Controls on surface soil drying rates observed by SMAP, GPS-IR, and NLDAS-Noah

SMAP cal/val workshop

6/21/17

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Oklahoma photo by Sarah Machin.

Goal

- Quantify surface soil drying behavior from SMAP and other sources
- Controls on drying:
  - Volumetric soil moisture (VSM)
  - Potential evaporation (PE) rate
  - Vegetation cover (NDVI)
  - Soil texture class

Surface soil moisture observations

- in situ probes (17 CVS)
- PBO H_2O GPS-IR
  (74 stations)
- SMAP level 3 enhanced
  (80,000 pixels)

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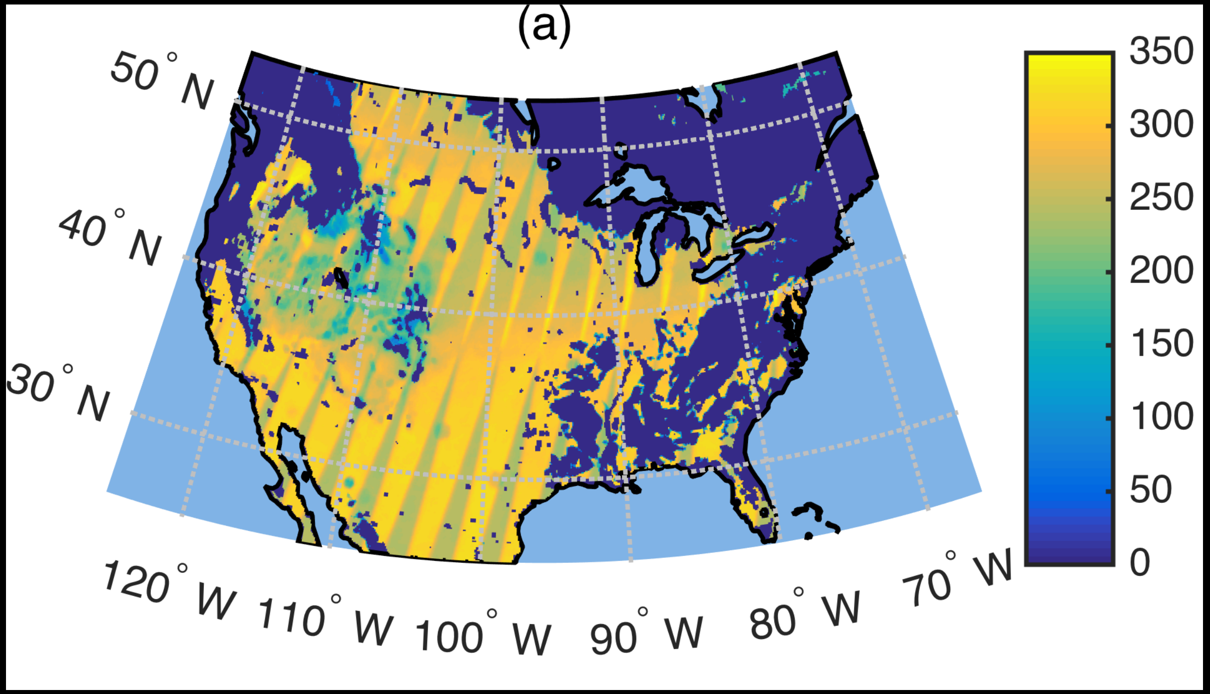
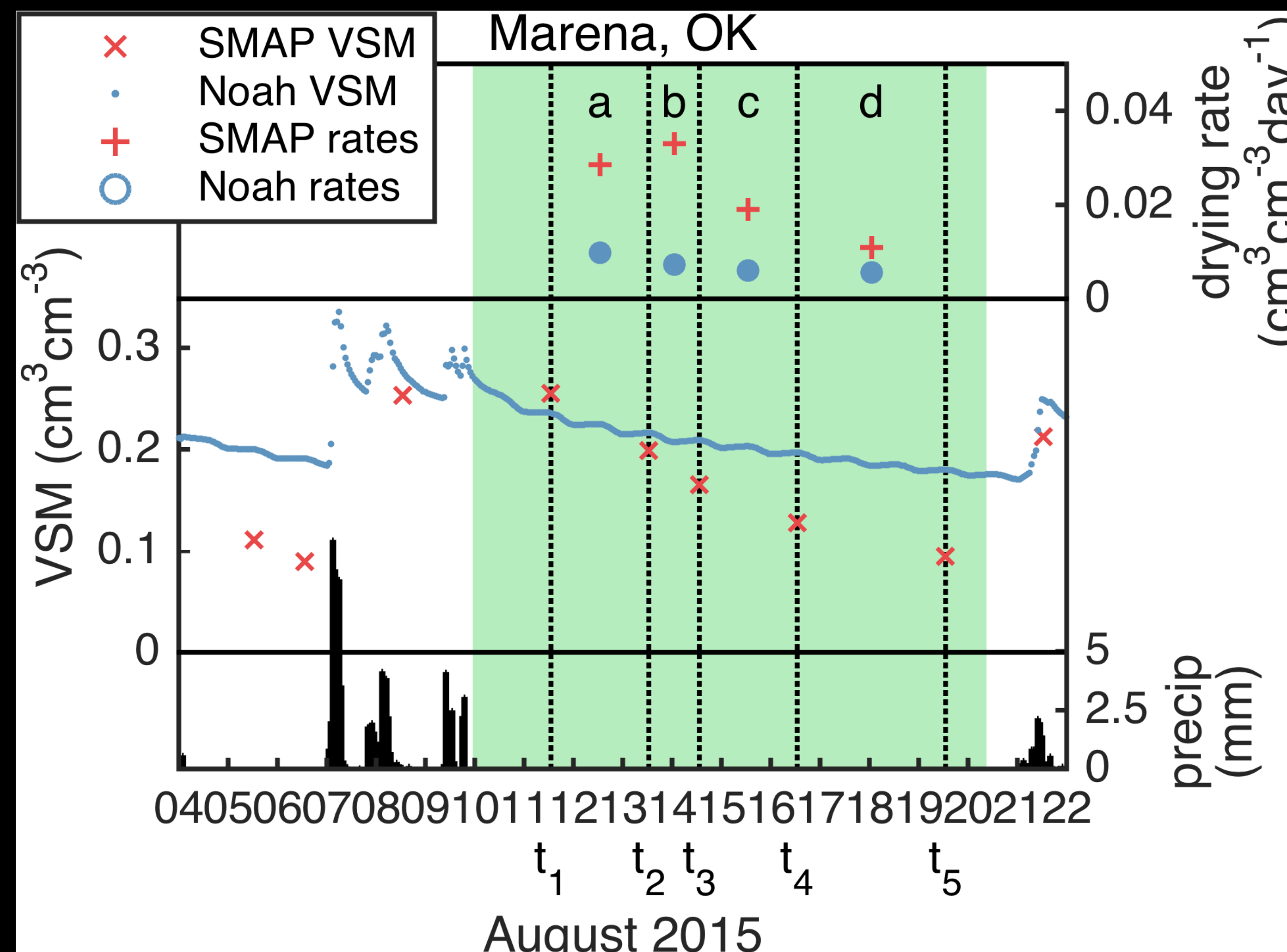


Number of SMAP observations between launch and winter 2017

Additional data from

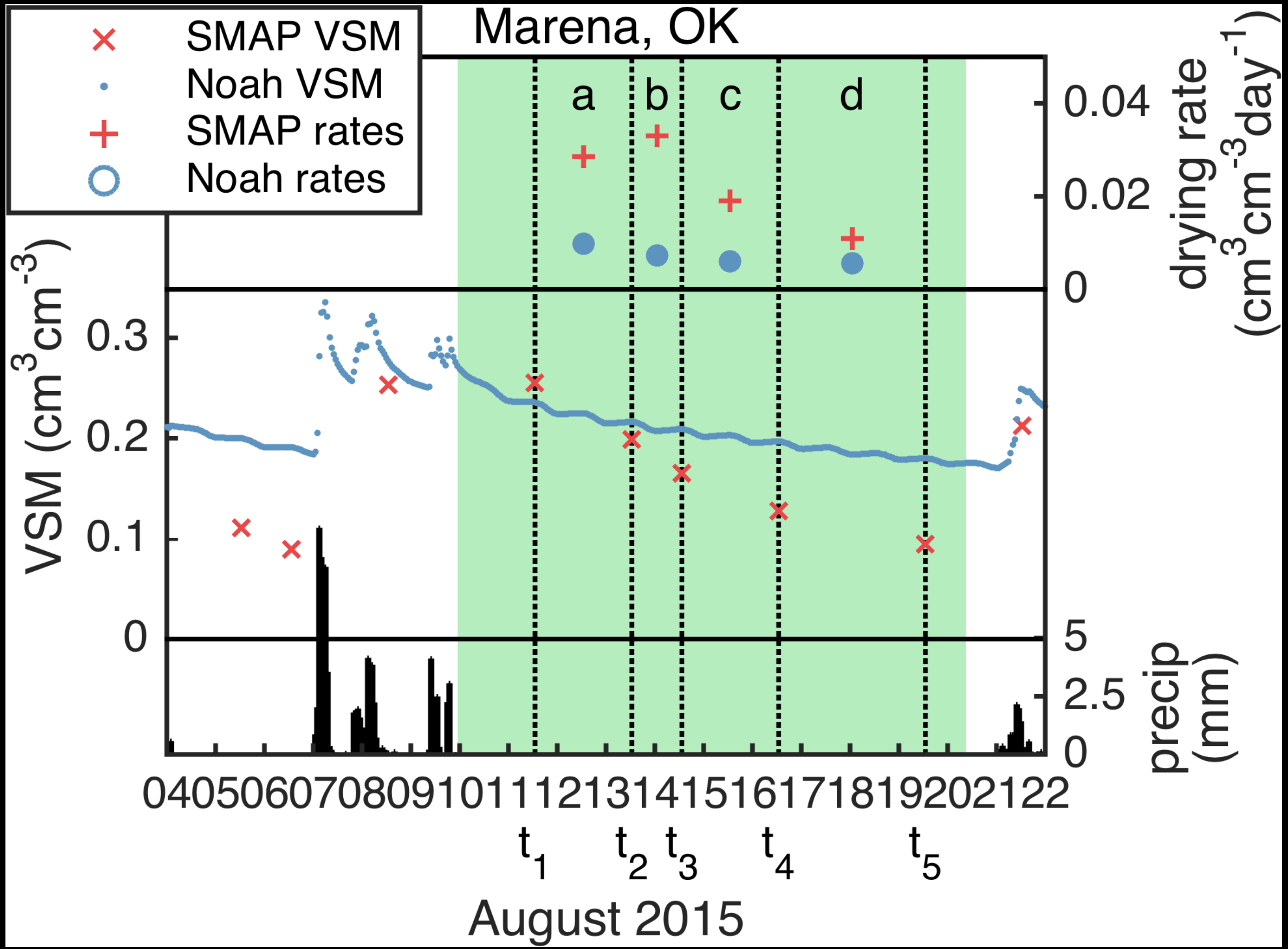
- Noah LSM
  - Layer 1 soil moisture (0-10 cm)
  - Surface evaporation rate
- NDLAS soil texture classifications
- NDLAS forcings:
  - Potential evaporation
  - Precipitation
- MODIS NDVI

Quantify soil drying



Quantify soil drying

- Identify drydown periods (at least 4 days of no rain)

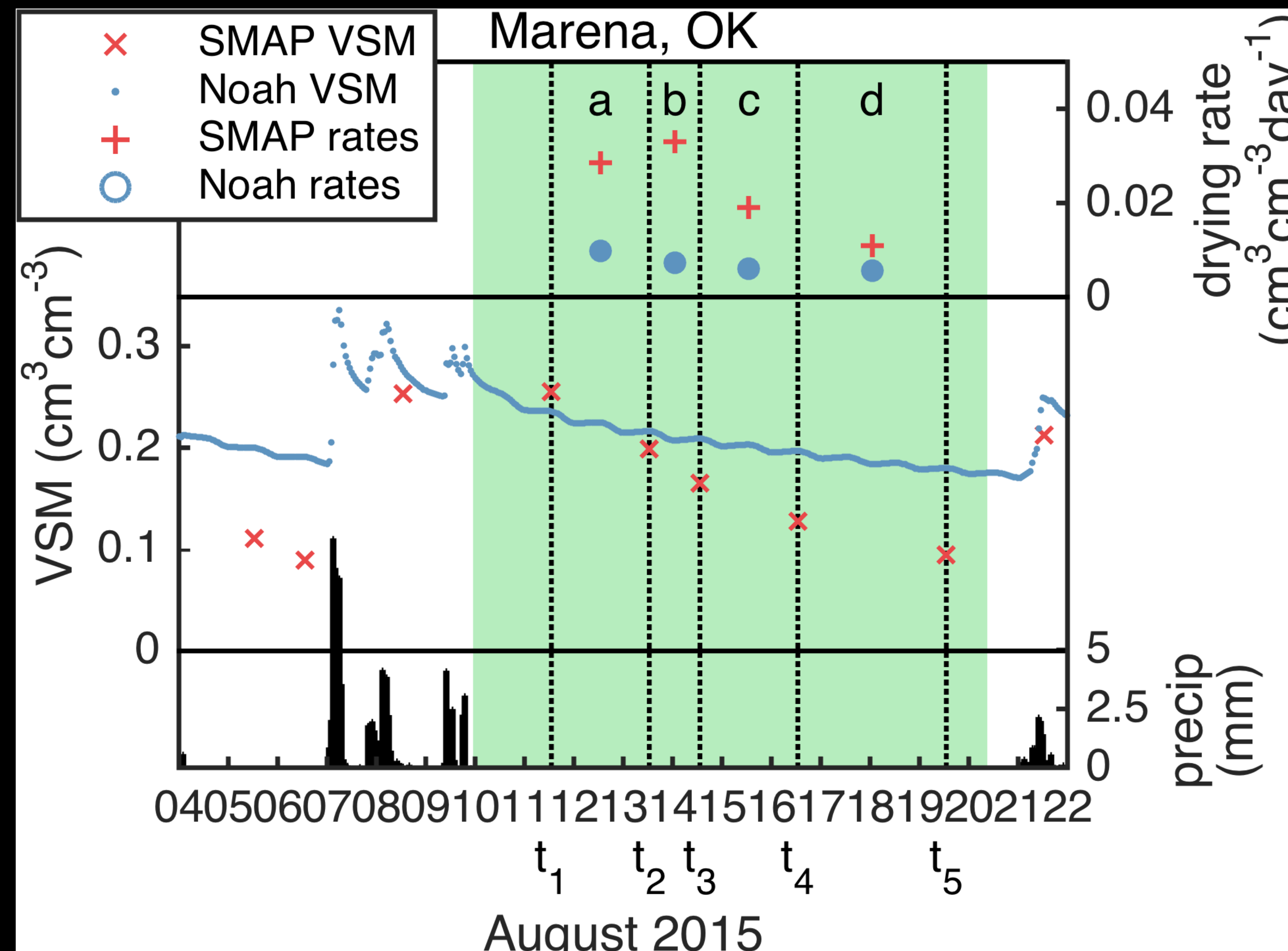


Quantify soil drying

- Identify drydown periods (at least 4 days of no rain)

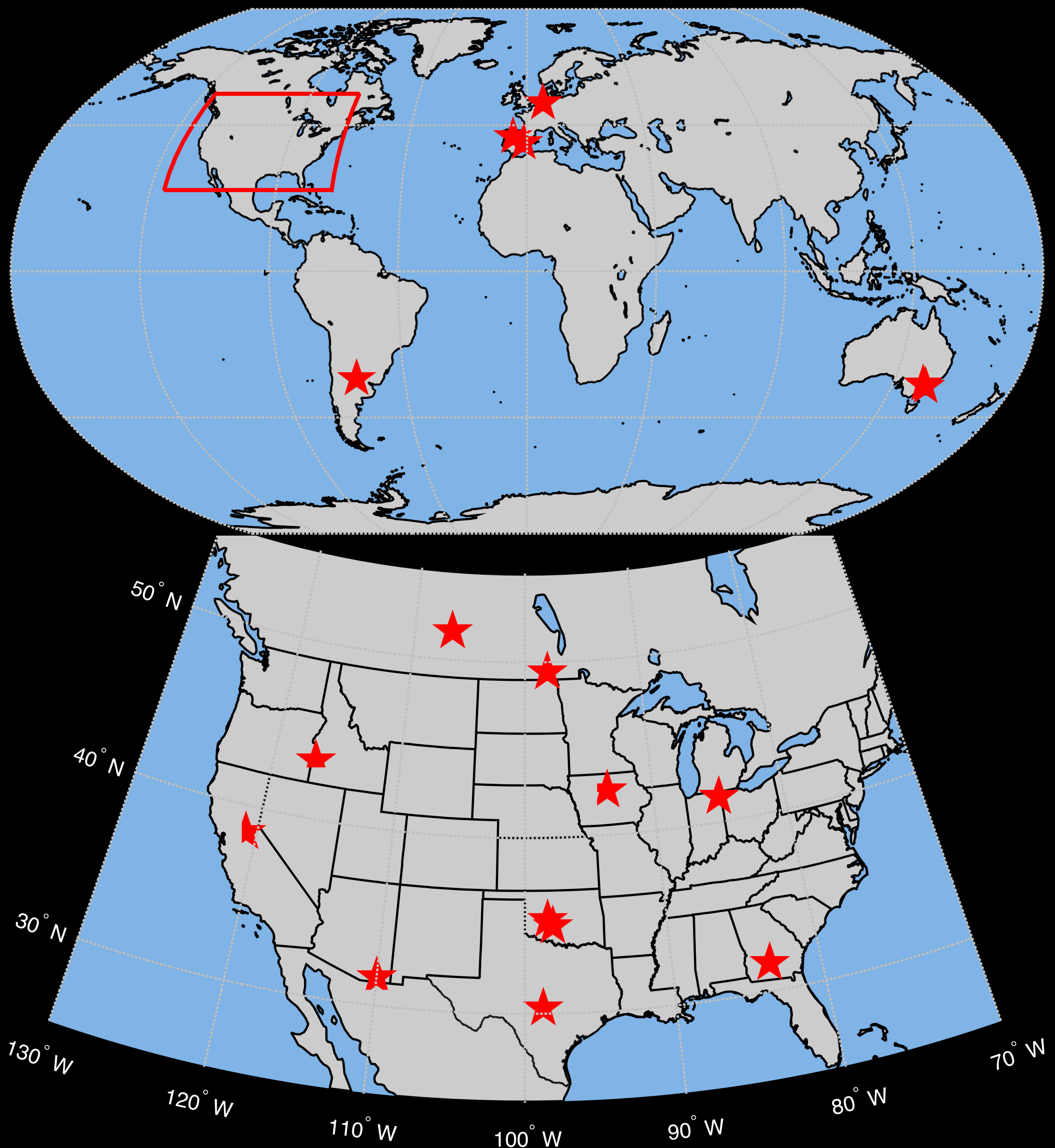
- Finite differences $cm^3\ cm^{-3}\ day^{-1}$

$$\frac{d\theta}{dt} = \frac{\theta_{n+1} - \theta_n}{t_{n+1} - t_n}$$

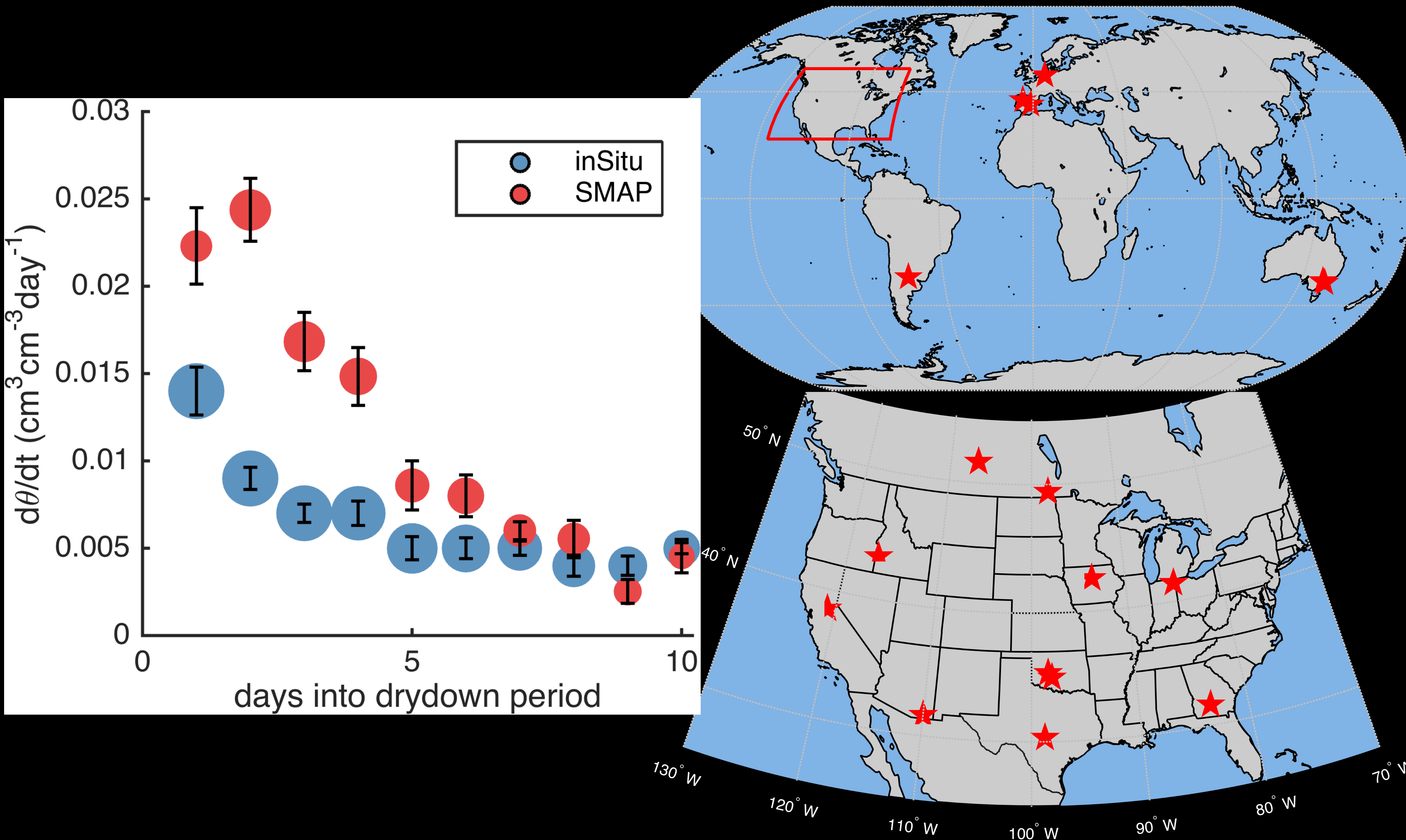


Drying rates

- Calculated rates at CVS:
  - SMAP
  - In situ
- ~770 rates

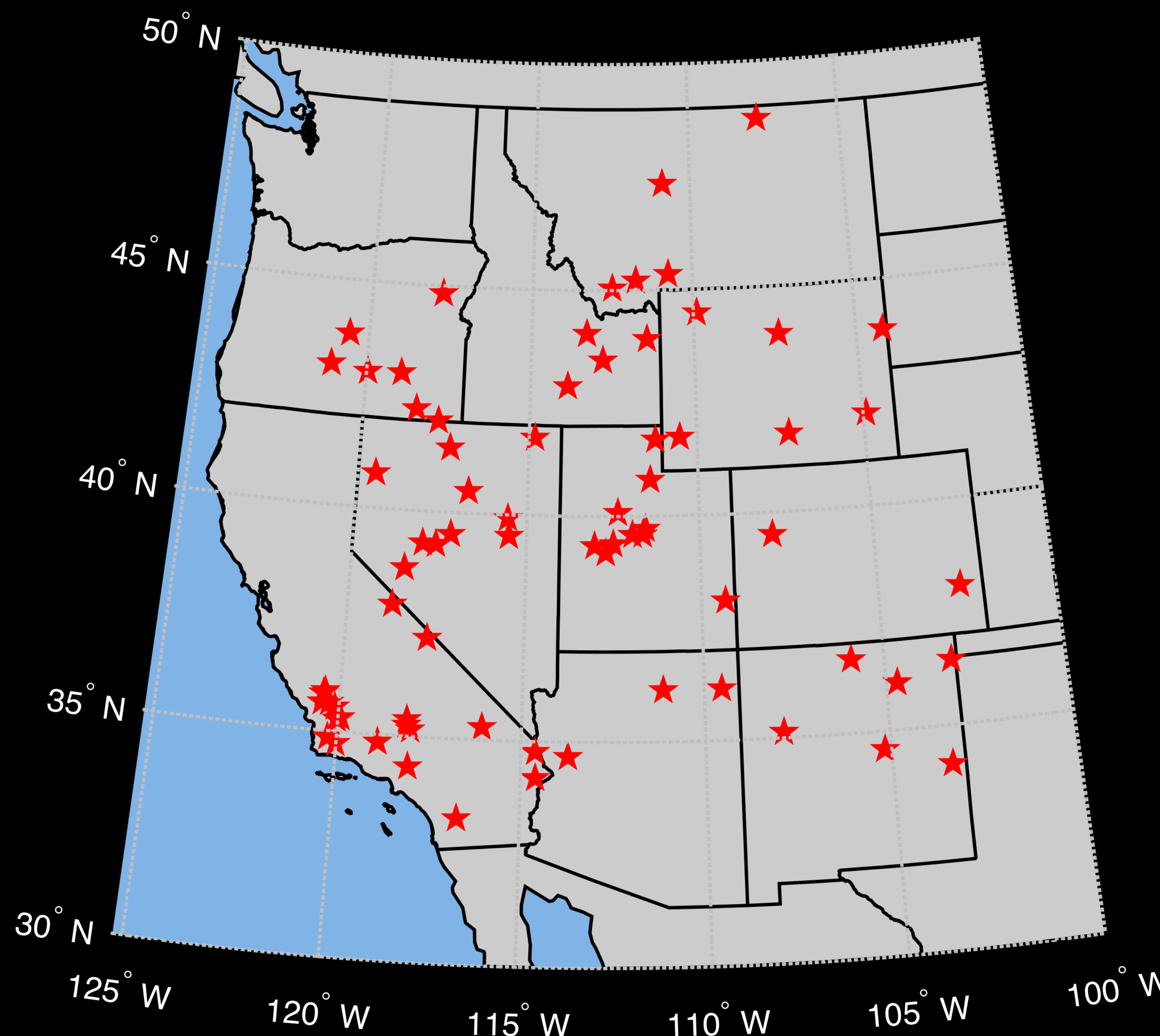


Drying rates

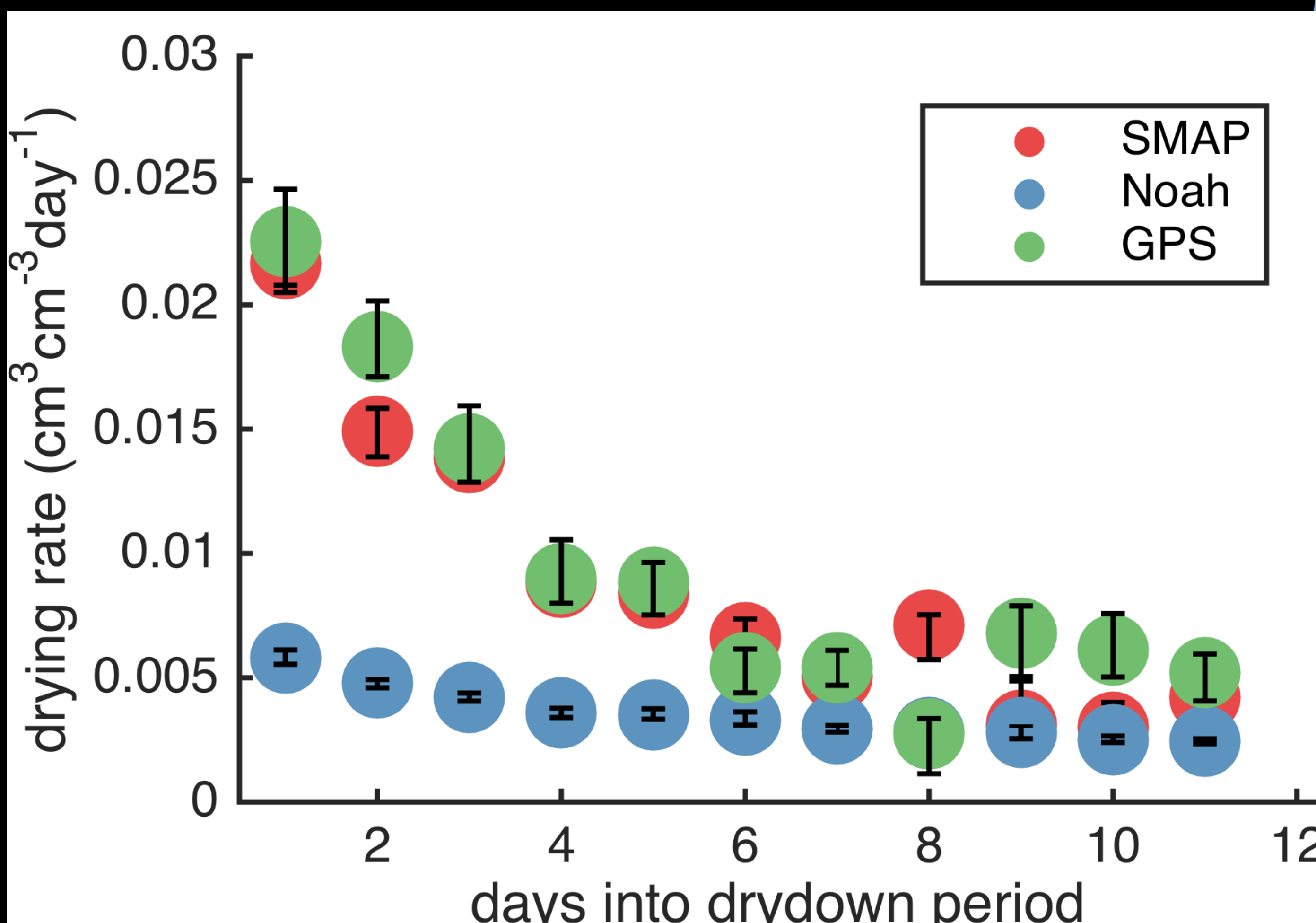


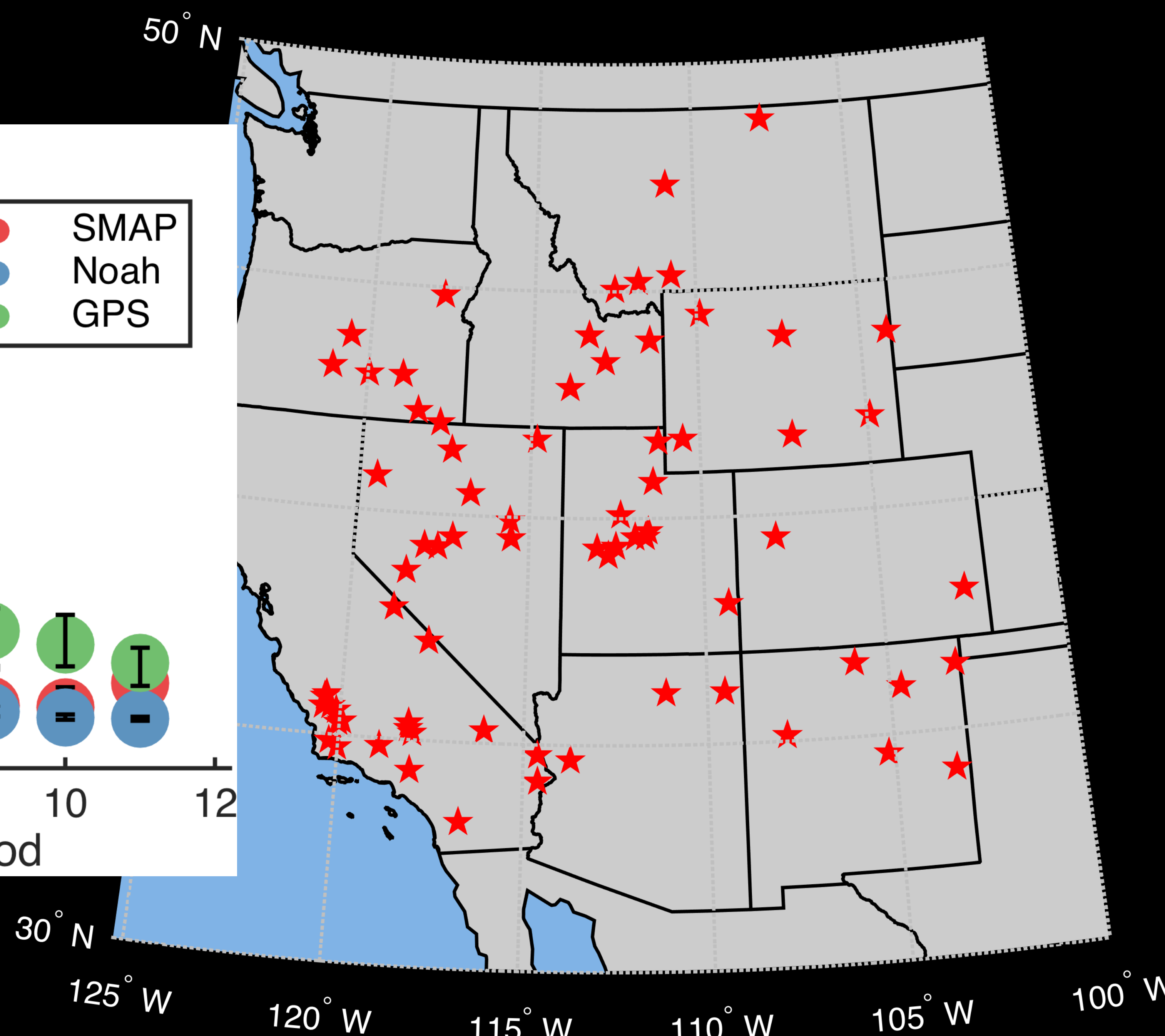
Drying rates

- At GPS stations:
  - SMAP
  - Noah
  - GPS-IR
- ~1,200 rates



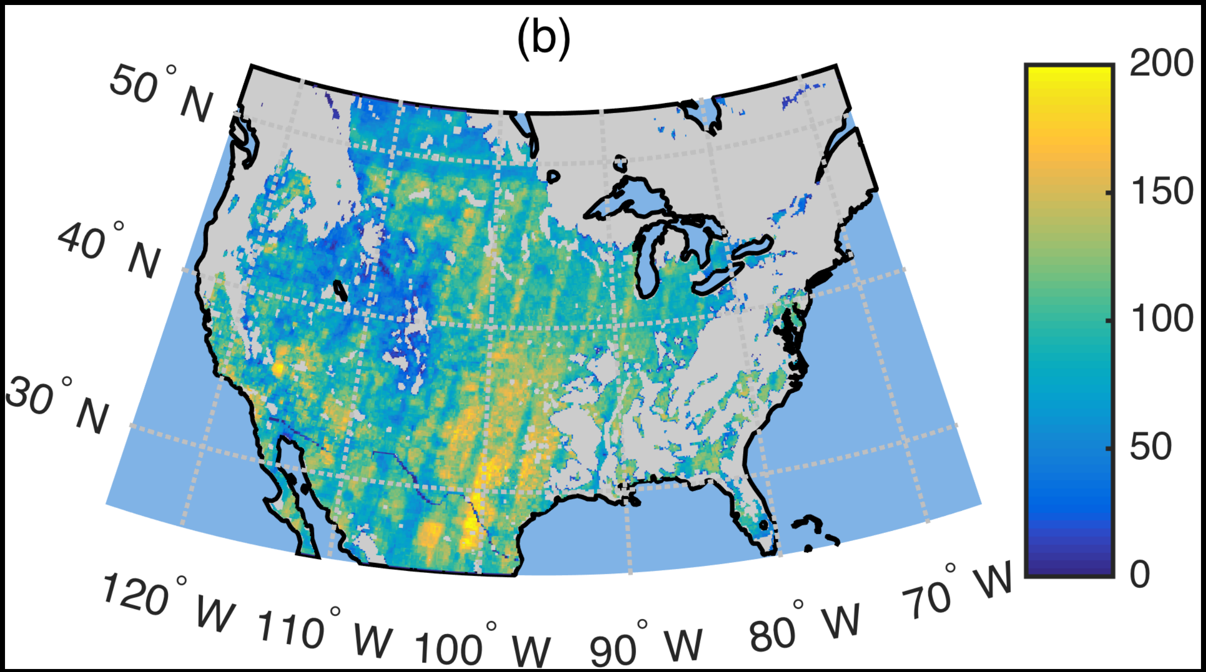
Drying rates





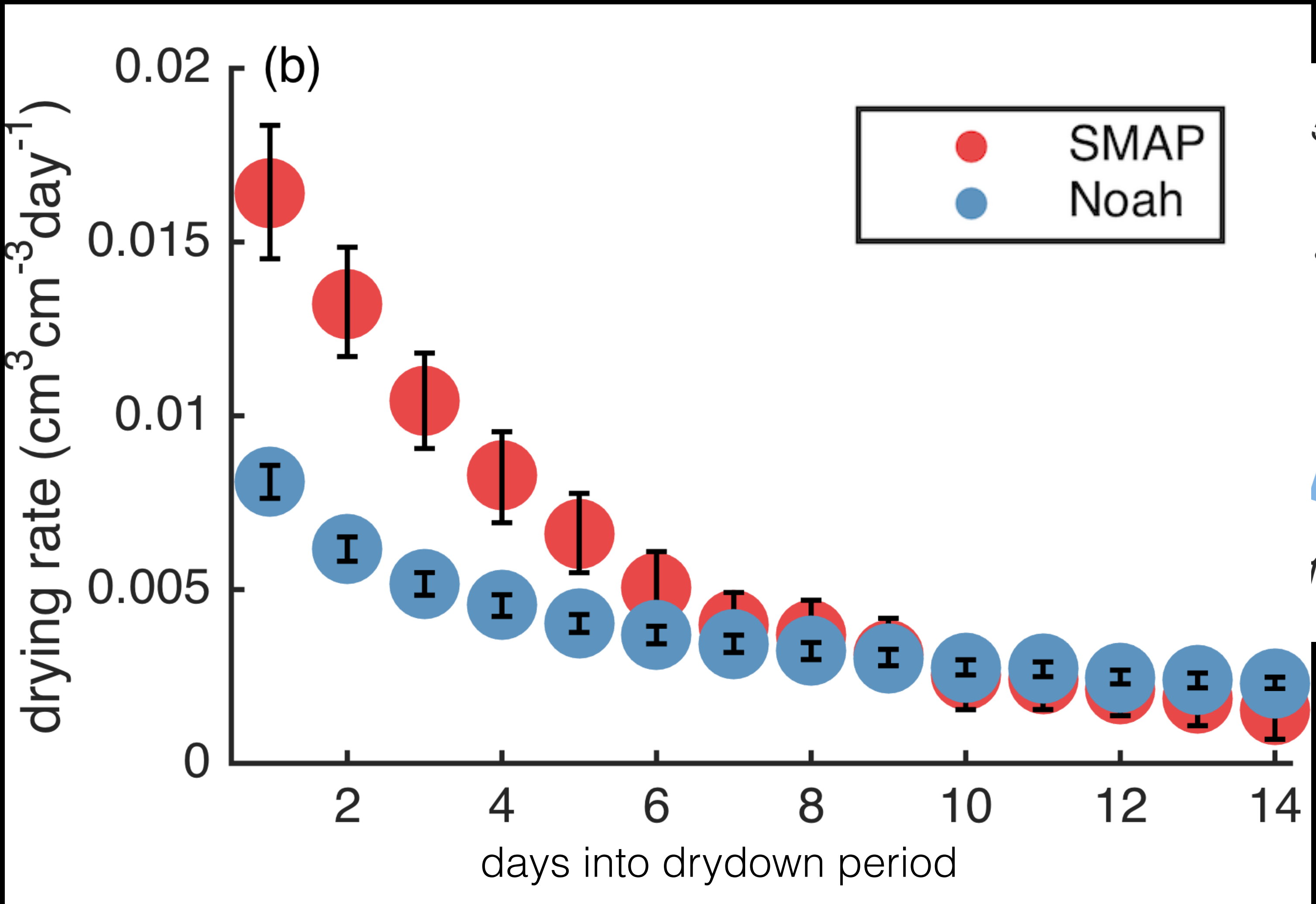
Drying rates

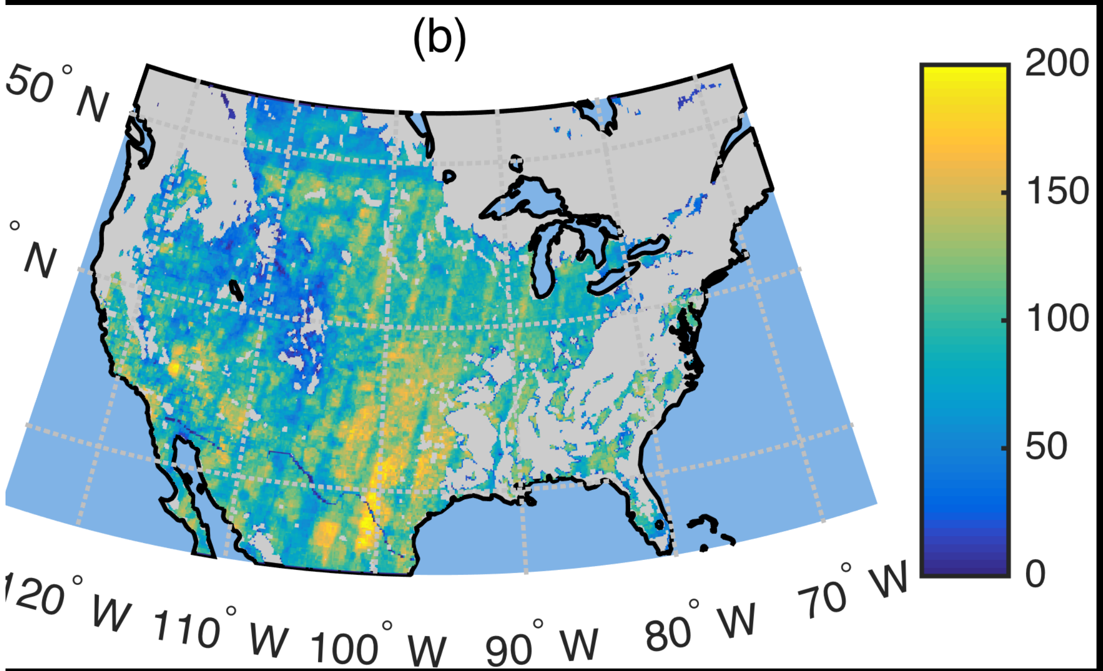
- Present study:
  - SMAP
  - Noah
- ~5 million rates



Number of drydowns between SMAP launch and winter 2017

Drying rates





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Summary so far

- Drying is faster:
  - SMAP, GPS-IR
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Can a continental-scale comparison of SMAP and Noah help us understand what controls these drying rates?

Units

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- Change in water volume: $cm^3\ cm^{-3}\ day^{-1}$

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- Change in water volume: $cm^3 \ cm^{-3} \ day^{-1}$
- Change in water depth: $mm \ day^{-1}$
  - Noah simulation depth (x100 mm)
  - SMAP sensing depth (x50 mm)
- Equivalent evaporative efficiency: (evaporation) / (potential evaporation)

Drying vs. evaporation

- Drying rate = evap + transp + drainage/diffusion

Drying vs. evaporation

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Noah simulations show latter two play a minor role

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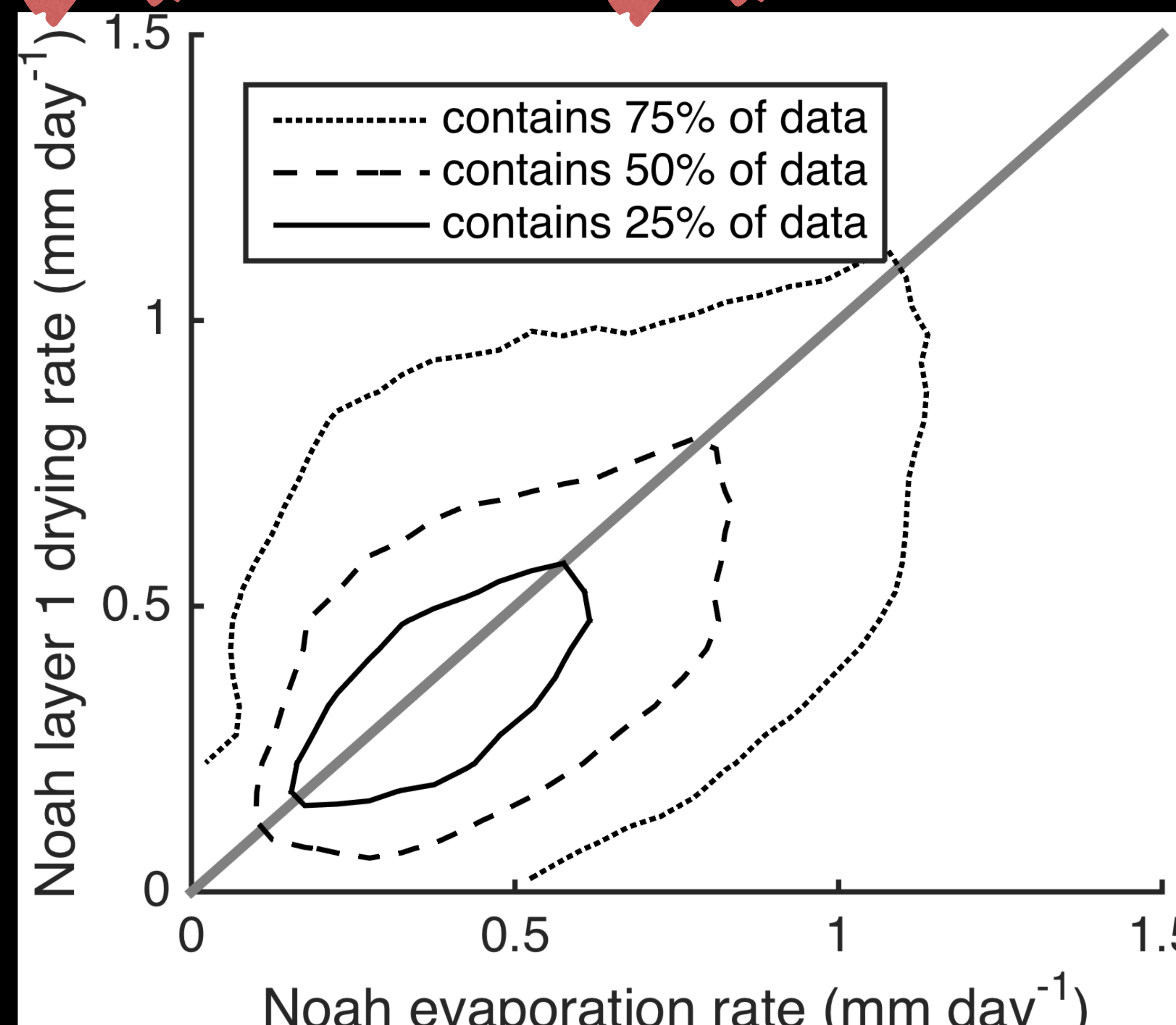
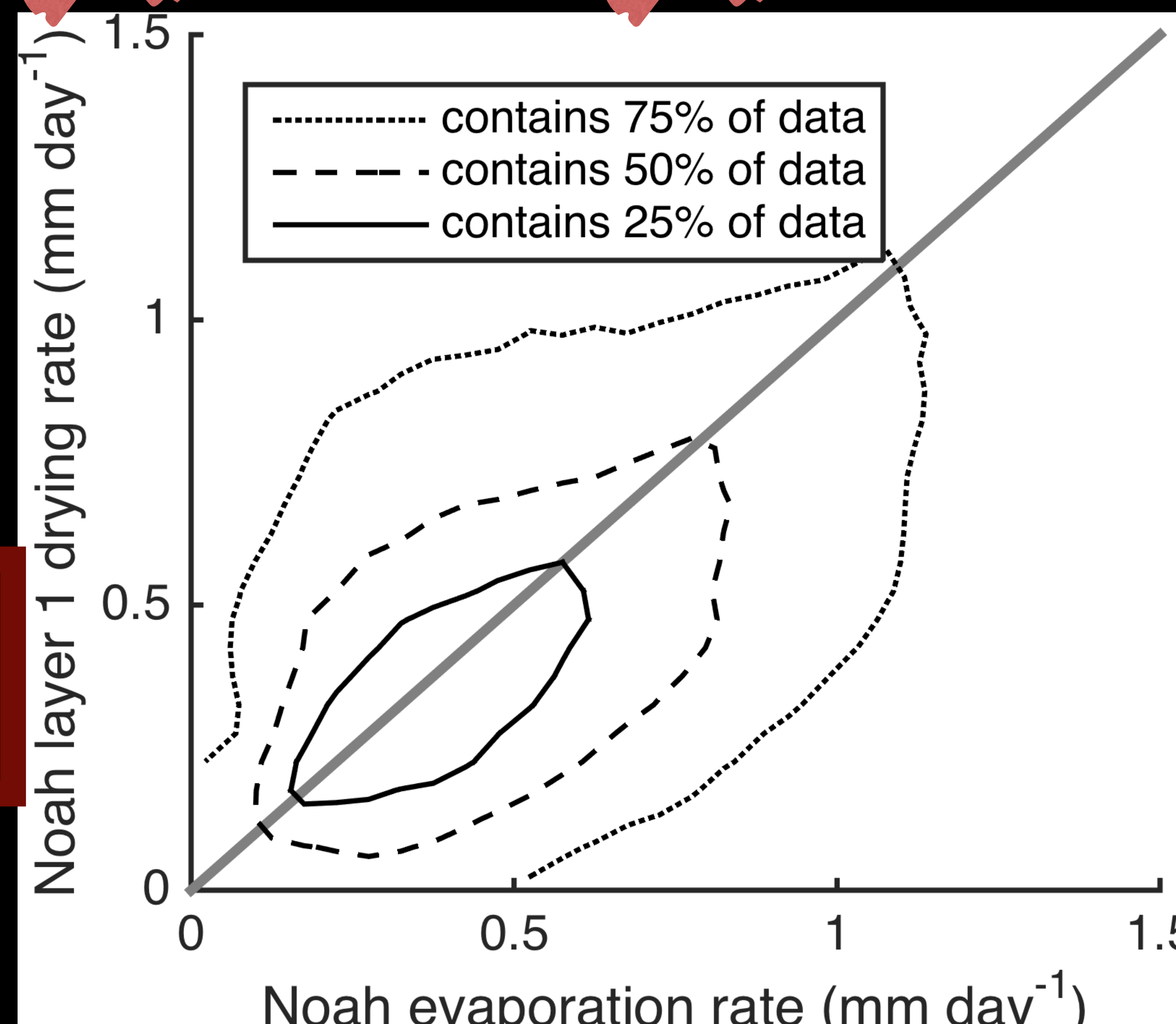


Drying vs. evaporation

- Drying rate = evap + ~~transp~~ + ~~drainage~~ + diffusion

Noah simulations show latter two play a minor role

$$\boxed{\frac{\text{drying rate}}{\text{PE rate}} = \text{evaporative efficiency}}$$



Role of VSM and PE

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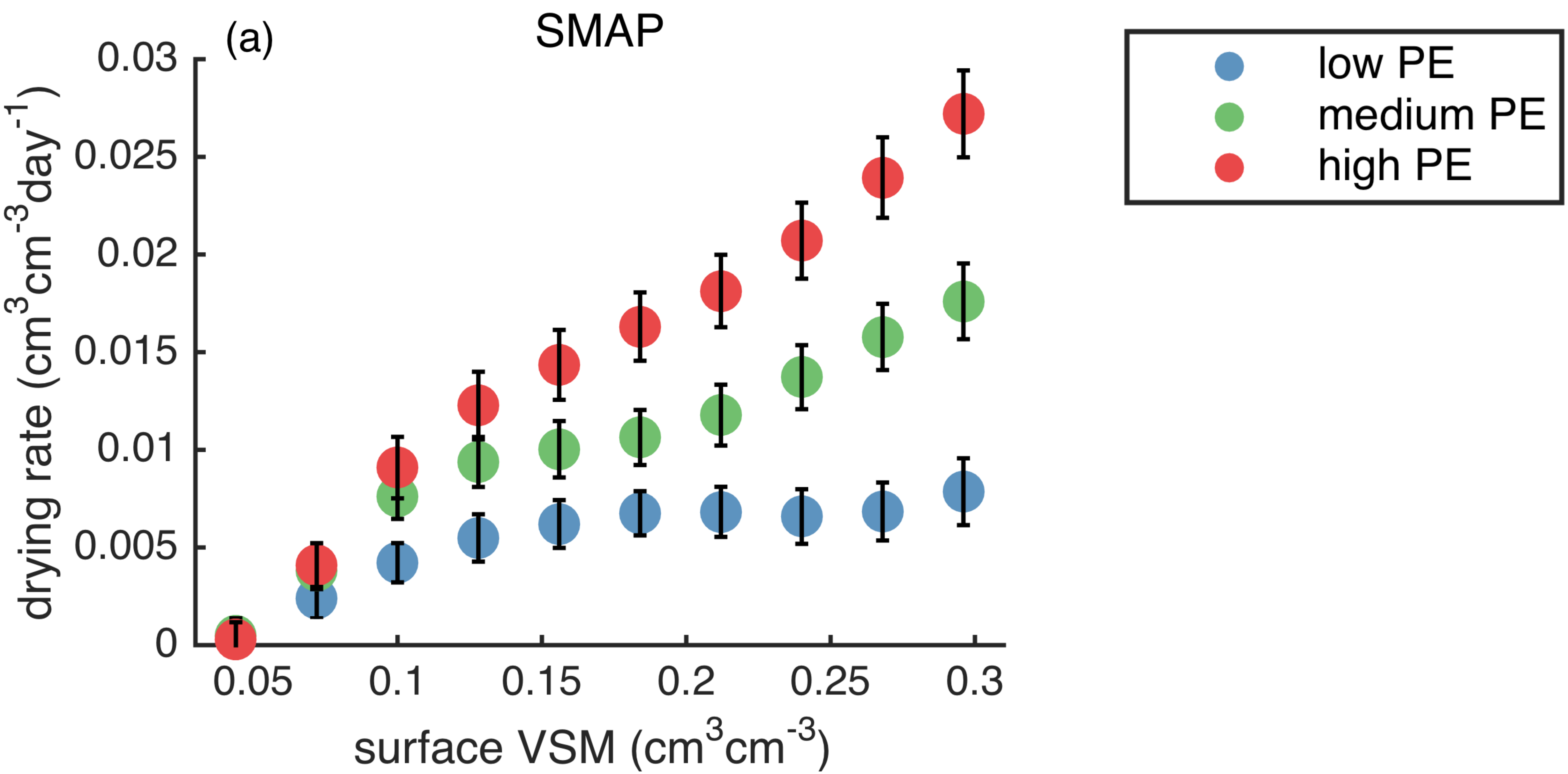

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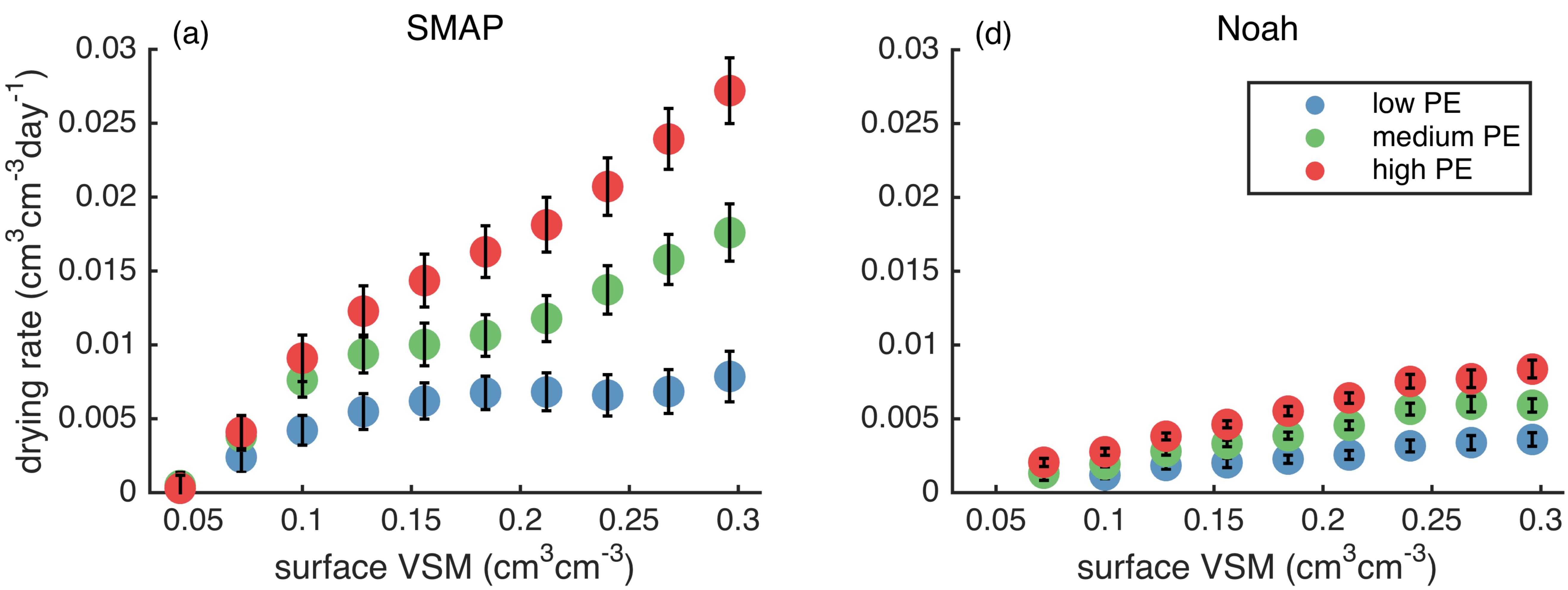

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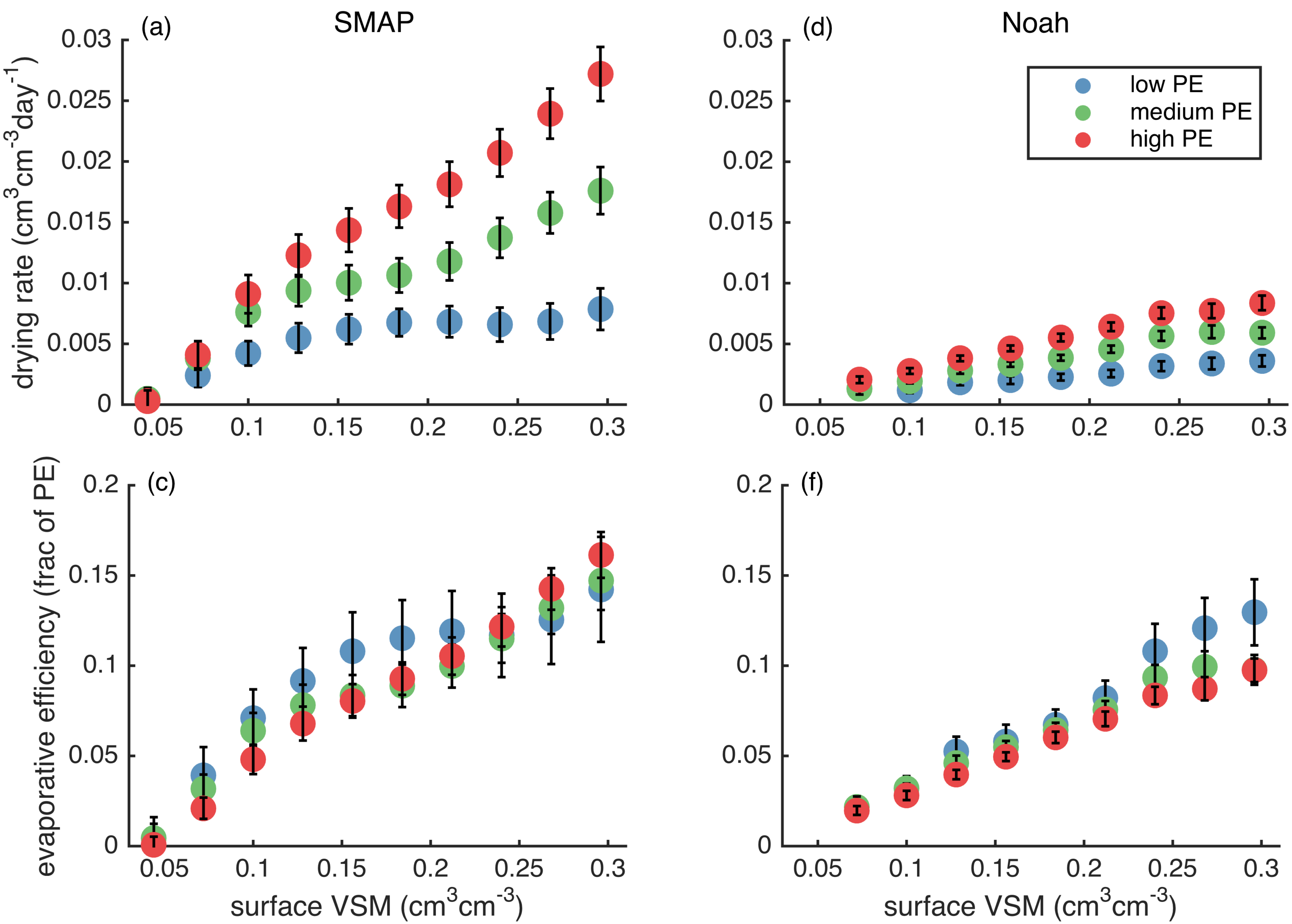
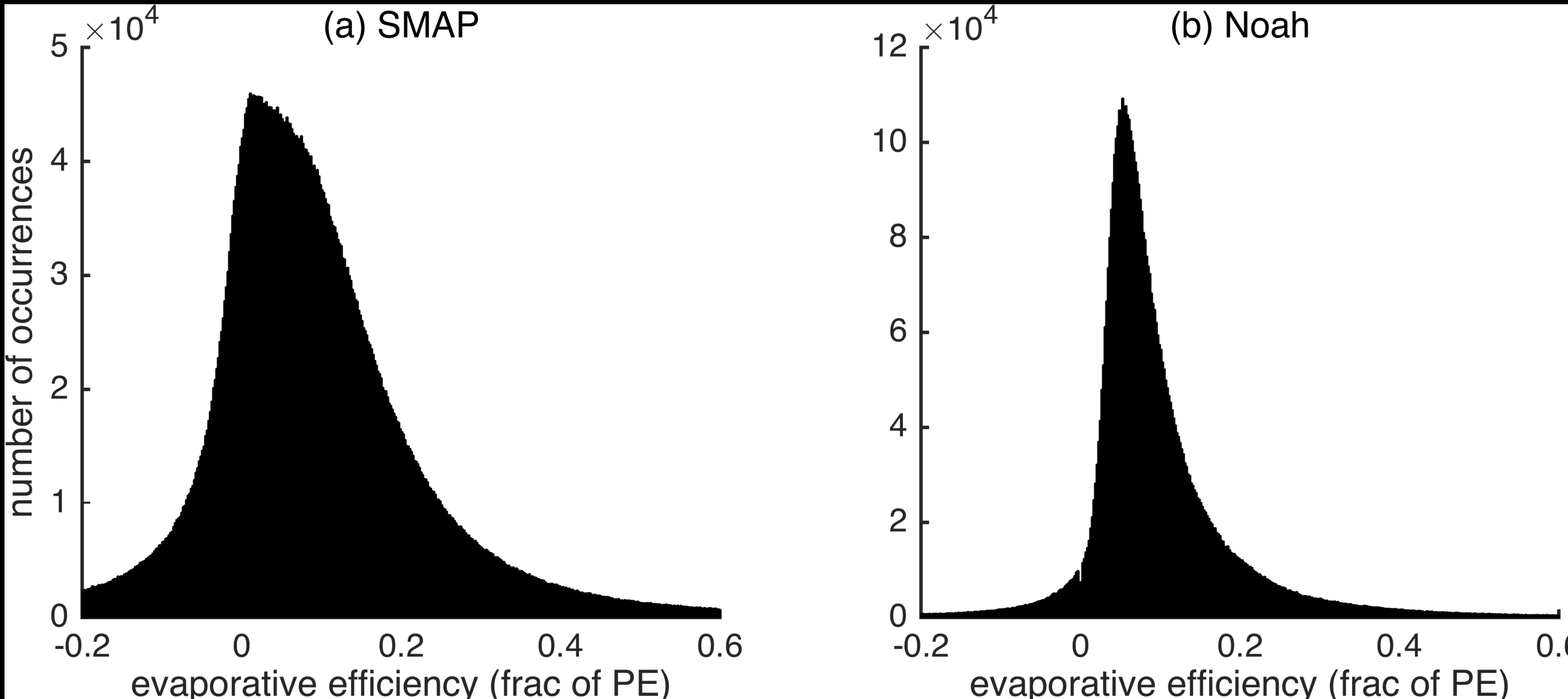
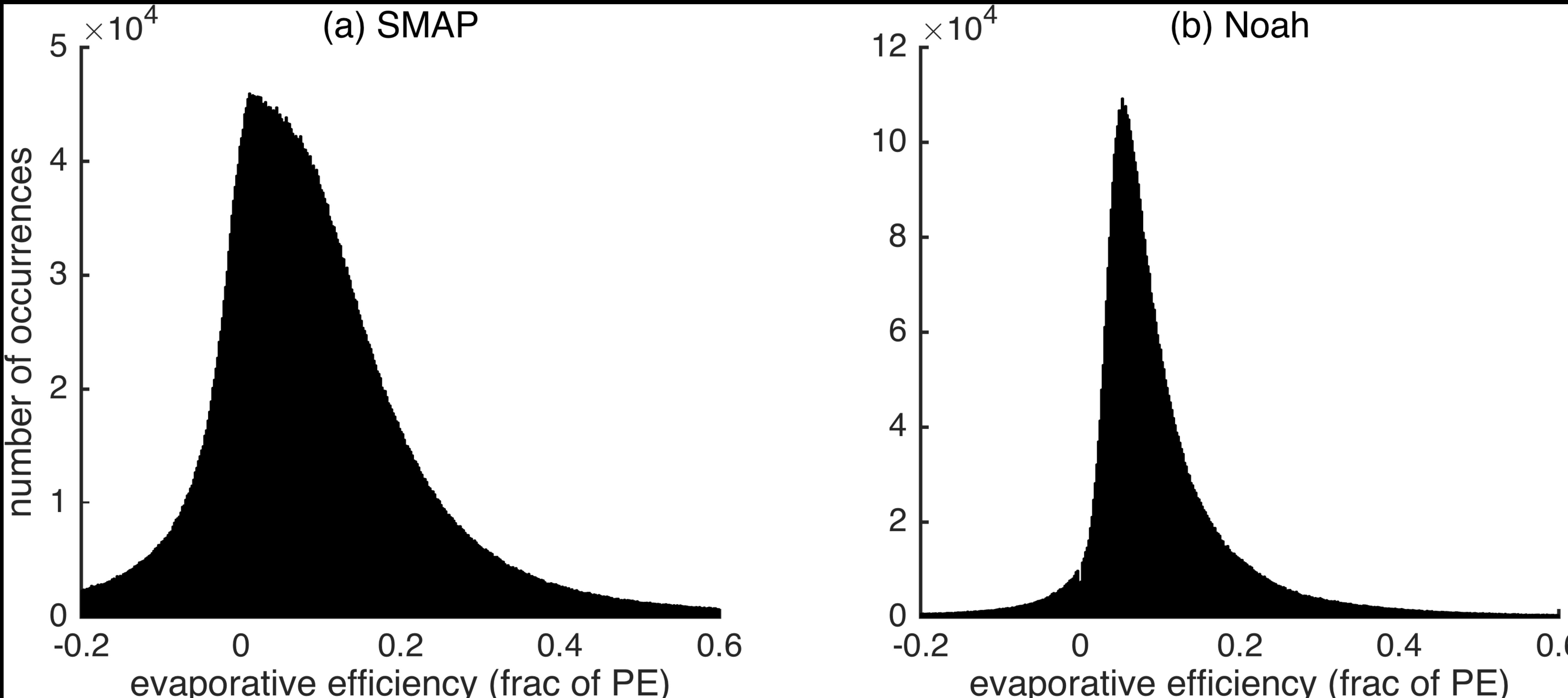


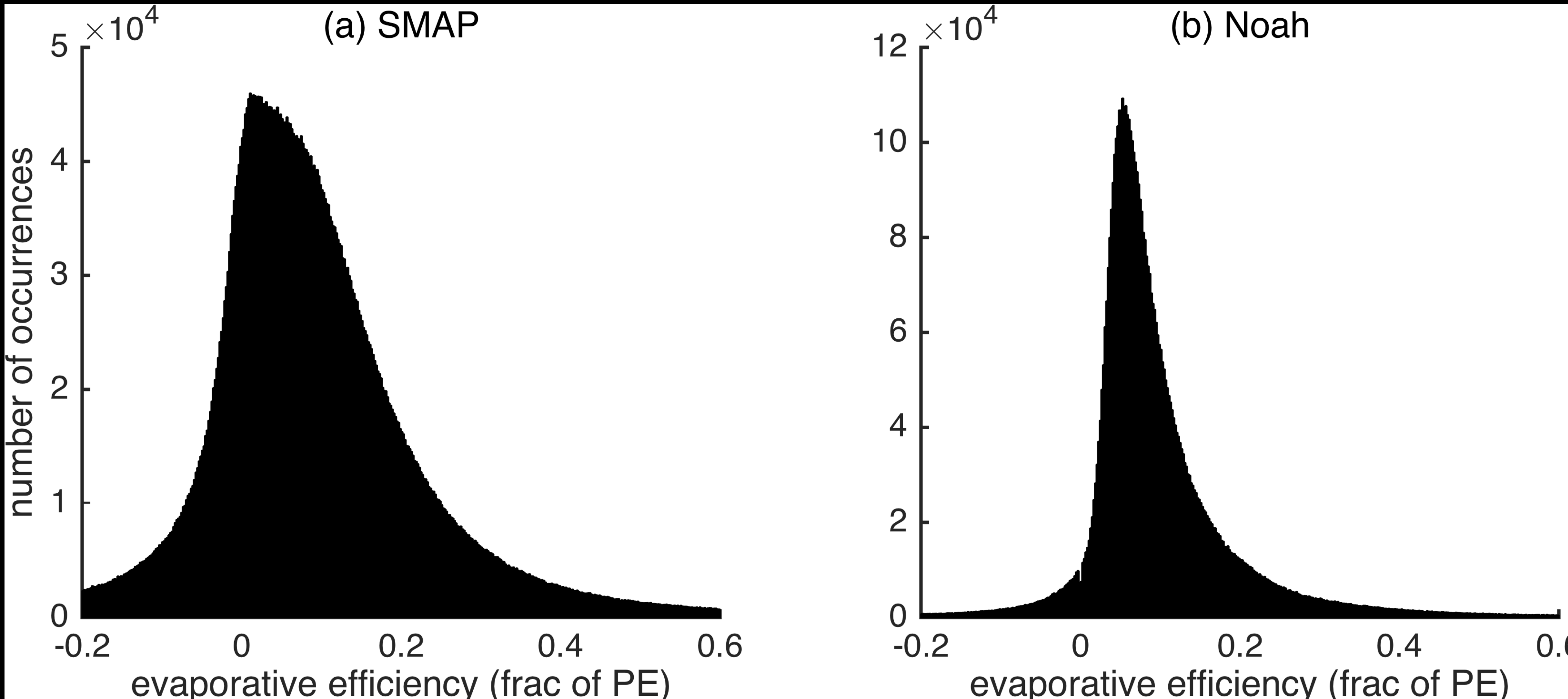


Evaporative efficiencies low



Evaporative efficiencies low

Water-limited



Evaporative efficiencies low

Water-limited
Transpiration

Role of Vegetation (NDVI)

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- Shading slows drying

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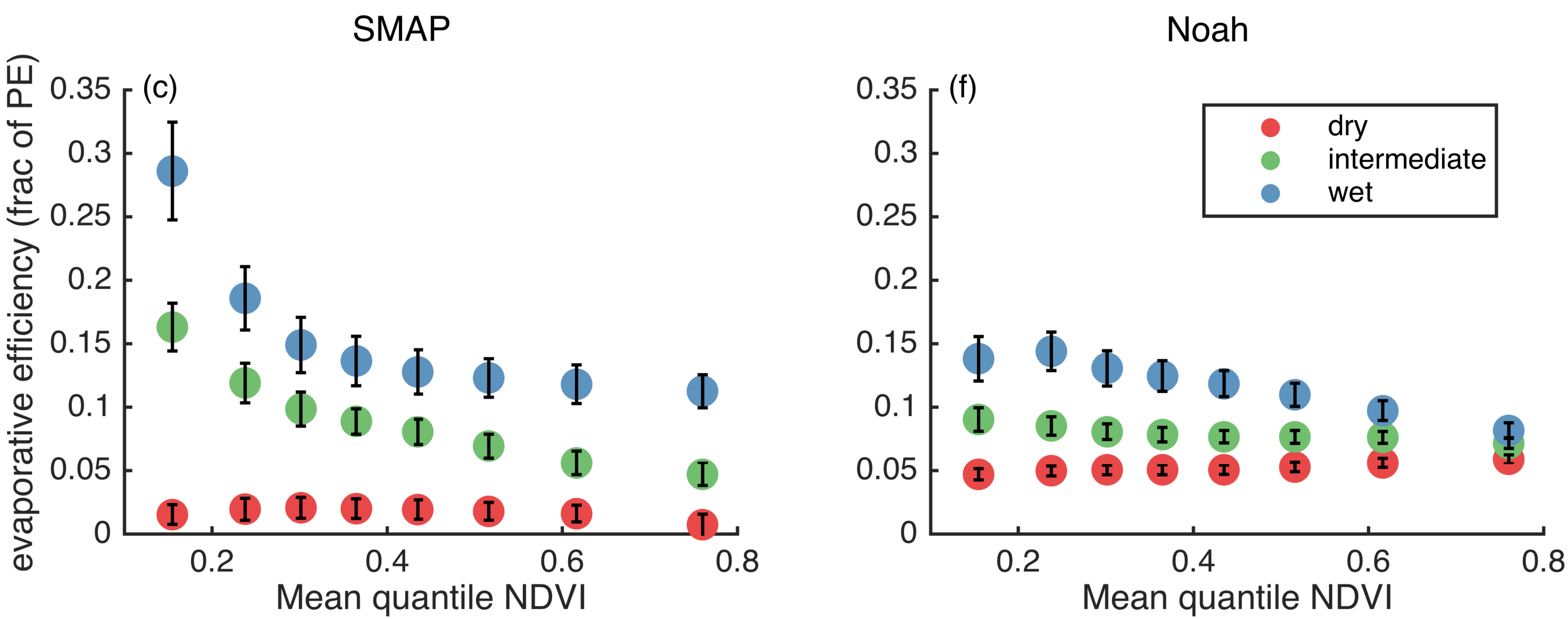
- Correlated with PE

Role of Vegetation (NDVI)



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- At SMAP scales, surface soil drying is water-limited (jibes with McColl et al., 2017, GRL)
    - Drying rates vary linearly with VSM

Conclusions

- SMAP and GPS capture similar soil moisture drying rates; both are faster than Noah and in situ
- At SMAP scales, surface soil drying is water-limited (jibes with McColl et al., 2017, GRL)
  - Drying rates vary linearly with VSM
  - Higher PE rates increase the sensitivity of drying rates to VSM

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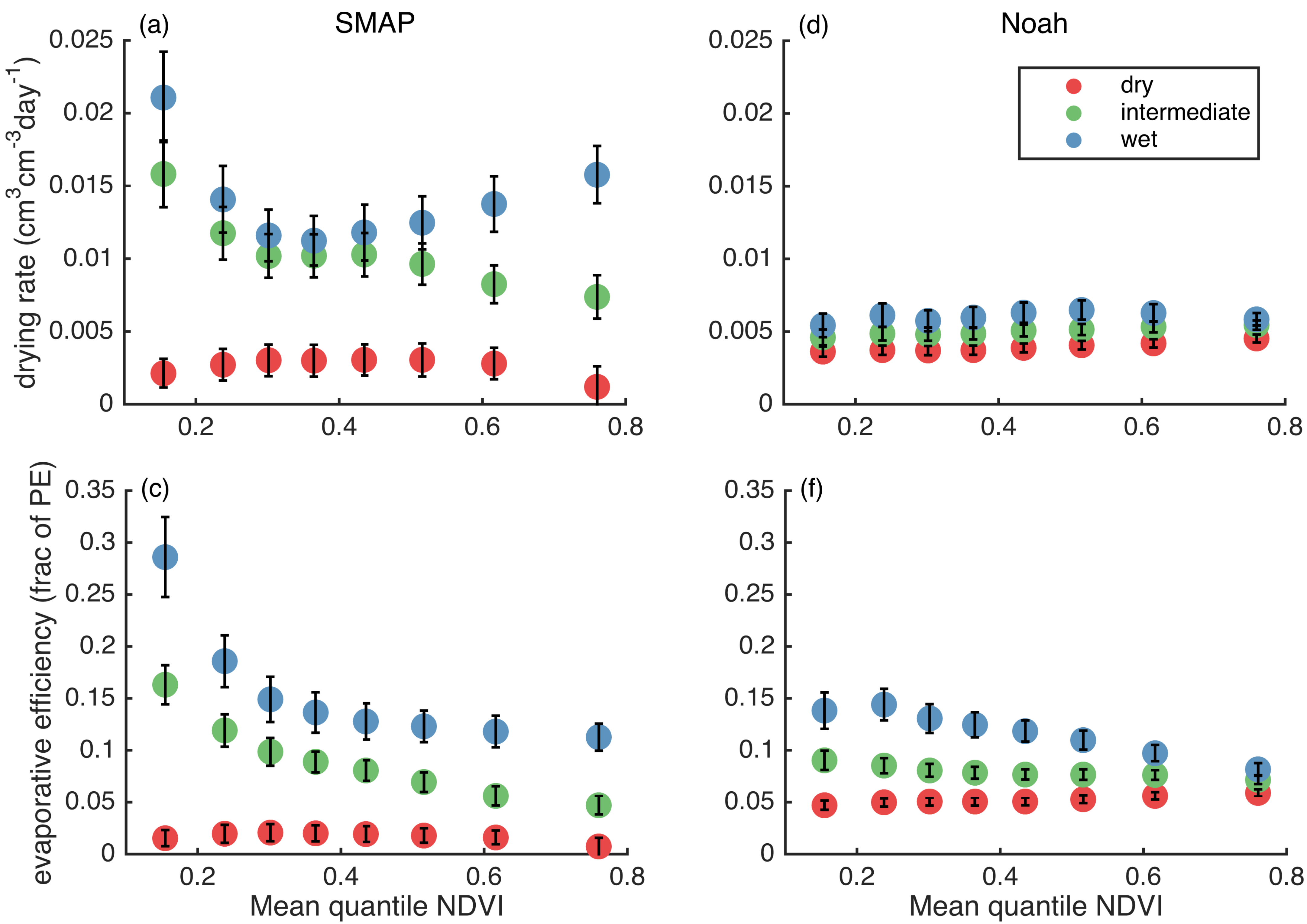
  - Vegetation hinders evaporation more than it facilitates transpiration
  - Noah simulated soil moisture largely fails to show this effect of veg, implying a structural deficiency
- Soil texture (not shown) has a small influence on SMAP drying rates (also McColl et al., 2017, GRL)

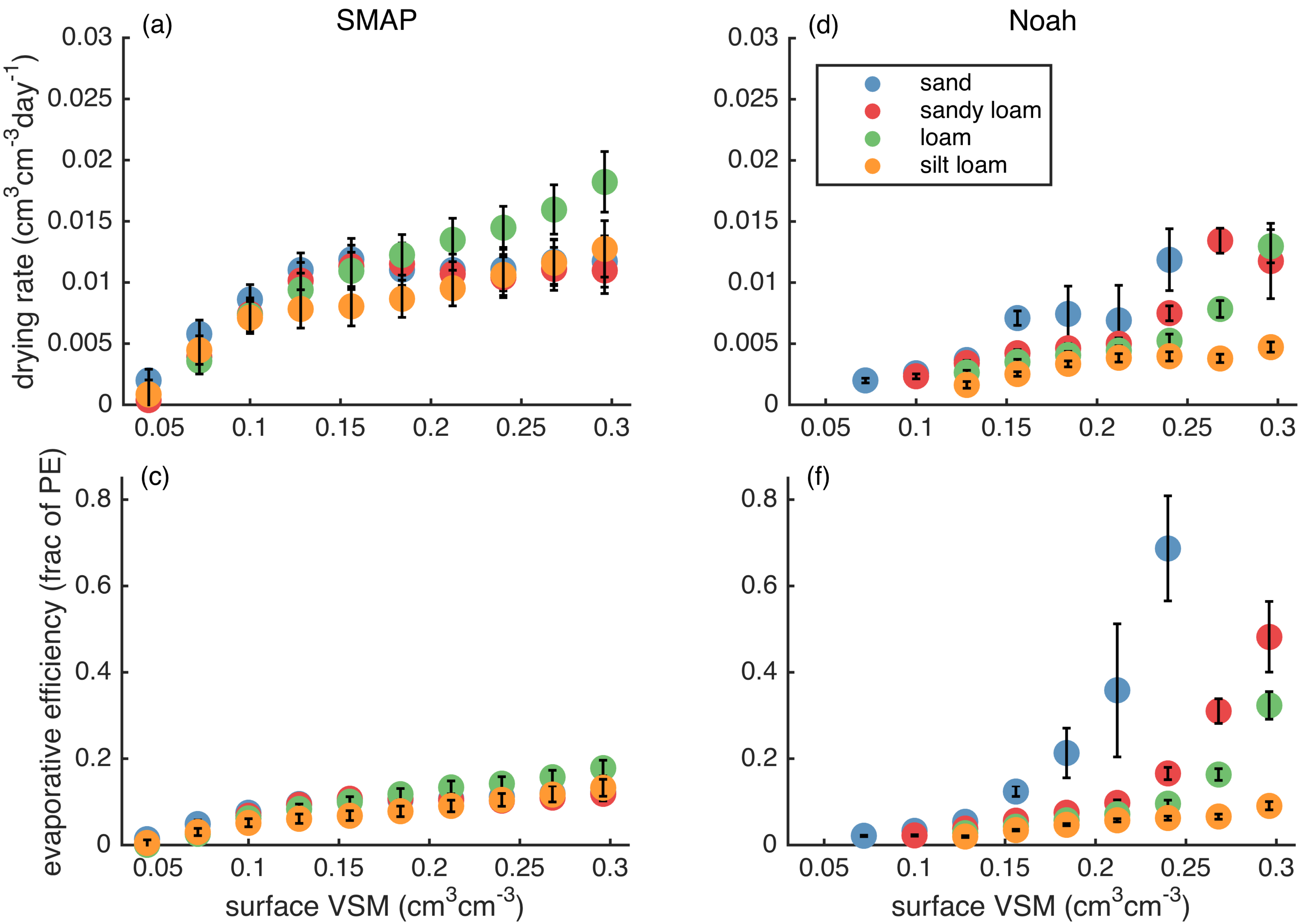
Thank you

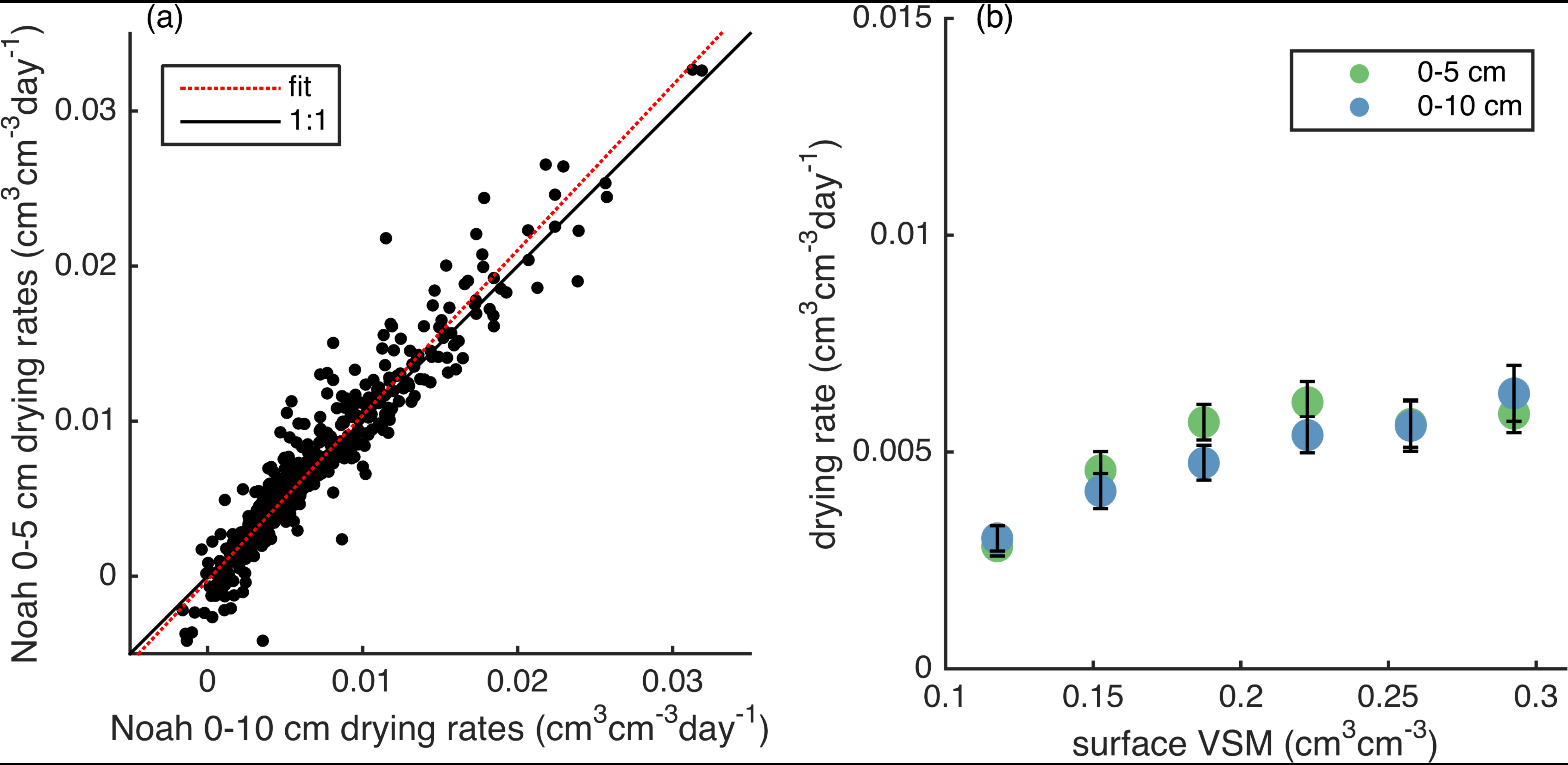
Extra slides

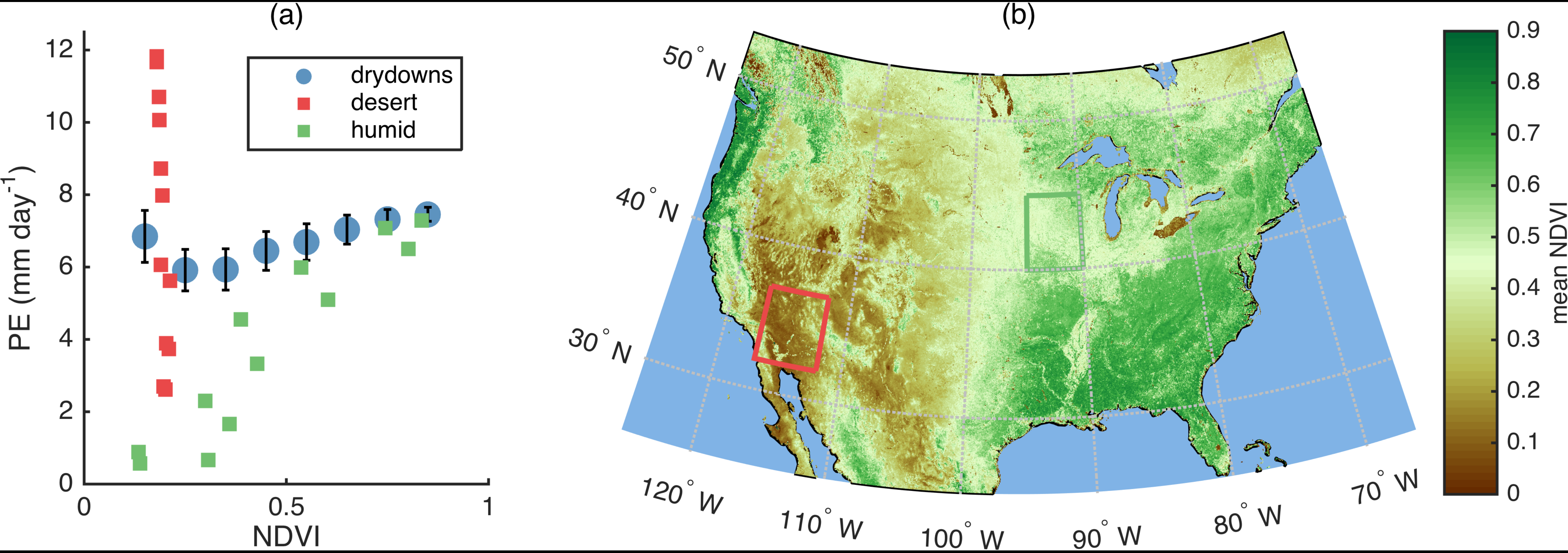
Role of Vegetation (NDVI)

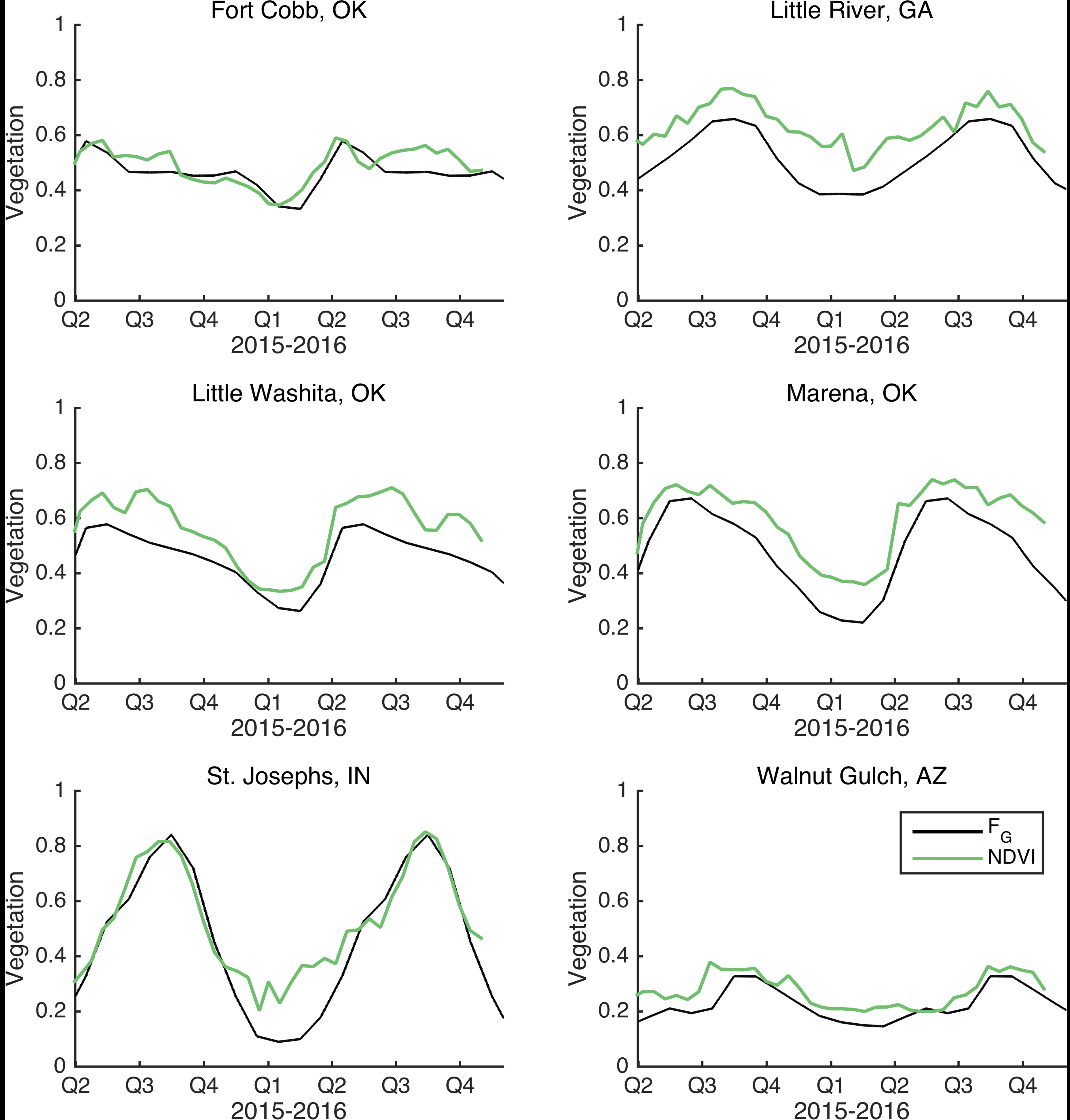


Role of Soil Texture

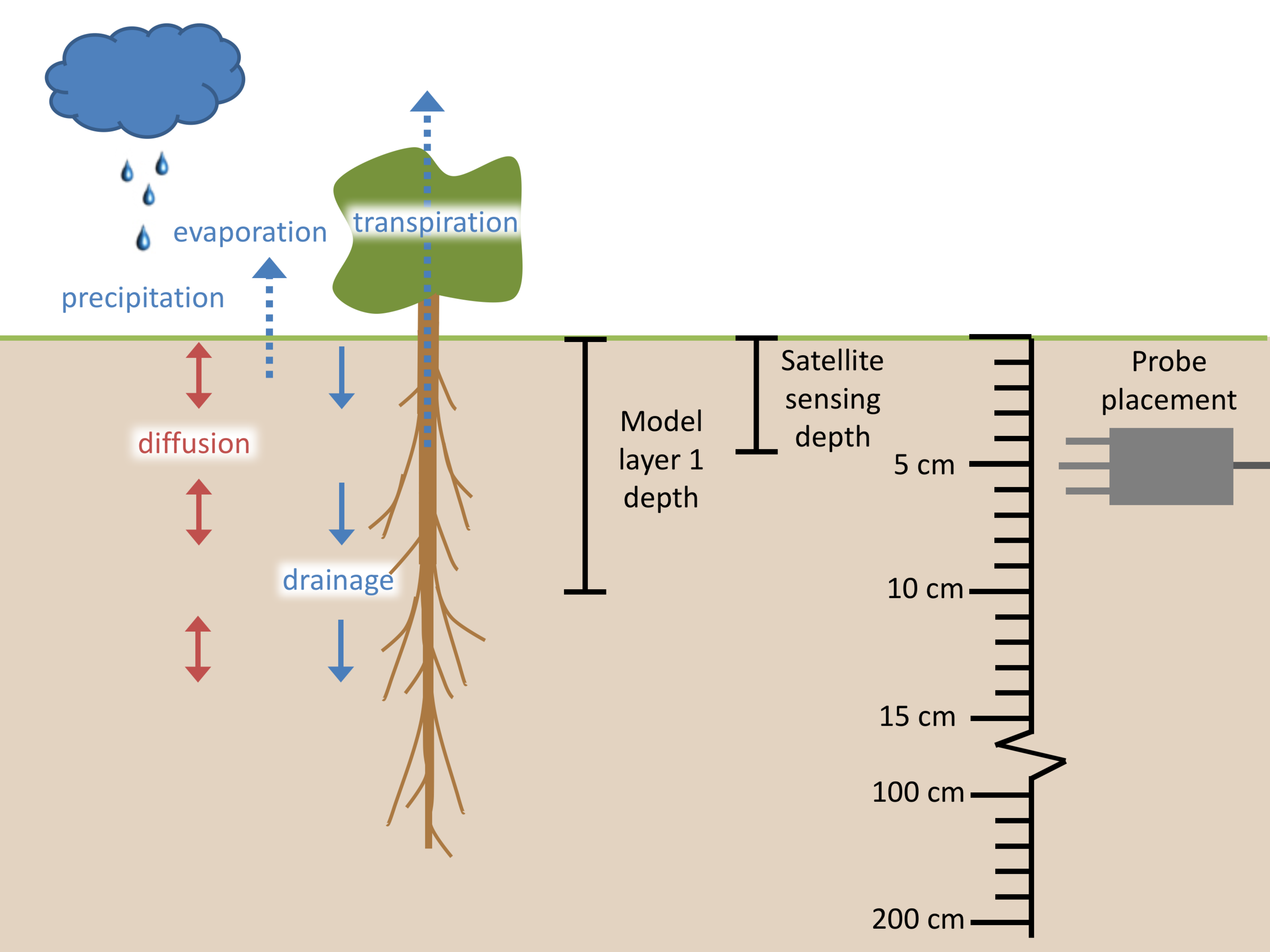



(a)
fit
1:1
Noah 0-5 cm drying rates (cm3cm-3day-1)
Noah 0-10 cm drying rates (cm3cm-3day-1)
0.03
0.02
0.01
0
(b)
0-5 cm
0-10 cm
drying rate (cm3cm-3day-1)
surface VSM (cm3cm-3)
0.015
0.005
0.1
0.15
0.2
0.25
0.3


(a)
(b)
drydowns
desert
humid
PE (mm day^{-1})
NDVI
0
0.5
1
0
2
4
6
8
10
12
50° N
40° N
30° N
120° W
110° W
100° W
90° W
80° W
70° W
mean NDVI
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9



Fort Cobb, OK
Little River, GA
Little Washita, OK
Marena, OK
St. Josephs, IN
Walnut Gulch, AZ
Vegetation
1
0.8
0.6
0.4
0.2
0
Q2
Q3
Q4
Q1
Q2
Q3
Q4
2015-2016
F G
NDVI


evaporation
transpiration
precipitation
diffusion
drainage
Model layer 1 depth
Satellite sensing depth
Probe placement
5 cm
10 cm
15 cm
100 cm
200 cm