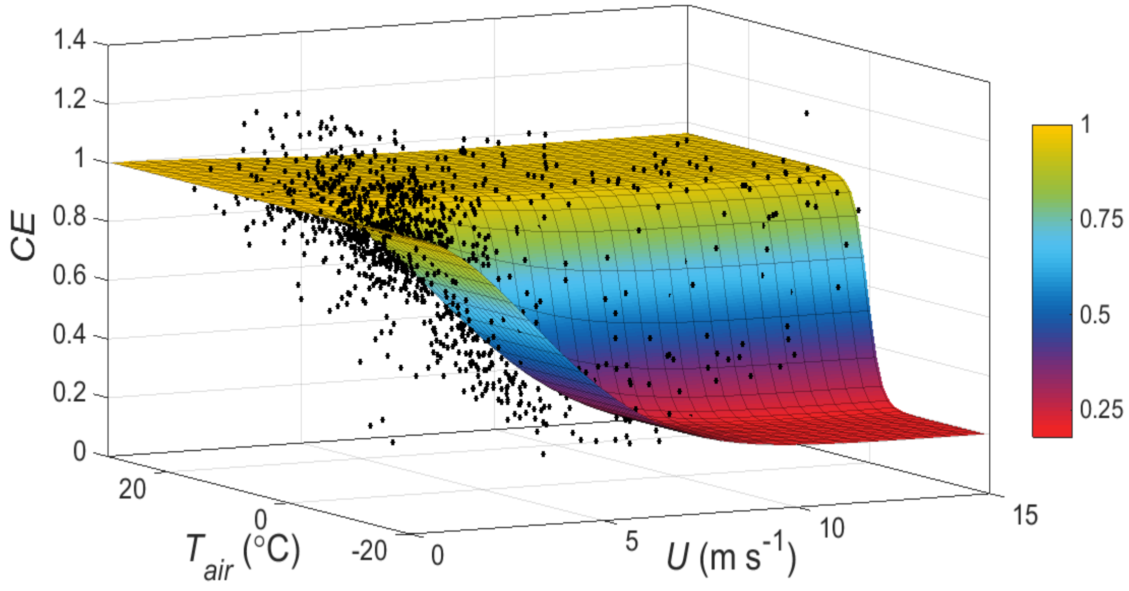


Example Transfer Functions

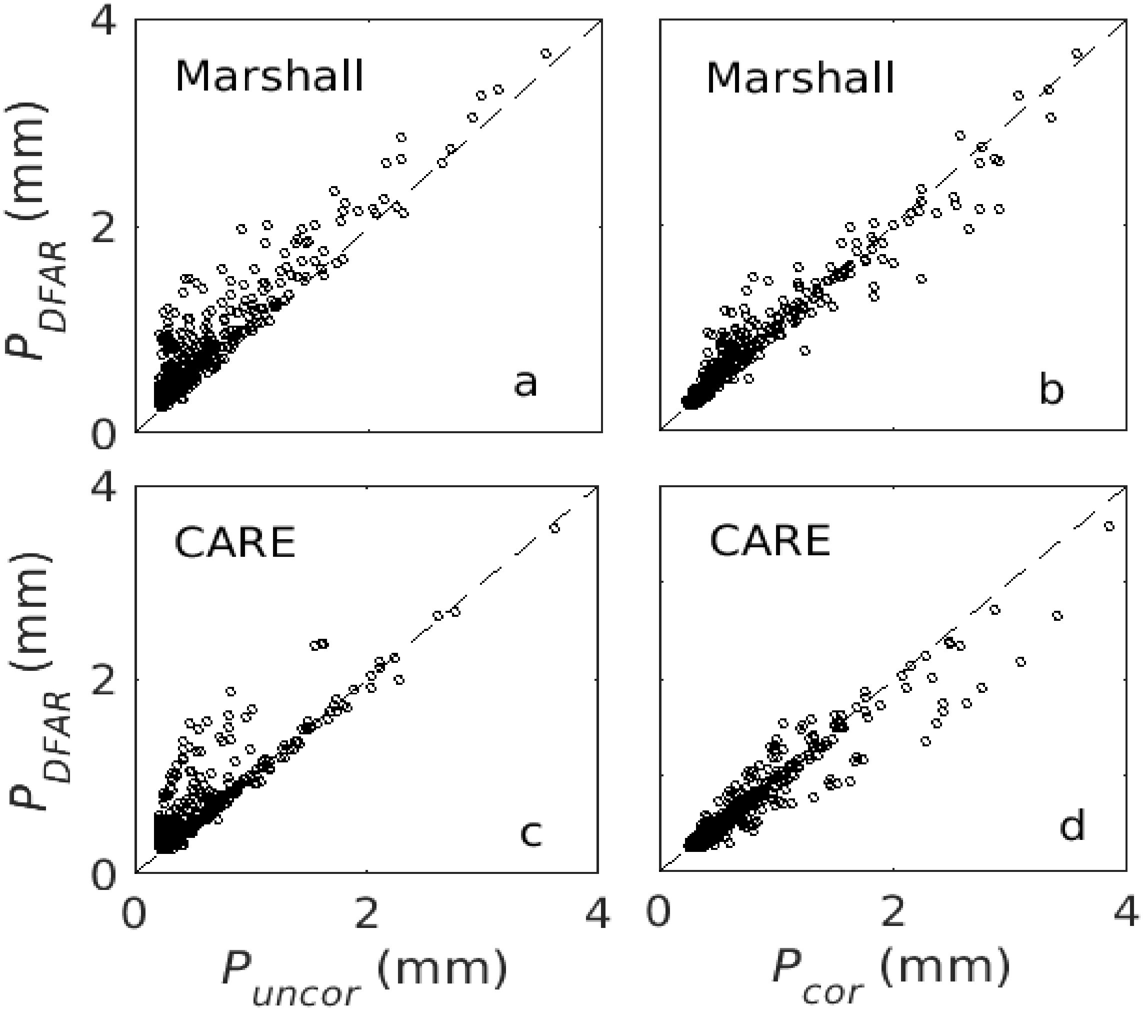
$$CE = f(U)$$



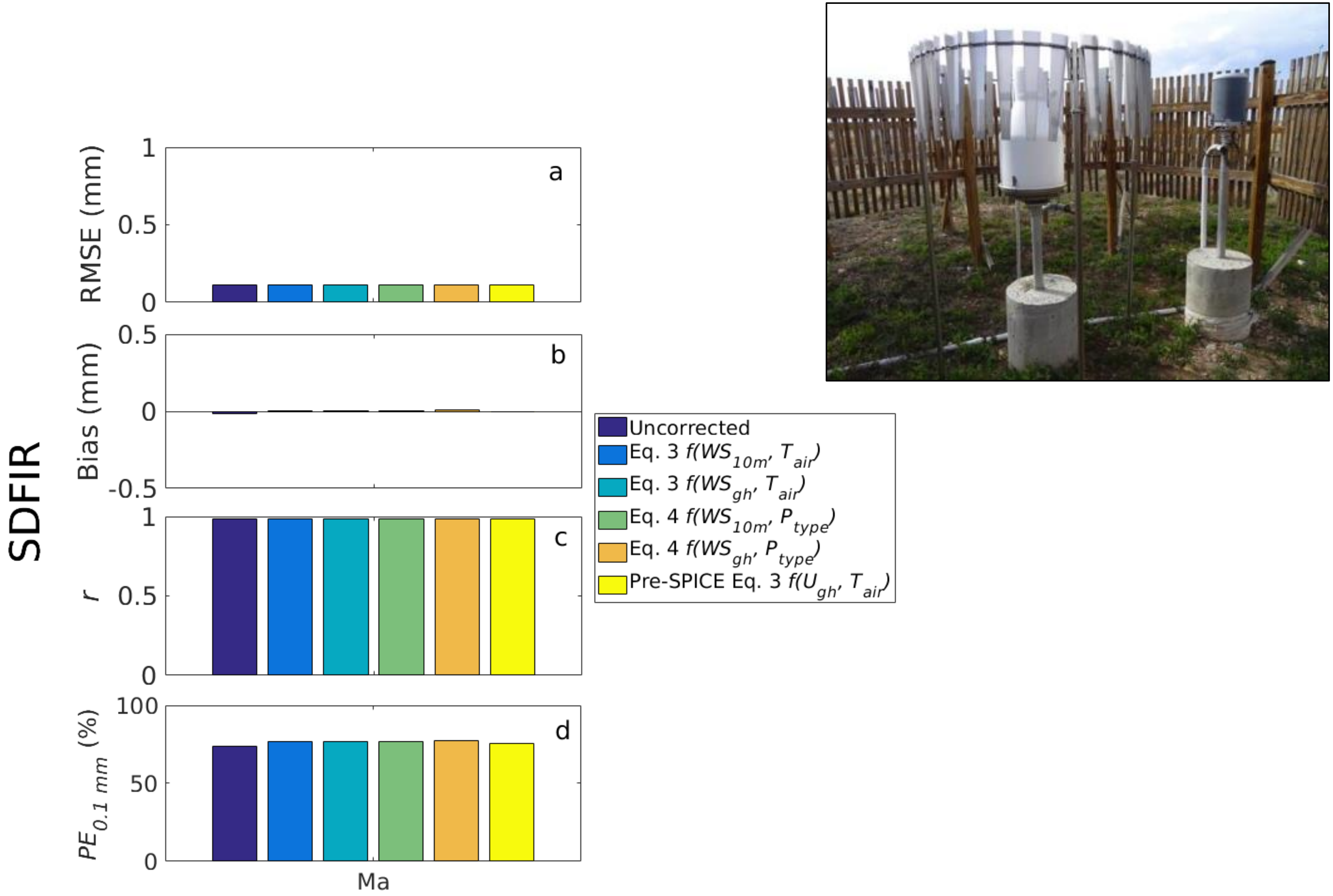
$$CE = f(U, Tair)$$



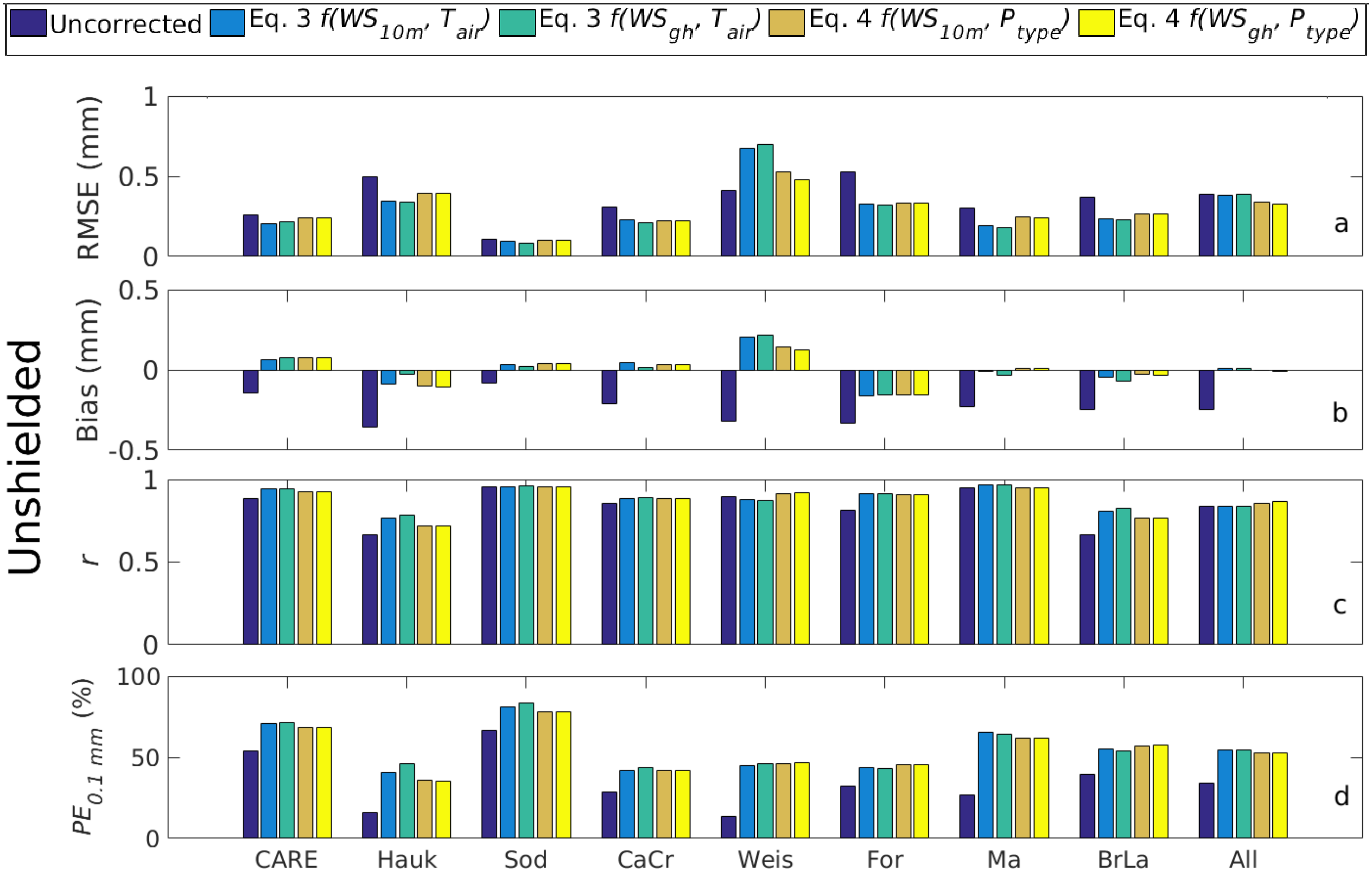
Uncorrected and Corrected Measurements



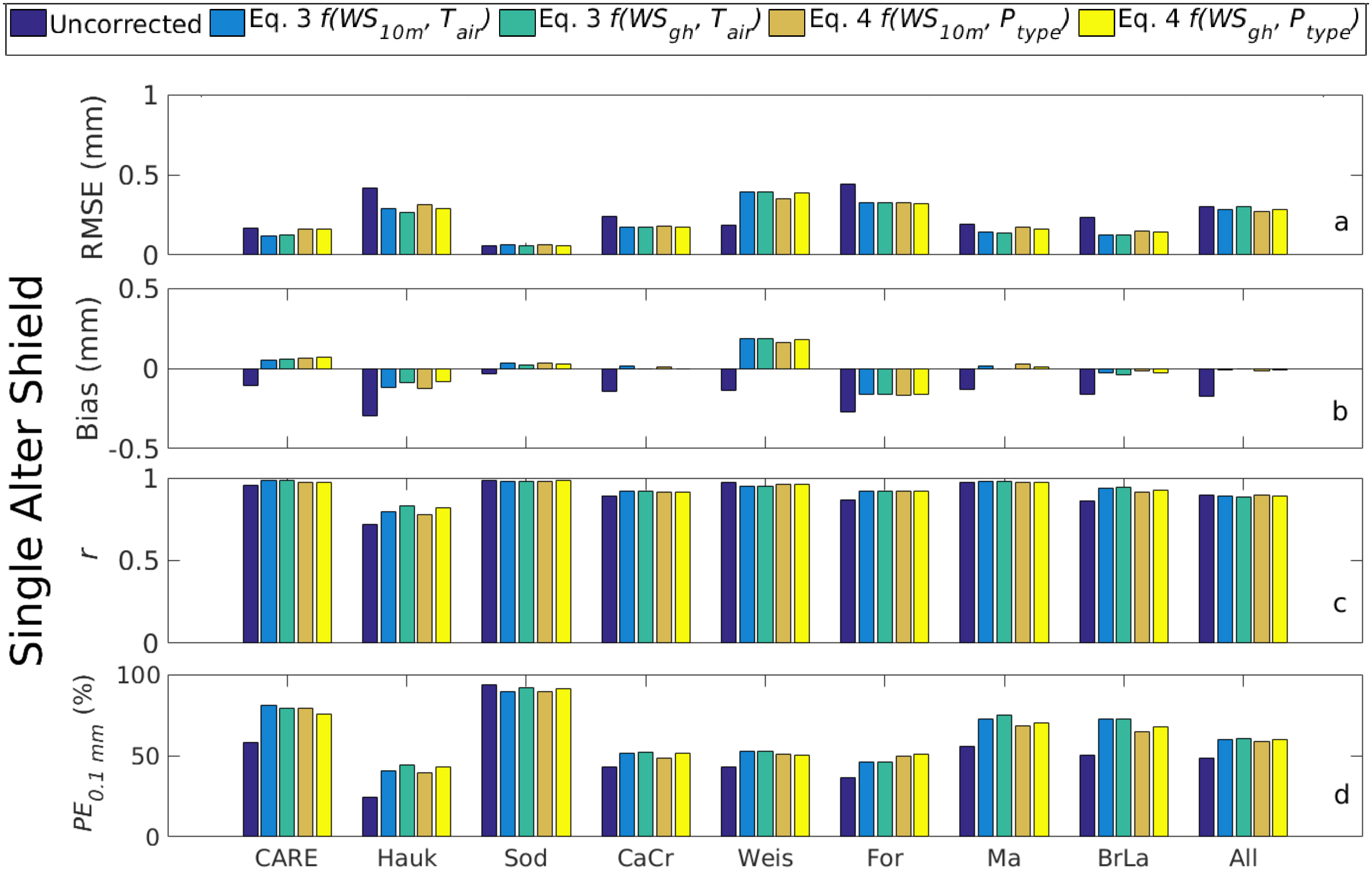
Small DFIR


SDFIR
RMSE (mm)
1
0.5
0
a
Bias (mm)
0.5
0
-0.5
b
r
1
0.5
0
c
$PE_{0.1\ mm}$ (%)
100
50
0
d
Ma
Uncorrected
Eq. 3 $f(WS_{10m}, T_{air})$
Eq. 3 $f(WS_{gh}, T_{air})$
Eq. 4 $f(WS_{10m}, P_{type})$
Eq. 4 $f(WS_{gh}, P_{type})$
Pre-SPICE Eq. 3 $f(U_{gh}, T_{air})$

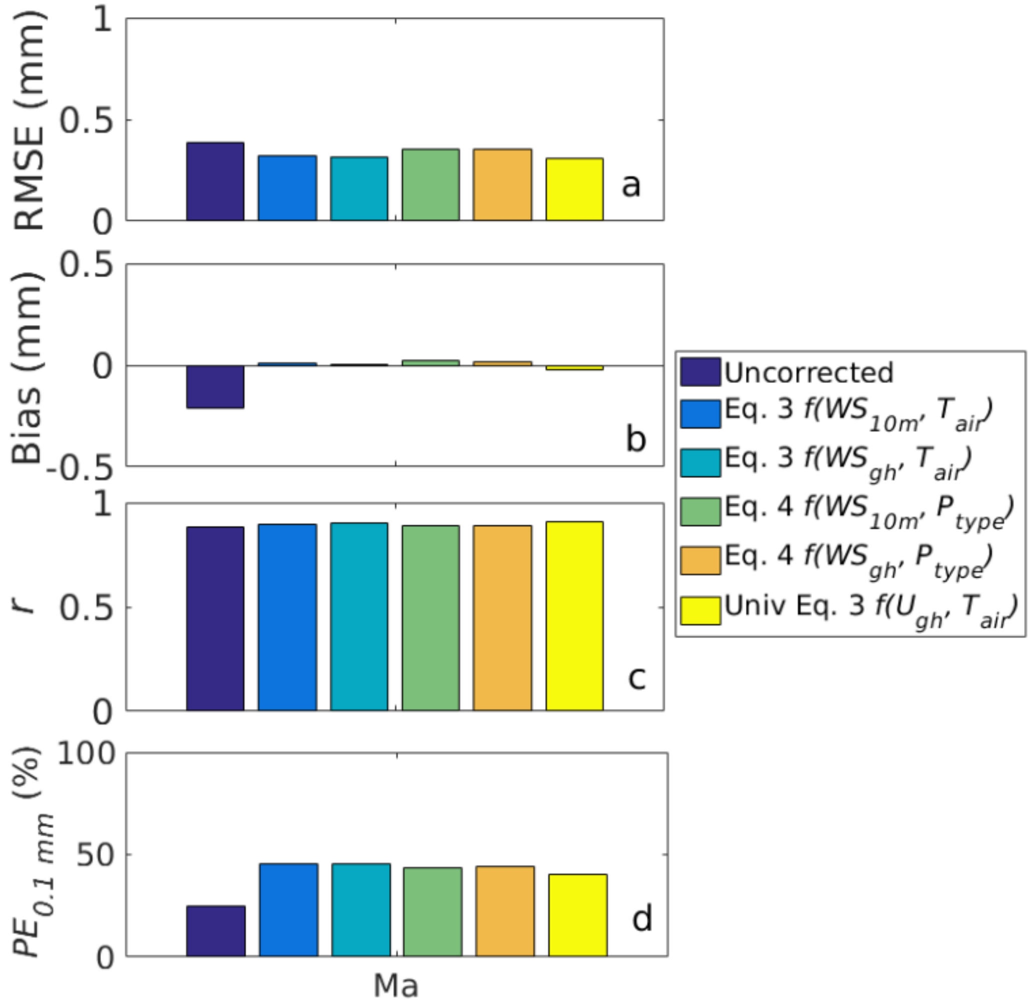
Unshielded Results



Single Altar Results

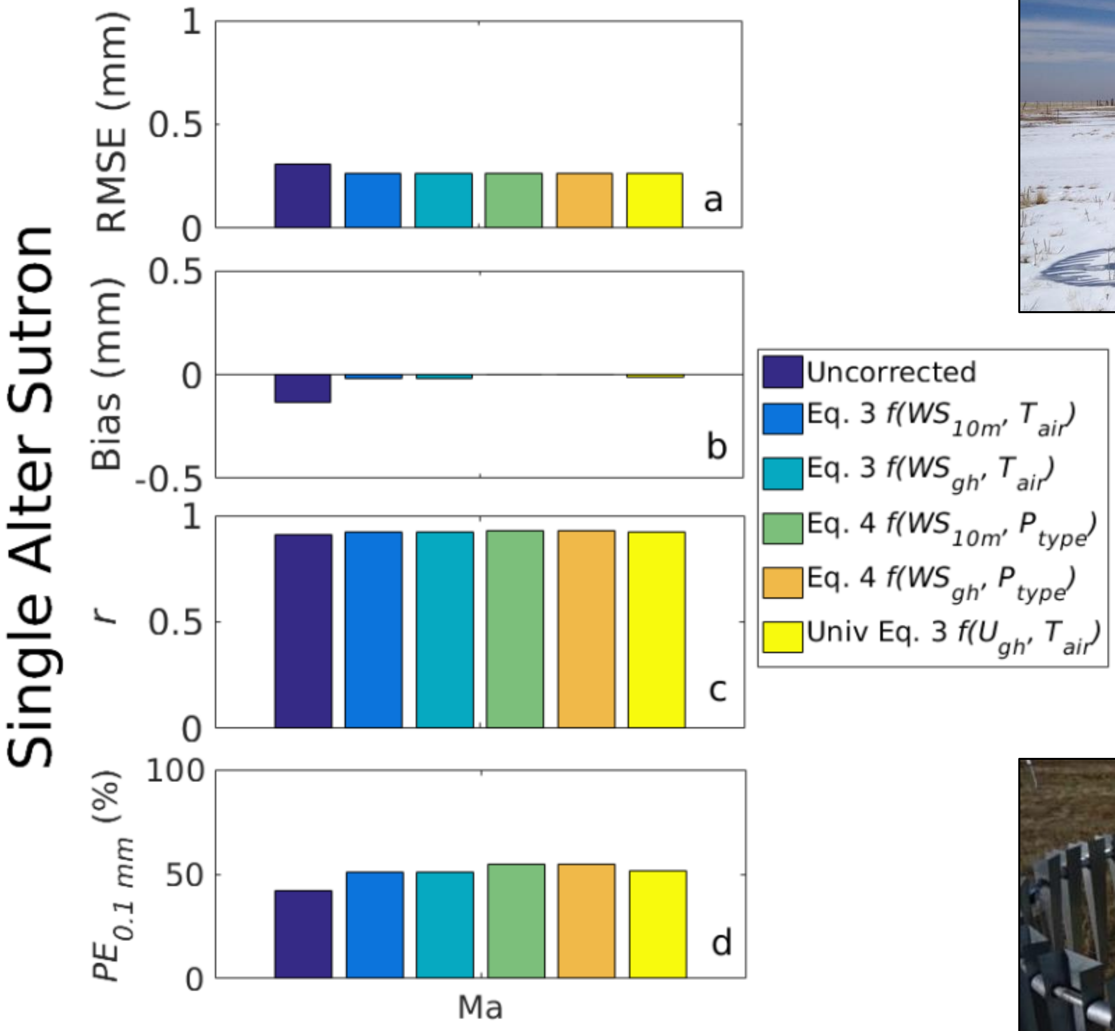


Sutron



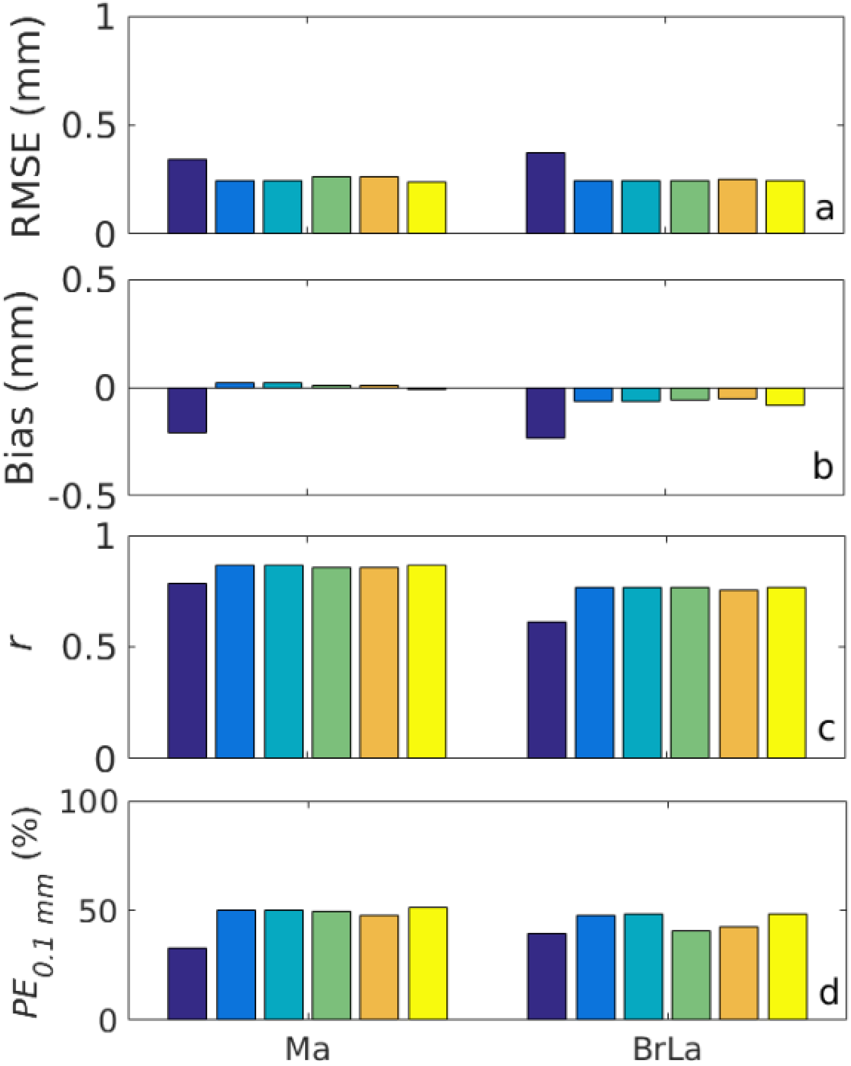
Unshielded Sutron

Single-Alter Shielded Sutron



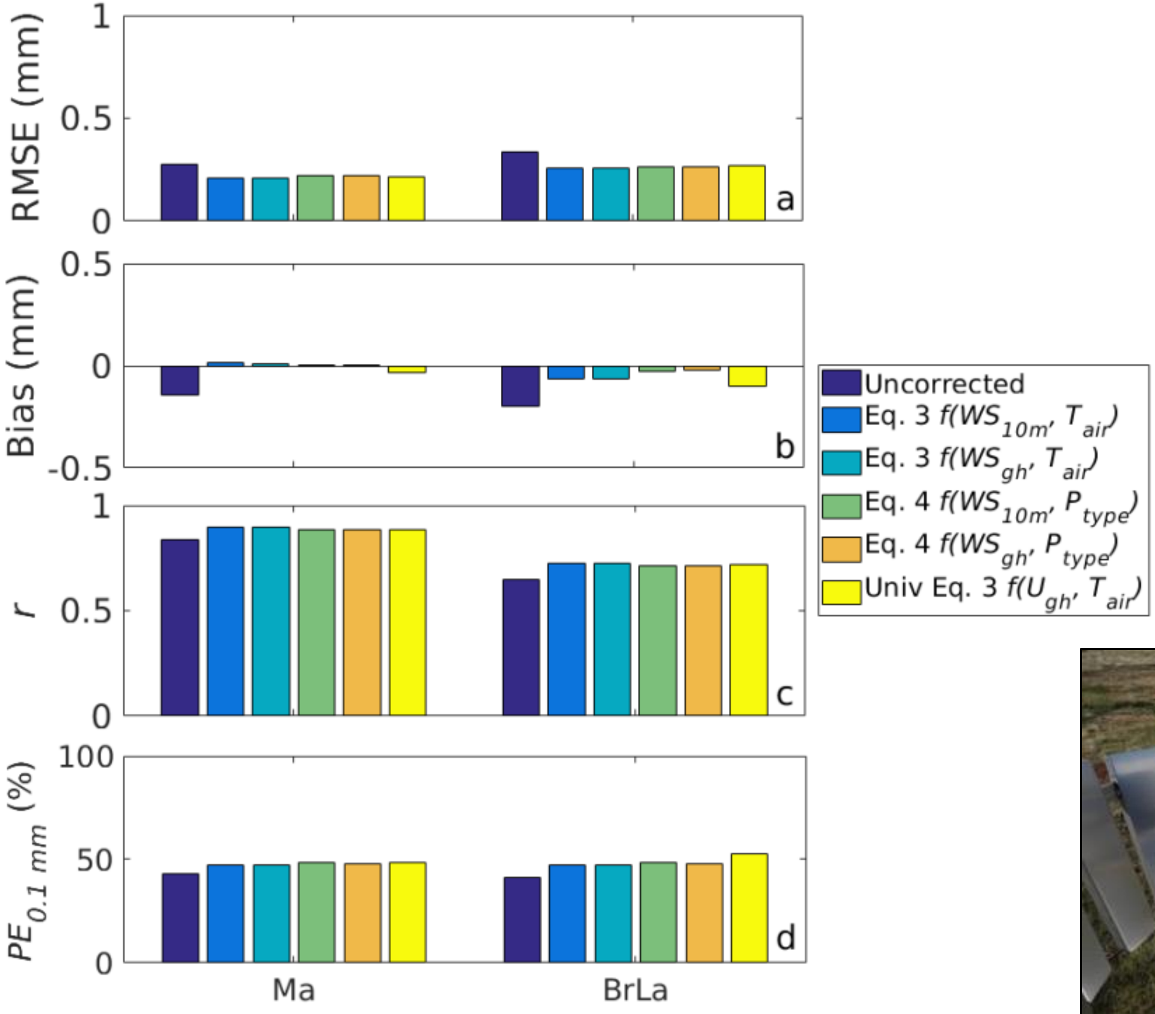
MRW500

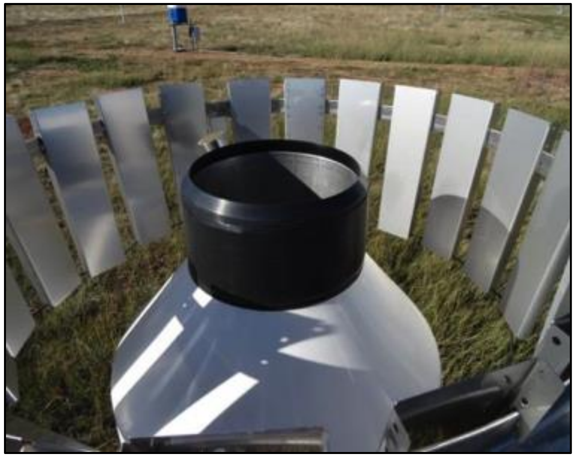
Unshielded MRW500



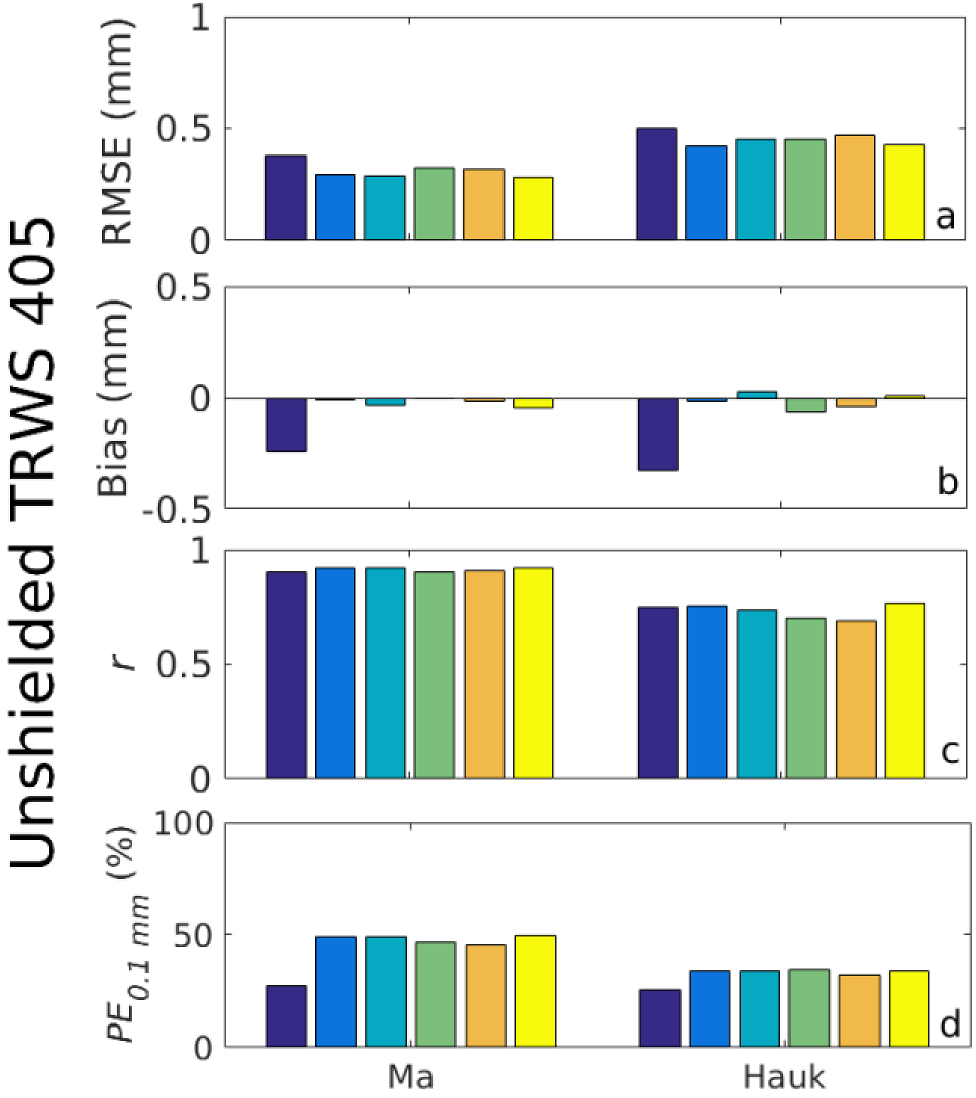
Shielded MRW500

Shielded MRW500





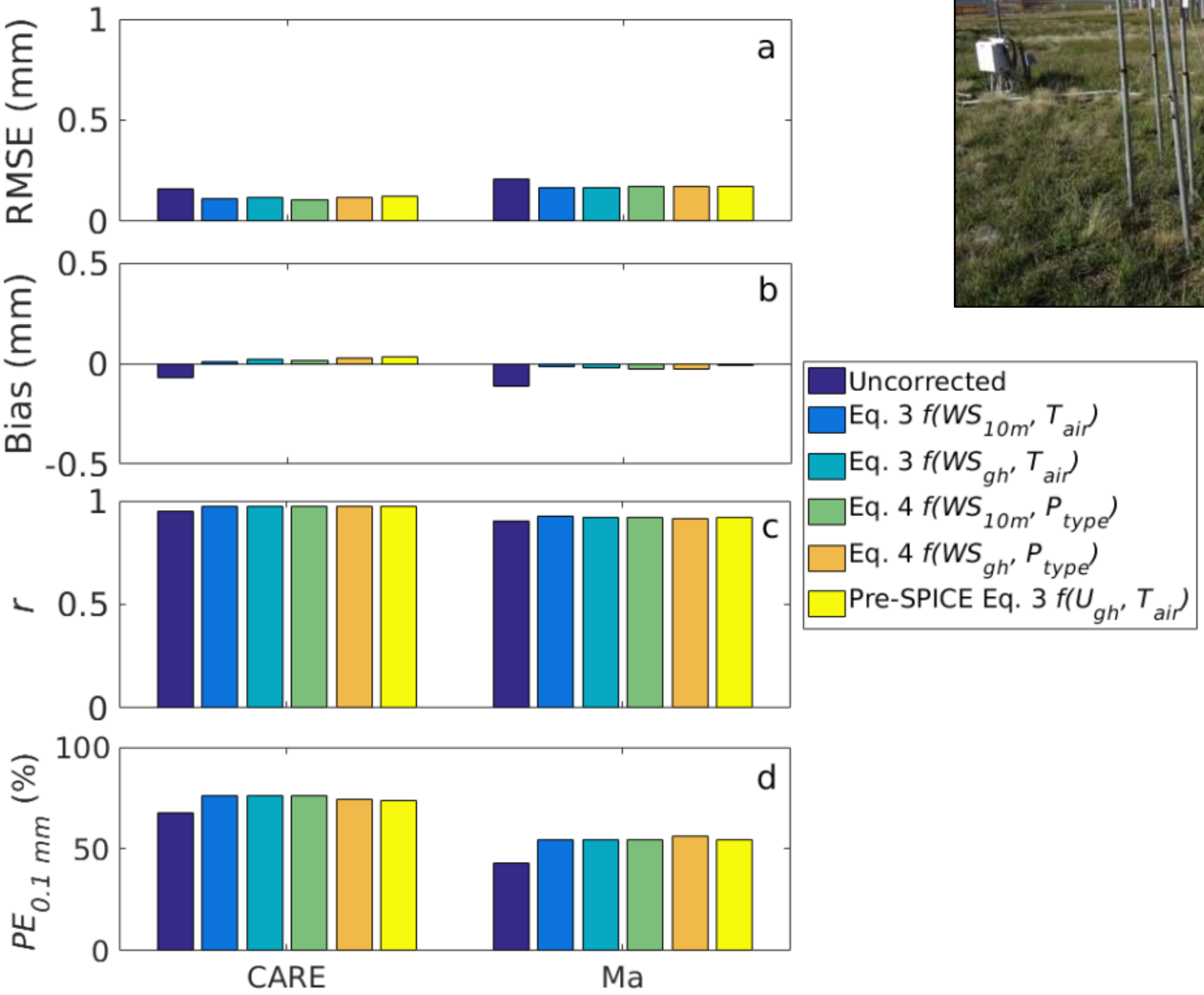
TRWS 405

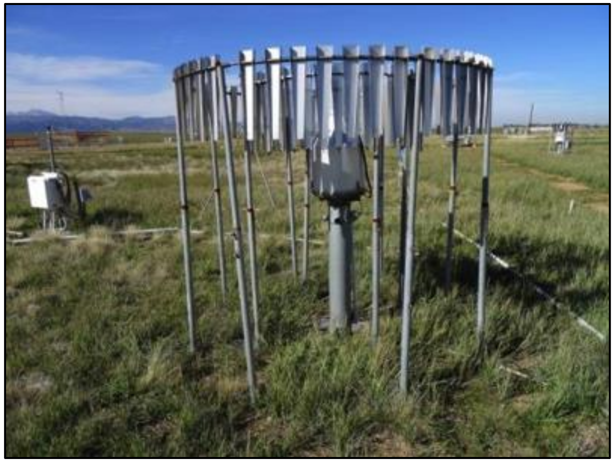

Unshielded TRWS 405
RMSE (mm)
1
0.5
0
a
Bias (mm)
0.5
0
-0.5
b
r
1
0.5
0
c
$PE_{0.1\ mm}$ (%)
100
50
0
d
Ma
Hauk
Uncorrected
Eq. 3 $f(WS_{10m}, T_{air})$
Eq. 3 $f(WS_{gh}, T_{air})$
Eq. 4 $f(WS_{10m}, P_{type})$
Eq. 4 $f(WS_{gh}, P_{type})$
Univ Eq. 3 $f(U_{gh}, T_{air})$

TRwS 405

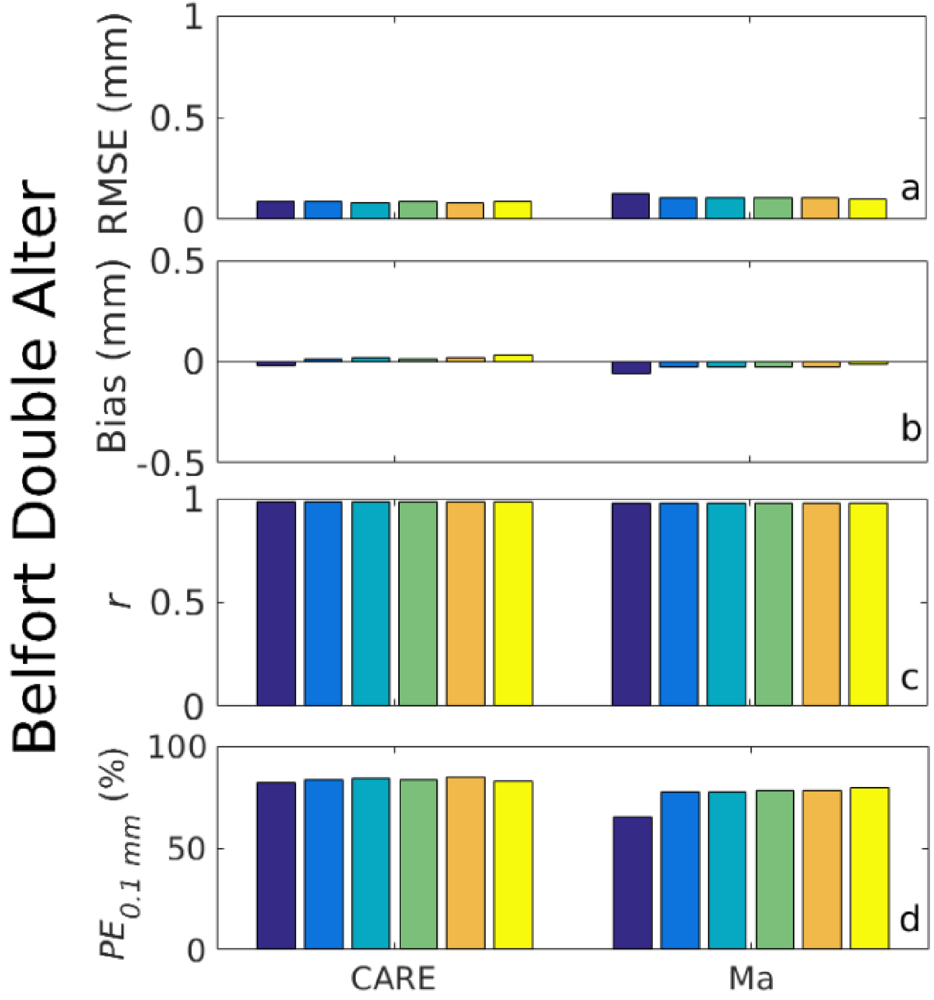
Double Alter Shield

Double Alter

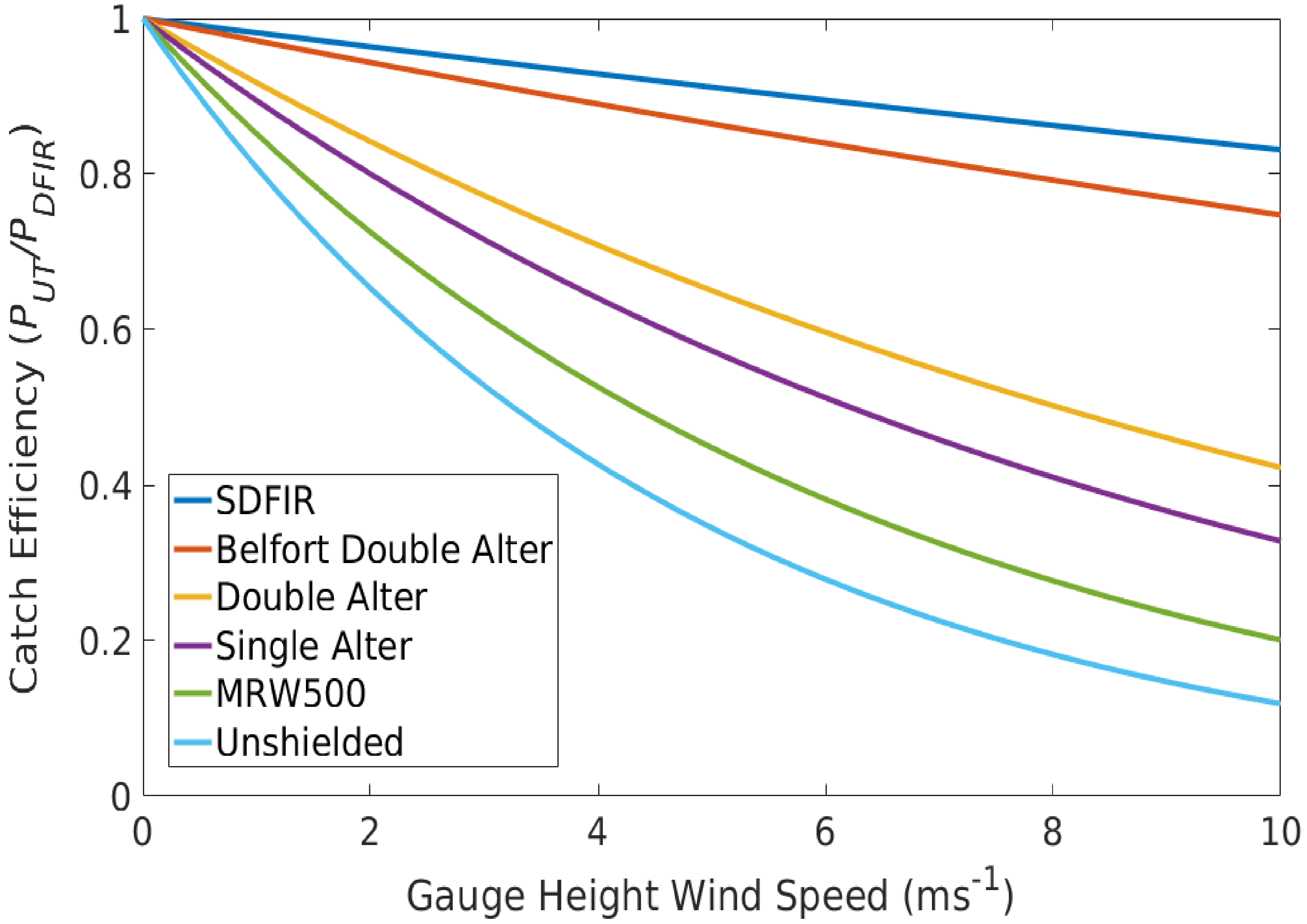




Belfort Double Alter Shield



Resultant transfer functions



The End

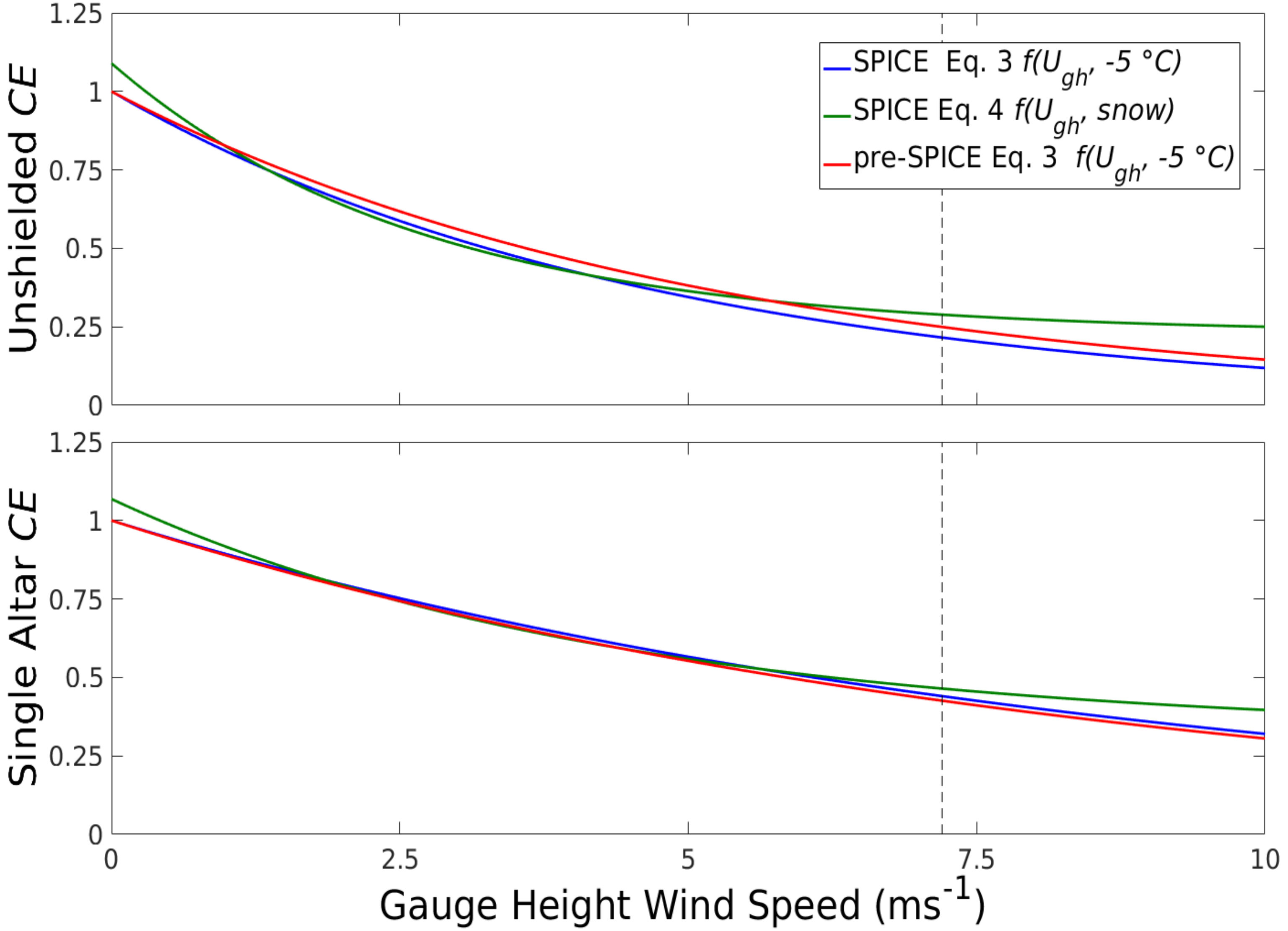
What type of function works best?

$$CE = \; e^{-a(U)\left(1 - \;\left[\tan^{-1}\left(b(T_{air})\right)+c\right]\right)} \qquad (3)$$

$$CE = \; (a)e^{-b(U)}+c \qquad (4)$$

- U is wind speed, T_{air} is air temperature, and a, b, and c are coefficients
- Eq. 4 is defined separately for liquid, mixed, and solid precipitation

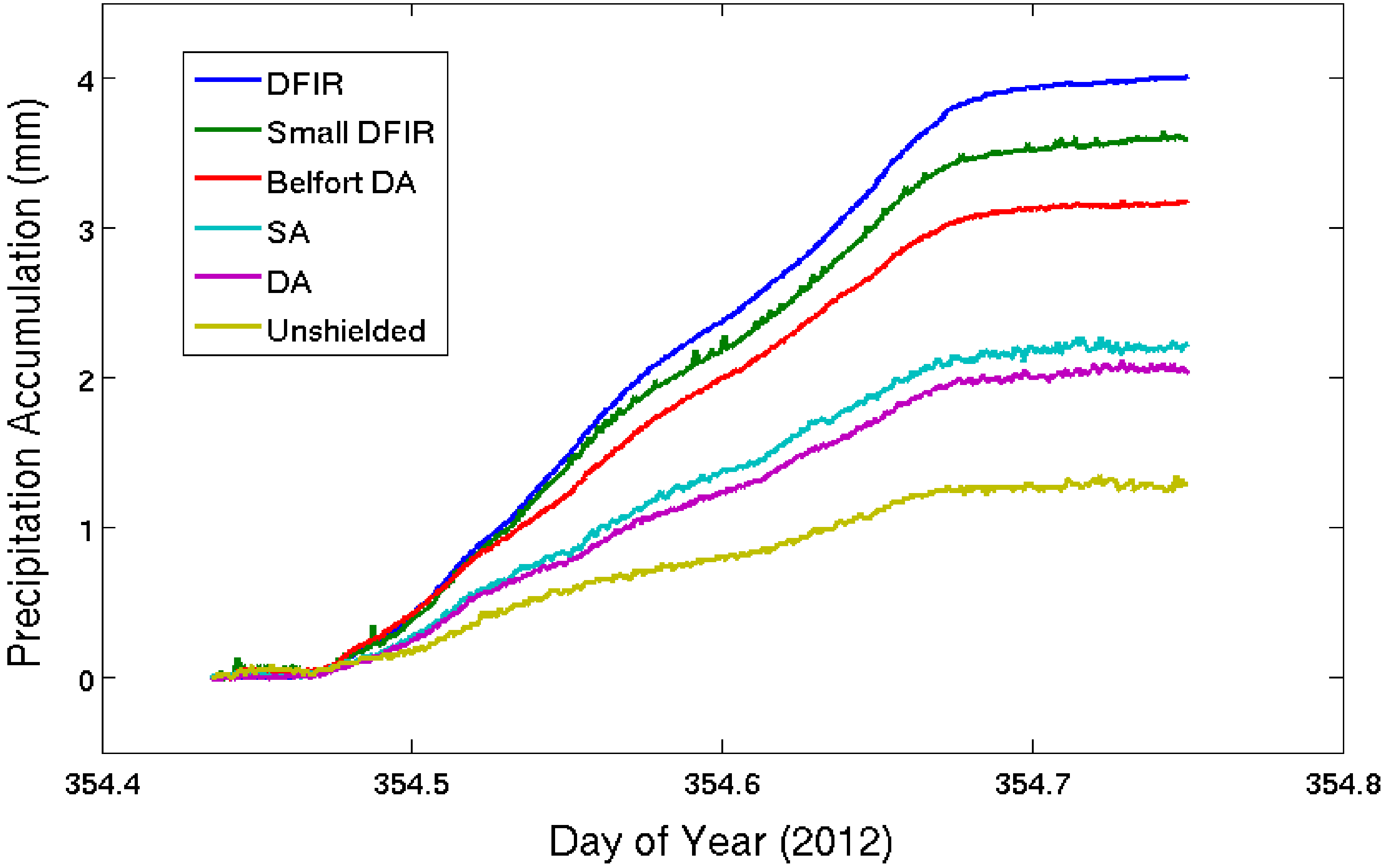
Transfer Function Comparison



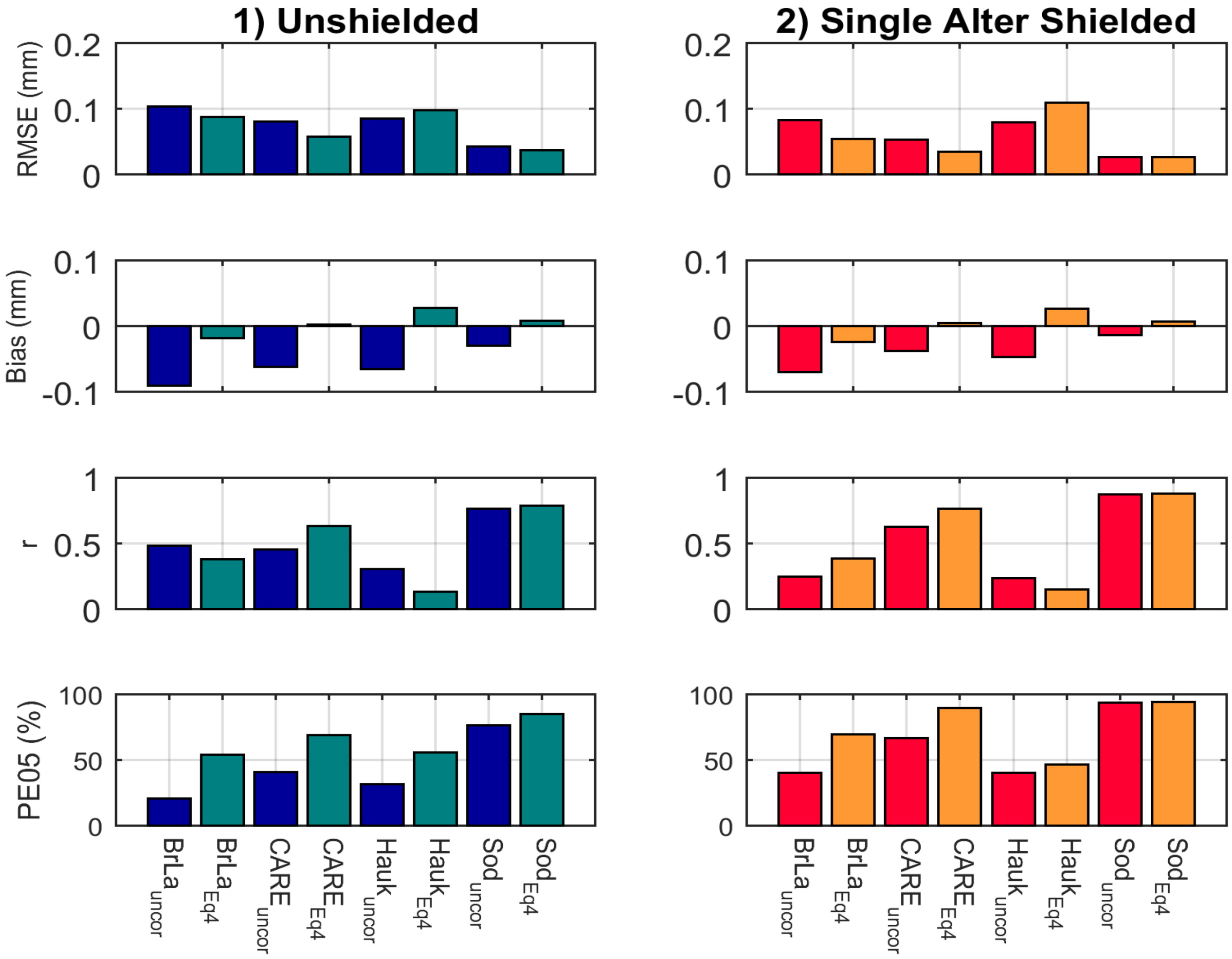
Sites with reference DFIR, unshielded, and SA measurements

Site	**Country**	**Abbr**	**Elev.**	**Lat.**	**Mean U_{gh}**	**Max U_{gh}**	**Mean T_{air}**	**N_{UN}**	**N_{SA}**
CARE	Canada	Care	251 m	44.23°	3.2 ms^{-1}	8.2 ms^{-1}	-3.3 °C	484	364
Haukeliseter	Norway	Hauk	991 m	59.81°	6.7 ms^{-1}	20.6 ms^{-1}	-1.7 °C	565	635
Sodankyla	Finland	Sod	179 m	67.37°	1.6 ms^{-1}	4.0 ms^{-1}	-2.1 °C	507	507
Caribou Creek	Canada	CaCr	519 m	53.94°	2.6 ms^{-1}	7.2 ms^{-1}	-6.3 °C	413	388
Weissfluhjoch	Switzerland	Weiss	2537 m	46.83°	3.8 ms^{-1}	11.6 ms^{-1}	-7.2 °C	508	537
Formigal	Spain	For	1800 m	42.76°	2.3 ms^{-1}	6.0 ms^{-1}	-0.7 °C	669	656
Marshall	USA	Ma	1742 m	39.59°	2.8 ms^{-1}	10.2 ms^{-1}	-2.0 °C	466	459
Bratt’s Lake	Canada	BrLa	585 m	50.20°	4.4 ms^{-1}	7.3 ms^{-1}	-1.5 °C	168	182

Example Event (USA)



Light Events



Weissfluhjoch