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

SMAP cal/val workshop
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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 H₂O GPS-IR (74 stations)
- SMAP level 3 enhanced (80,000 pixels)
Surface soil moisture observations

- in situ probes (17 CVS)
- PBO H$_2$O GPS-IR (74 stations)
- SMAP level 3 enhanced (80,000 pixels)

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

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- Finite differences \( \frac{d\theta}{dt} = \frac{\theta_{n+1} - \theta_n}{t_{n+1} - t_n} \)
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

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

Number of drydowns between SMAP launch and winter 2017
Drying rates

Number of drydowns between SMAP launch and winter 2017
Summary so far

- Drying is faster:
  - SMAP, GPS-IR

- Drying is slower:
  - in situ, Noah
Summary so far

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Can a continental-scale comparison of SMAP and Noah help us understand what controls these drying rates?
Units
Units

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

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

• Change in water depth: mm day$^{-1}$
Units

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• Change in water depth: mm day$^{-1}$

• Noah simulation depth (x100 mm)
Units

• Change in water volume: cm³ cm⁻³ day⁻¹
• Change in water depth: mm day⁻¹
  • Noah simulation depth (x100 mm)
  • SMAP sensing depth (x50 mm)
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 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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\[
\text{drying rate} / \text{PE rate} = \text{evaporative efficiency}
\]
Role of VSM and PE
Role of VSM and PE

![Graph showing the relationship between surface VSM and drying rate with different PE levels.](image)
Role of VSM and PE

(a) SMAP

(d) Noah

- low PE
- medium PE
- high PE

Drying rate (cm$^3$ cm$^{-3}$ day$^{-1}$)

Surface VSM (cm$^3$ cm$^{-3}$)
Role of VSM and PE

(a) SMAP

(d) Noah

low PE  medium PE  high PE

(c) evaporative efficiency (frac of PE)

(f) surface VSM (cm$^3$cm$^{-3}$)

surface VSM (cm$^3$cm$^{-3}$)
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
Role of Vegetation (NDVI)

- Shading slows drying
- Transpiration speeds drying
Role of Vegetation (NDVI)

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- Correlated with PE
Role of Vegetation (NDVI)

- **SMAP**
  - Plot showing evaporative efficiency (frac of PE) against mean quantile NDVI.
  - Data points for different NDVI values are shown with error bars.

- **Noah**
  - Similar plot to SMAP but with different colors representing dry, intermediate, and wet conditions.
  - Data points for different NDVI values are shown with error bars.
Conclusions
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  - Drying rates vary linearly with VSM
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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
  • Higher PE rates increase the sensitivity of drying rates to VSM
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• 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) SMAP

(d) Noah

(e) evaporative efficiency (frac of PE)

(f) surface VSM (cm$^3$ cm$^{-3}$)

Legend:
- sand
- sandy loam
- loam
- silt loam

Surface VSM (cm$^3$ cm$^{-3}$)

(0.05, 0.1, 0.15, 0.2, 0.25, 0.3)

Drying rate (cm$^3$ cm$^{-3}$ day$^{-1}$)

(0, 0.005, 0.01, 0.015, 0.02, 0.025, 0.03)

Evaporative efficiency (frac of PE)

(0, 0.2, 0.4, 0.6, 0.8)