Informing earth system models using soil observations and geospatial science

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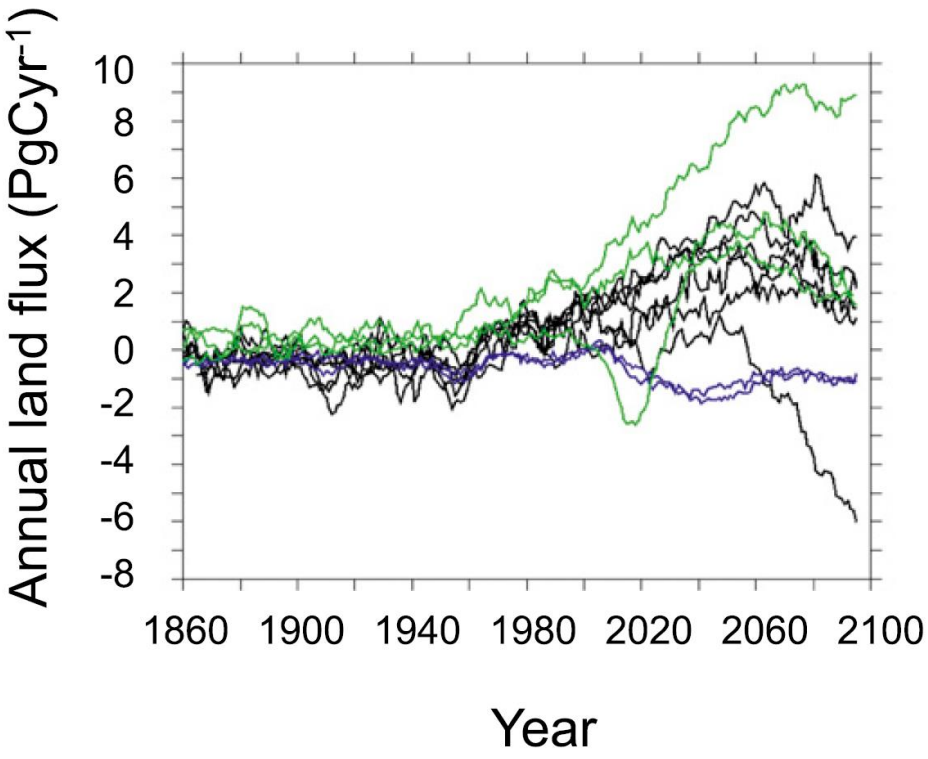
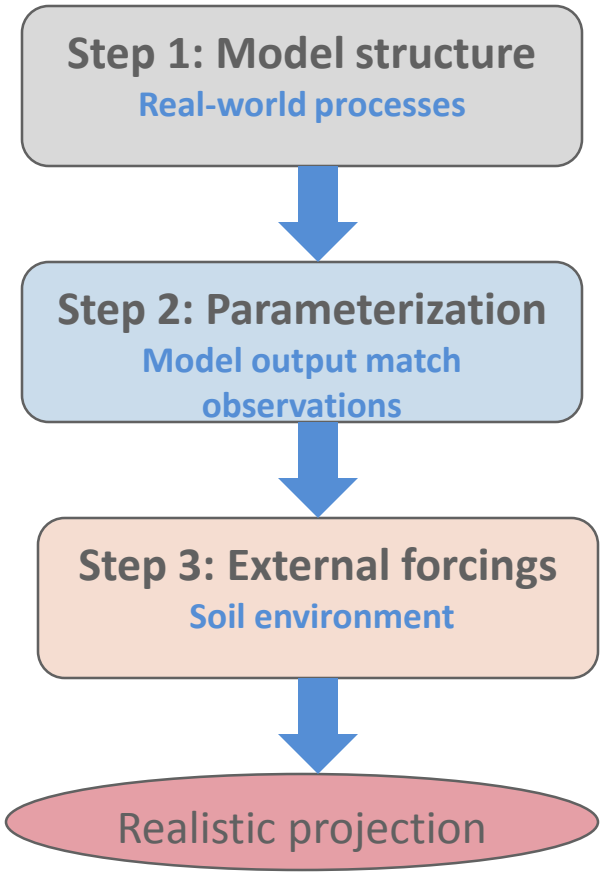
Uncertain land carbon sensitivity to environmental change and steps to achieve realistic projections

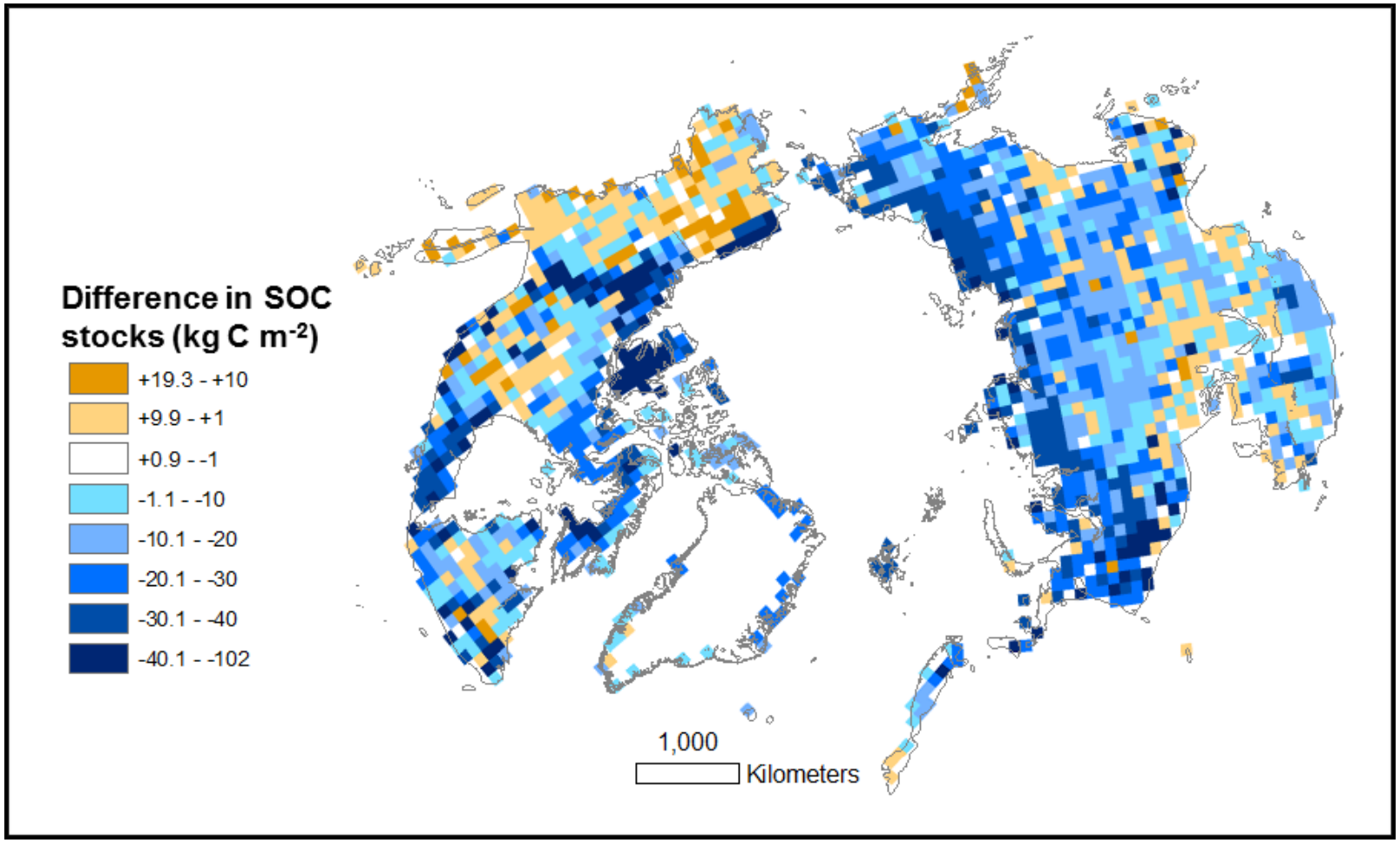


(Friedlingstein et al., 2014)



(Luo et al., 2016)

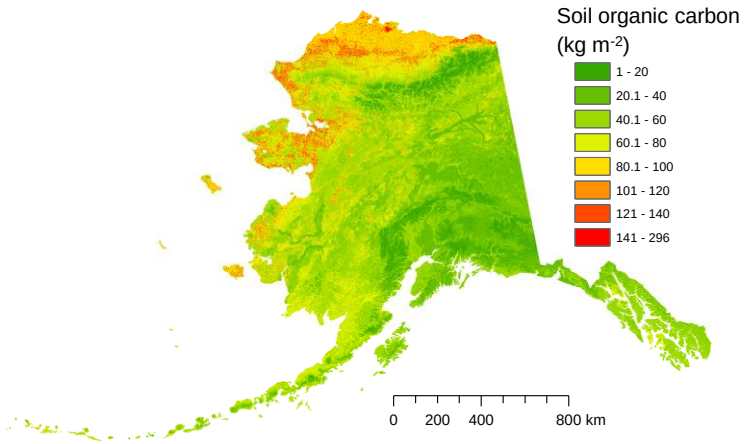
Magnitude of model data disagreement in northern circumpolar region



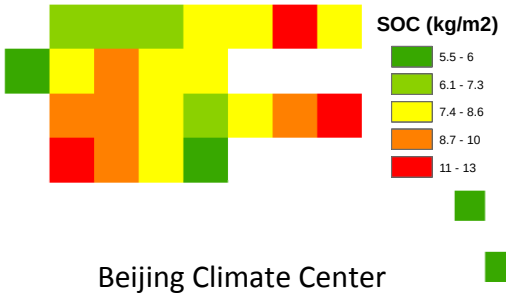
A 348 billion ton Disparity to 1 m depth

(Mishra et al., 2013)

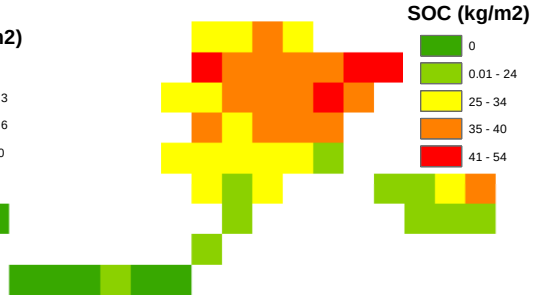
Comparing geospatial and ESM estimates of SOC stocks



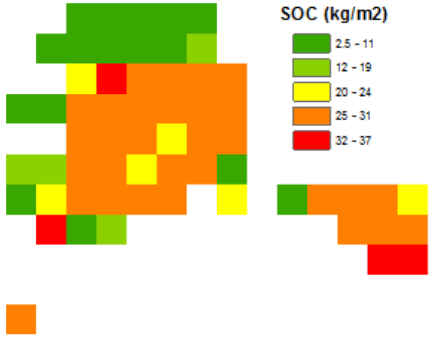
n = 472 samples
Environmental predictors:
Topography
Land cover types
Climate
Bedrock geology



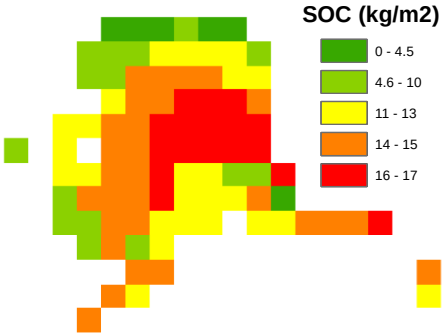
Beijing Climate Center
CSM1.1 (295 km)



Canadian Center for Climate
modeling & Analysis (211 km)



Atmosphere & Ocean Research
Institute, Tokyo (158 km)

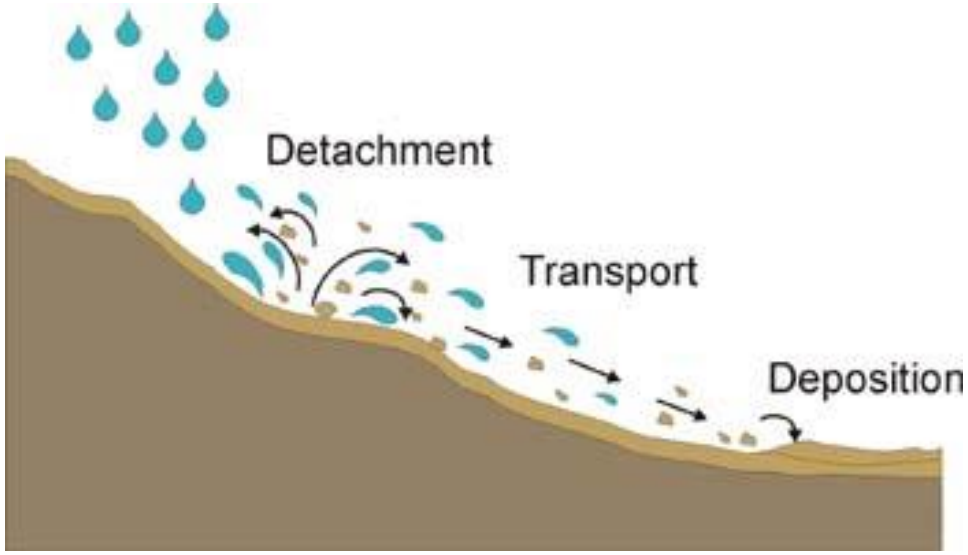


Geophysical Fluid Dynamics
Lab ESM (131 km)

- Spatial variability of SOC stocks vary widely among ESM models
- Spatial variability in ESM models do not match with observation based geospatial estimates

Predicted spatial variability in different models across Alaska

Major high-latitude soil-forming processes



Soil erosion and deposition

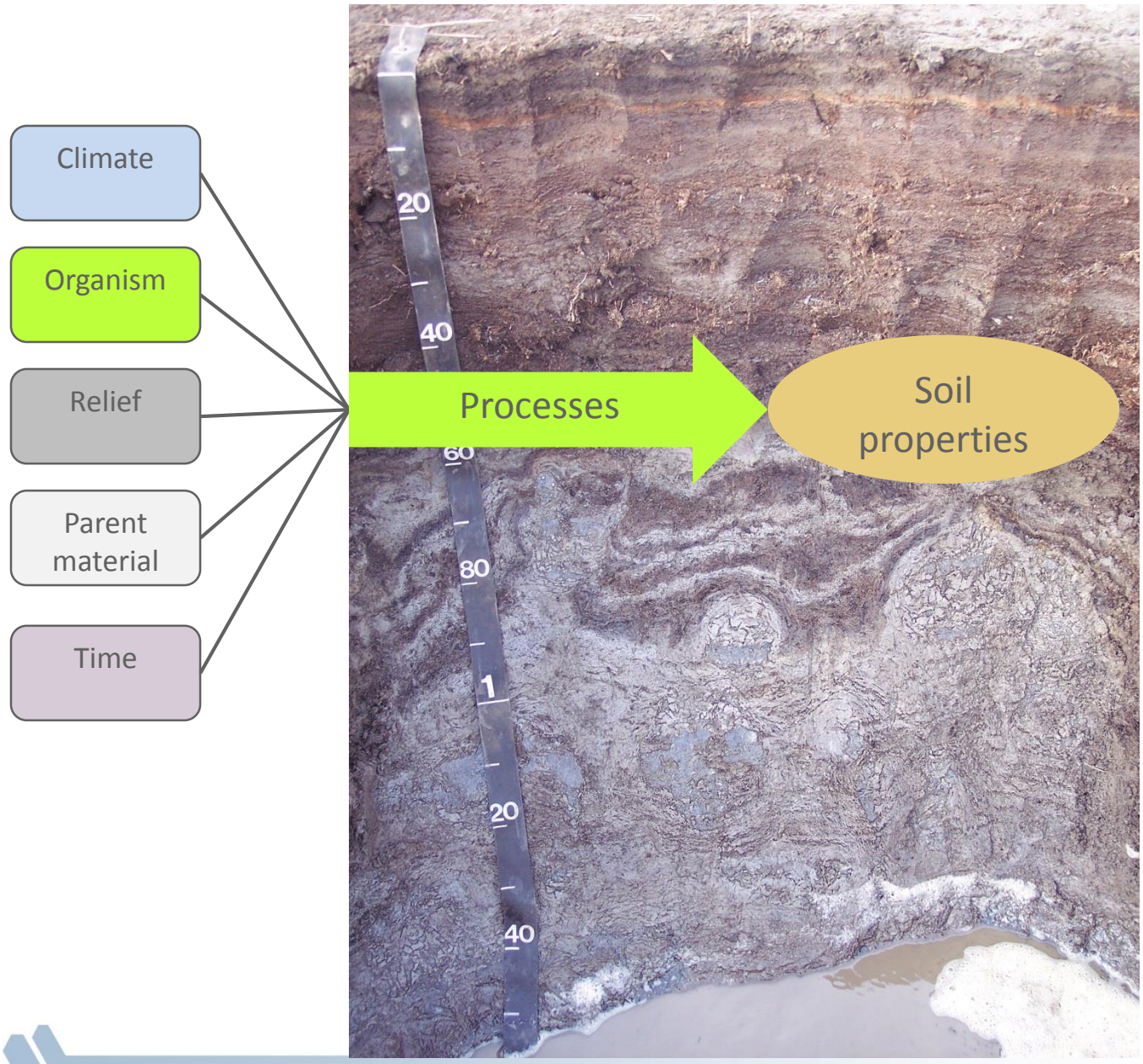
Peat formation

Podzolization

Cryoturbation

Riverine and deltaic soil formation

Spatial variability of soil properties



Heterogeneity of soil-forming factors provide the spatial structure to soil properties

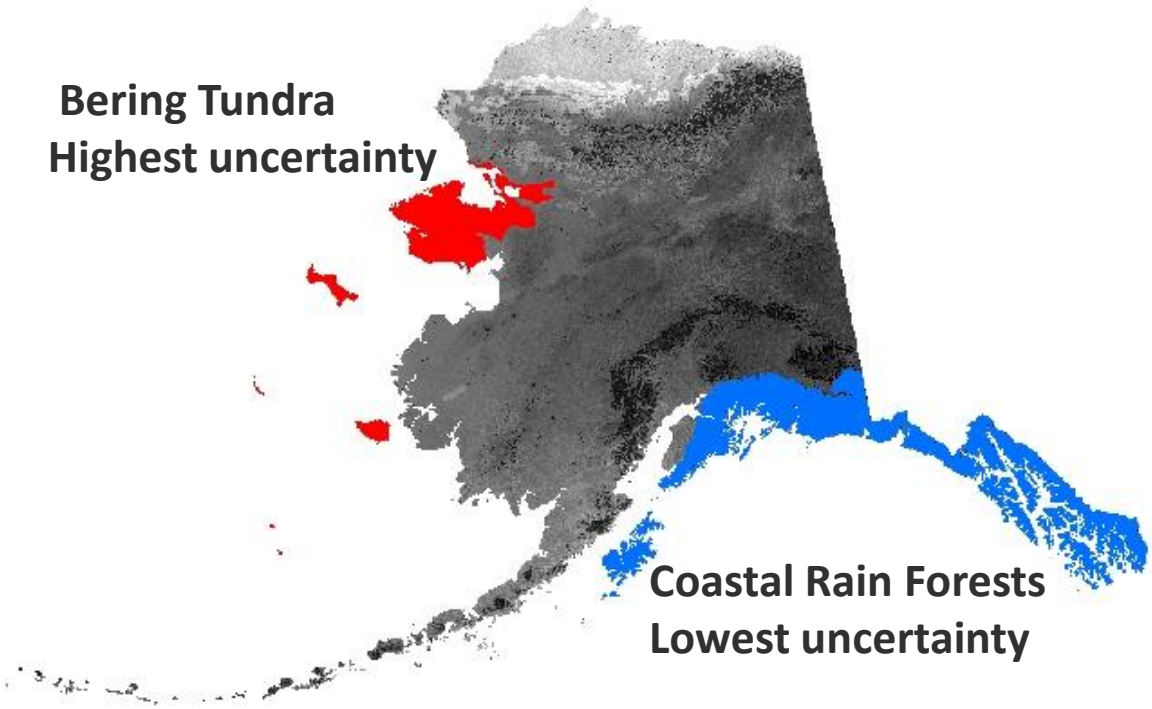
Environmental controllers of SOC change with scale

Environmental factors	***Spatial Scale***							
	50 m	*100 m*	*200 m*	*500 m*	*1 km*	*2 km*	*5 km*	*10 km*
Elevation	●	●	●	●	●	●	●	●
Slope								●
Aspect	●							
Soil Wetness Index	●			●			●	
Sediment Transport Index				●				
Temperature	●	●	●	●	●	●	●	●
Potential Evapotranspiration	●	●	●	●	●	●	●	●
Barren	●	●	●				●	●
Scrub	●	●	●	●	●	●	●	●
Herb						●		
Pasture						●	●	
Glacial Moraine				●	●		●	●
Fluvial				●	●	●	●	●
Undifferentiated Mosaic							●	
Coastal delta						●		●
Volcanic mountain						●	●	
Predicted variance	476.5	354	304	263	261	257	256.4	258

Black dots represent significant predictors at 95% confidence level

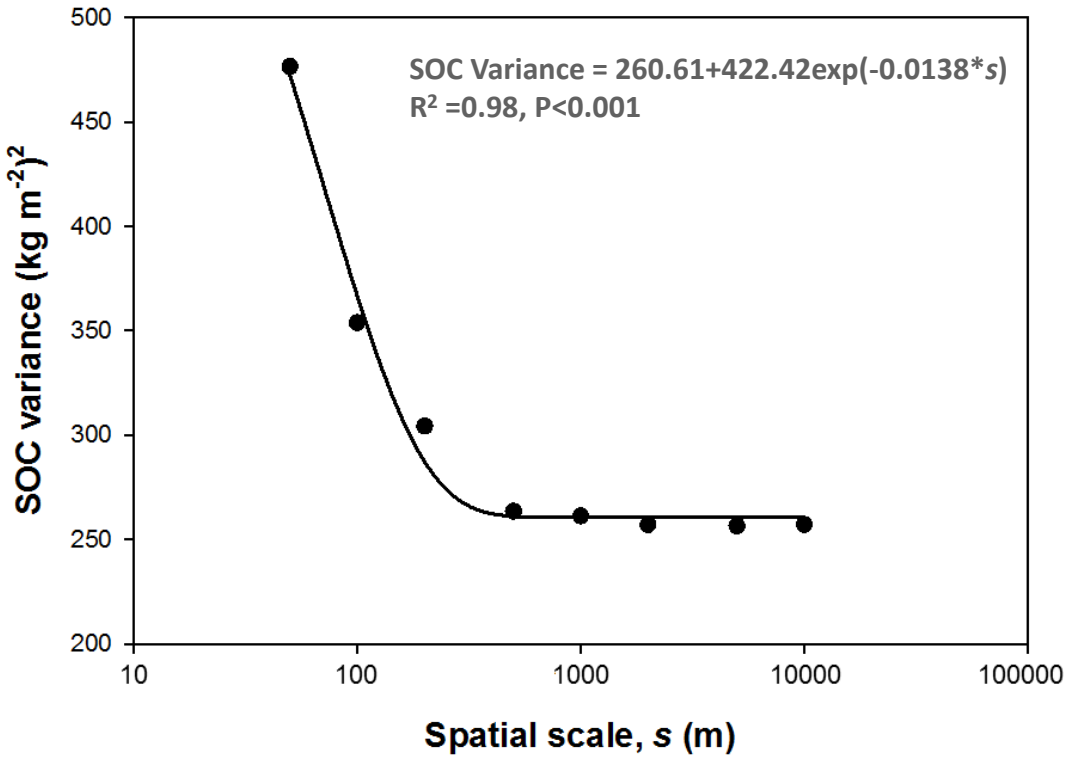
Areas of higher and lower uncertainty can be identified using geospatial modeling

Environmental factors	Percent difference
Elevation	5627
Potential ET	244
Aspect	200
Land cover	133
Temperature	118
Surficial geology	28



(Mishra et al., 2017)

Variance of SOC stocks decreases with scale



- Predicted variance decreased exponentially with scale, and it didn't change substantially beyond 500 m.
- The point of inflection of variance curve provides important implication for studies intended to capture spatial heterogeneity of SOC stocks.
- Our result is similar (non linear) with recent findings of soil moisture studies.

(Mishra and Riley, 2015)

Summary

- **Absence of soil-forming processes in model structures and factors in forcing variables could be a reason for large model-data disagreement.**

- **Geospatial science offers an opportunity to improve the spatial heterogeneity and environmental control representations of soil biogeochemistry.**

- **Global benchmarking efforts are critical to understand model-to-model variations in biogeochemistry, determine priorities for model development, guide future field experiments, and ultimately reduce existing uncertainty in predicting carbon-climate feedbacks.**

- **Soil scientists have a prominent role to play in this domain.**

Thank you for your time and attention!