Errors and adjustments for WMO-SPICE tipping-bucket precipitation gauges

John Kochendorfer, National Oceanic and Atmospheric Association
Michael Earle, Environment and Climate Change Canada
Audrey Reverdin, MétéoSuisse
Rodica Nitu, World Meteorological Organization
Roy Rasmussen, National Center for Atmospheric Research
Yves-Alain Roulet, MétéoSuisse
Samuel Buisan, AEMET
Scott Landolt, NCAR
Timo Laine, Finnish Meteorological Institute

WMO-SPICE Testbeds

Tipping Bucket WMO-SPICE Testbeds

Sensor	Site(s)	Reporting resolution	Maximum heating power
CAE PMB25R	CARE, Marshall	0.1 mm	300 W
Hydrological Services (HSA) TBH	CARE, Marshall (x2)	0.2 mm	70 W
Meteoservis MR3H-FC	CARE, Marshall, Sodankylä	0.1 mm	555 W
Meteoservis MR3H-FC, ZAMG	CARE, Weissfluhjoch	0.1 mm	555 W
Thies Precipitation Transmitter, model 5.4032.35.228	Formigal	0.2 mm	49 W
Thies Precipitation Transmitter, model 5.4032.45.008	Marshall	0.1 mm	113 W

CAE

HSA TBH

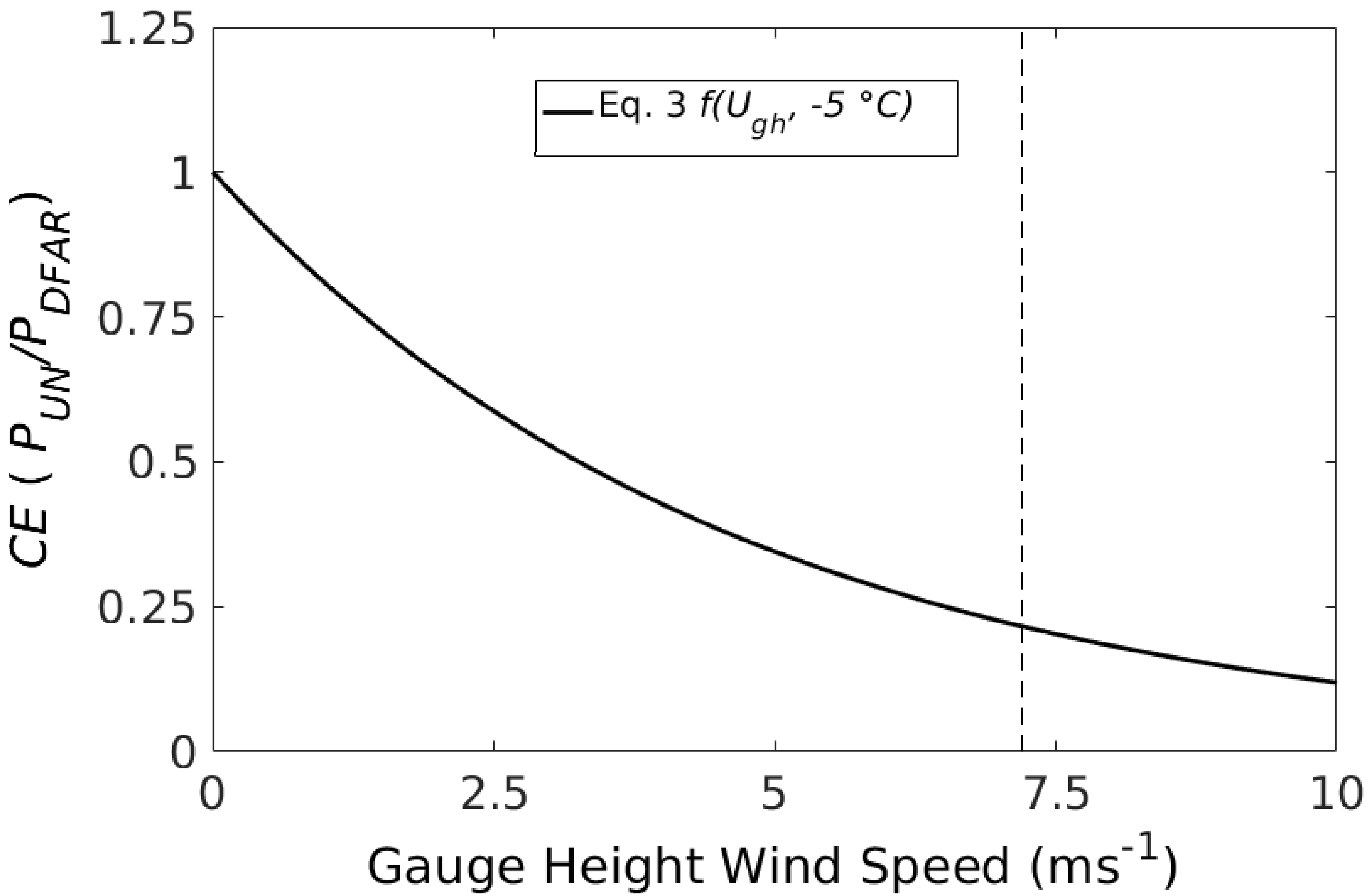
MR3H-FC

Thies
Model 45.008

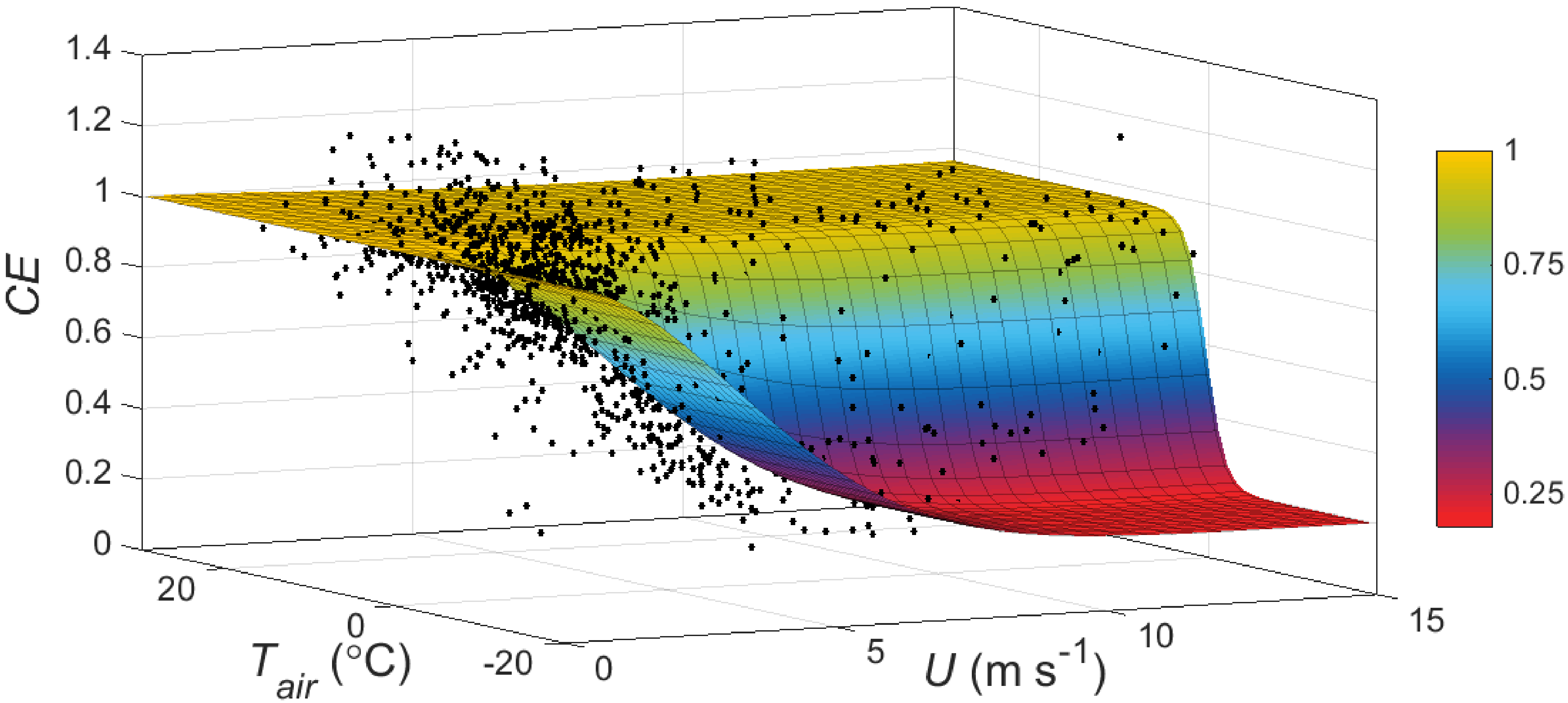
Double Fence Automated Reference (DFAR)

DFAR

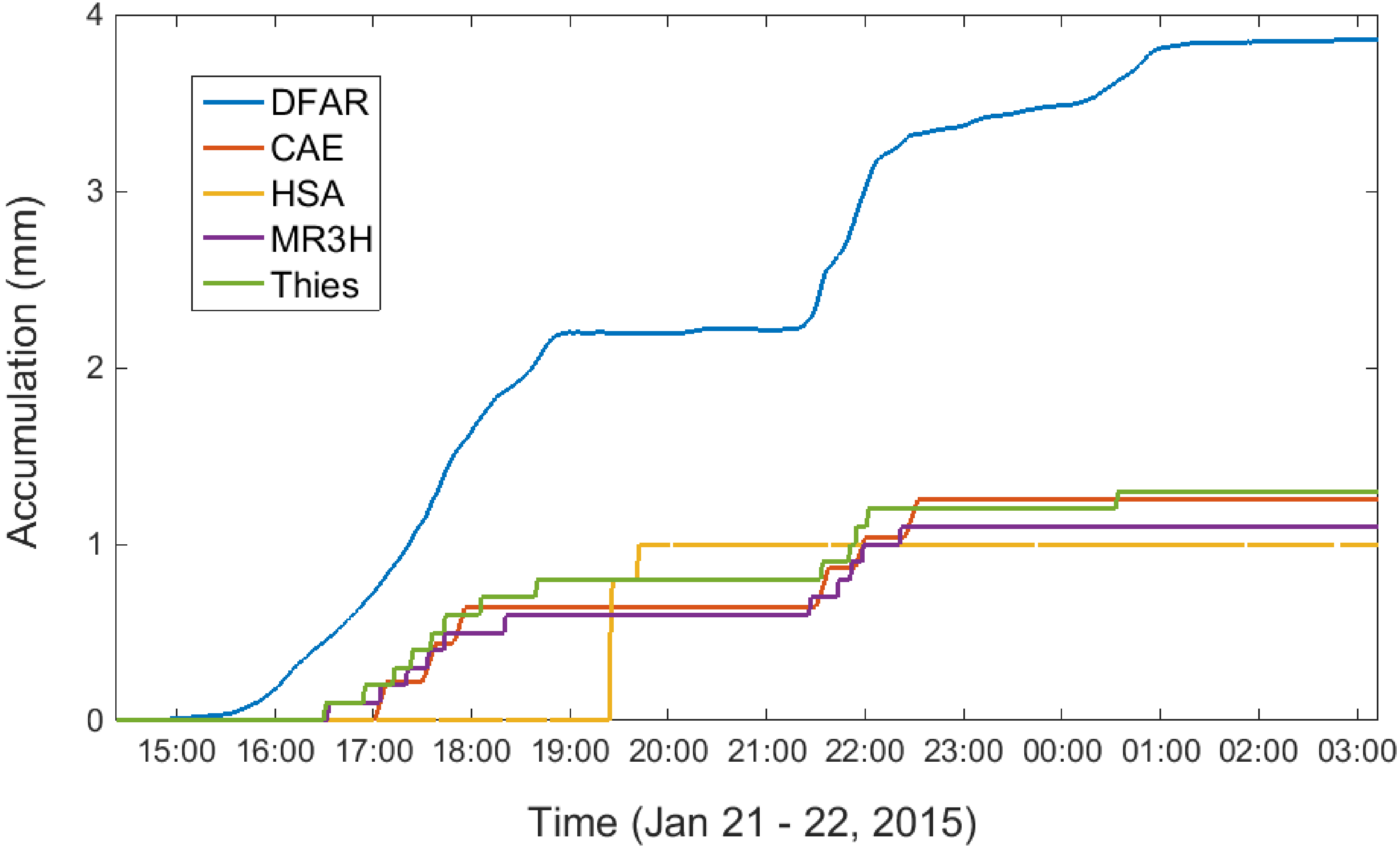
Example transfer function



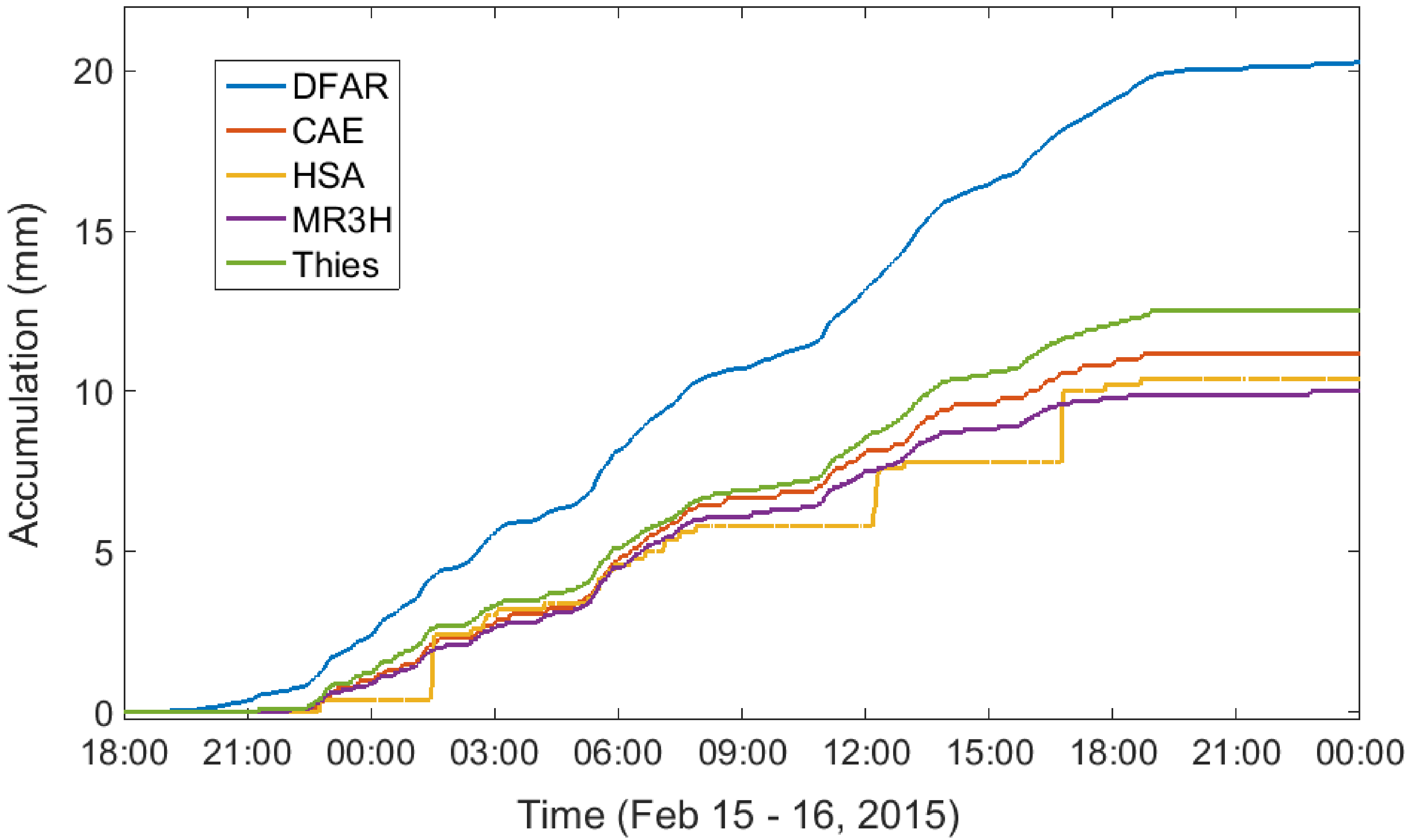
Example transfer function



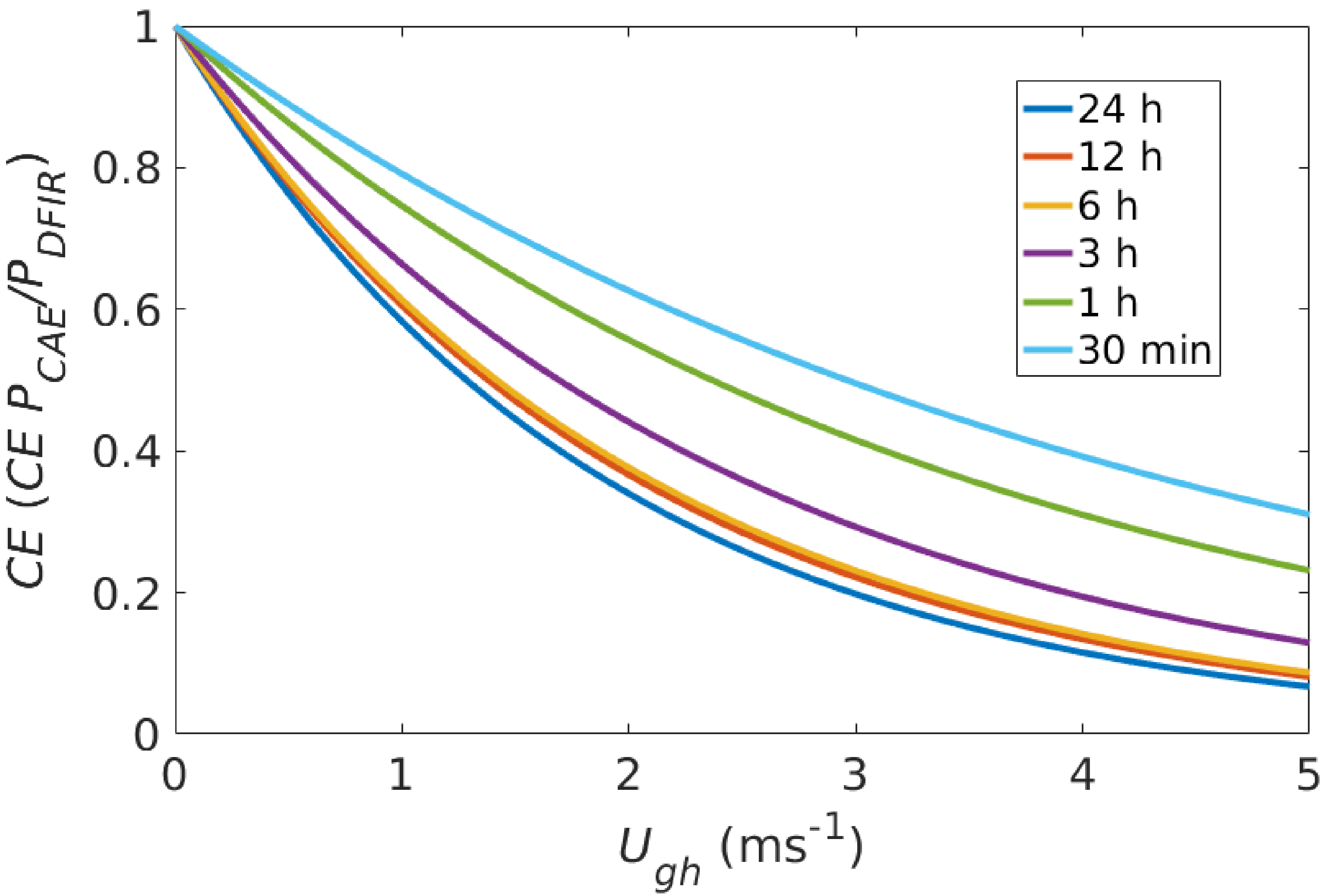
Example tipping bucket accumulations



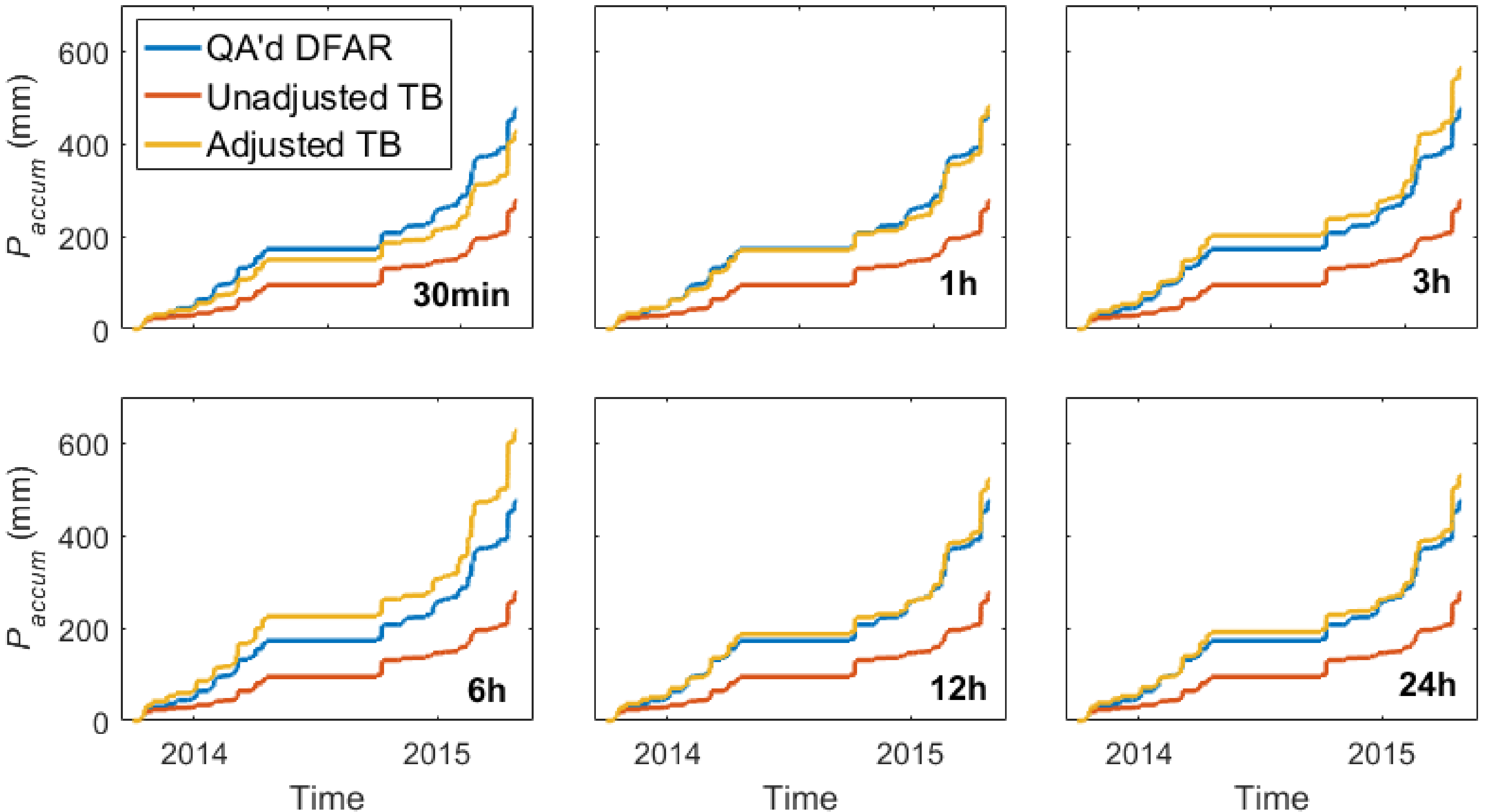
Example tipping bucket accumulations



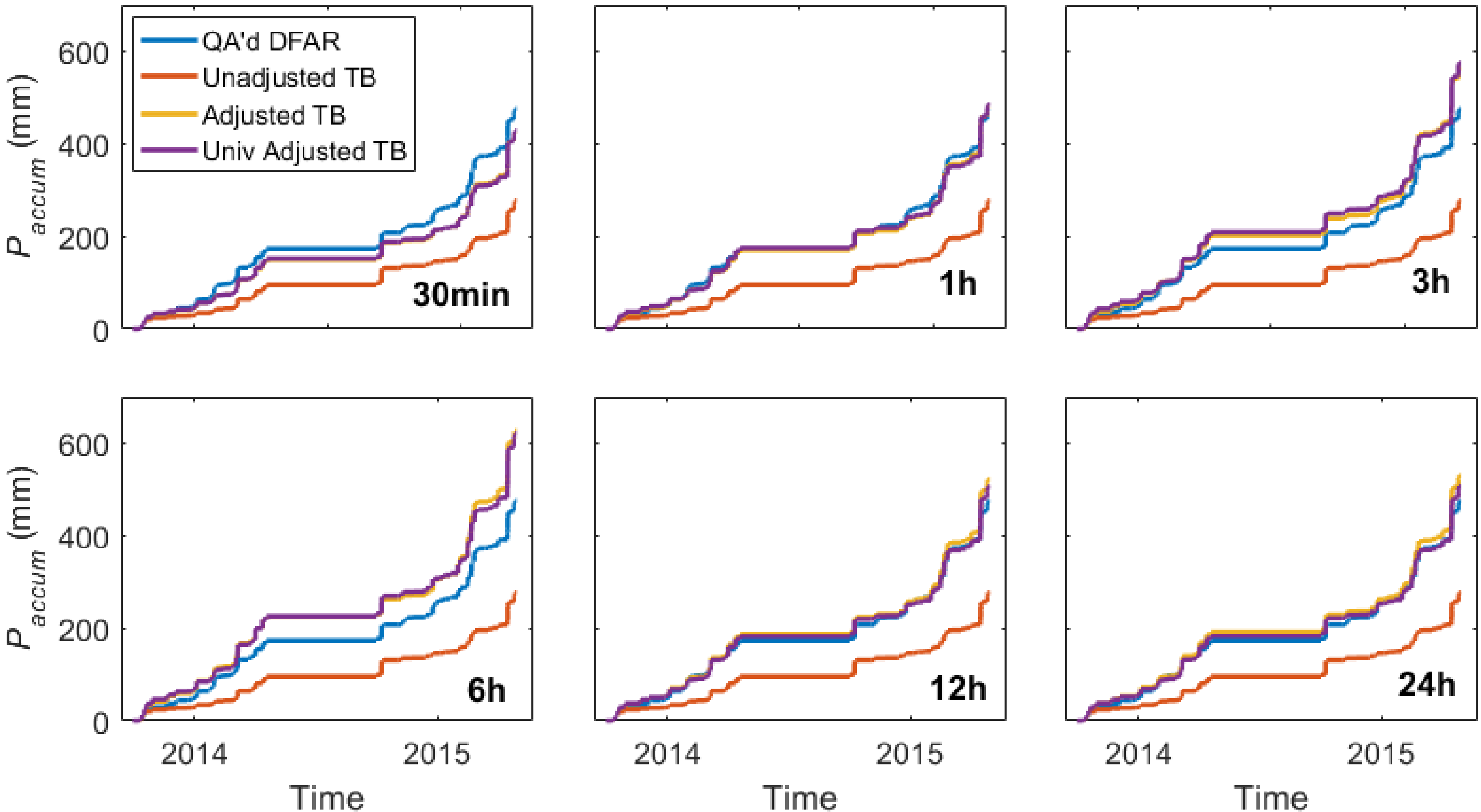
Analysis methods affect catch efficiency



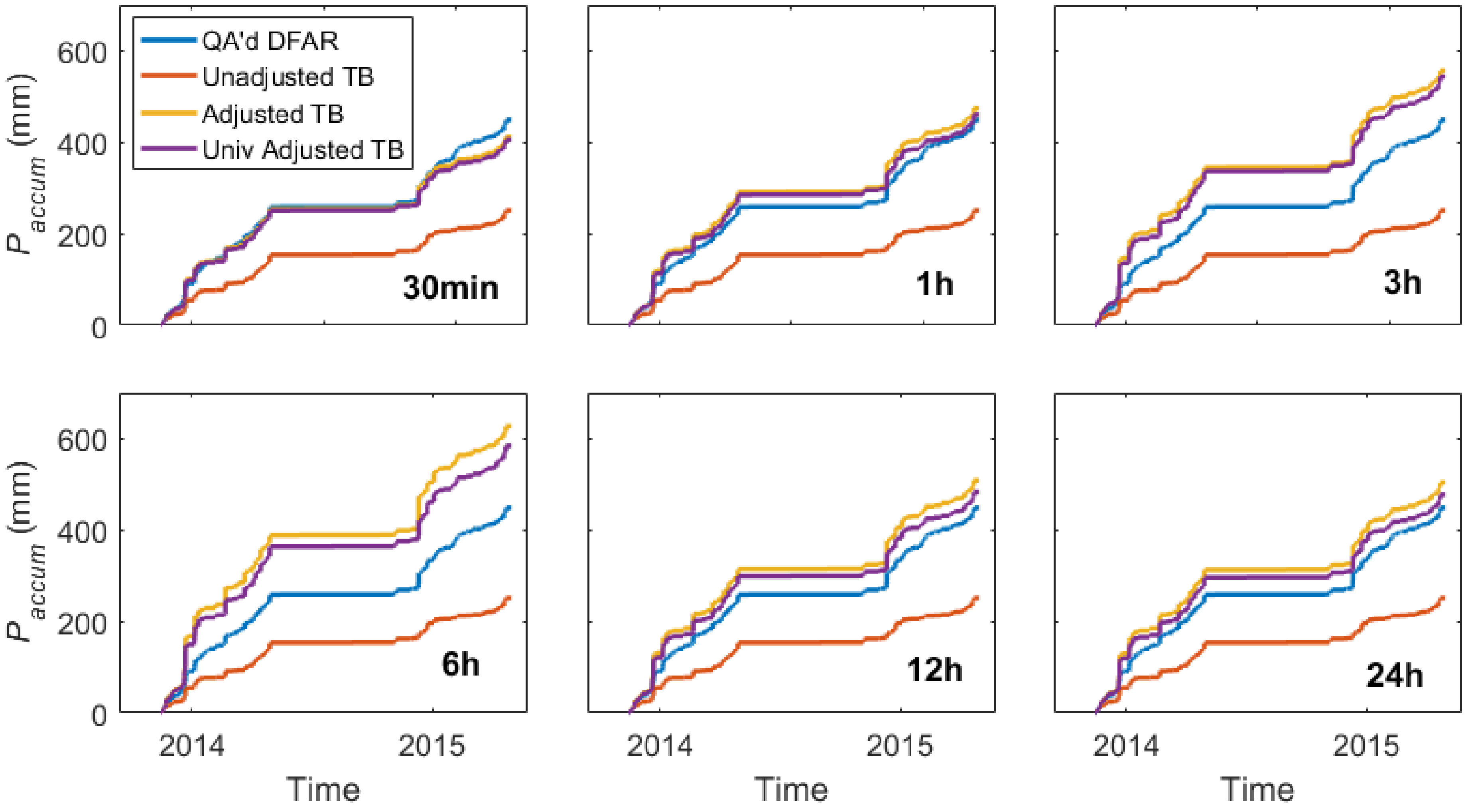
Evaluation of CAE transfer functions using continuous measurements from Marshall



CAE at Marshall, with a multi-gauge adjustment

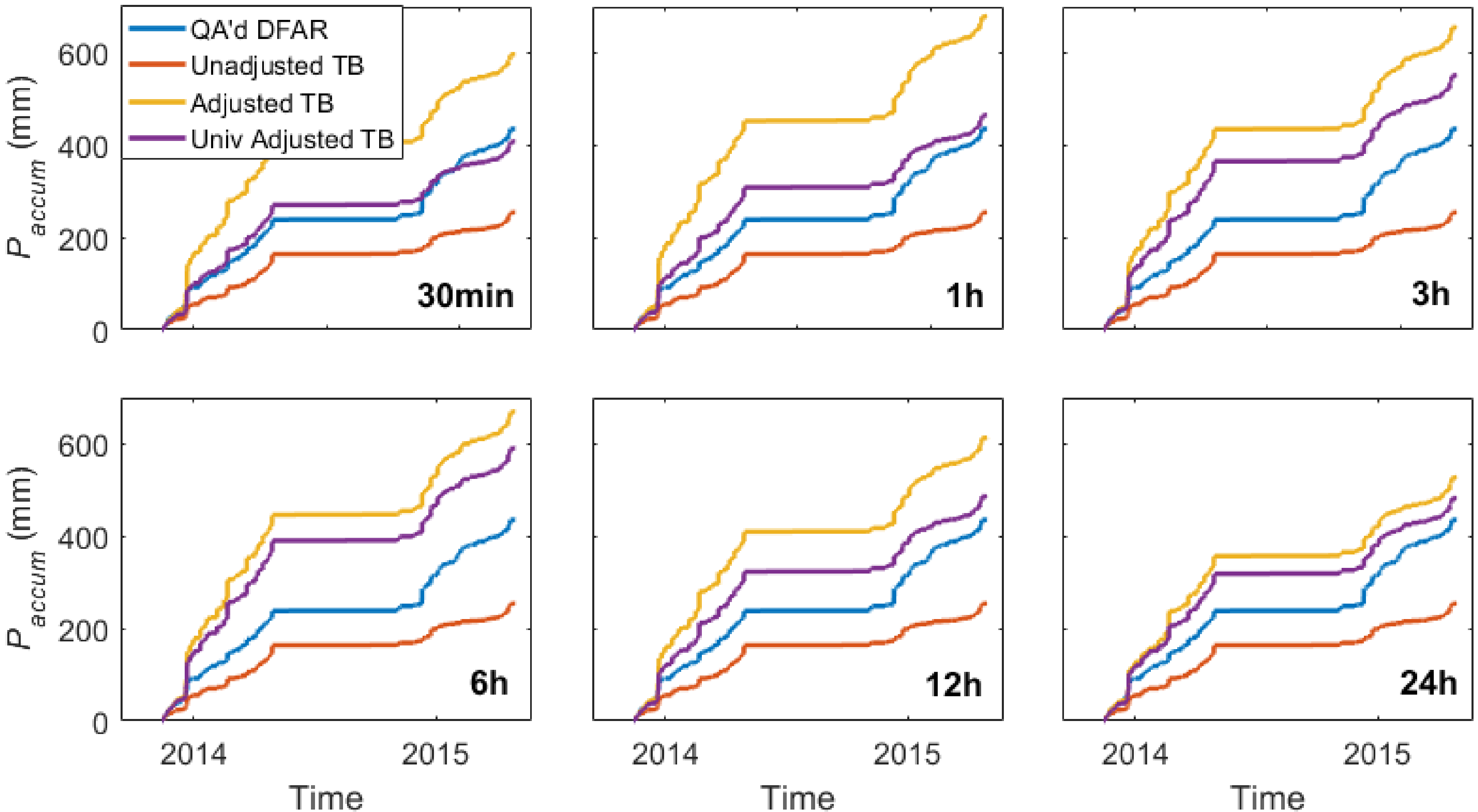


CAE at CARE



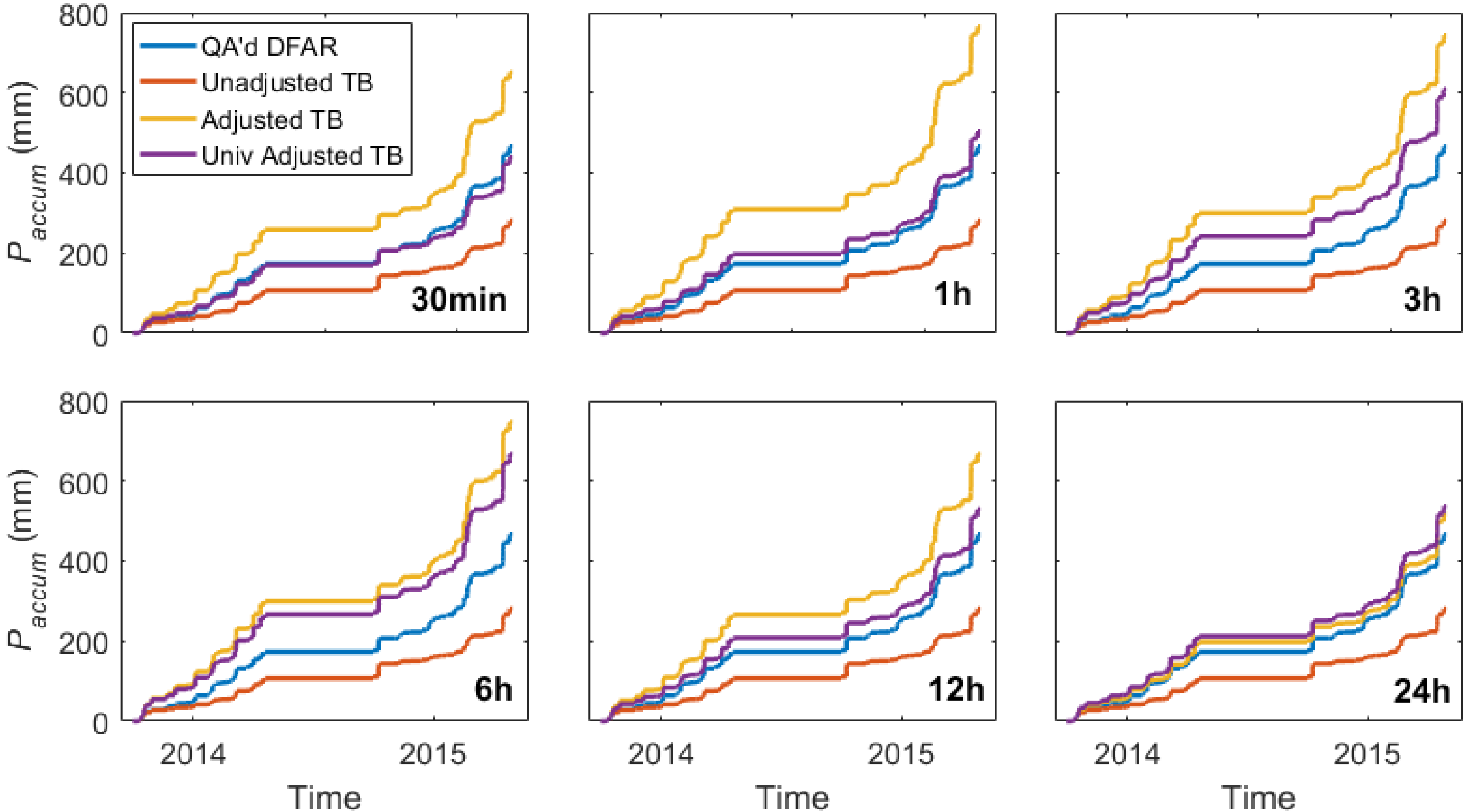
QA'd DFAR
Unadjusted TB
Adjusted TB
Univ Adjusted TB
P_{accum} (mm)
600
400
200
0
30min
1h
3h
6h
12h
24h
2014
2015
Time

HSA at CARE

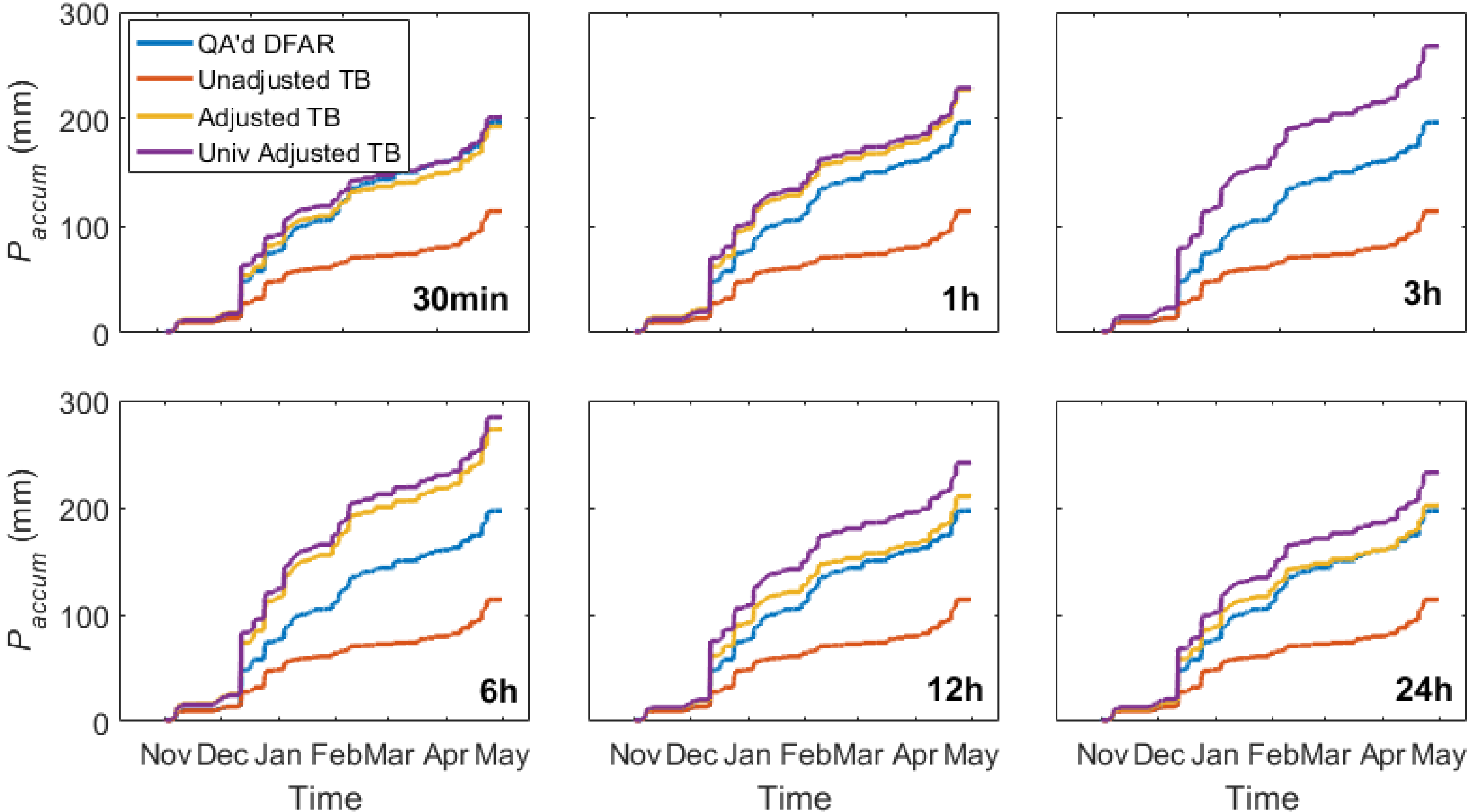


QA'd DFAR
Unadjusted TB
Adjusted TB
Univ Adjusted TB
P_{accum} (mm)
0
200
400
600
30min
1h
3h
6h
12h
24h
2014
2015
Time

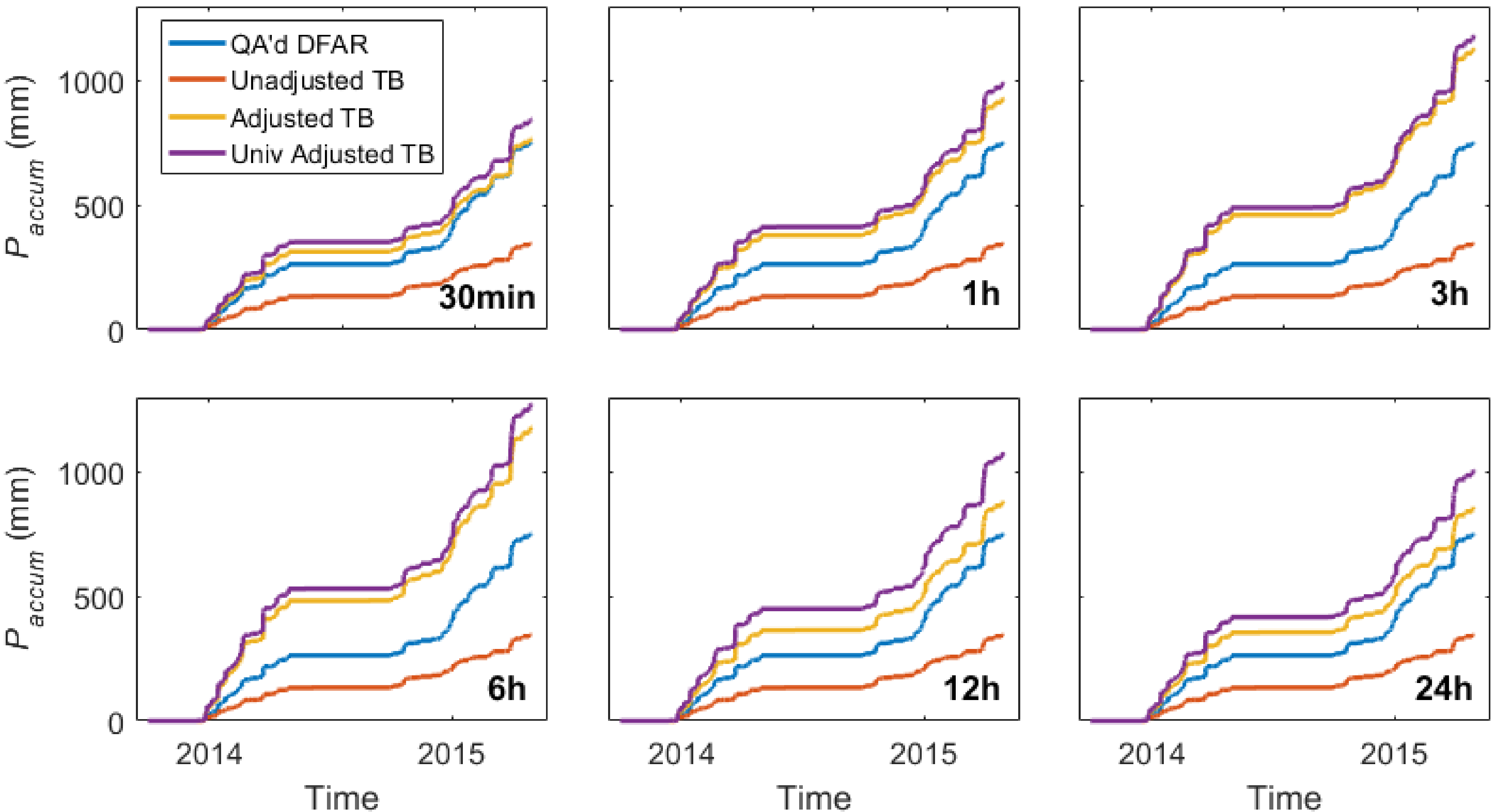
HSA at Marshall



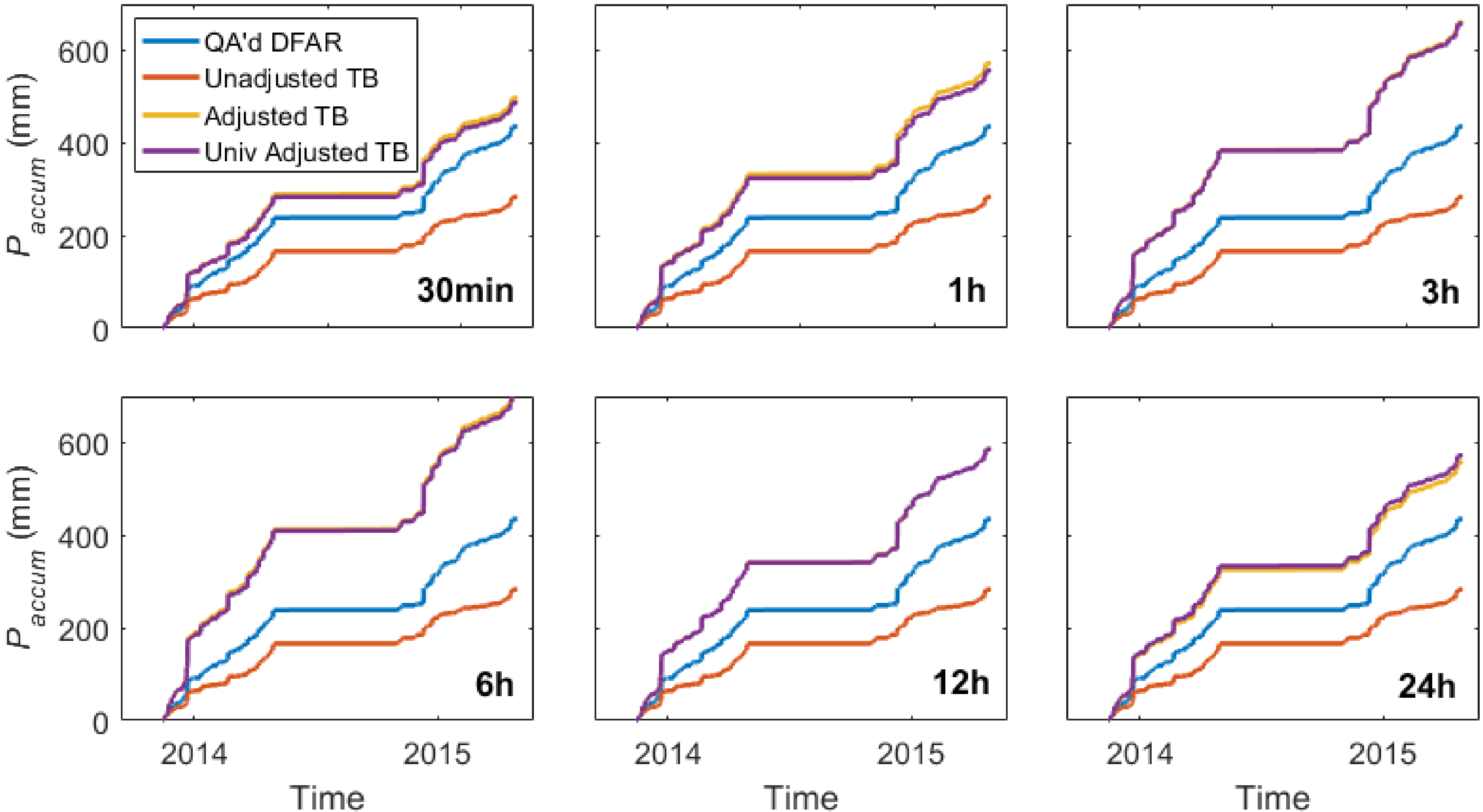
ZAMG MR3H at CARE



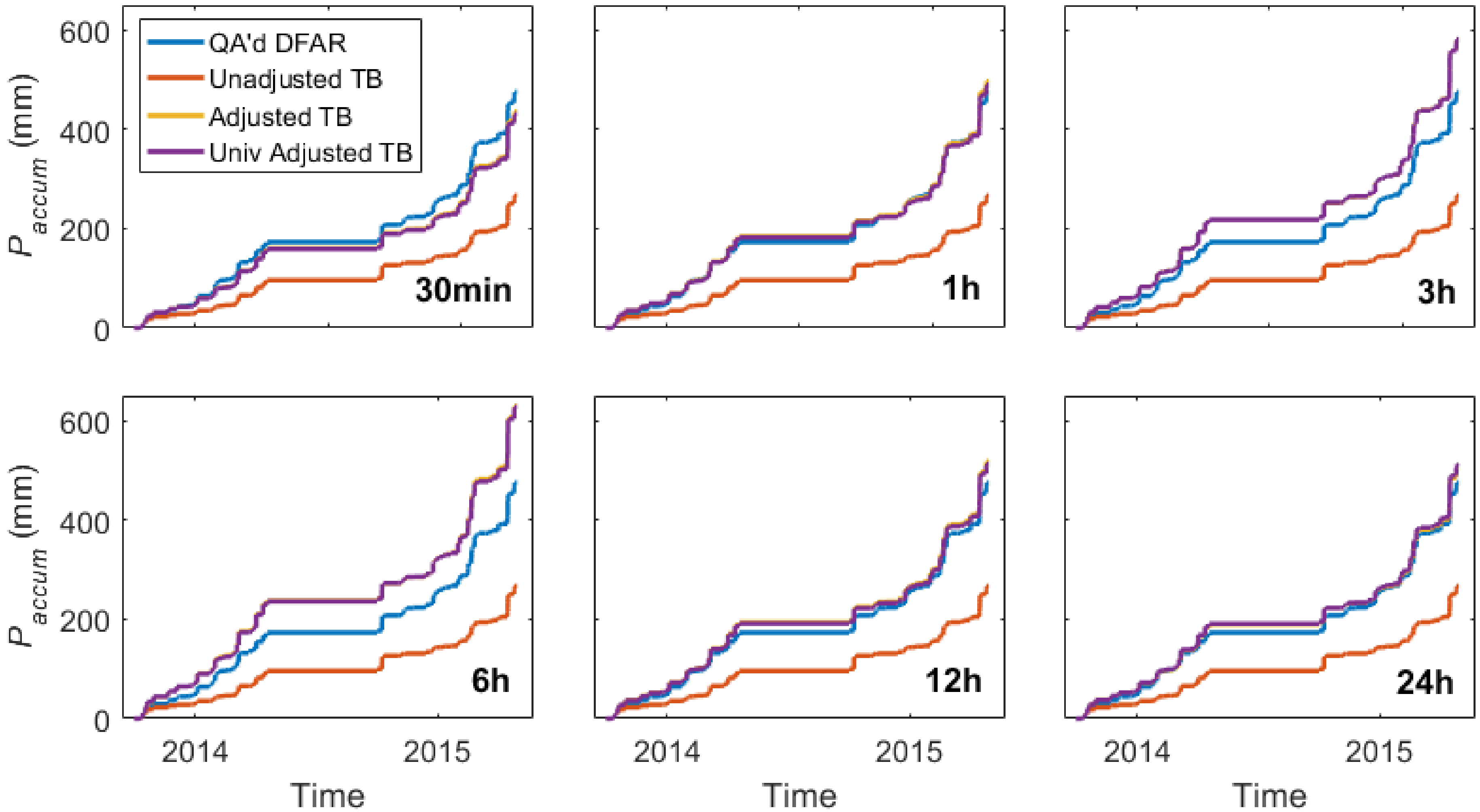
ZAMG MR3H at Weissfluhjoch



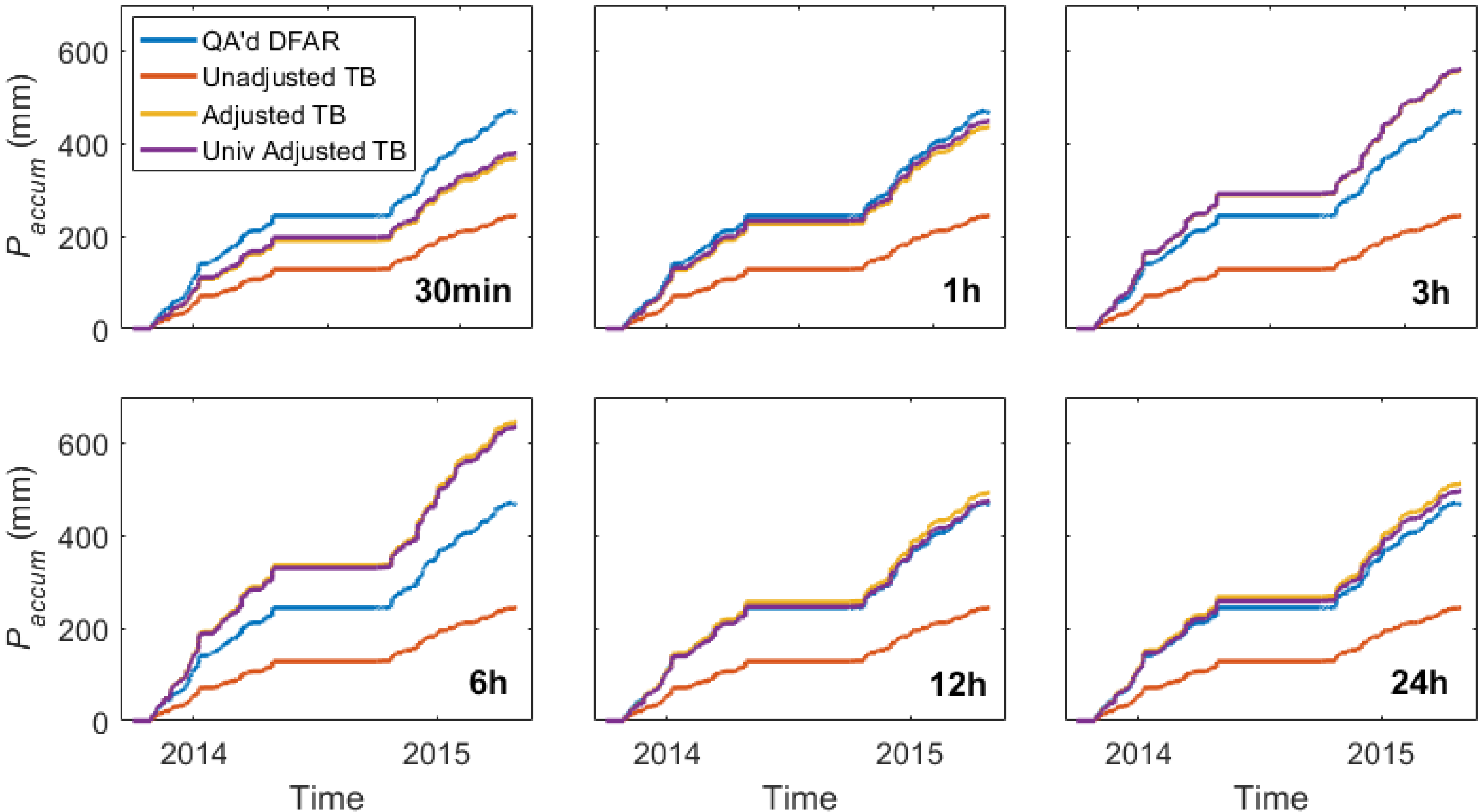
MET MR3H at CARE



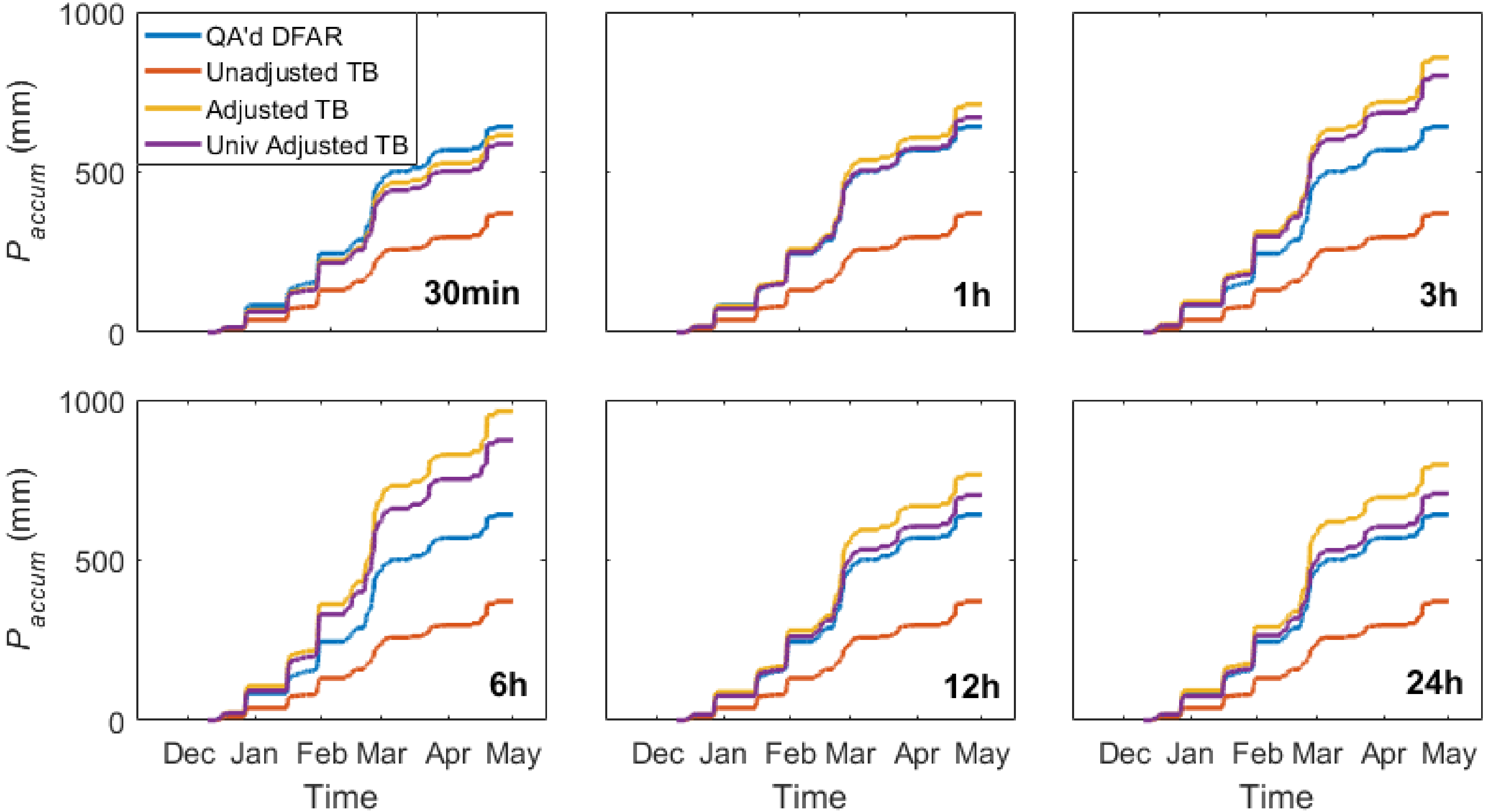
MET MR3H at Marshall



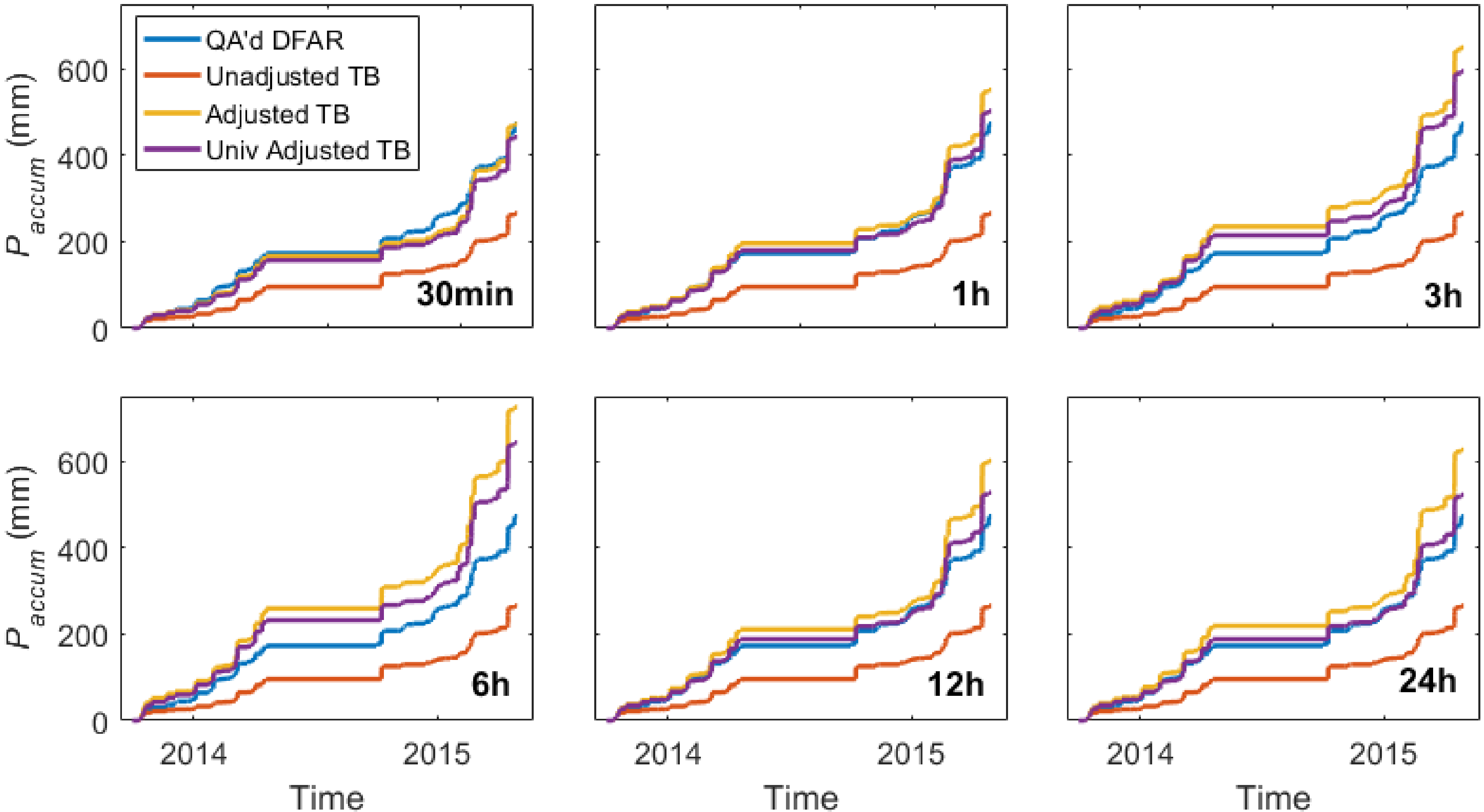
MET MR3H at Sodankyla



Thies at Formigal



Thies at Marshall



Future work

- Develop a more objective method to select the best transfer function
- Develop and test different forms of transfer functions

1) $$R_i = \left[1 - \tau_1 - (\tau_2 - \tau_1)\frac{e^{\left(\frac{T_i - T_\tau}{s_\tau}\right)}}{1 + e^{\left(\frac{T_i - T_\tau}{s_\tau}\right)}}\right] e^{-\left(\frac{V_i}{\theta}\right)^\beta} + \tau_1 + (\tau_2 - \tau_1)\frac{e^{\left(\frac{T_i - T_\tau}{s_\tau}\right)}}{1 + e^{\left(\frac{T_i - T_\tau}{s_\tau}\right)}} + \sigma(T_i)\,\varepsilon_i,$$ Wolff et al., 2015

2) $$CE = e^{-a(U)\left(1 - \tan^{-1}\left(b(T_{air})\right) + c\right)}$$ Kochendorfer et al., 2017

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

Questions?

- Develop a more objective method to select the best transfer function
- Develop and test different forms of transfer functions

1) $$R_i = \left[1 - \tau_1 - (\tau_2 - \tau_1)\frac{e^{\left(\frac{T_i - T_\tau}{s_\tau}\right)}}{1 + e^{\left(\frac{T_i - T_\tau}{s_\tau}\right)}}\right] e^{-\left(\frac{V_i}{\theta}\right)^\beta} + \tau_1 + (\tau_2 - \tau_1)\frac{e^{\left(\frac{T_i - T_\tau}{s_\tau}\right)}}{1 + e^{\left(\frac{T_i - T_\tau}{s_\tau}\right)}} + \sigma(T_i)\,\varepsilon_i,$$ Wolff et al., 2015

2) $$CE = e^{-a(U)\left(1 - \tan^{-1}\left(b(T_{air})\right) + c\right)}$$ Kochendorfer et al., 2017

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

Outline

- Background on precipitation measurements
  - Tipping buckets are the most prevalent type of automated precip gauge
  - Photos of gauges and sites (from TB, DFAR as well, wind too?
- WMO-SPICE background – map of all sites, map of TB sites?
- Background on transfer functions
- Challenges specific to tipping bucket measurements – difficult to compare to a standard, delays, missed precip, poor resolution for small snowfall events, sensitivity to time scales, differences in technology
  - Demonstrate this with a time series plot! We might be able to steal something from the TB report.
- What is the standard? What would an ‘ideal’ adjustment look like?
  - Show the dependence on length of SEDS and ask the question, which one is right?
  - Show with and without zeros-tip SEDS as well.
- For a ‘normal’ weighing gauge we define a time period (event) and compare precip to the standard. For a tipping bucket many ‘events’ are associated with zero tips, and some tips occur after the ‘event’ has ended due to delays in the TB measurement. Excluding 0-tip events will likely over-estimate the catch efficiency, and including them will likely underestimate the catch efficiency.
- We need a validation dataset that can be used to test these transfer functions – a different way of looking at the data. Mimicking operational networks, we created a continuous 1 h dataset that included every tip of the gauge, irrespective of whether it occurred during an actual precip event. We also QA/QC’d the DFAR measurements to create defensible seasonal accumulations.