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Validation of remotely sensed and modeled soil moisture at forested and unforested sites

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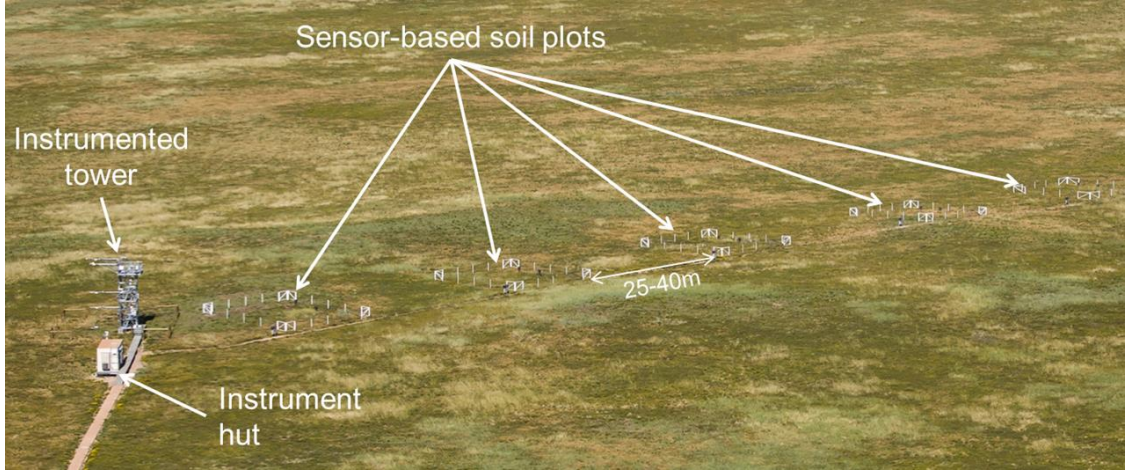
Motivation

- 20-30% land surface is forested.
- Soil moisture is important for:
  - Tree growth
  - Fire occurrence and extent
  - Insect and pathogen impacts
- Reliability of remotely sensed and modeled soil moisture in forests is not well understood:
  - Few forested validation sites
  - Vegetation water content interference

Photo by Matt Peterson; NEON MLBS site, VA

NEON validation sites

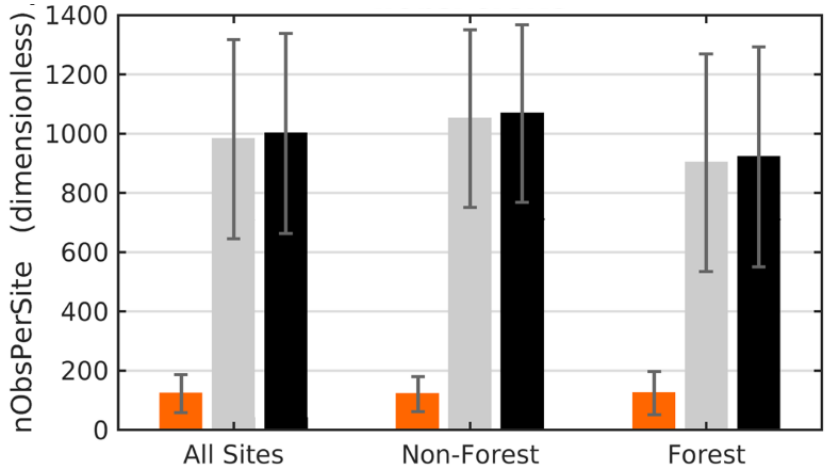
- 39 sites in contiguous US
  - 21 unforested
  - 18 forested
- Soil moisture
  - 5 soil plots along ~200 m transect
  - Up to 8 depths down to ≤2 m
- Co-located data includes
  - Aboveground biomass
  - Canopy height
  - Vegetation water content index



Data products

	SMAP/Sentinel	SMAP-L4	NLDAS
Product type	Remotely sensed	Remotely sensed data assimilation model	Modeled
Spatial resolution	3 km	9 km	13 km
Temporal resolution	6-12 days	3 h	1 h
Surface soil moisture	0-5 cm	0-5 cm	0-10 cm
Root-zone soil moisture	n/a	0-100 cm	0-100 cm

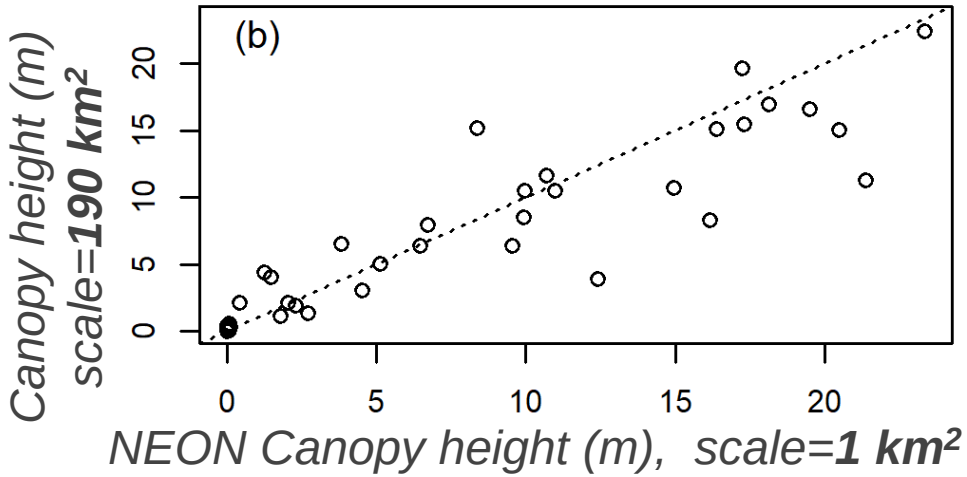
Number of data product-NEON pairs per site



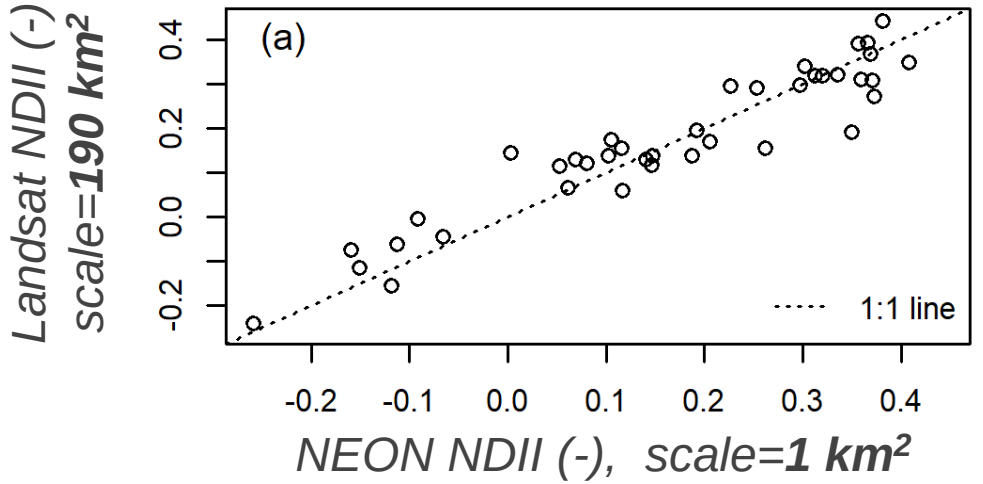
Expectations:

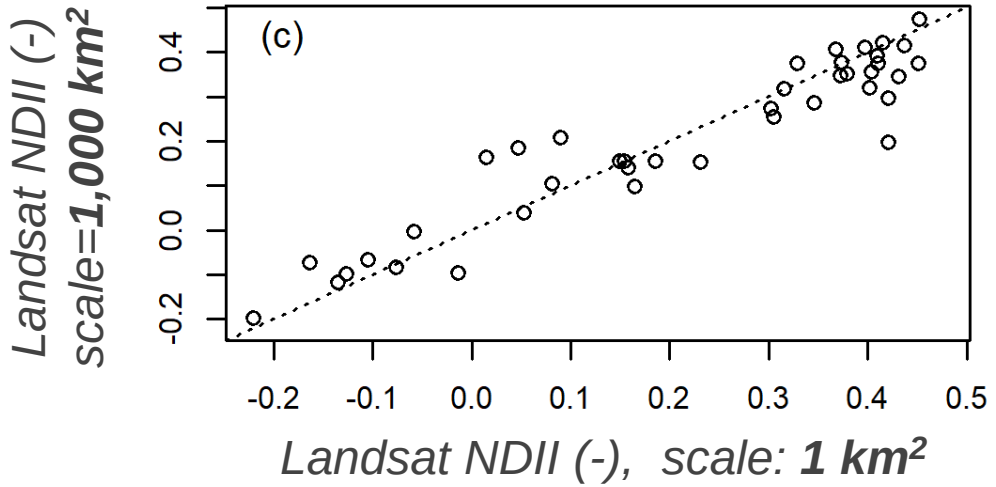
- At unforested sites, expect broadly similar performance, with SMAP/Sentinel performing best due to higher spatial resolution.
- At forested sites, expect degraded performance, particularly for SMAP/Sentinel due to sensitivity to vegetation water content.

Spatial representativeness



Vegetation water content index (NDII)

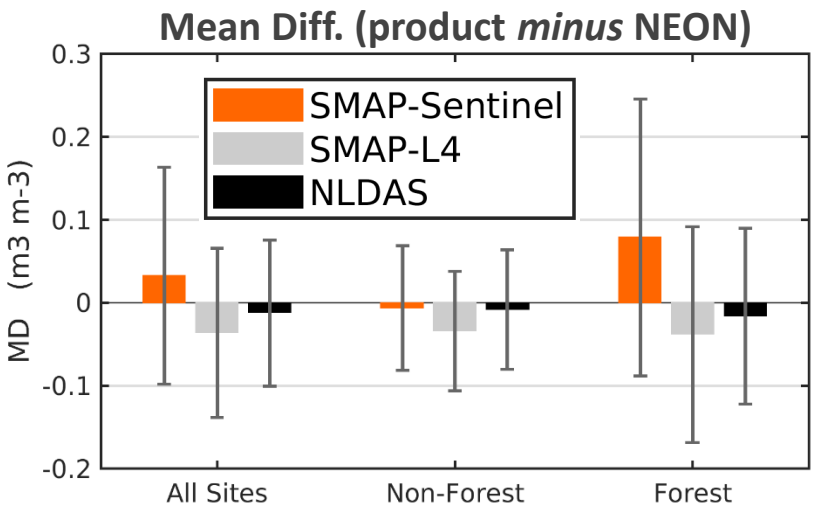


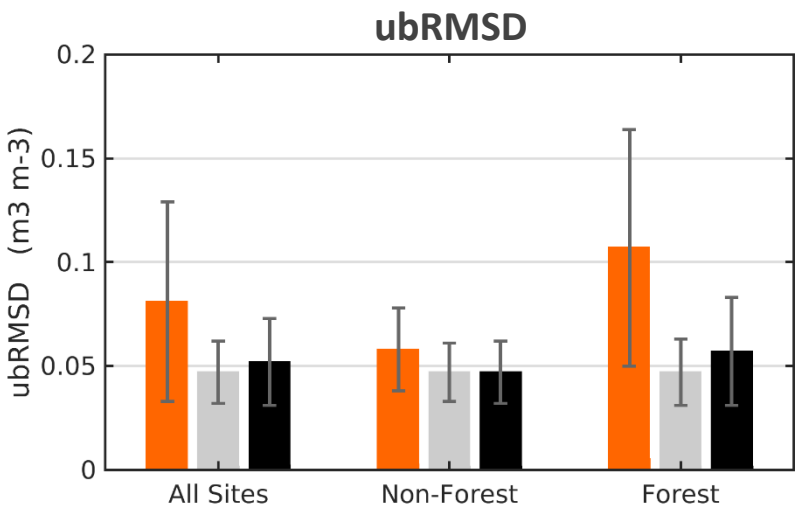


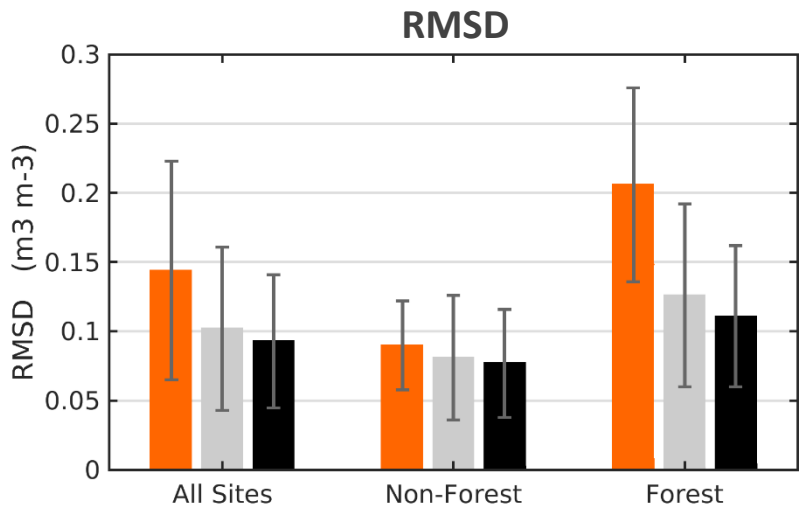
- **NEON sites are broadly representative of SMAP radiometer footprint** (Ayres et al. 2021).
  - Compared ecosystem properties for 1 km^2 and 190-1,000 km^2 areas centered on NEON sites.
    - Index of vegetation water content (r^2 = 0.9)
    - Canopy height (r^2 = 0.8)
- Dominant land cover occupies ~70% of SMAP radiometer footprint.

Ayres et al. 2021. JSTARS 14, 10903-10918, doi:10.1109/JSTARS.2021.3121206.

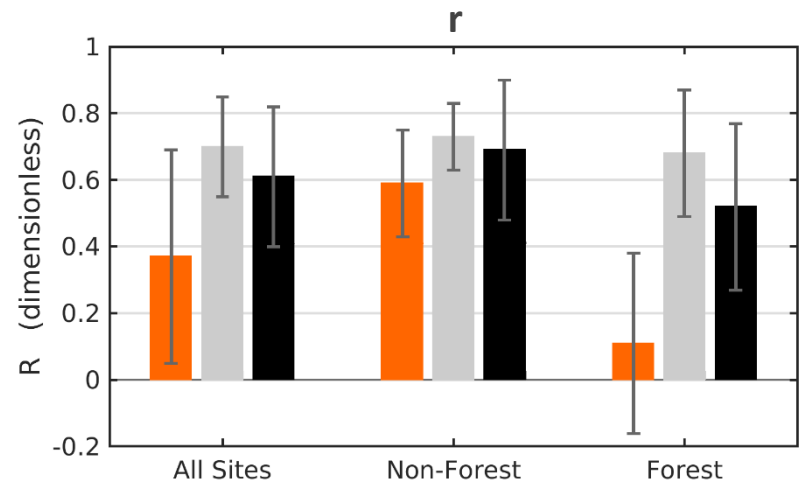
Performance metrics: Surface soil moisture





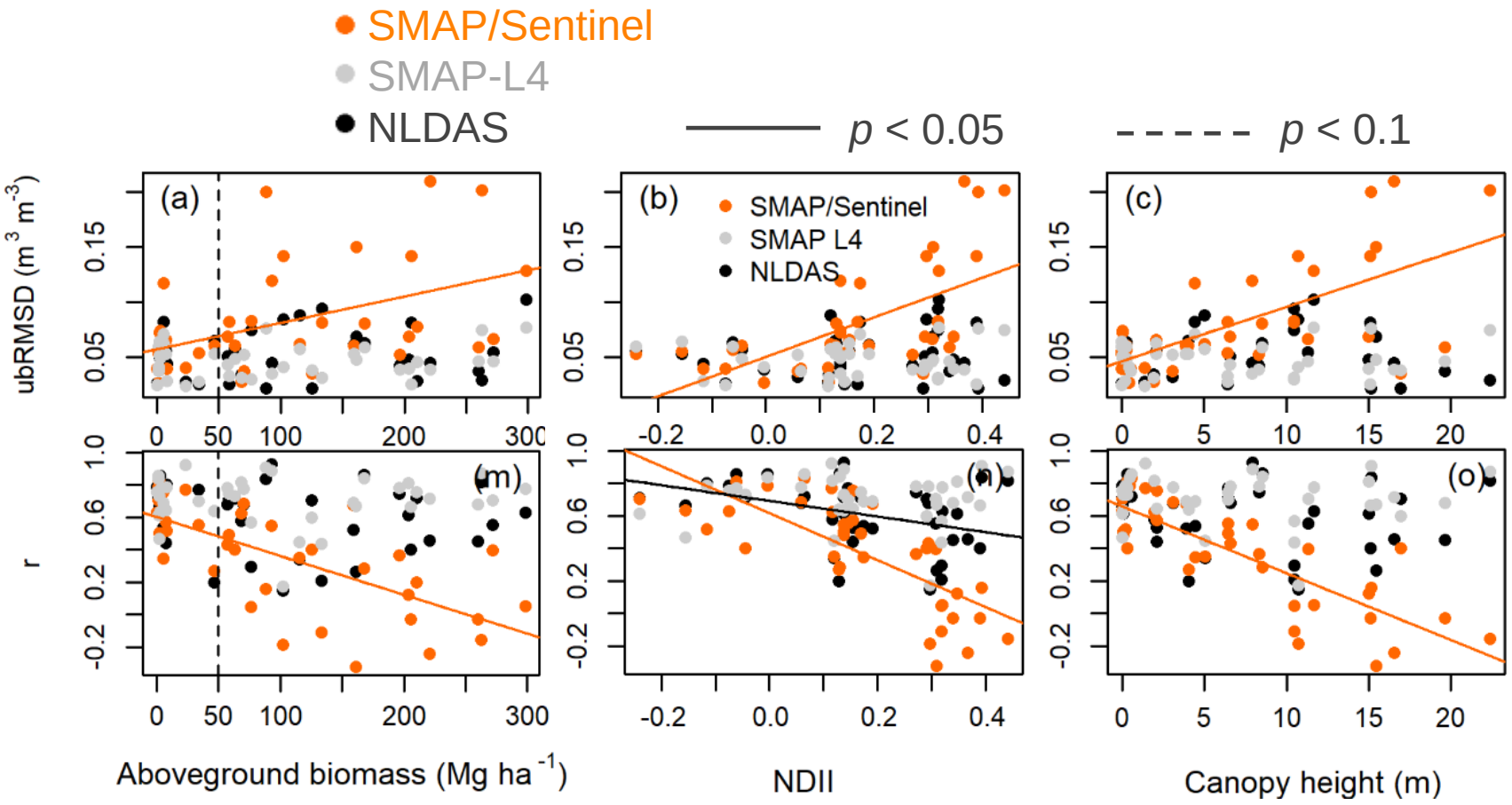


- At unforested sites:
  - Similar performance across all products (ubRMSD ≈ 0.05 $m^3\ m^{-3}$).
- At forested sites:
  - SMAP-L4 and NLDAS performance like that at unforested sites.
  - SMAP/Sentinel performance poor (ubRMSD ≈ 0.1 $m^3\ m^{-3}$, r ≈ 0.1).

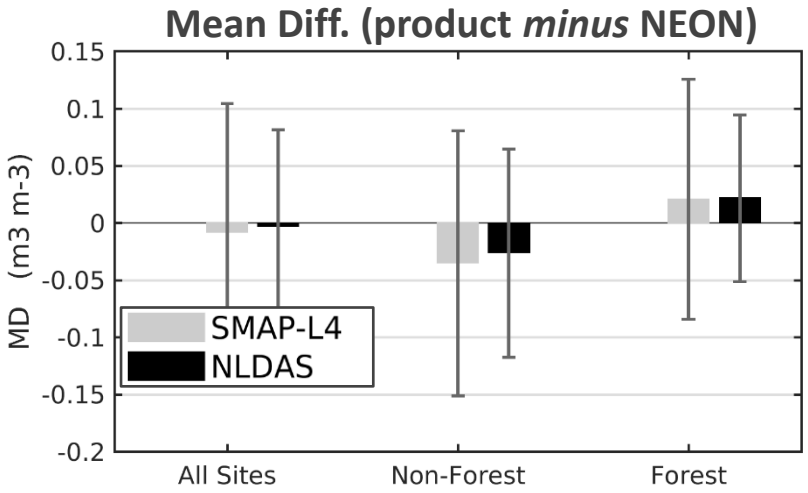


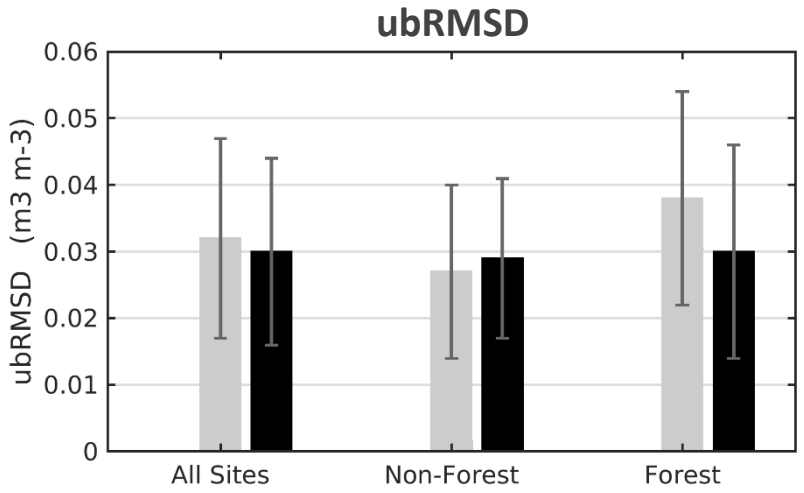
Ecosystem properties: Surface soil moisture

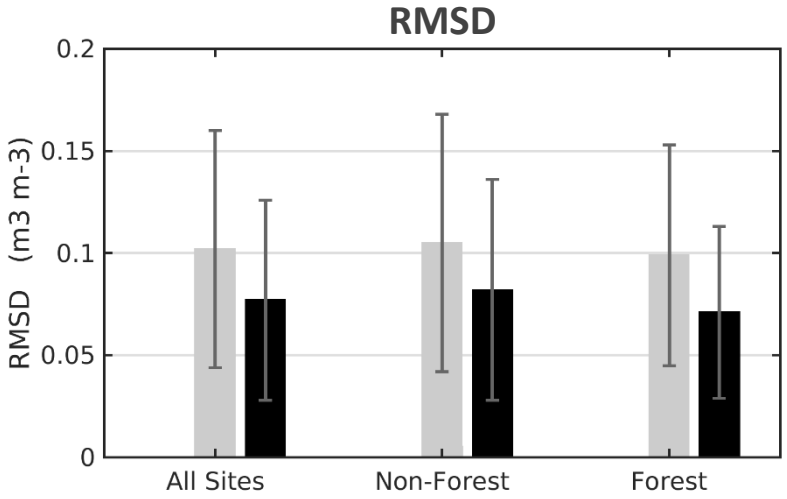
- Performance as a function of proxies for vegetation water content.
- SMAP/Sentinel performance:
  - unreliable in tall dense forests,
  - degrades in relatively short-stature, low biomass ecosystems.
- SMAP-L4 and NLDAS performance relatively insensitive to these ecosystem properties.



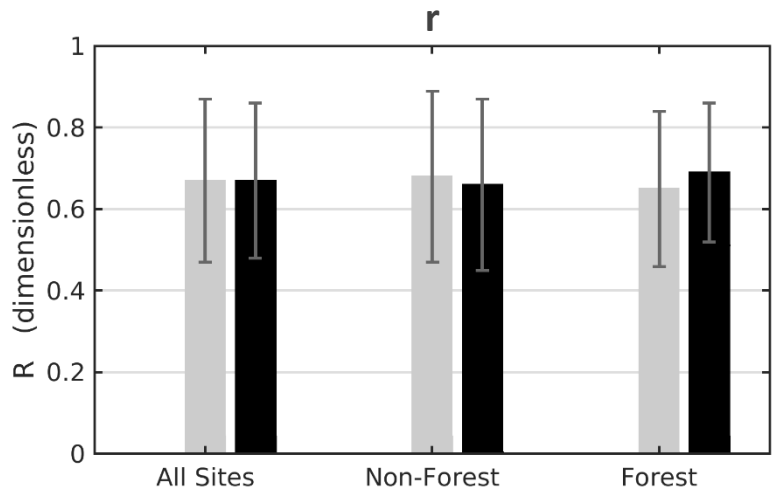
Performance metrics: Root-zone soil moisture





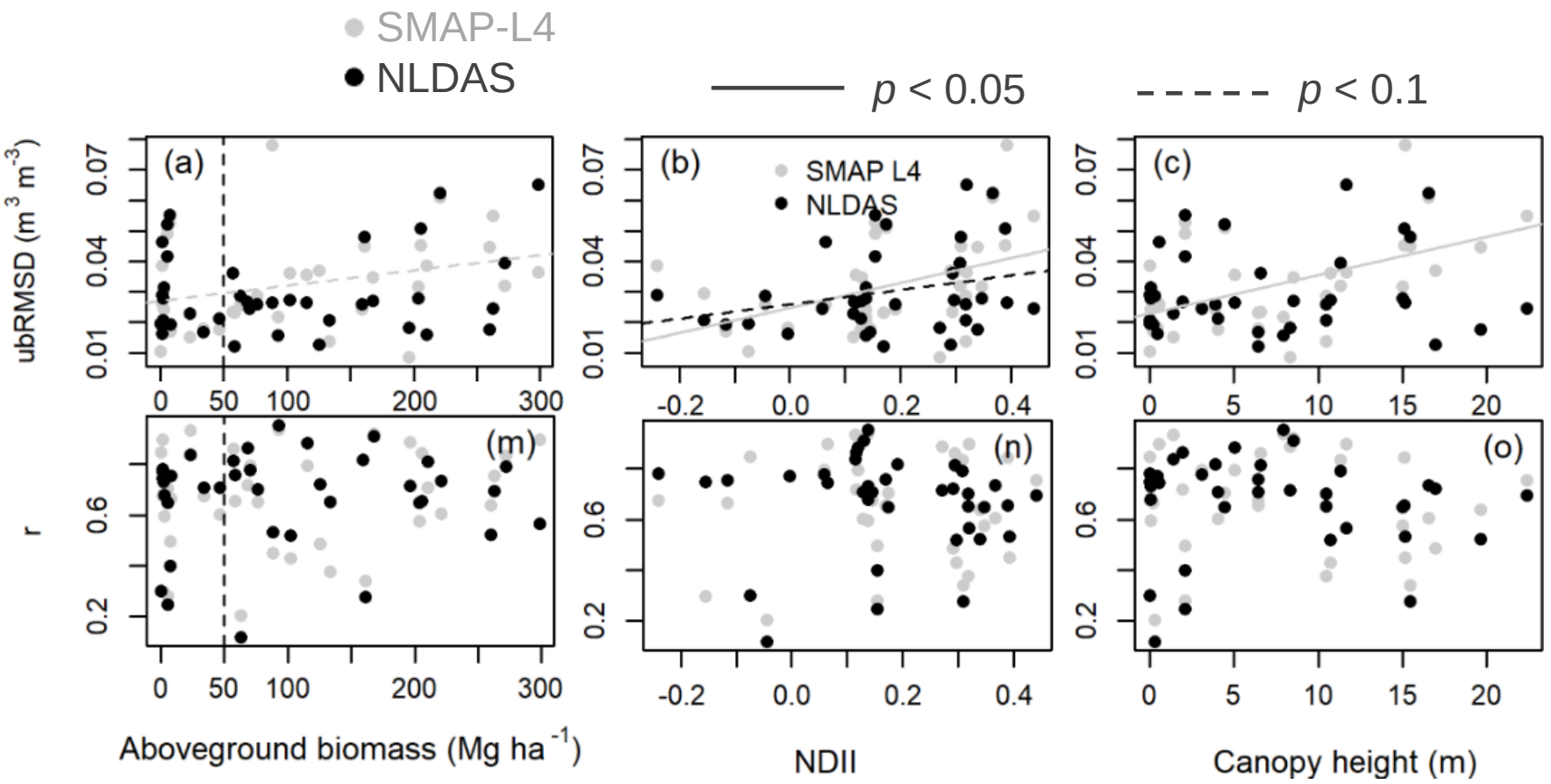


- Performance similar for SMAP-L4 and NLDAS.
- Performance similar at unforested and forested sites.
- Lower ubRMSD for root-zone than surface soil moisture.
  - However, little change in the correlation coefficient (r).
  - Suggesting reduction in ubRMSD owing to muted temporal dynamics in root-zone.



Ecosystem properties: Root-zone soil moisture

- Performance not related to ecosystem properties in most cases.
- Slight increase in SMAP-L4 ubRMSD as vegetation becomes denser, taller, and wetter.



Conclusion

- SMAP-L4 and NLDAS reliably track changes in surface and root-zone soil moisture at forested and unforested sites.
  - At least when aggregating across widely distributed sites.
- SMAP/Sentinel can reliably track changes in surface soil moisture at unforested sites, but not at forested sites (outside primary use case).
  - Higher spatial resolution (3 km) cannot compensate for sensitivity to vegetation water content.
  - Large reduction in performance in forests attributed to Sentinel's C-band measurements, which are particularly sensitive to vegetation water content.
- NISAR L-band measurements are less sensitive to vegetation; combining NISAR with SMAP may allow for tracking of soil moisture dynamics in forests at ultra-high resolutions (~200 m) of more relevant to land managers.