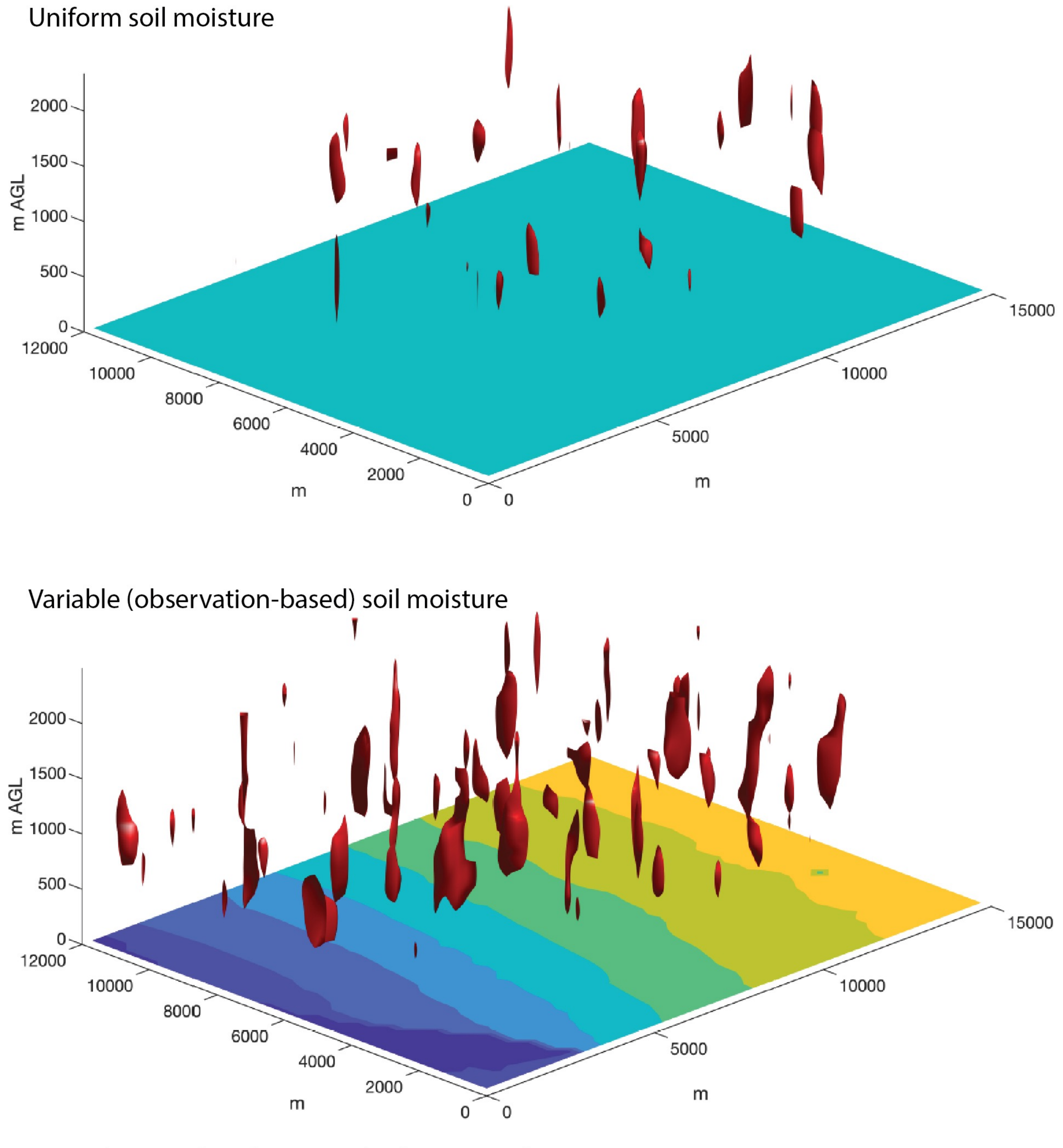
Spatial Scales of Soil Moisture – Cloud Coupling Pathways using Semi-Idealized Simulations

June 24, 2021
2021 ARM/ASR Joint User Facility PI Meeting

Koichi Sakaguchi
Koichi.Sakaguchi@pnnl.gov

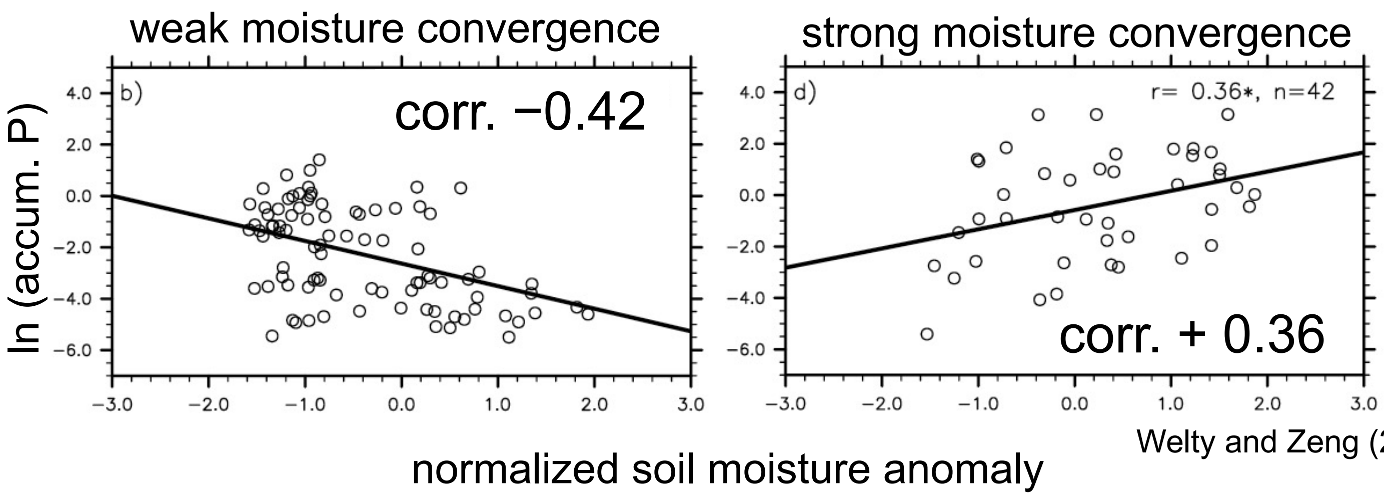


3 m s^{-1} iso-surface for vertical velocity & soil moisture contours

U.S. DEPARTMENT OF ENERGY BATTELLE
PNNL is operated by Battelle for the U.S. Department of Energy

What is the characteristic scale of Land-Atmosphere coupling over the Southern Great Plains?

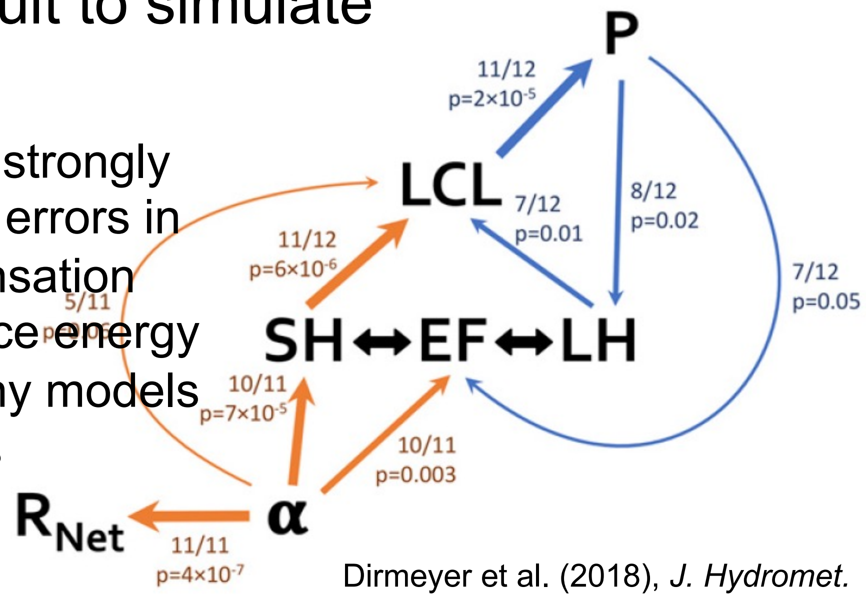
Evidence for the importance of L-A coupling accumulating



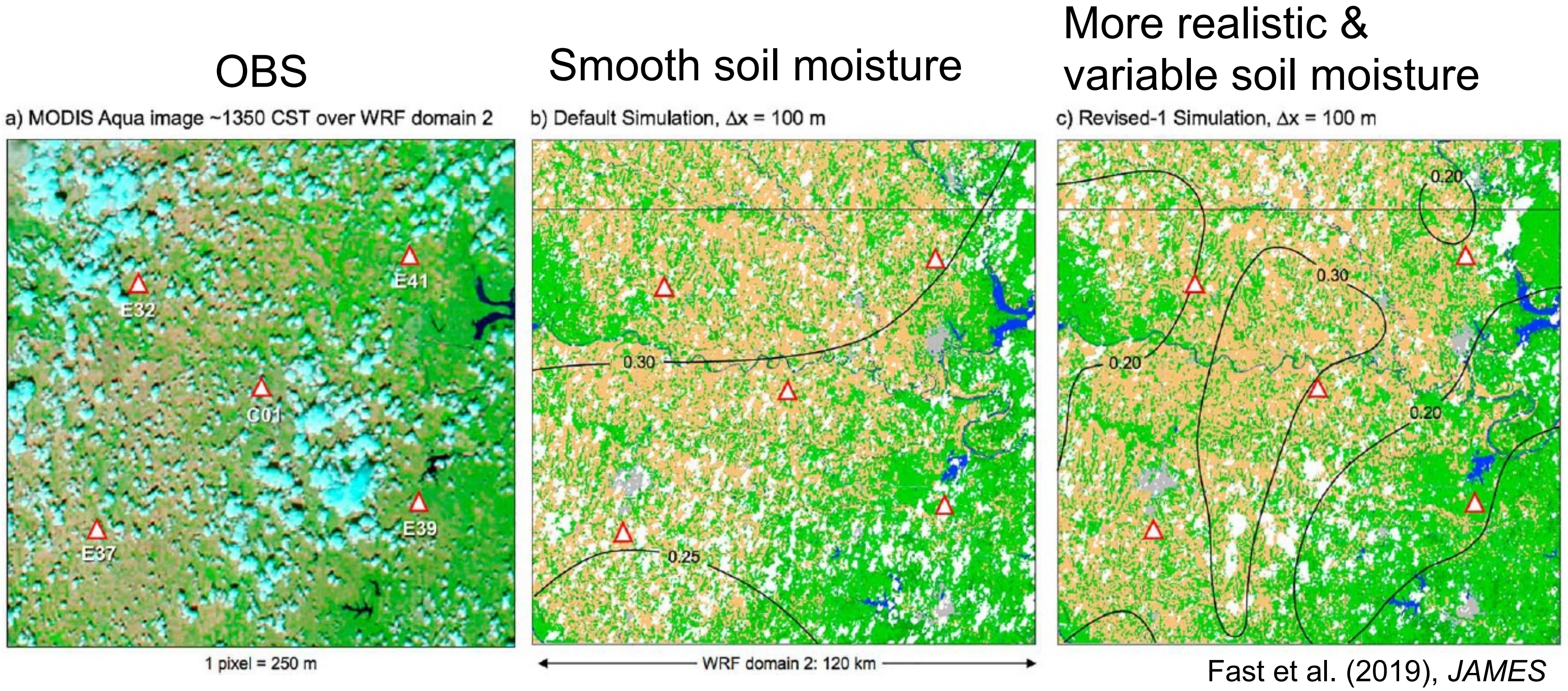
Welty and Zeng (2018), *GRL*

... but difficult to simulate

Precip. error strongly correlated to errors in lifting condensation level & surface energy fluxes in many models & reanalyses



Dirmeyer et al. (2018), *J. Hydromet.*



Fast et al. (2019), *JAMES*

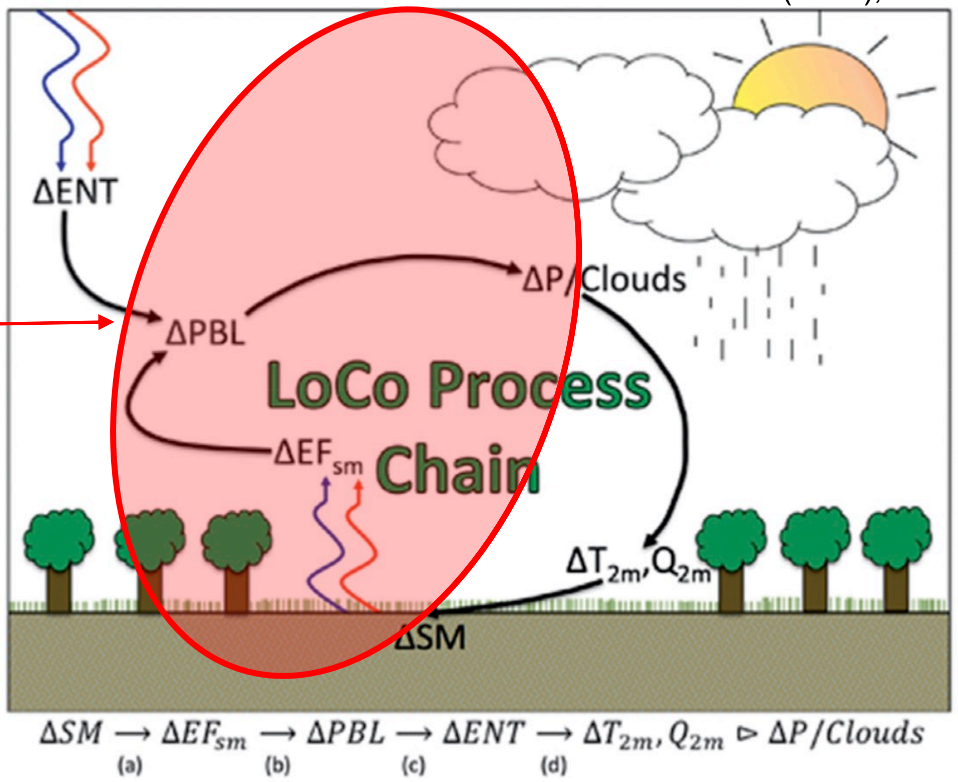
Knowing the dominant scales of relevant processes is a key for modeling multi-scale systems (e.g., Honnert et al. 2020)

Clouds change their scales with soil moisture variability (Fast et al., 2019)

What are the spatial scales of the **process chain from soil moisture to the clouds**?

WRF simulations & focus of the study

Santanello et al. (2018), *BAMS*

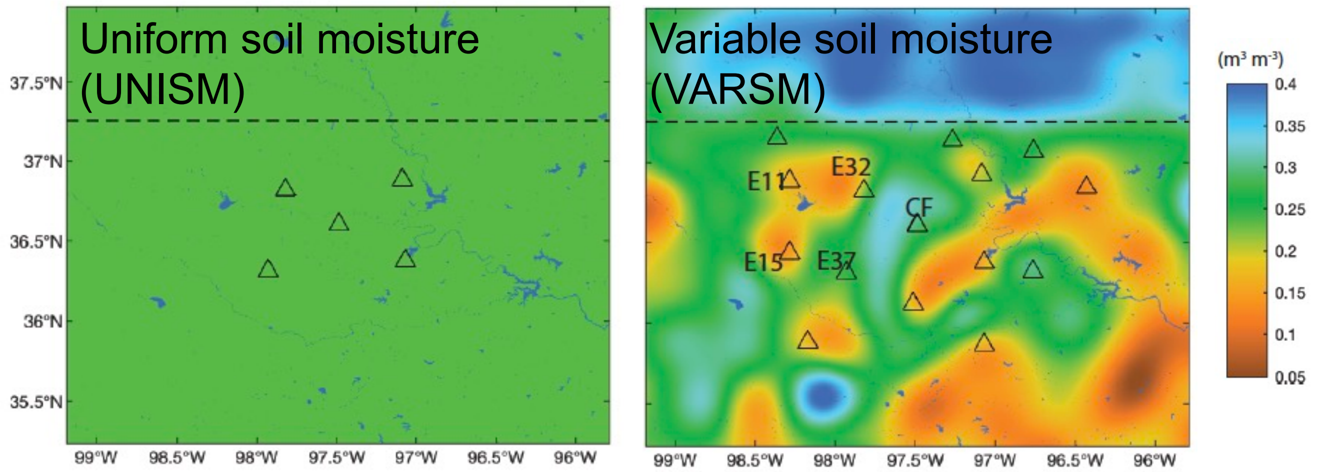


Most of the model input data and configuration are the same as those in Fast et al., 2019: WRF model is run for 12 hours without PBL and convection parameterizations for the HI-SCALE August 30 case

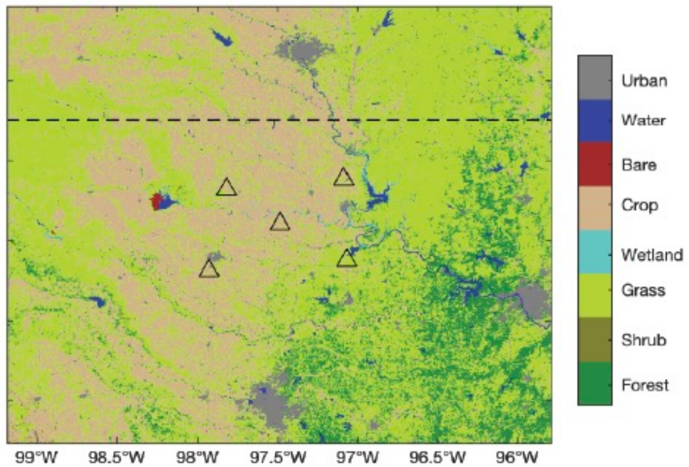
Simplifications (e.g., no topography, no large-scale forcing) to focus on **responses of surface and atmosphere to soil moisture forcing before atmospheric feedback** Chen et al., 2020, *JGR-Atmo.* (poster in session 2))

Name	Grid spacing (m)	Atmospheric I.C./B.C.	Soil moisture I.C.	Soil texture	Topography	Model domain	Analysis domain
UNISM	300	Uniform & zero winds / doubly periodic	Uniform	Uniform (silt)	Flat	297 km x 297 km	250 km x 180 km
VARSM	300	Uniform & zero winds / doubly periodic	Interpolated from STAMP, Mesonet, GLEAM	WRF default (STATSGO)	Flat	297 km x 297 km	250 km x 180 km

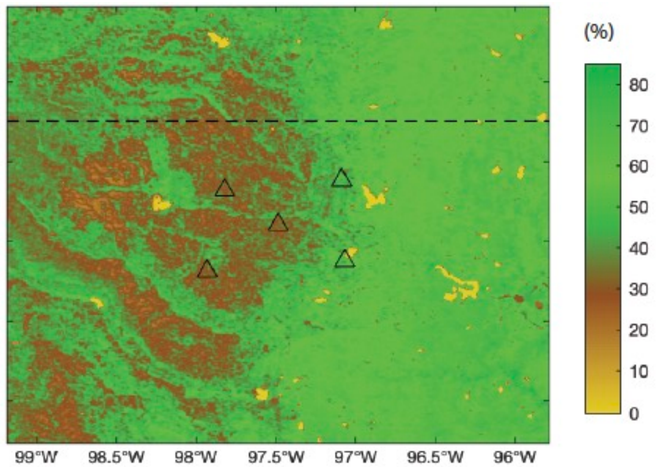
Soil moisture



Landcover

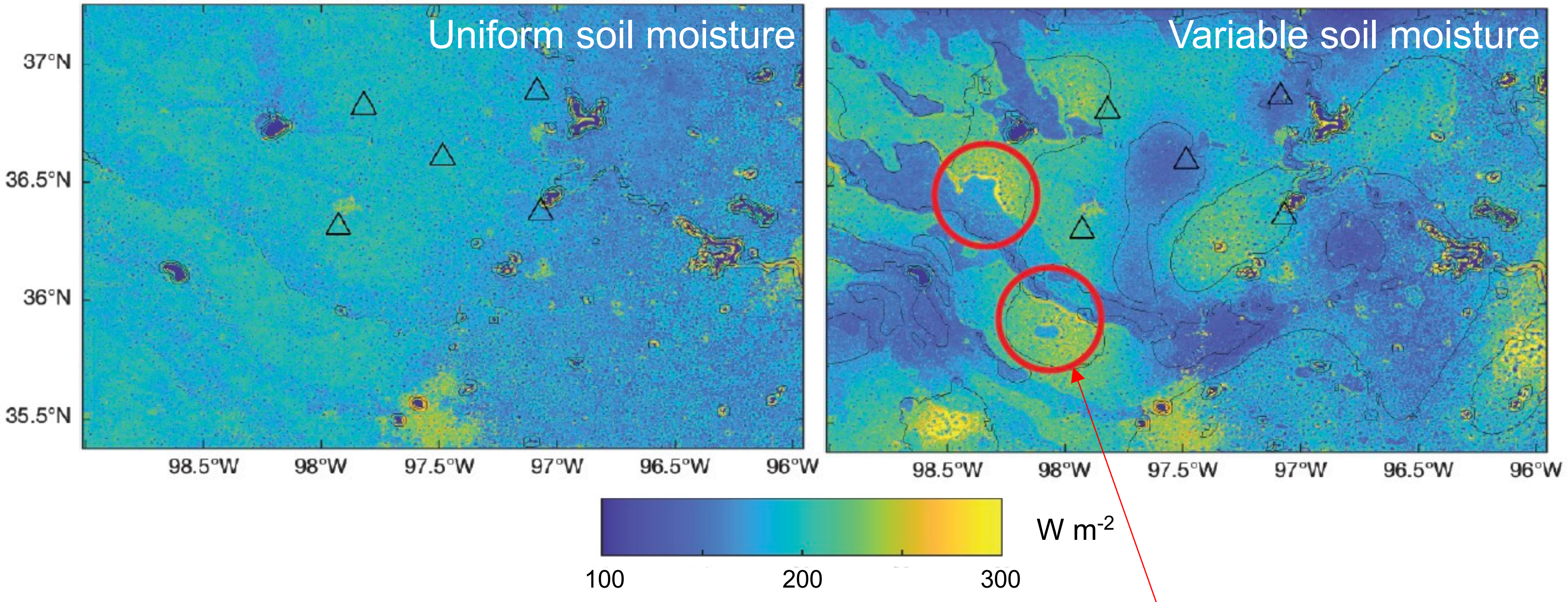


Green vegetation fraction



Two-scale surface responses to the single-scale soil moisture forcing

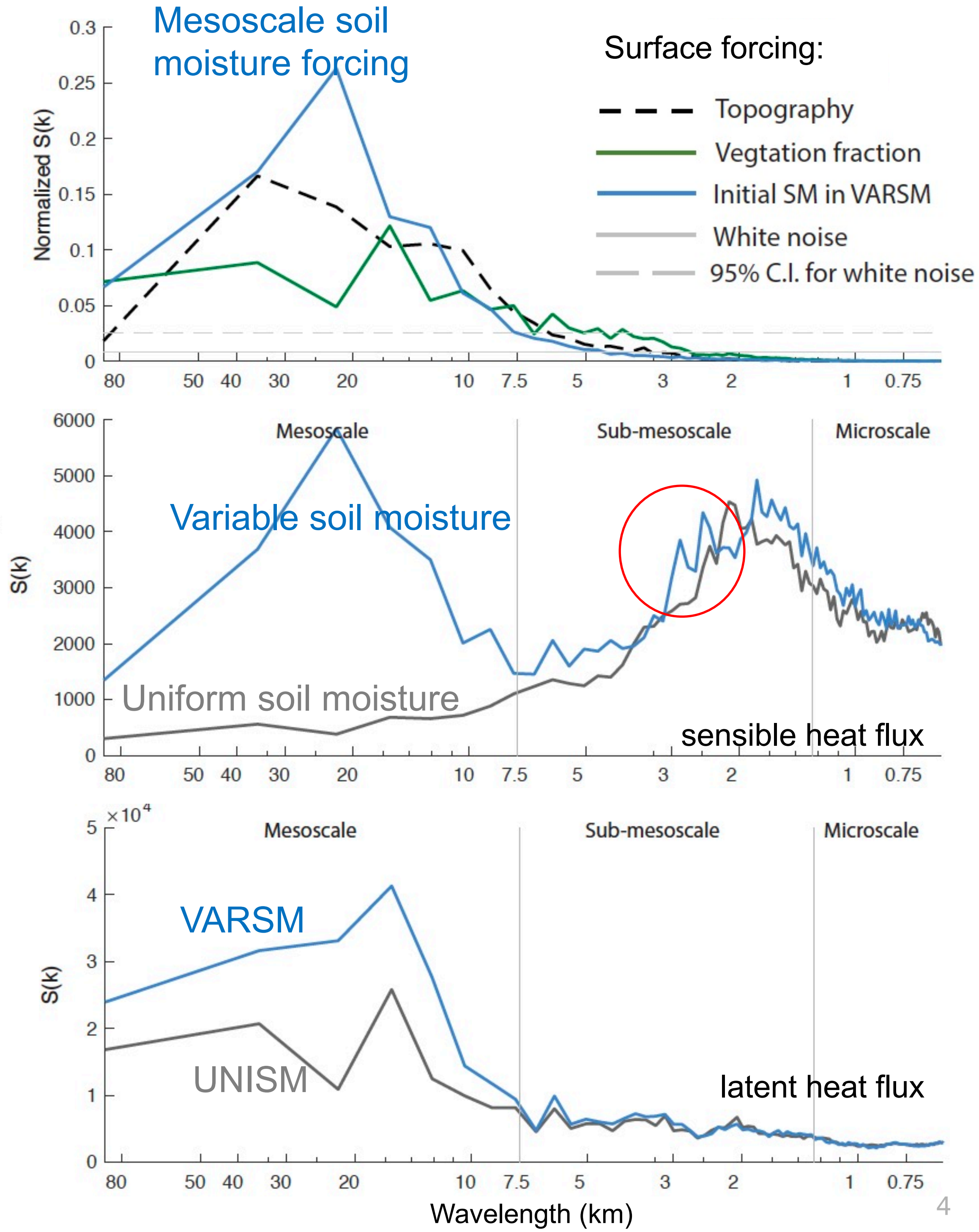
Simulated surface sensible heat flux (1000CST)



The input soil moisture forcing has the dominant scale of variability in **mesoscale (> 7.5 km in this study)**

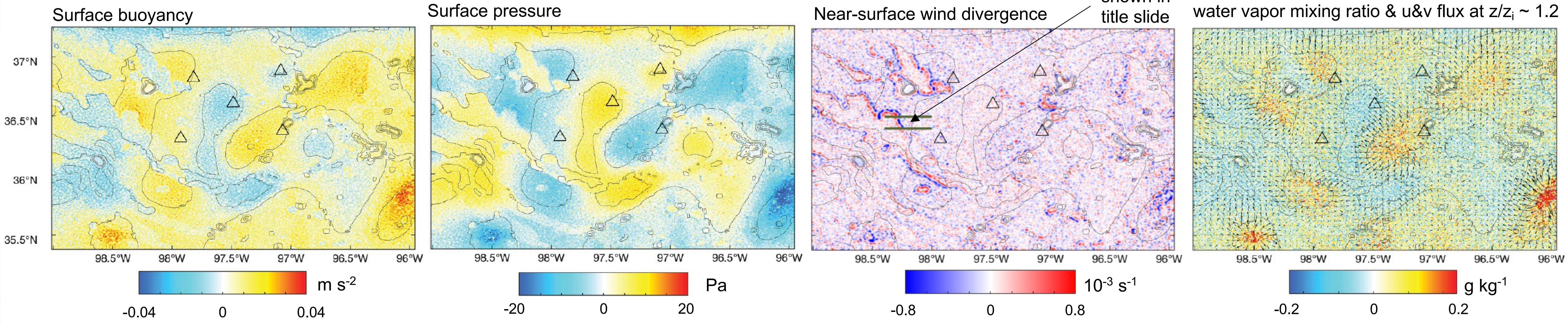
Mesoscale variabilities are enhanced in both sensible and latent heat fluxes

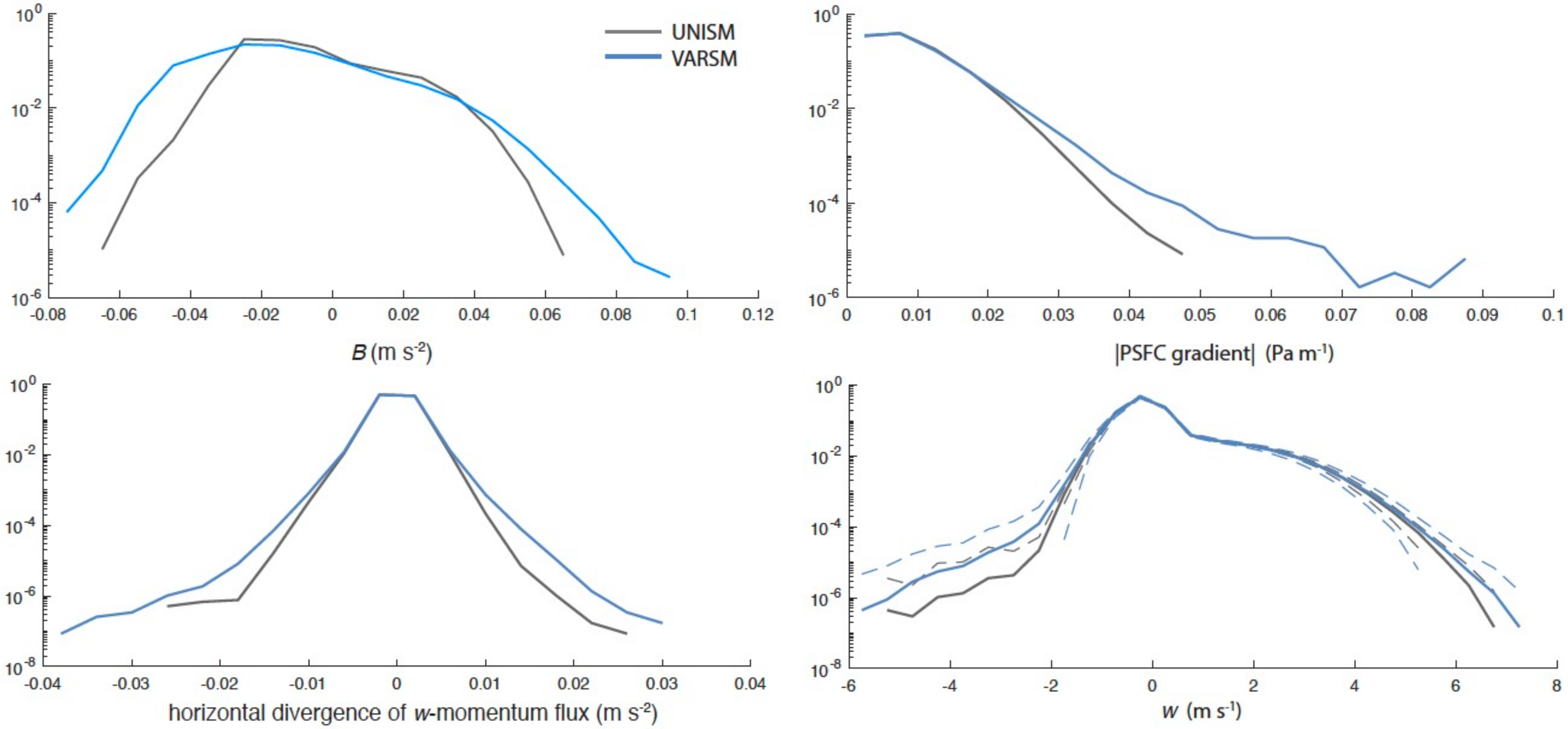
Sub-mesoscale (1.5 – 7.5 km) variability is also increased in sensible heat flux, corresponding to **stronger flux gradients** produced by soil moisture variability



Coupling hot spots are extreme

Differences as [VARSM] − [UNISM], 1000 LT





Extreme values of surface buoyancy, pressure gradient, wind speeds, moisture fluxes, TKE, and others are enhanced in VARSM over **local maxima** and **sharp gradient** of **surface sensible heat flux**

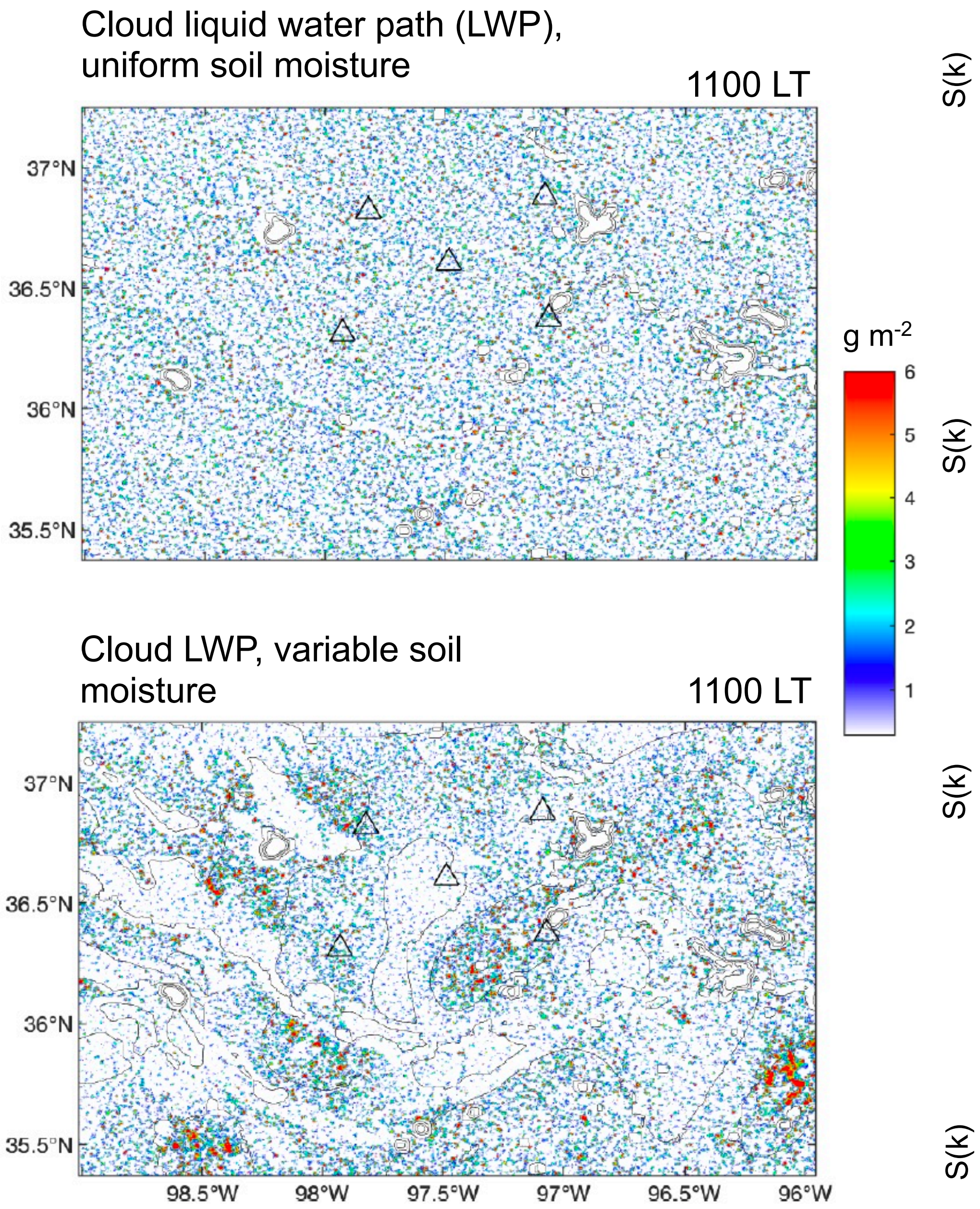
w difference is less substantial

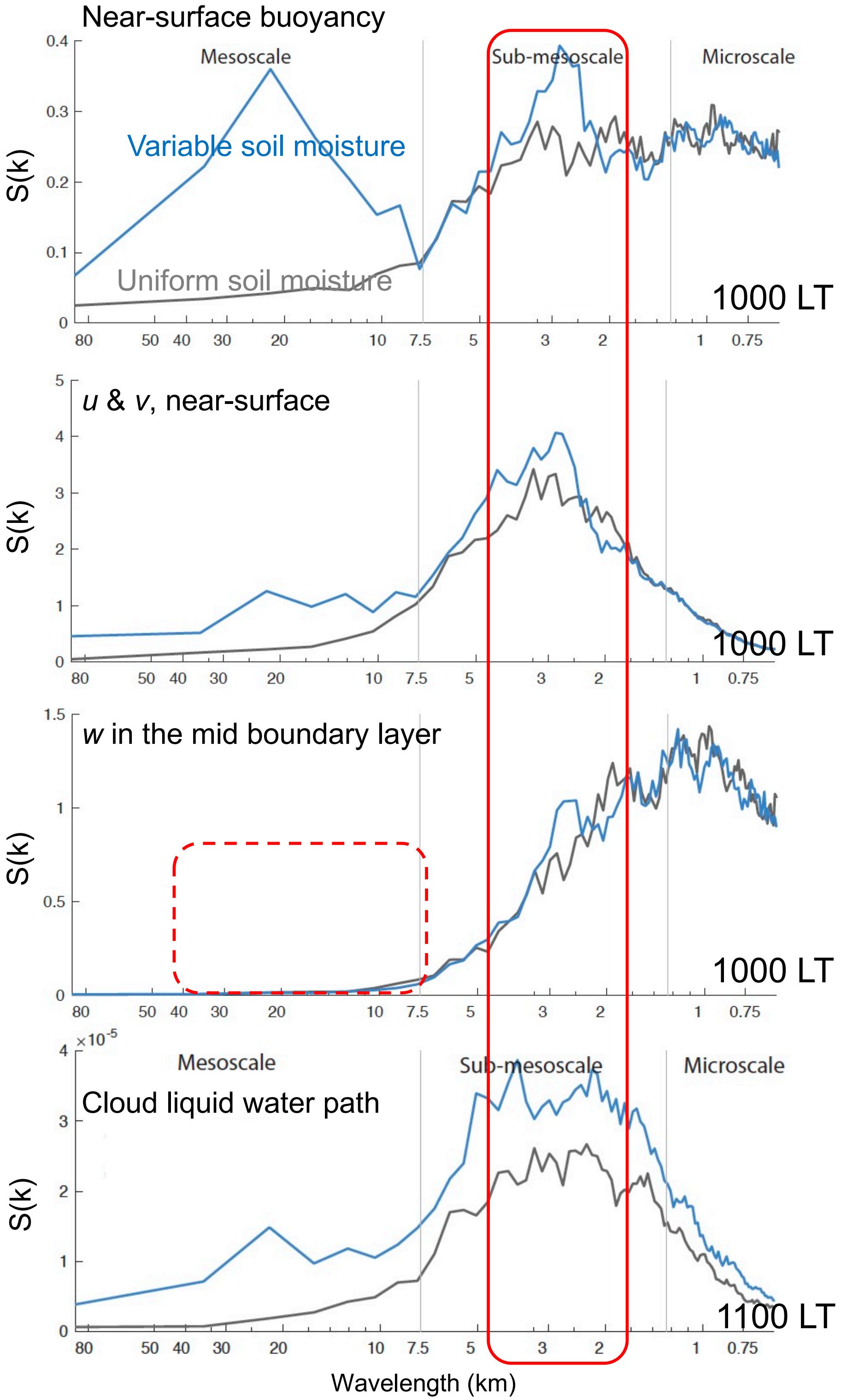
Atmosphere responds at both scales

Both mesoscale and sub-mesoscale variabilities are enhanced in buoyancy and horizontal winds

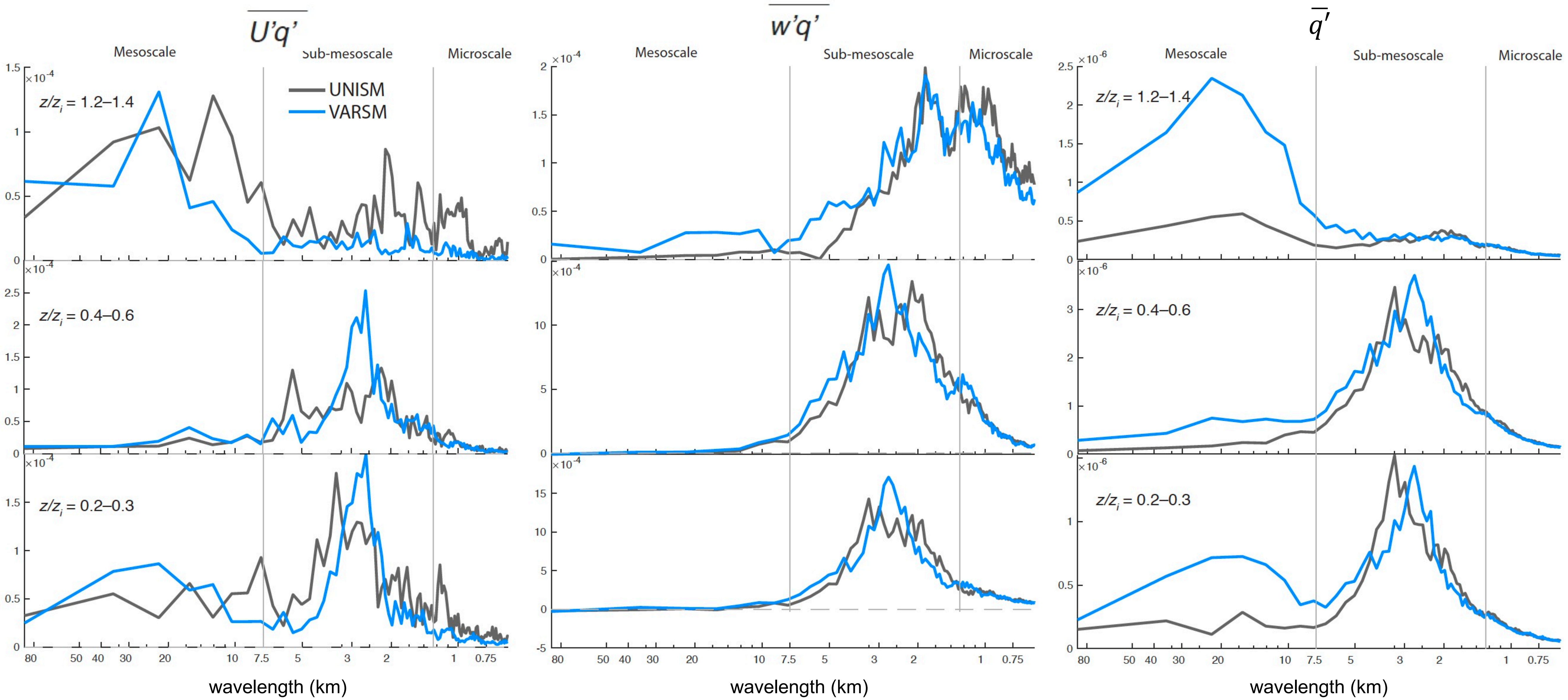
w **and near-surface divergence** respond to soil moisture forcing **only in the sub-mesoscale**

Clouds first form in the **sub-mesoscale, then upscale to mesoscale quickly with variable soil moisture**



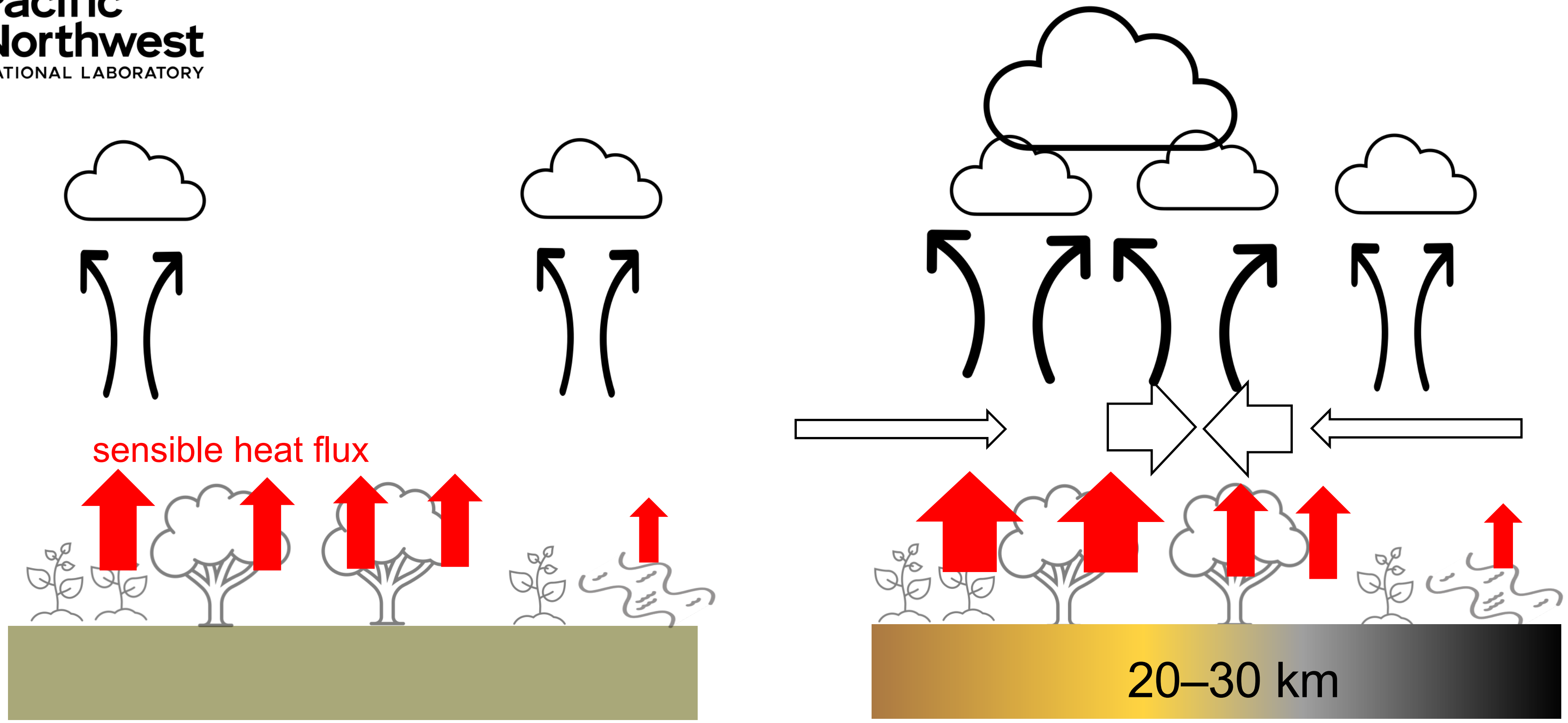


Clear sub-mesoscale signature in scalar fluxes



Both horizontal and vertical q fluxes, and q variance, are intensified in the **2–3 km** scale within boundary layer by soil moisture variability

Scales of soil moisture–cloud process chain



Clouds form at sub-mesoscale and grow into mesoscale with variable soil moisture

Stronger rising motion in sub-mesoscale

Mesoscale & sub-mesoscale horizontal circulations

Mesoscale variation (in 20–30 km) + Stronger sub-mesoscale gradient (peak in 2–3 km) in sensible heat flux

On-going & future work:

- More cases
- Sensitivity to land models & grid resolutions
- Scales of landcover & topography influence
- Observed spectra

Also see J. Chen et al., 2020, *JGR-Atmo.* (poster in session 2) & *Z.Yang et al., 2021, JGR-Atmo.* (poster in session 4)

Manuscript submitted to *JGR-Atmospheres*

Questions? -> Koichi.Sakaguchi@pnnl.gov

Contributors (PNNL): L. Berg, J. Chen, J. Fast, R. Newsom, S.-L. Tai, Z. Yang, W. I. Gustafson Jr., B. J. Gaudet, M. Huang*, M. Pekour, K. Pressel, and H. Xiao

*now at NOAA NWS

Supported by ICLASS SFA under ASR