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Validation of SMAP soil moisture at forested and unforested NEON sites

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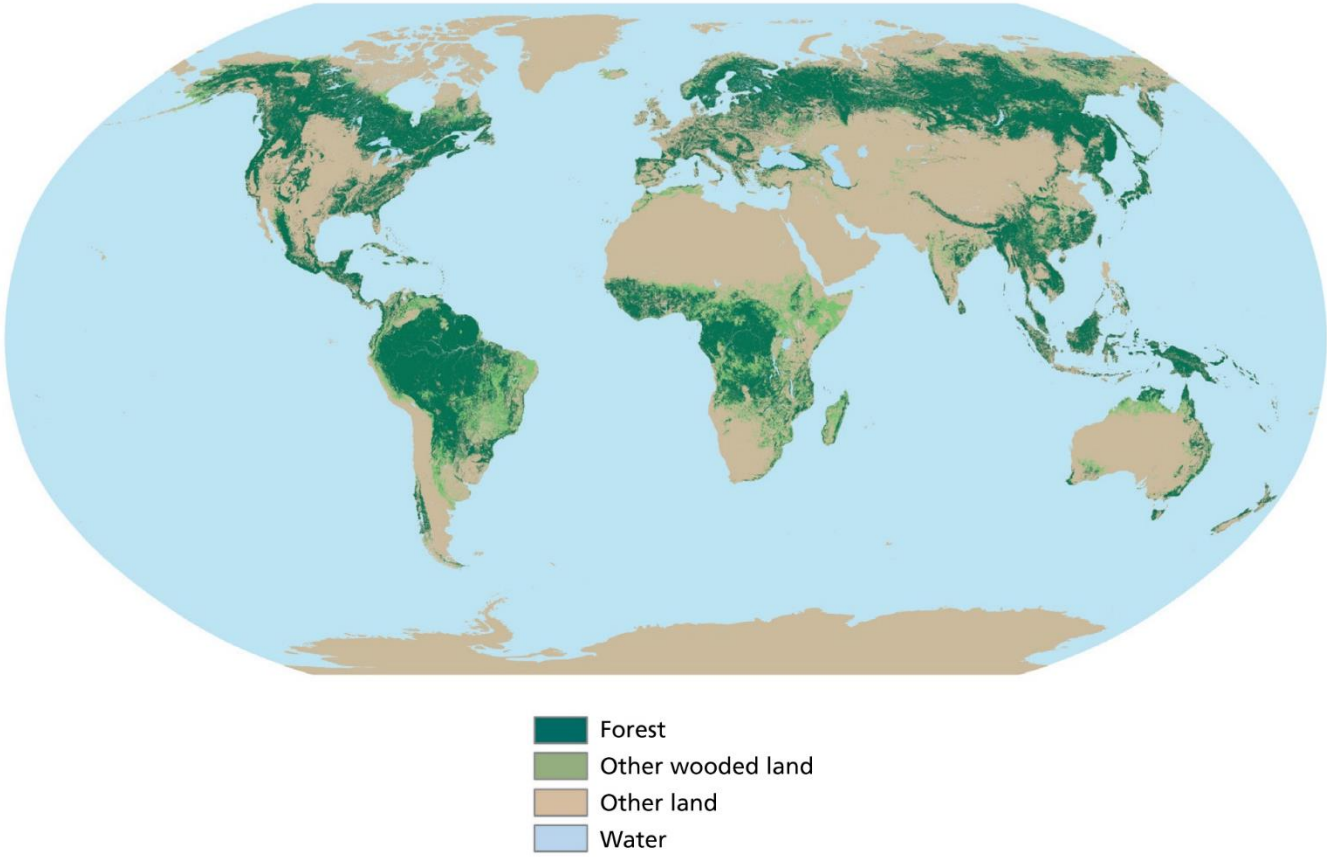
Project motivation

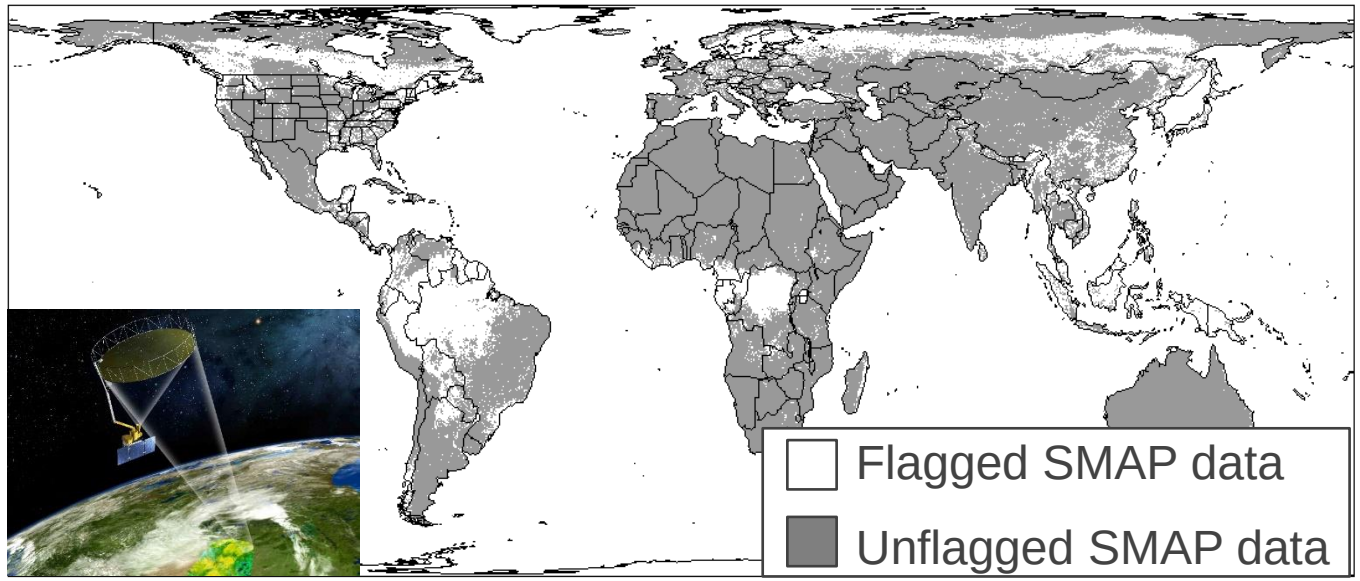
- Soil moisture is important for forest health
  - Tree mortality
  - Fire occurrence and extent
  - Insect and pathogen impacts
- 20-30% land surface is forested
- SMAP soil moisture data for forests is flagged as potentially unreliable
- Forests are underrepresented in SMAP validation campaigns (~1%)

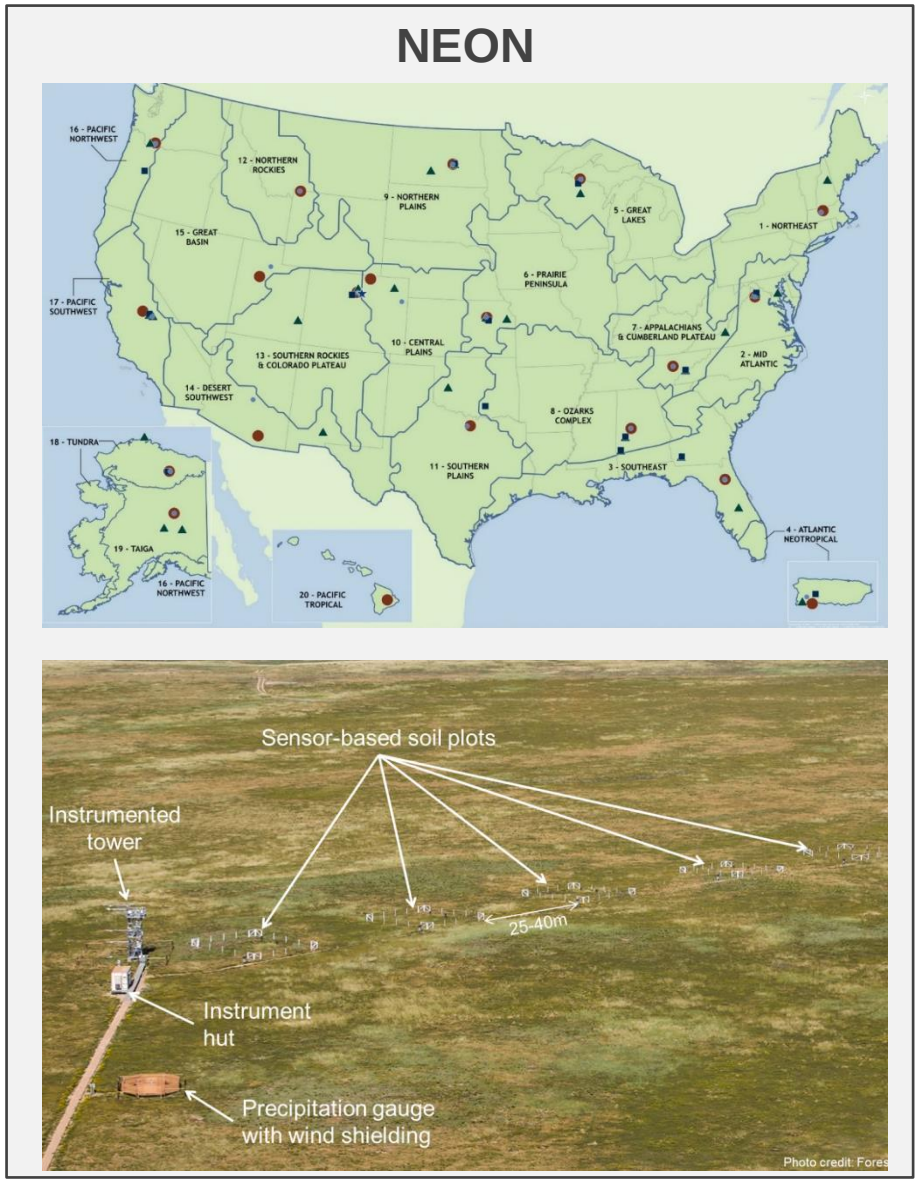


FAO 2006. http://www.fao.org/forest-resources-assessment/past-assessments/fra-2005/maps-and-figures/en/

SMAP & NEON data

	SMAP	NEON
Measurement depth	0-5 cm	6 cm
Temporal resolution	2-3 days	30 mins
Spatial resolution	1089 km^2	~0.1 km^2
Coverage	global	47 sites
Data product	L2SMPE	DP1.00094.001

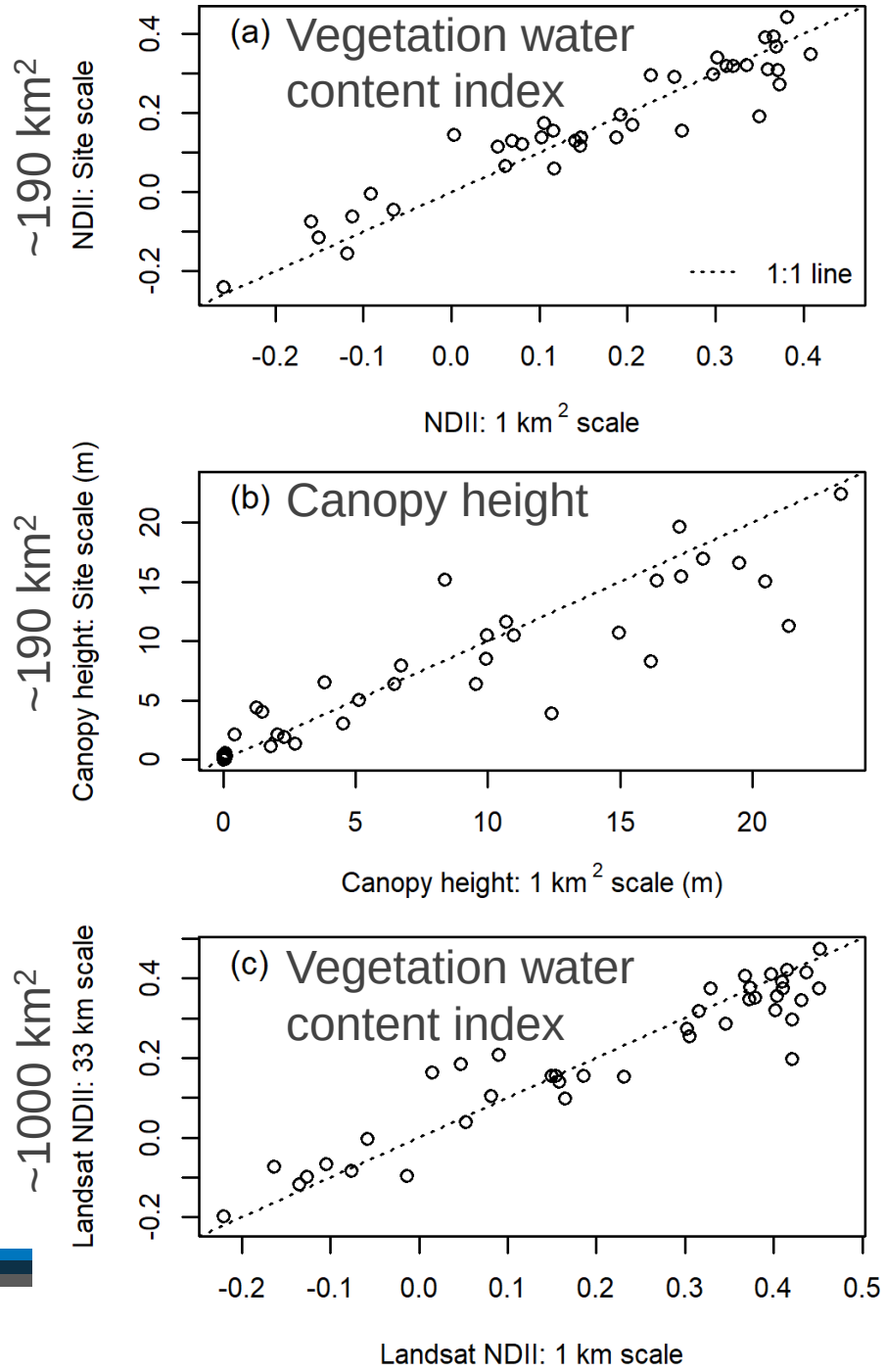




S. Chan, R. Bindlish, R. Hunt, T. Jackson, J Kimball, “Soil Moisture Active Passive (SMAP) Ancillary Data Report: Vegetation Water Content,” Preliminary, v.1, SMAP Science Document no. 047, 2013.

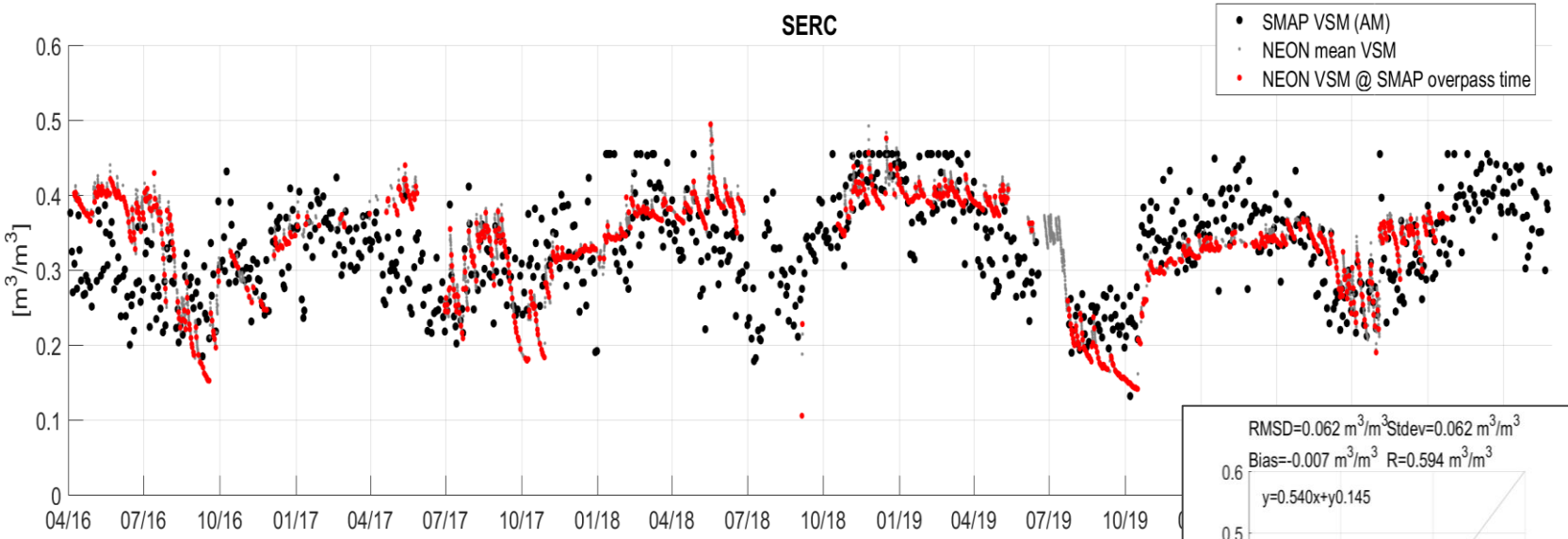
Measurement scale differences

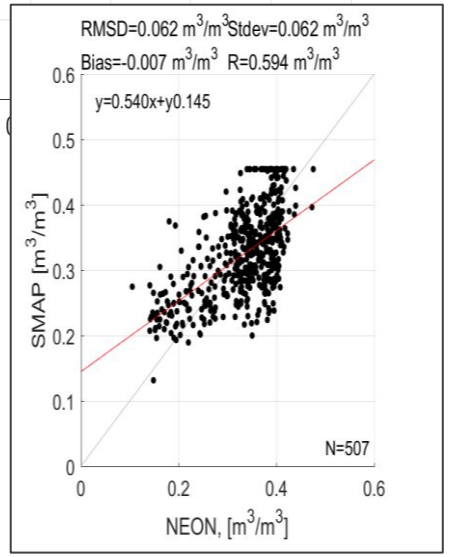
- Do NEON (~0.1 km^2) and SMAP (~1000 km^2) measurements represent similar environments?
  - Compared ecosystem properties for 1 km^2 and larger (~190 or ~1000 km^2) areas centered on NEON sites
    - Index of vegetation water content (r^2 = 0.9)
    - Canopy height (r^2 = 0.8)
  - Dominant land cover occupied ~70% of the SMAP footprint
- Despite differences in scale, NEON and SMAP measurements reflects similar environments



Combined NEON-SMAP dataset

- 12,881 measurements
  - 40 sites (7 excluded due to data quality)
    - 21 unforested
    - 19 forested
  - 88 site-years of data
- Correlation parameters
  - RMSD
  - **Unbiased RMSD** - sensitivity to changes in soil moisture
  - Mean difference - includes measurement bias and representativeness errors
  - Absolute mean difference
  - Pearson correlation (r)
  - Slope





Correlations at unforested sites

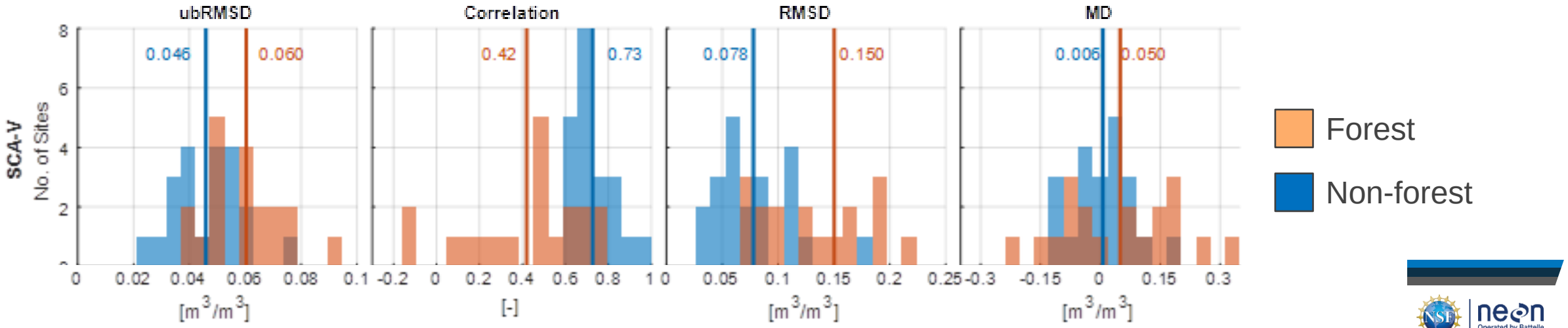
- SMAP is sensitive to changes in soil moisture at unforested sites
- Very similar to other SMAP sparse network validations
  - Colliander et al. 2021
    - Unbiased RMSD: 0.05 $m^3\ m^{-3}$
    - r: 0.68
    - Core validation sites have an even lower unbiased RMSD: ~0.04 $m^3\ m^{-3}$
- NEON soil moisture is as reliable as other sparse networks

	Non-forest sites (n=21)
RMSD ($m^3\ m^{-3}$)	0.08 ±0.04
Mean difference ($m^3\ m^{-3}$)	0.01 ±0.07
Absolute mean difference ($m^3\ m^{-3}$)	0.06 ±0.04
Unbiased RMSD ($m^3\ m^{-3}$)	**0.05 ±0.01**
r	0.73 ±0.09
Slope	0.79 ±0.48

Correlations at forested sites

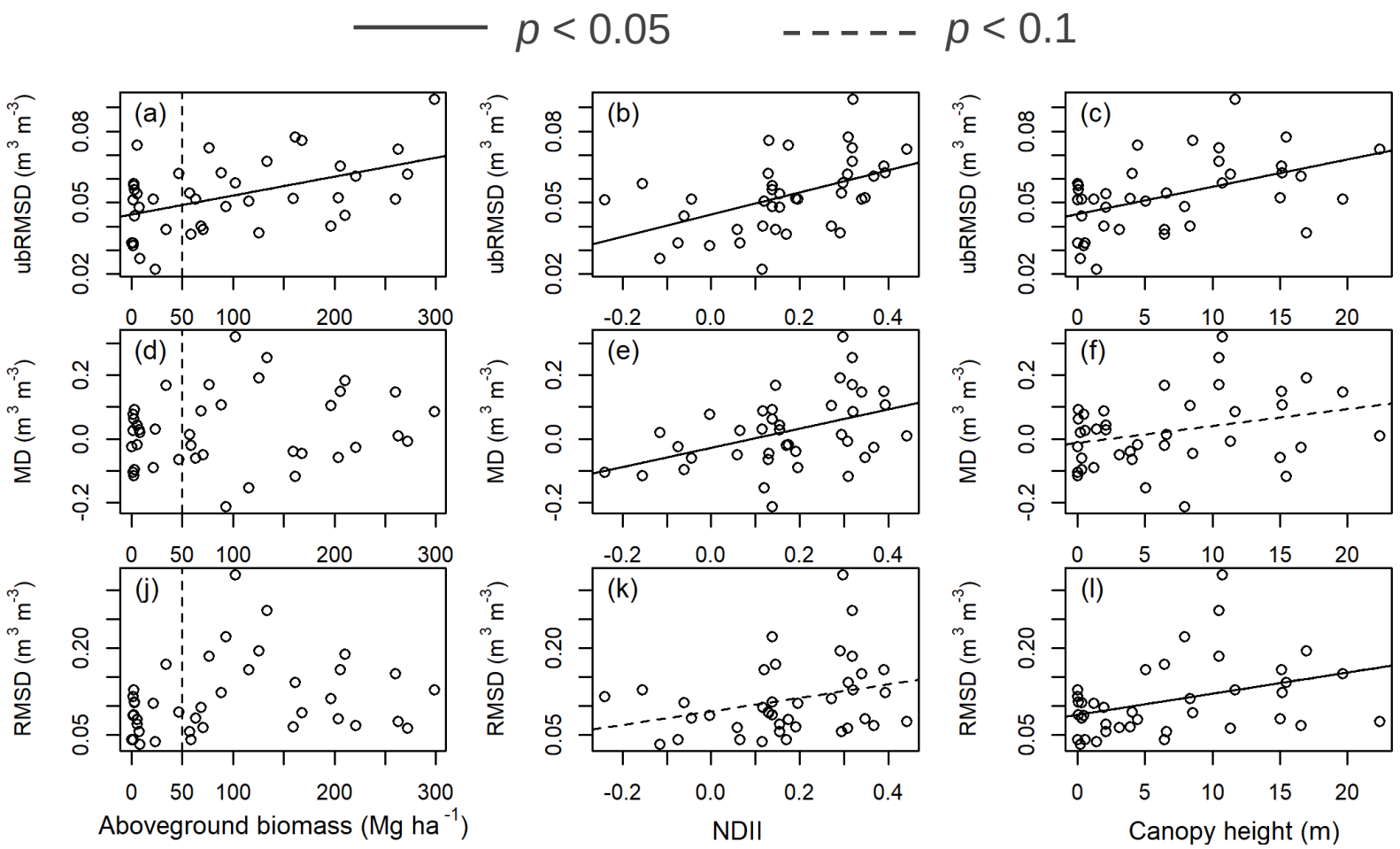
- Weaker correlations at forested sites, but still useful
  - Temporal trends in soil moisture in forests can be reliably assessed across sites
  - Absolute values are not very reliable
    - Partly due to representativeness errors
    - Add more sensors to forested validation sites?

	Forest sites (n=19)
RMSD ($m^3\ m^{-3}$)	0.15 ±0.07
Mean difference ($m^3\ m^{-3}$)	0.05 ±0.15
Absolute mean difference ($m^3\ m^{-3}$)	0.13 ±0.08
Unbiased RMSD ($m^3\ m^{-3}$)	**0.06 ±0.01**
r	0.42 ±0.28
Slope	0.60 ±0.53



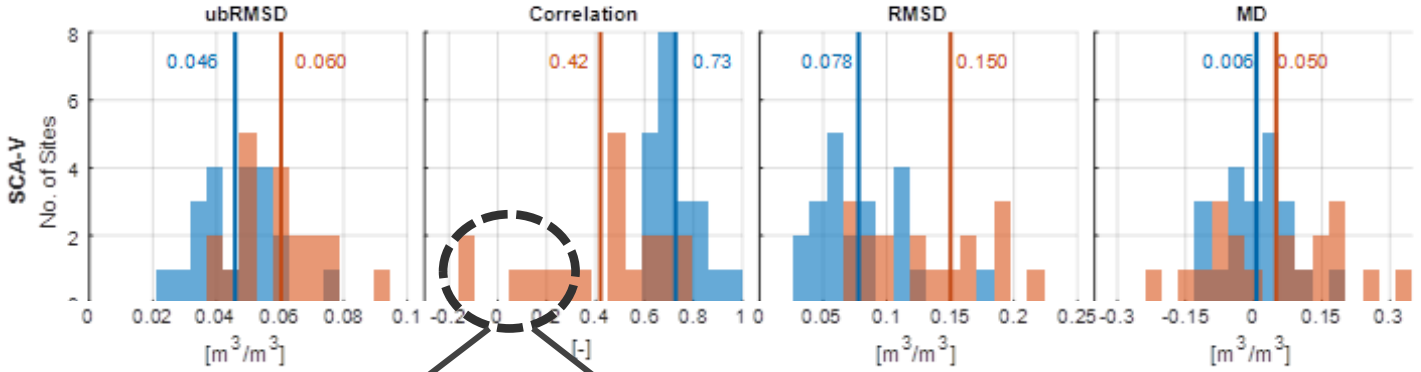
Relationship with vegetation water content

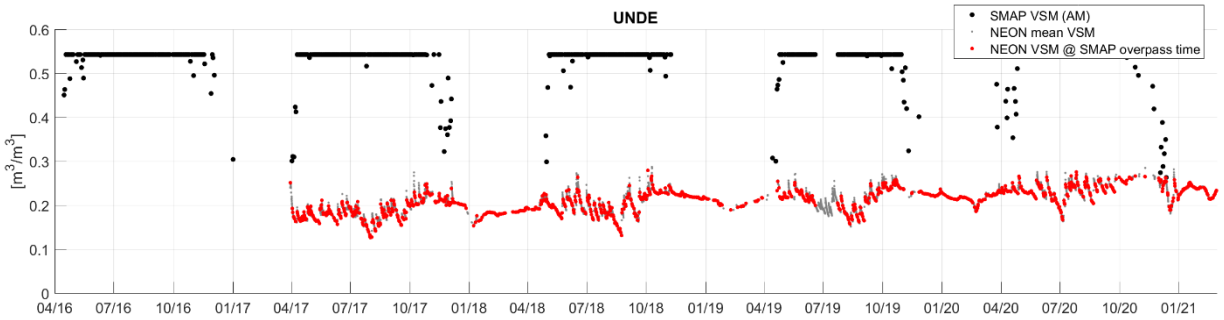
- Unbiased RMSD increased with vegetation water content
- Mean difference and RMSD positively correlated with two of these
  - SMAP algorithm parameterization not optimal for forests
  - But could be improved to increase accuracy

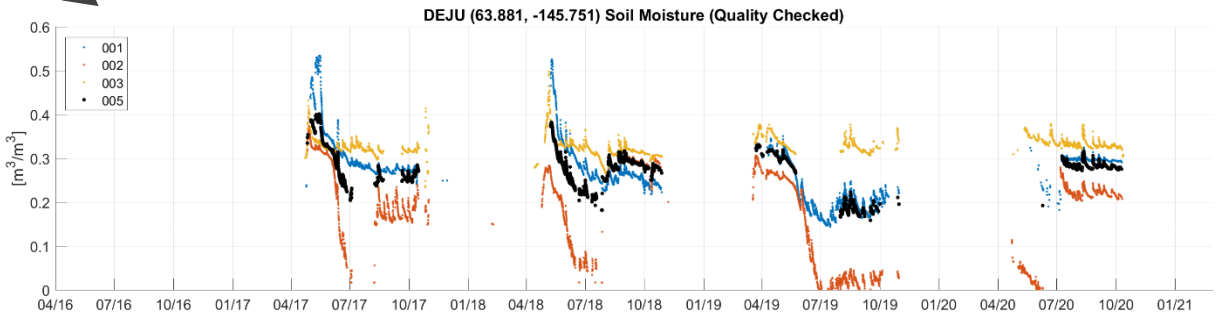


Poor correlations at some sites

- Five sites with r < 0.3
  - SMAP signal saturates
  - In-situ data quality and/or spatial variability







- Re-parameterization of SMAP algorithms for forest sites
- Ensure in-situ measurements are accurate (and representative?)

Conclusions

- SMAP reliably detects changes in soil moisture in forests
  - At least when aggregating across widely distributed sites
  - Trends at individual SMAP footprints require more caution
- Absolute SMAP soil moistures are often not representative in forests
  - Re-parameterizing SMAP algorithms for forests could help by accounting for:
    - Canopy height and/or vegetation water content indices
      - Remotely sensed data for both already exist globally
- Representativeness errors remain
  - Adding more widely distributed soil moisture monitoring locations to forest validation sites would help
  - Adding more forested core and sparse validation sites, especially underrepresented forests (e.g., tropical forests)

Ayres et al. 2021. Validation of SMAP Soil Moisture at Terrestrial National Ecological Observatory Network (NEON) Sites Show Potential for Soil Moisture Retrieval in Forested Areas. TechRxiv. Preprint. https://doi.org/10.36227/techrxiv.14681298.v1

Additional NEON data products

Data type	Data product ID	Frequency	Spatial resolution	Spatial coverage
Surface roughness	DP3.30024.001	Once per year	1 m	190 km^2
Canopy roughness	DP3.30015.001	Once per year	1 m	190 km^2
Vegetation water content				
- Sunlit leaf water content	DP1.10026.001	Once per year	Point	30 km^2
- Canopy water indices	DP3.30019.001	Once per year	1 m	190 km^2
Canopy temperature	DP1.00005.001	1-min & 30-min averages	One vertical profile through plant canopy	Point
Effective soil temperature	DP1.00005.001; DP1.00041.001	1-min & 30-min averages	Point	0.1 km^2
Bulk density & texture	DP1.10047.001; DP1.00096.001	Once	Point	30 km^2
LAI	DP3.30012.001	Once per year	1 m	190 km^2
Tree density	DP1.10098.001	Every 5 yrs (subset annually)	20x20 m and 40x40 m plots	30 km^2

Over 170 open-access data products. Find out more: neonscience.org