Controls on surface soil drying rates observed by SMAP and simulated by the Noah land surface model

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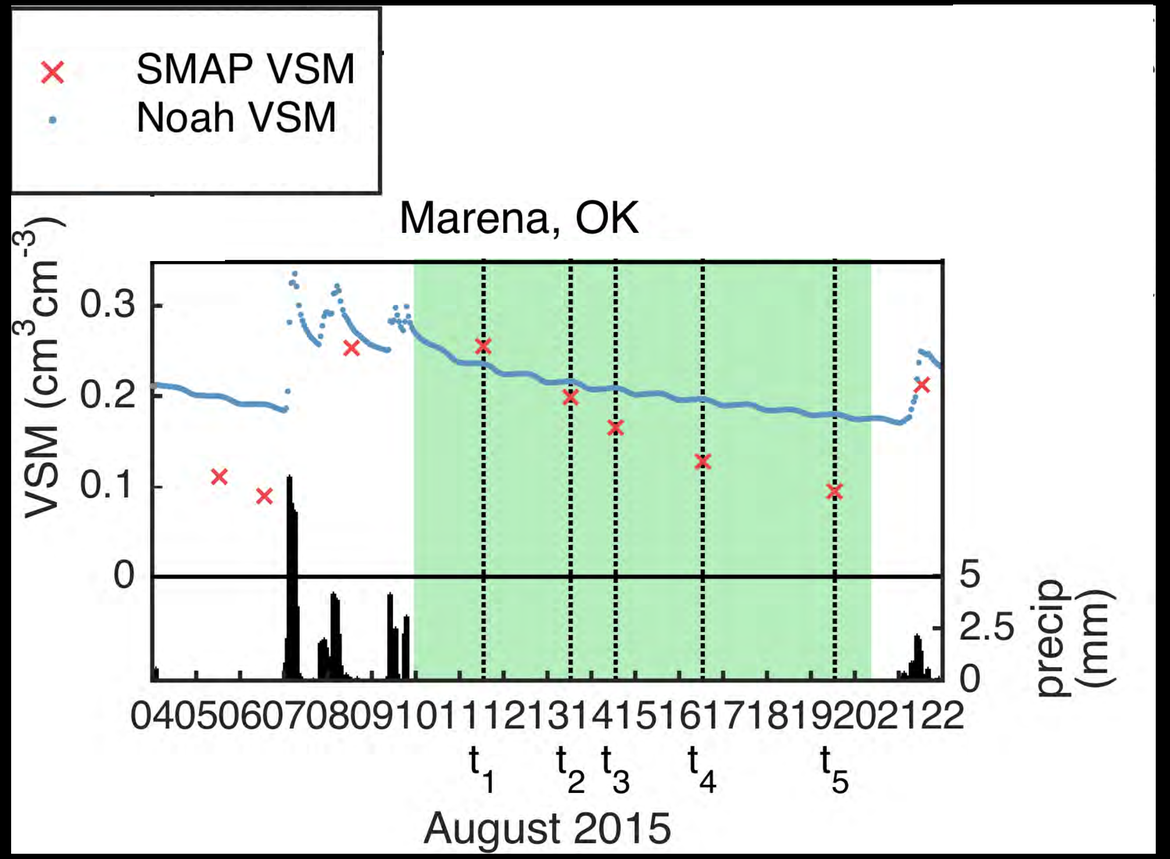
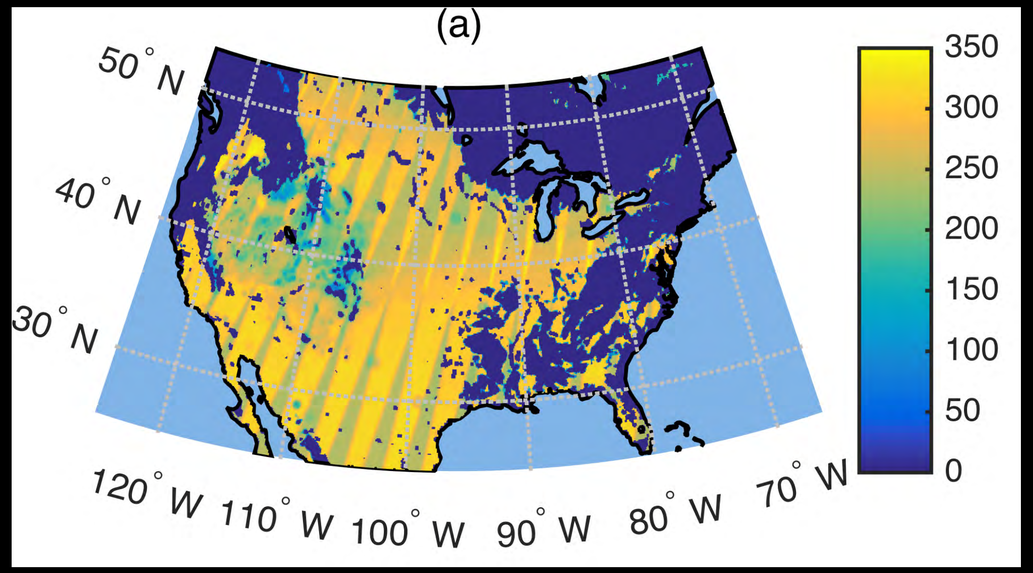
SMAP and Noah

- Both respond to precipitation events
- Drydowns depend on:
  - Volumetric soil moisture (VSM)
  - Potential evaporation (PE) rate
  - Vegetation cover (NDVI)
  - Soil texture class



SMAP and Noah

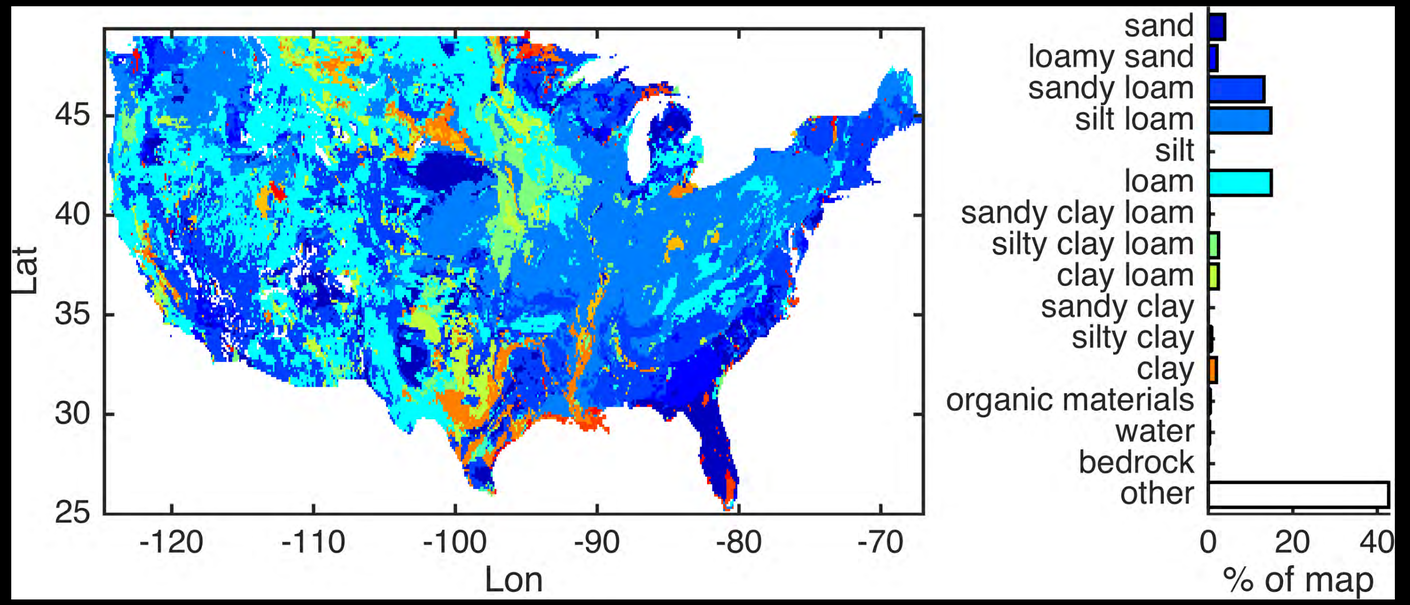
- ~5 cm soil moisture every 1-3 days
- NLDAS-2 domain
- March 31, 2015 through January 27, 2017
- Level 3 enhanced retrievals (33 km/9 km)



Number of SMAP observations between launch and winter 2017

SMAP and Noah

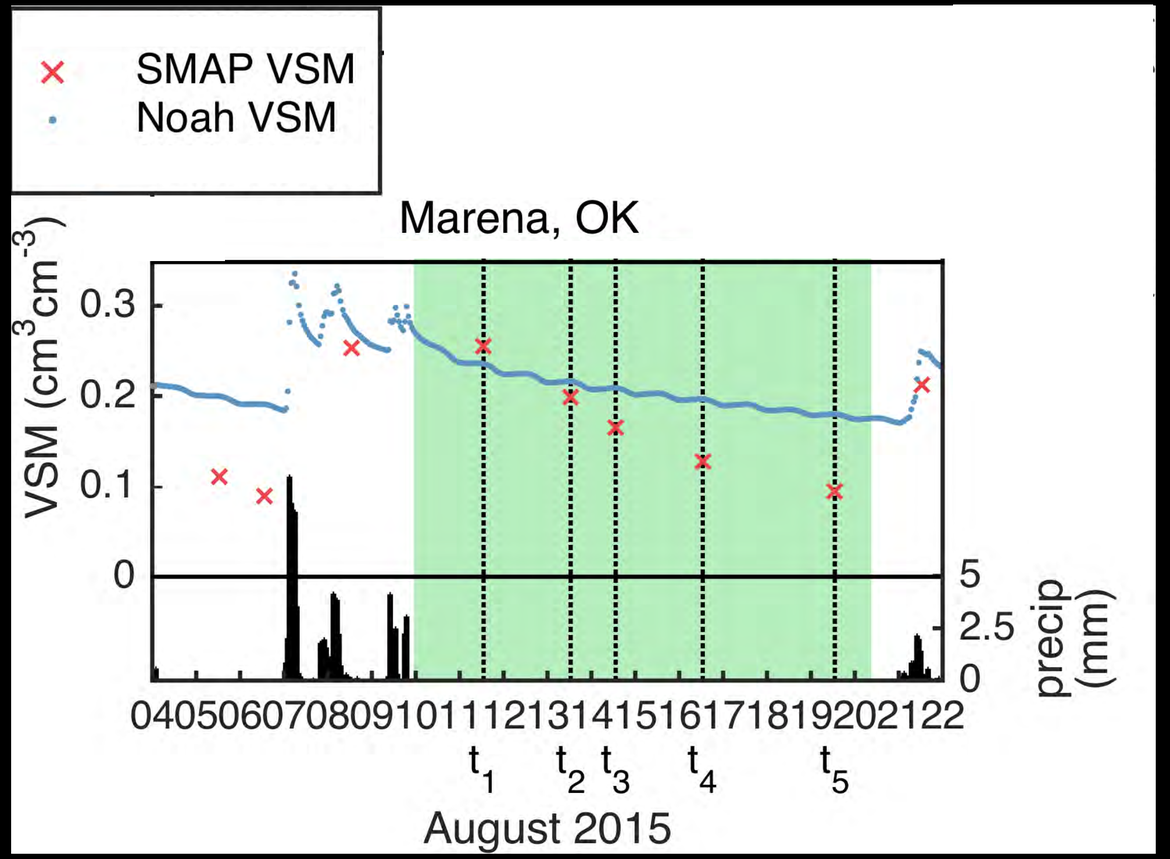
- Noah layer 1 soil moisture (0-10 cm; 1/8º)
- Noah surface evaporation rate
- NLDAS soil texture designations
- NLDAS forcing:
  - Potential evaporation
  - Precipitation
- MODIS NDVI



Quantify soil drying

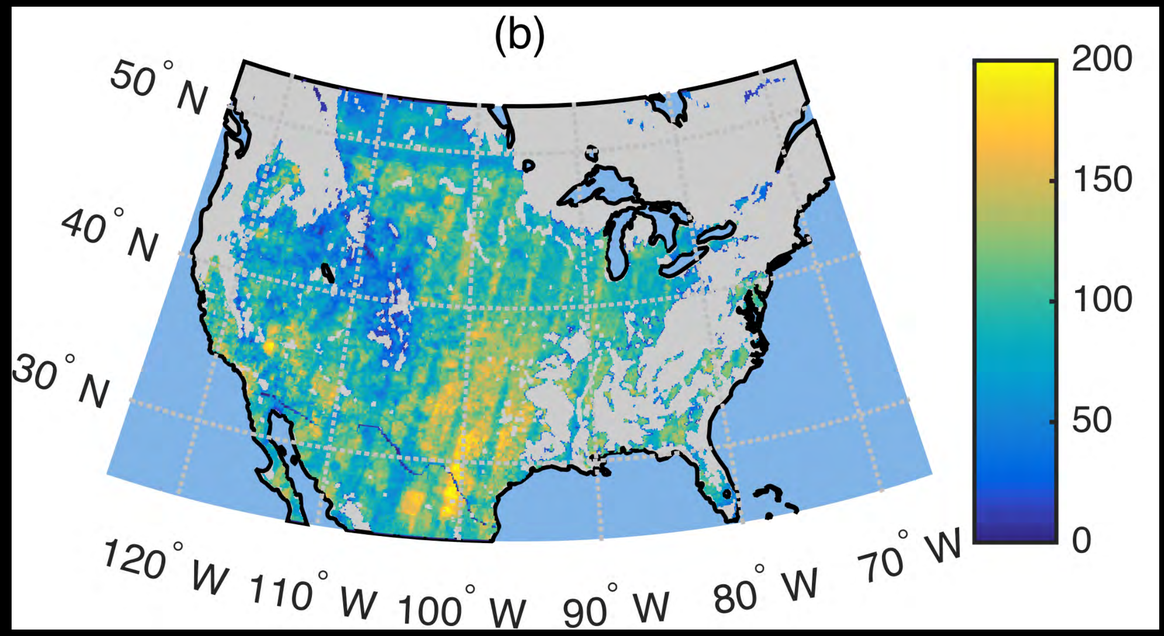
- Identify drydown periods (at least 4 days of no rain)
- Finite differences $cm^3\ cm^3\ day^{-1}$

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



Drying rates

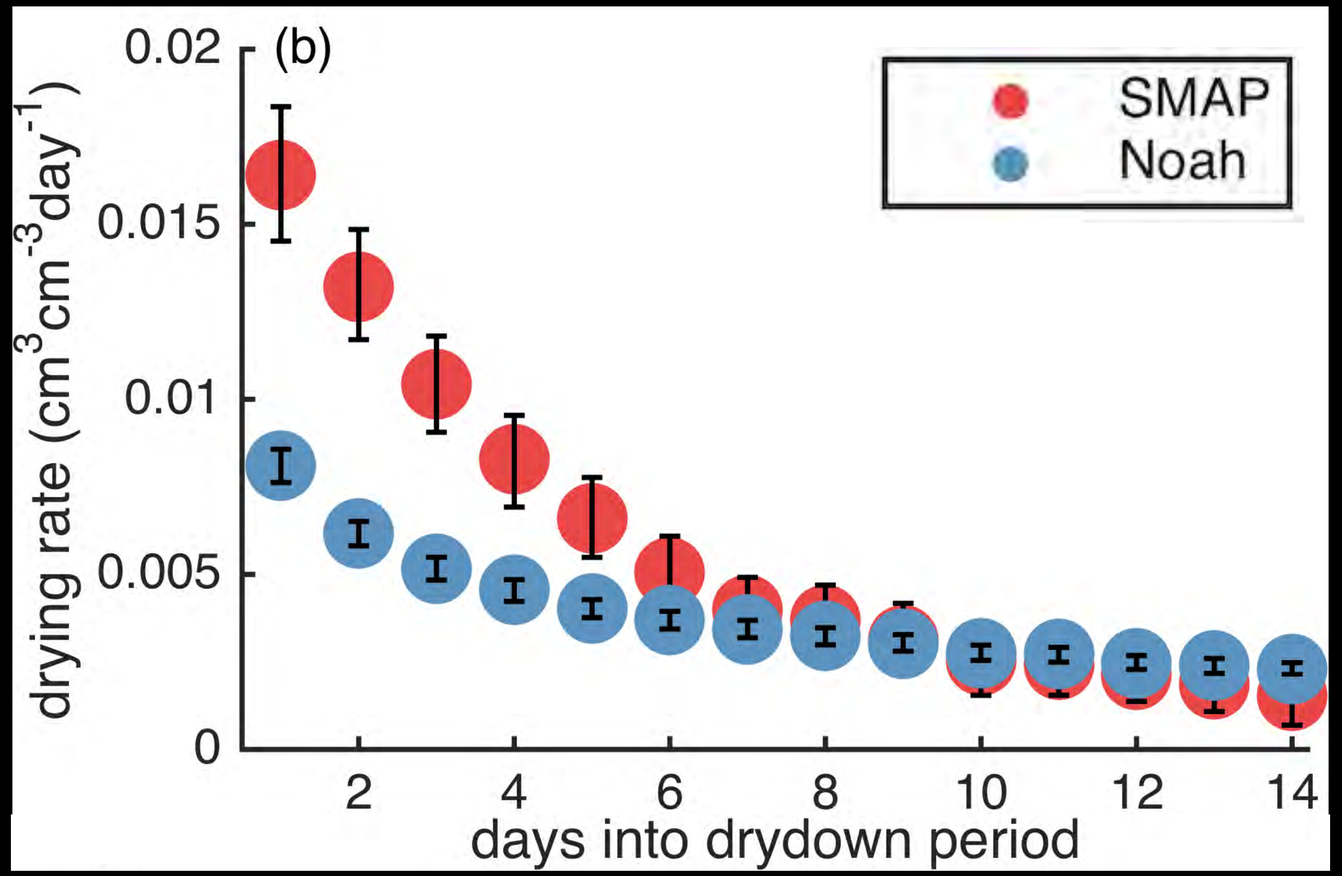
- ~5 million rates
  - From SMAP obs
  - From concurrent Noah sims



Number of drying rates calculated between SMAP launch and winter 2017

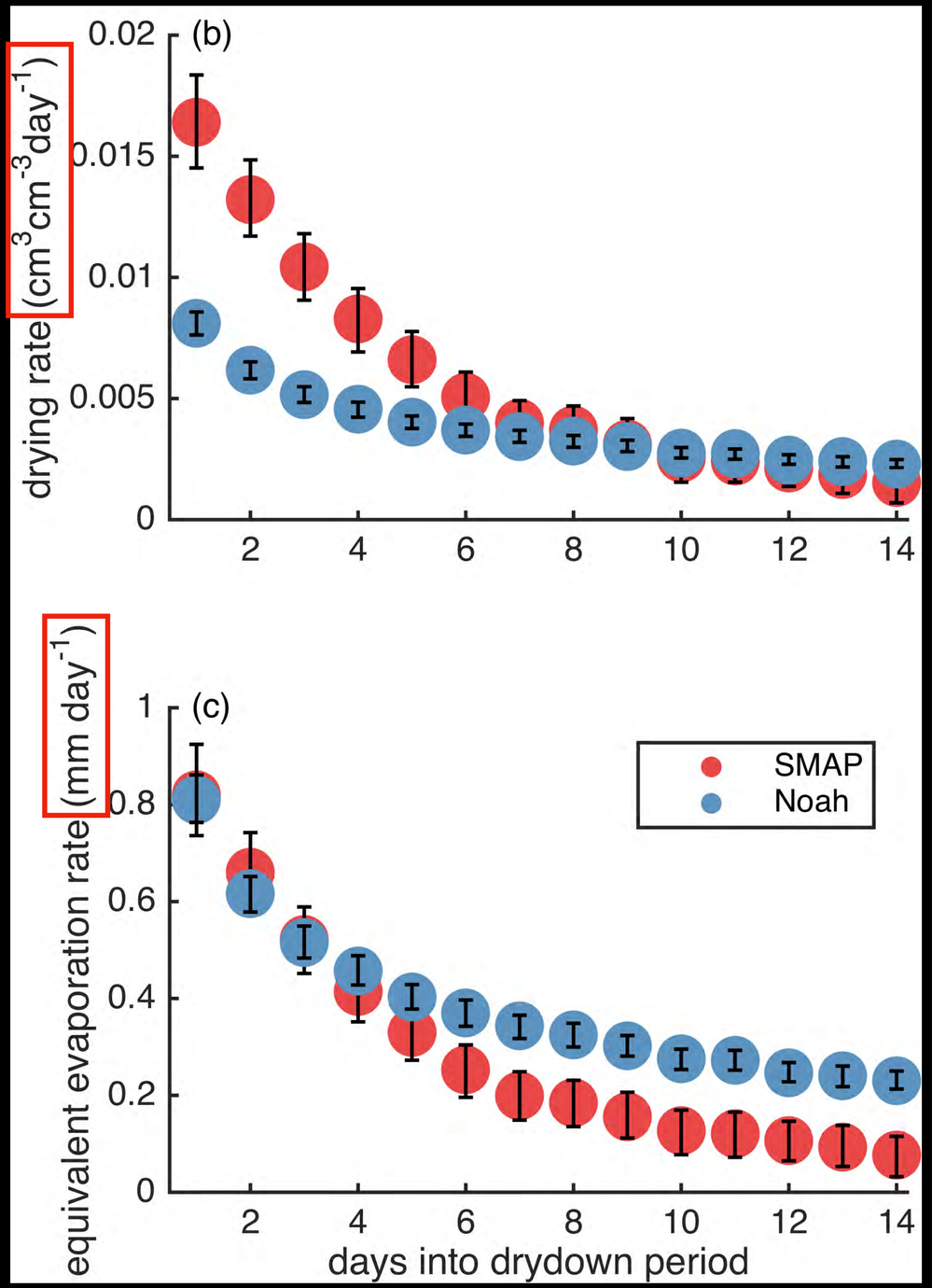
Drying rates

- ~5 million rates
  - From SMAP obs
  - From concurrent Noah sims
- Drying rates slow with time



Drying units

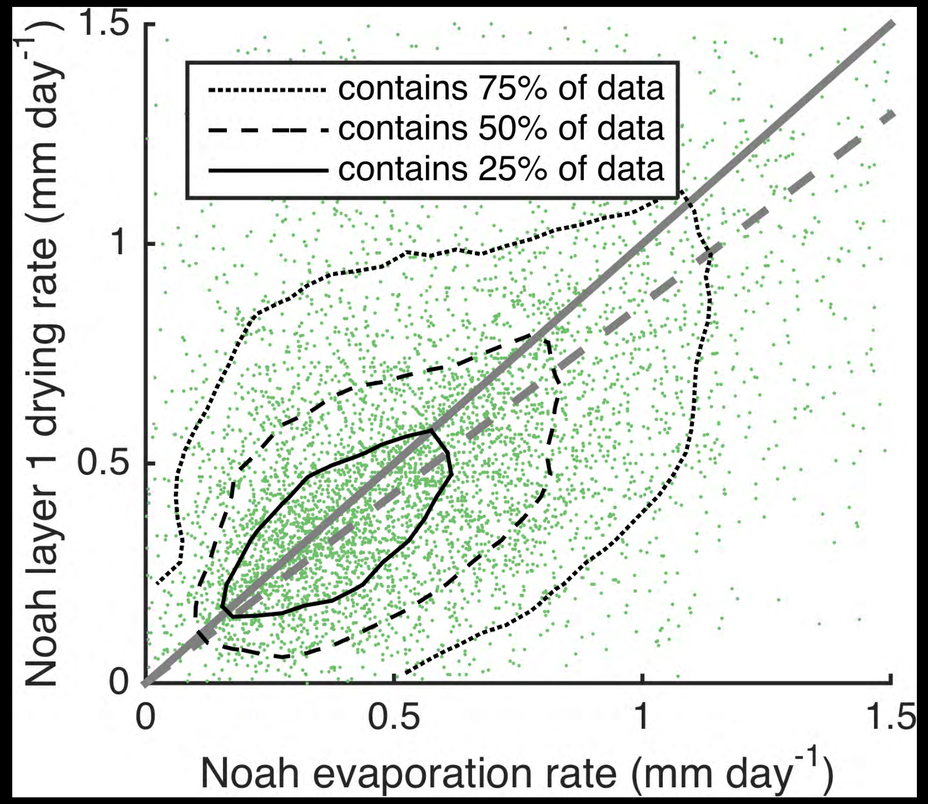
- Change in water volume: $cm^3\ cm^{-3}\ day^{-1}$
- Change in water depth: $mm\ day^{-1}$
  - Noah simulation depth (x100 mm)
  - SMAP sensing depth (x50 mm)
- "Equivalent evaporation rate"



Equivalent evaporation rate

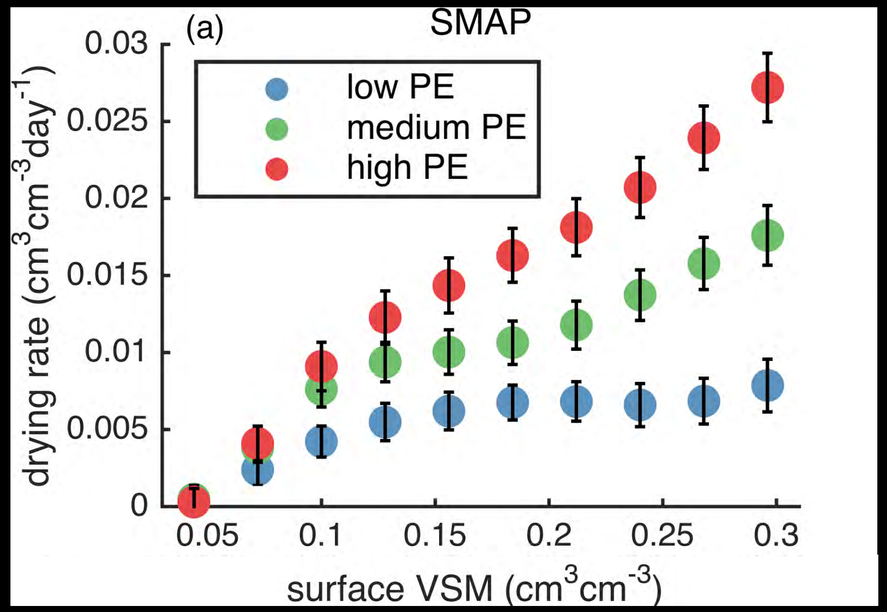
- drying rate = evap ~~+ transp + drainage + diffusion~~

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



Transpiration, drainage, and diffusion are on average balanced

Results



- Drydowns depend on :
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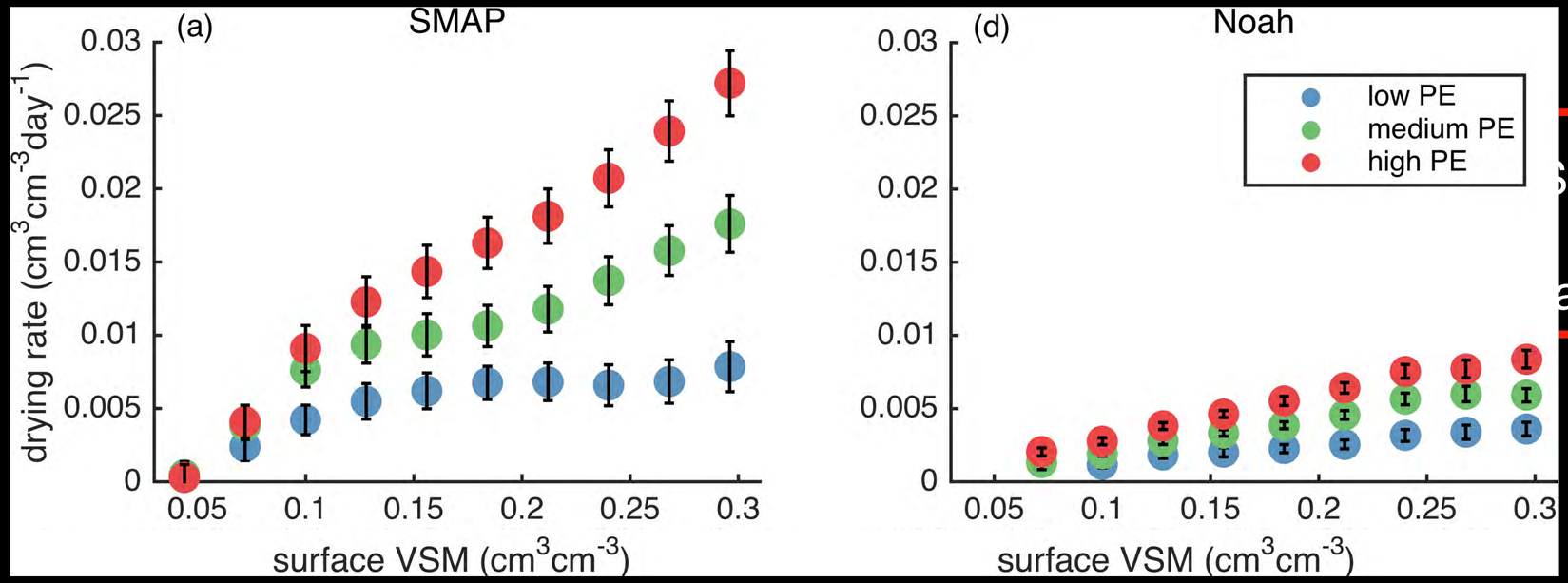
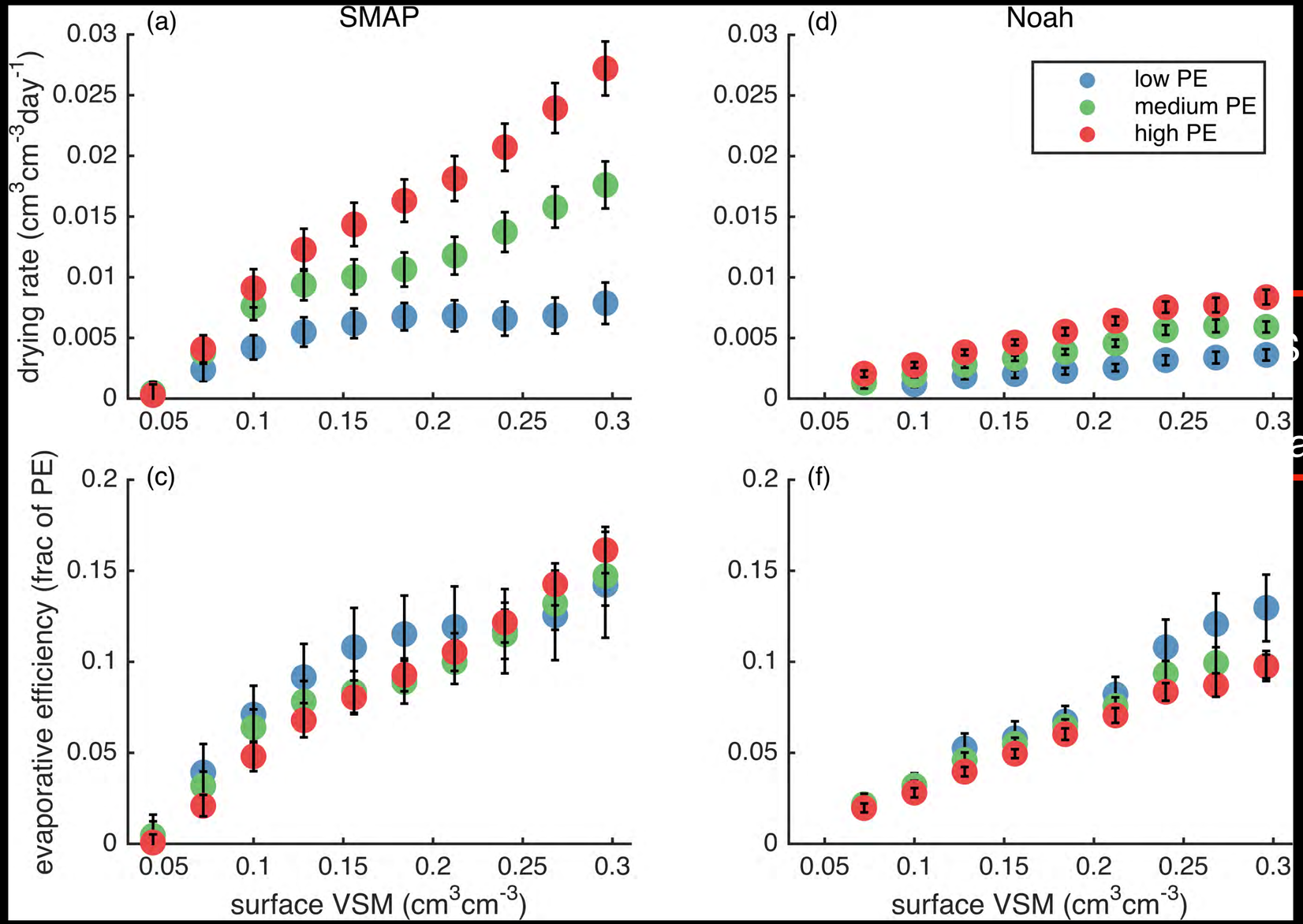
  - Soil texture class

Results

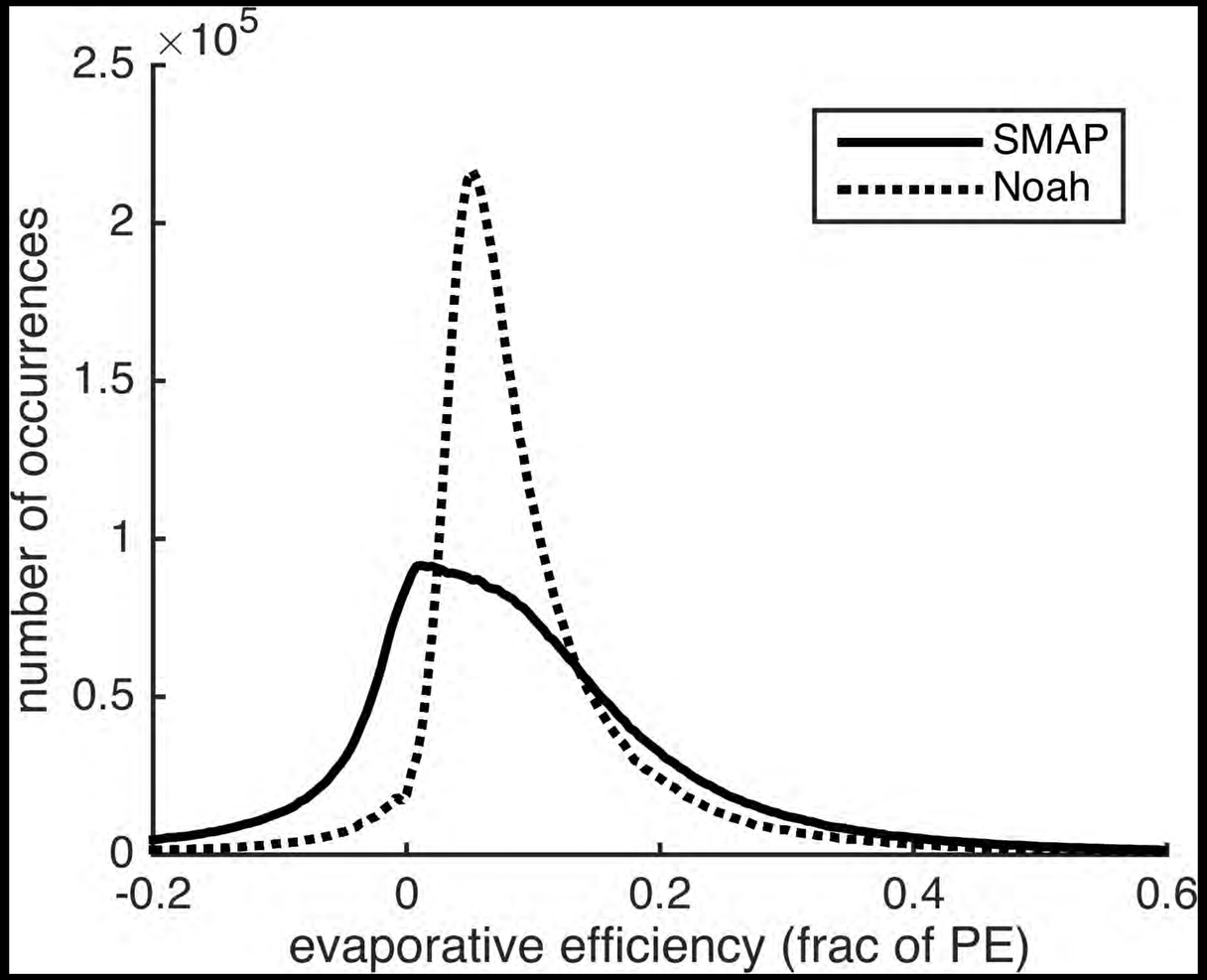

(a)
SMAP
(d)
Noah
drying rate (cm3cm-3day-1)
surface VSM (cm3cm-3)
surface VSM (cm3cm-3)
low PE
medium PE
high PE
0.03
0.025
0.02
0.015
0.01
0.005
0
0.05
0.1
0.15
0.2
0.25
0.3

Results



SM)

ate



Low evaporative efficiencies

Water-limited
Transpiration

Results

Shading slows drying

Transpiration speeds drying

Correlated with PE

- Drydowns depend on :
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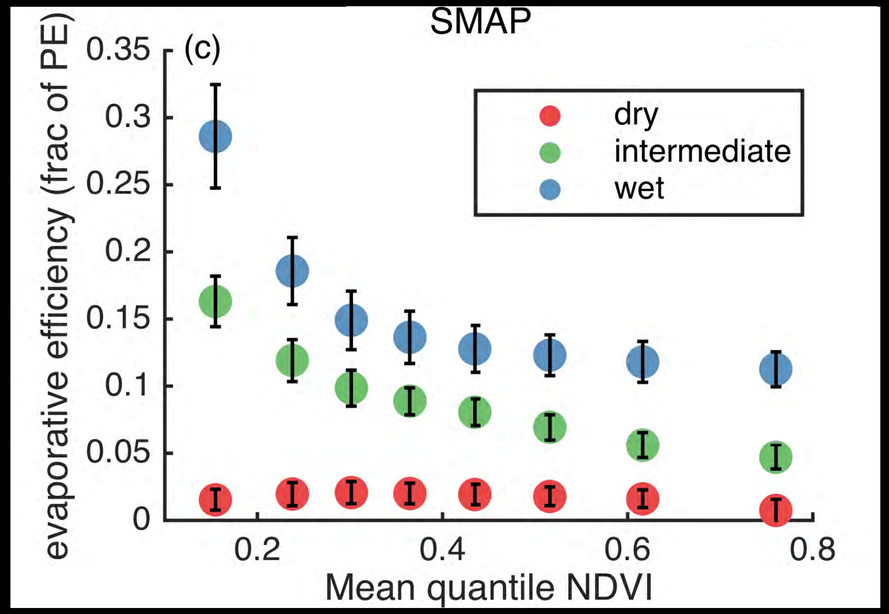
Results



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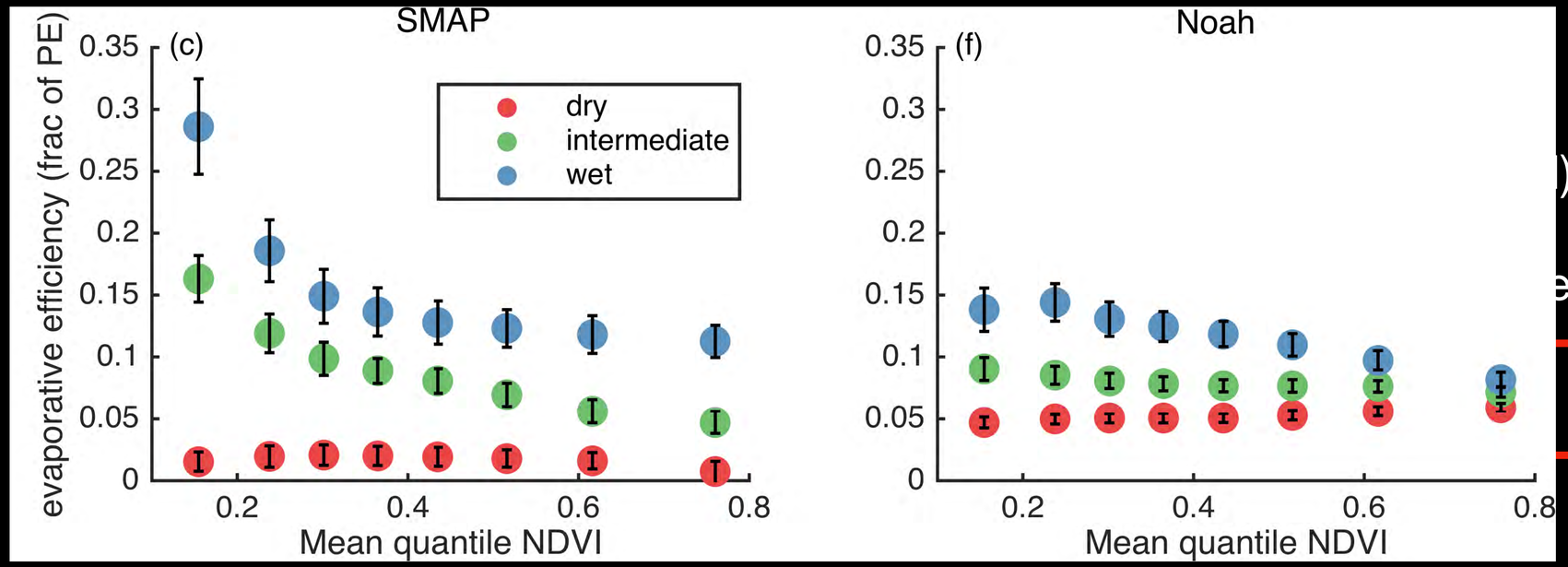
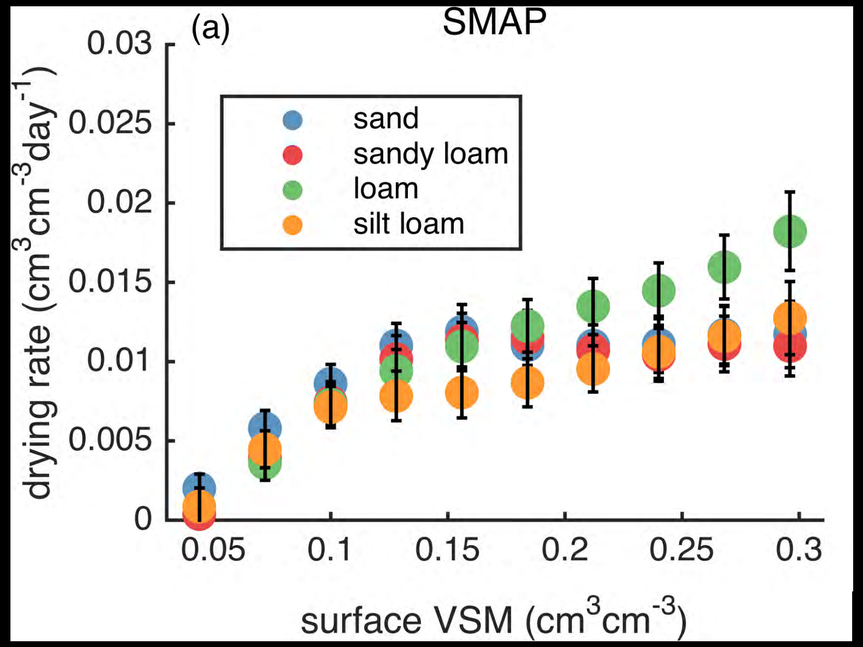

SMAP
(c)
evaporative efficiency (frac of PE)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
dry
intermediate
wet
0.2
0.4
0.6
0.8
Mean quantile NDVI
Noah
(f)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.2
0.4
0.6
0.8
Mean quantile NDVI

Results



- Drydowns depend on :
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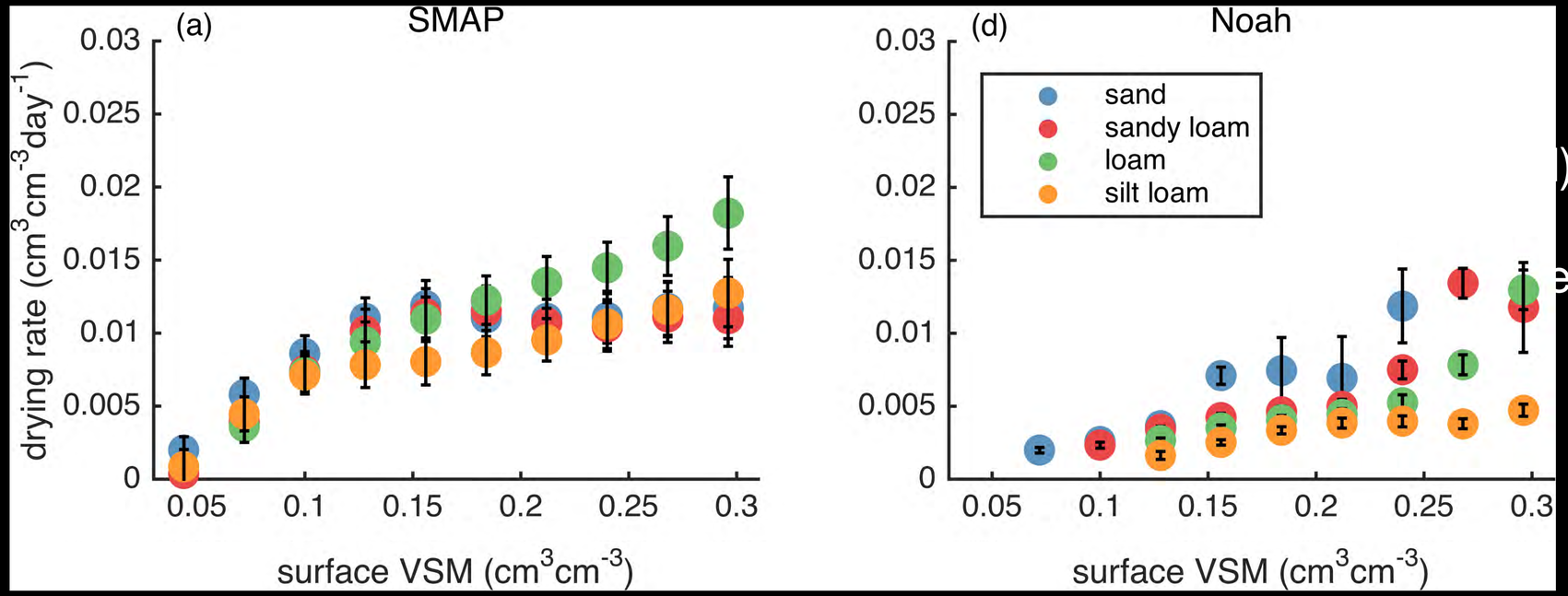
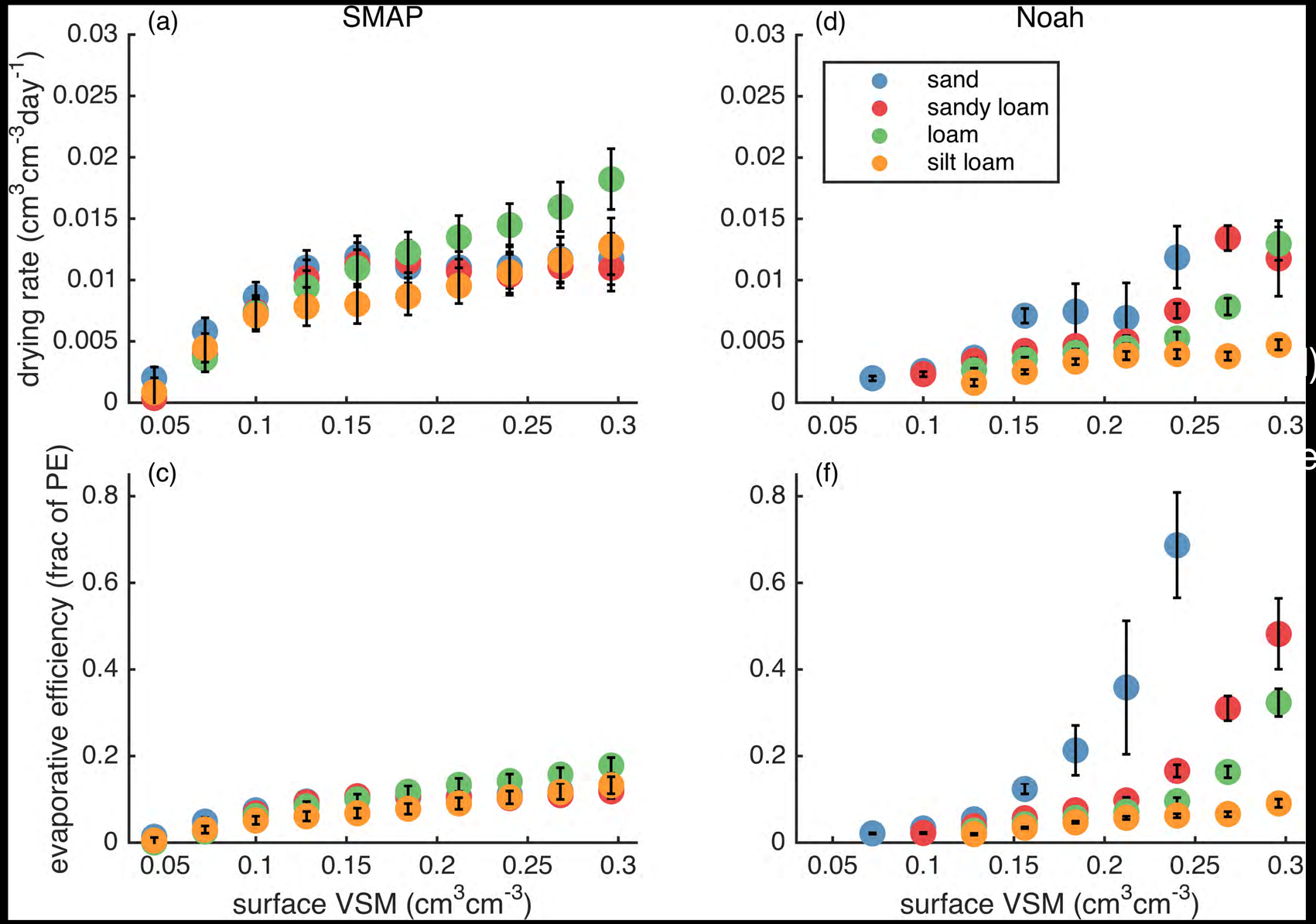
  - Vegetation cover (NDVI)
  - Soil texture class

Results


(a)
SMAP
(d)
Noah
drying rate (cm3cm-3day-1)
surface VSM (cm3cm-3)
surface VSM (cm3cm-3)
sand
sandy loam
loam
silt loam
0.03
0.025
0.02
0.015
0.01
0.005
0
0.05
0.1
0.15
0.2
0.25
0.3

Results


(a)
SMAP
(d)
Noah
drying rate (cm3cm-3day-1)
0.03
0.025
0.02
0.015
0.01
0.005
0
sand
sandy loam
loam
silt loam
0.05
0.1
0.15
0.2
0.25
0.3
(c)
(f)
evaporative efficiency (frac of PE)
0.8
0.6
0.4
0.2
surface VSM (cm3cm-3)

Conclusions

- At continental scales, the drying of the soil surface is water-limited (McColl et al., 2017, GRL)
  - Drying rates vary linearly with soil moisture content
  - Higher PE rates increase the sensitivity of drying rates to soil moisture
  - Continent-wide, most evaporative efficiencies are below 0.3

Conclusions

- SMAP shows that greater vegetation cover causes a decrease in the evaporative efficiency of shallow soil
    - Vegetation hinders evaporation more than it facilitates transpiration from the surface layer
    - Noah simulated soil moisture largely fails to show this effect of vegetation, which could imply a structural deficiency
- Soil texture designations have minimal influence on SMAP drying rates
    - Noah drying rates are overly sensitive to soil texture

Thank you
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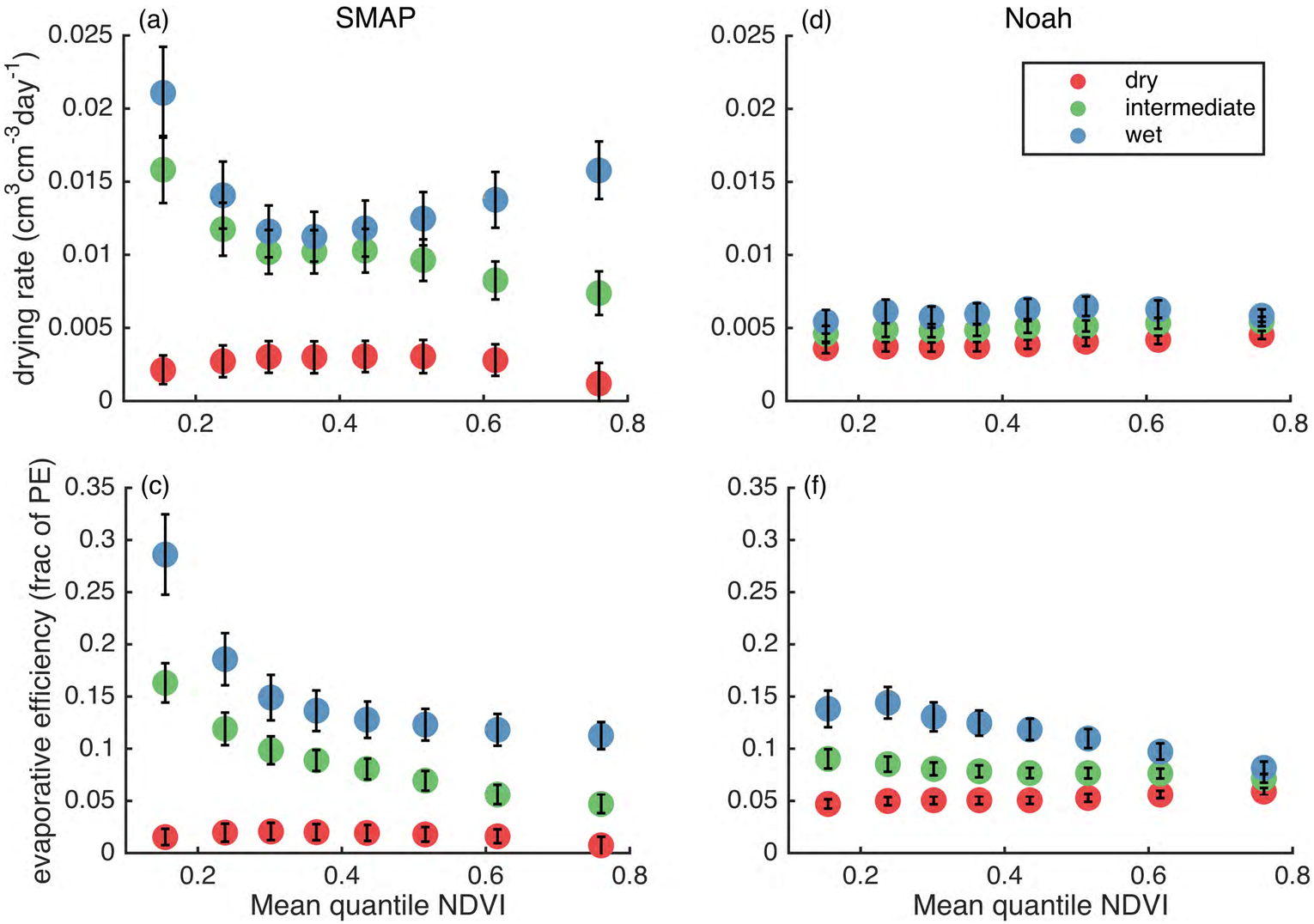
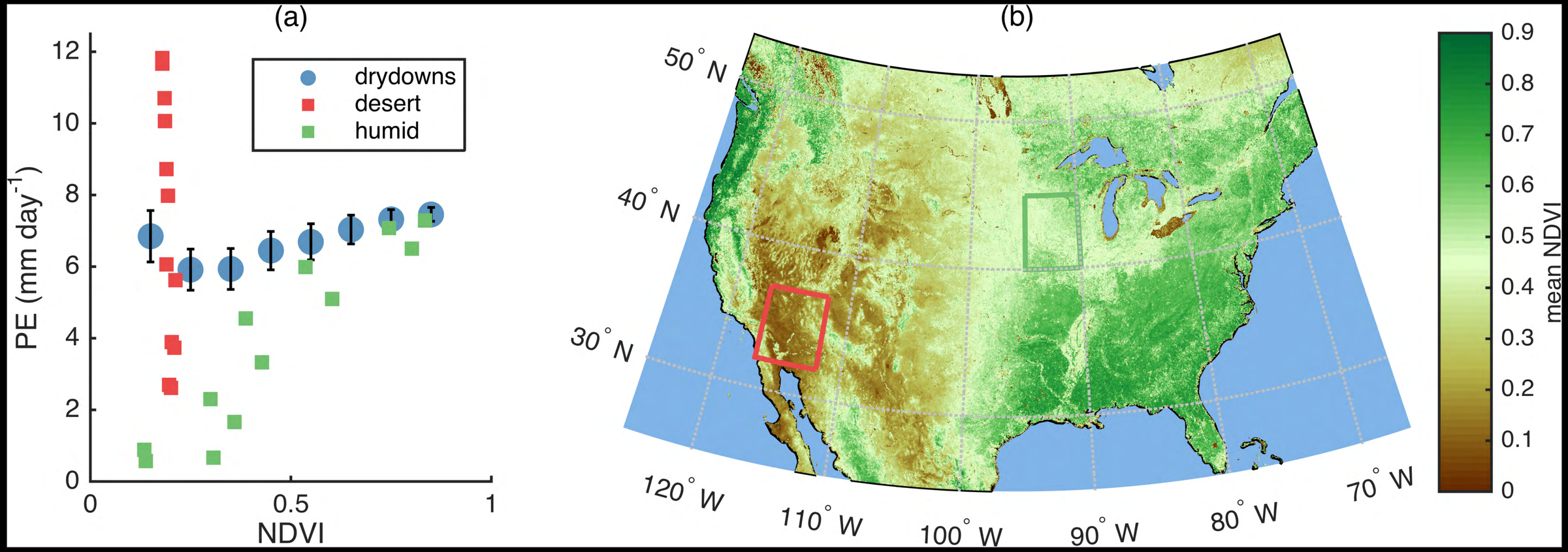
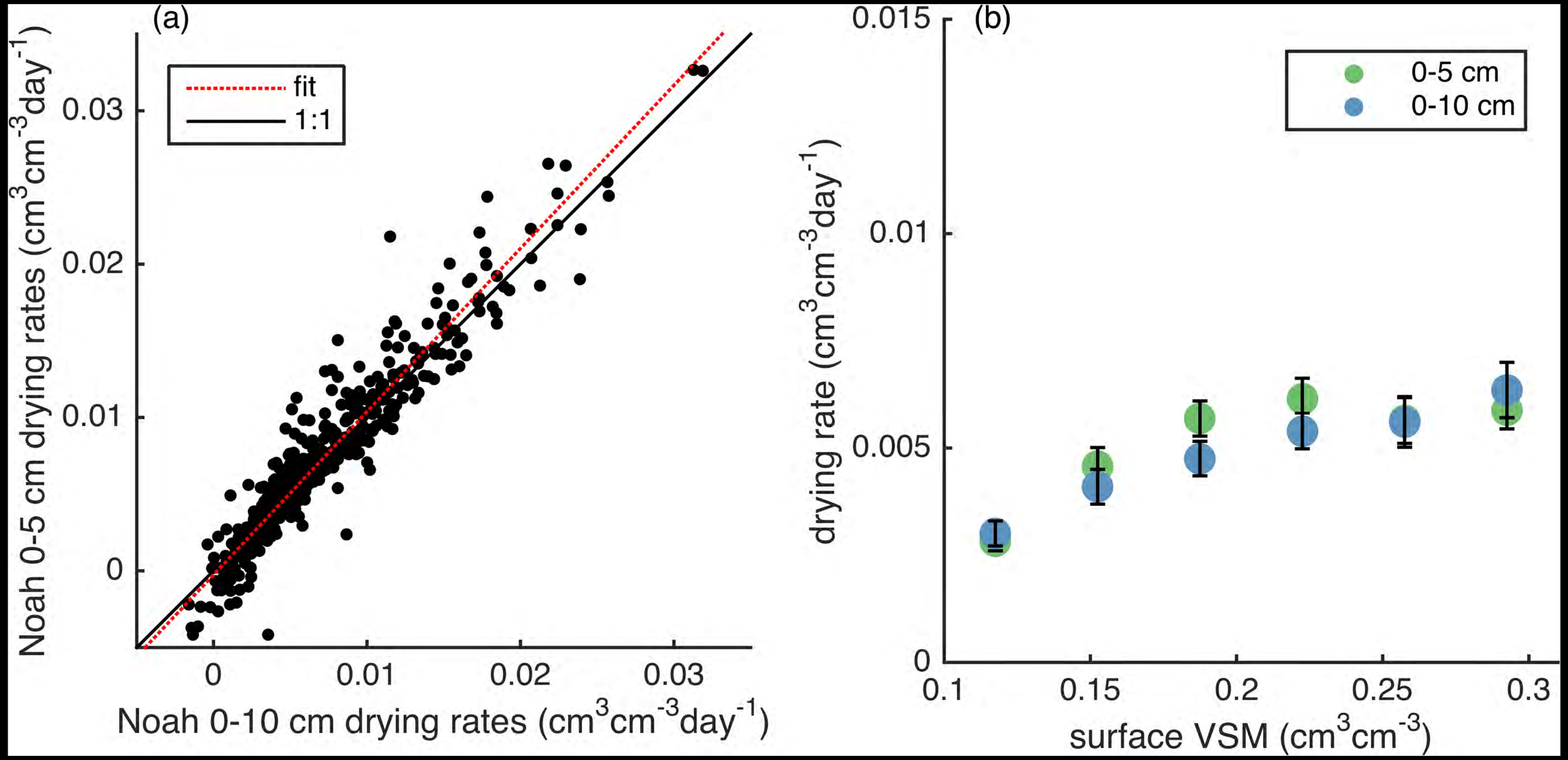
Shellito et al. (2018), HESS

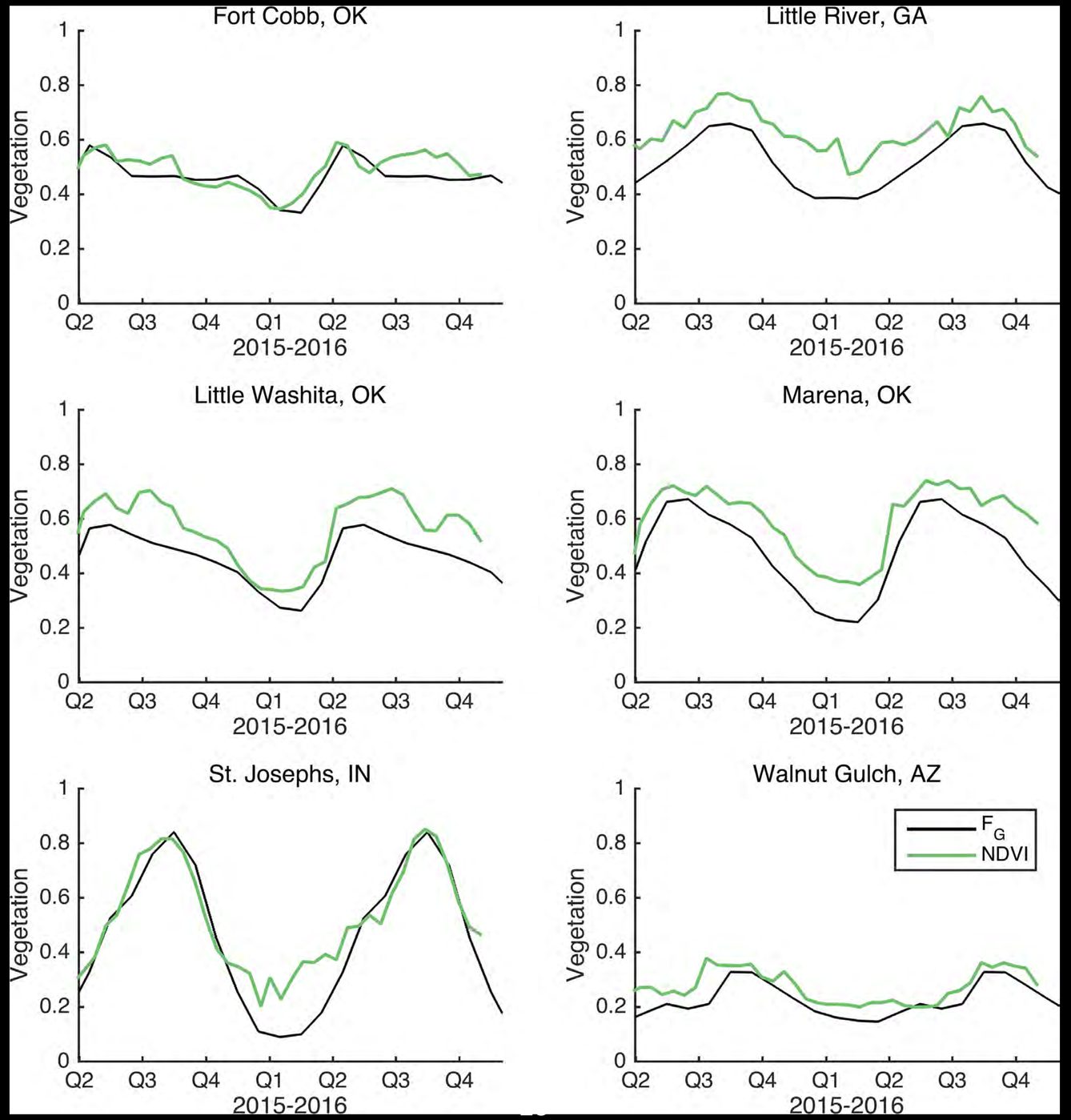
Extra slides

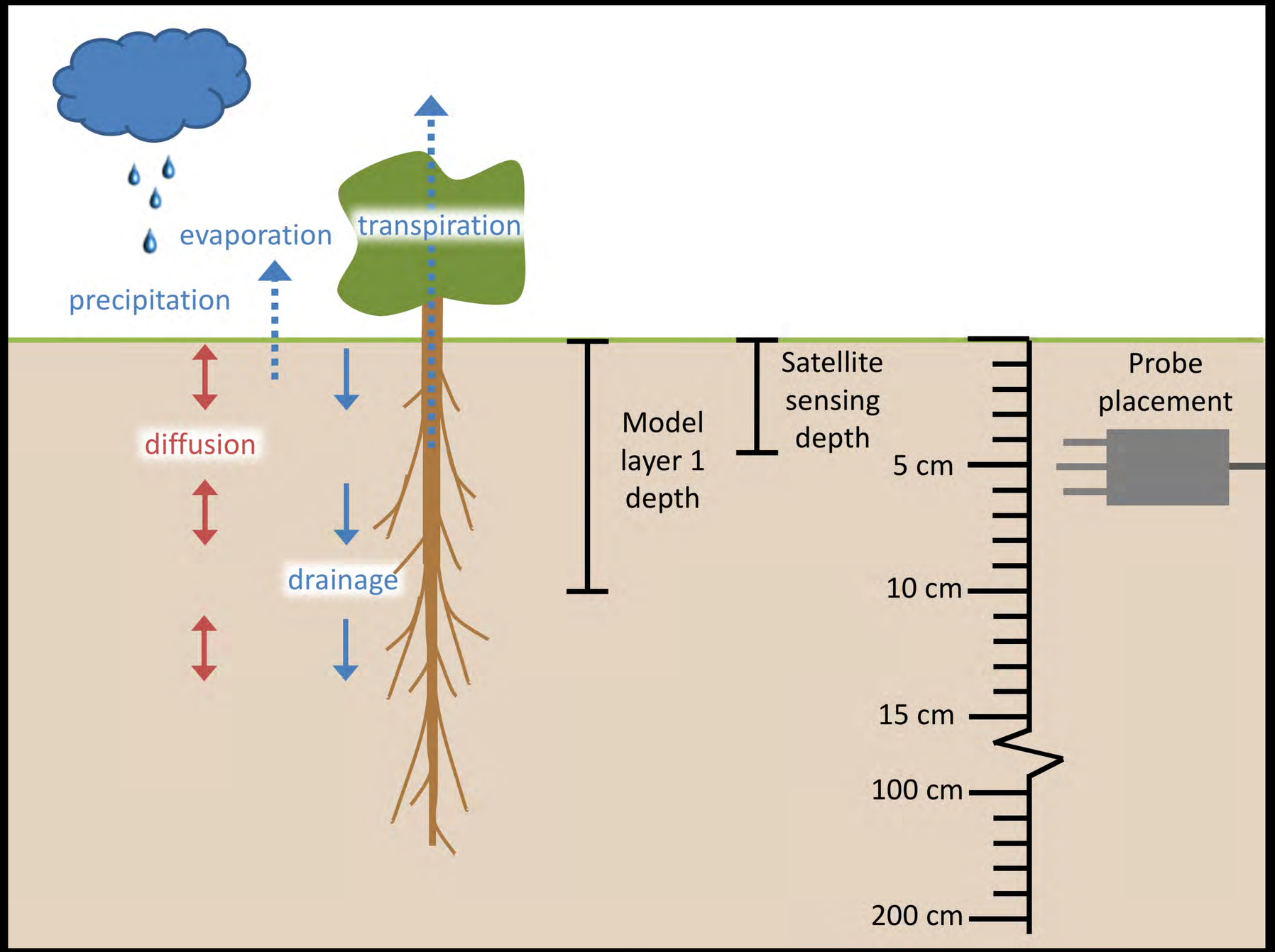
Role of Vegetation (NDVI)




(a)
PE (mm day^{-1})
NDVI
drydowns
desert
humid
0
2
4
6
8
10
12
0
0.5
1
(b)
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


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


Fort Cobb, OK
Little River, GA
Little Washita, OK
Marena, OK
St. Josephs, IN
Walnut Gulch, AZ
Vegetation
0
0.2
0.4
0.6
0.8
1
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