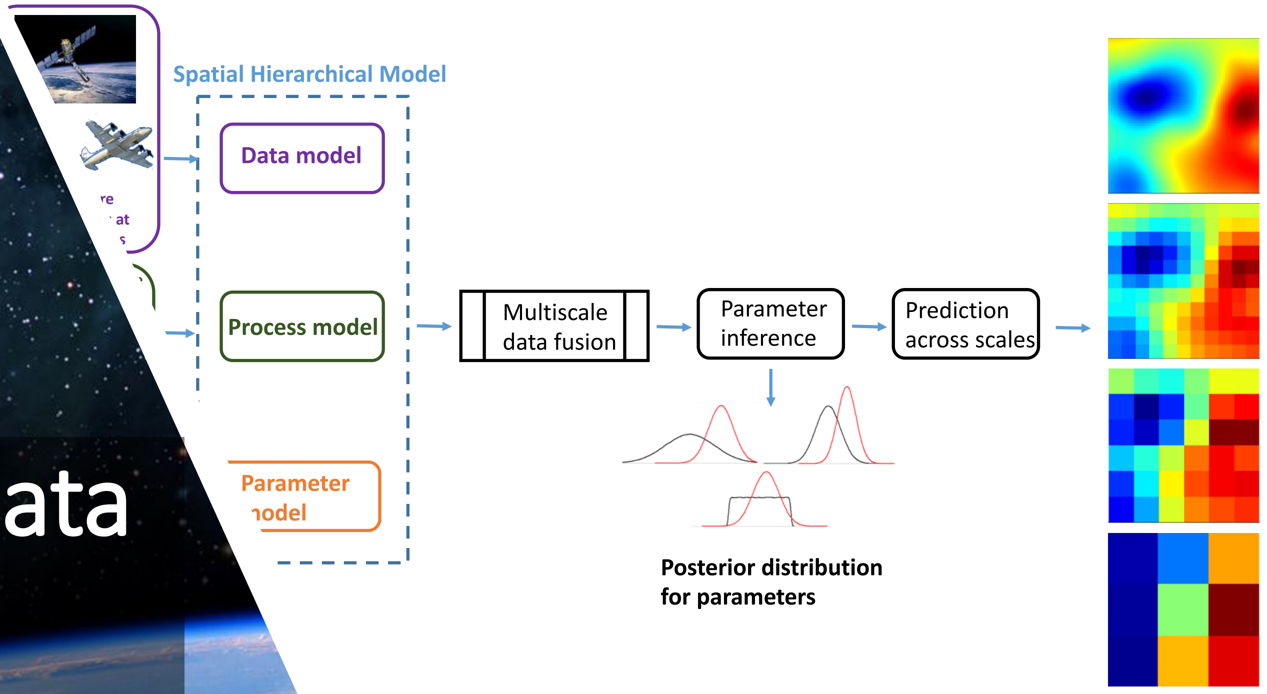
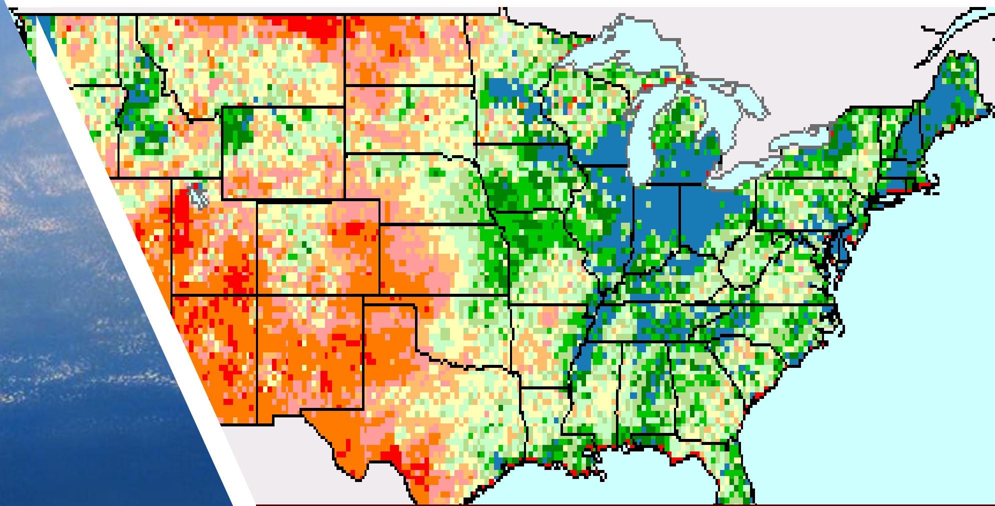
A non-stationary multiscale data fusion framework for soil moisture estimation





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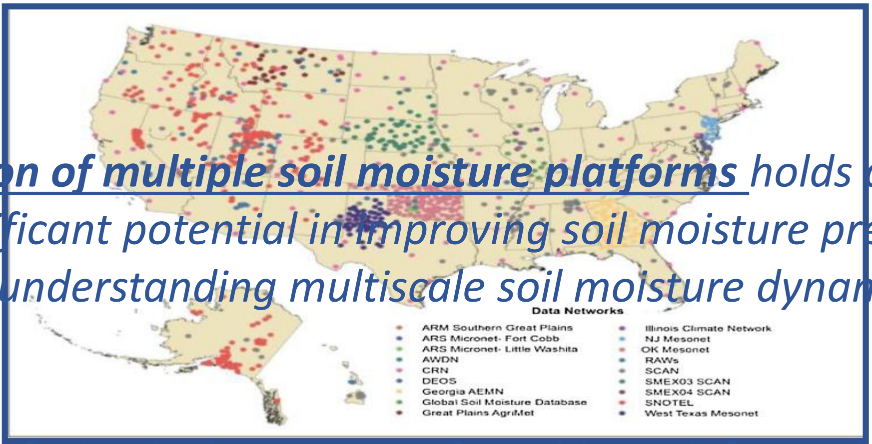
Multiplatform multiscale data fusion of soil moisture

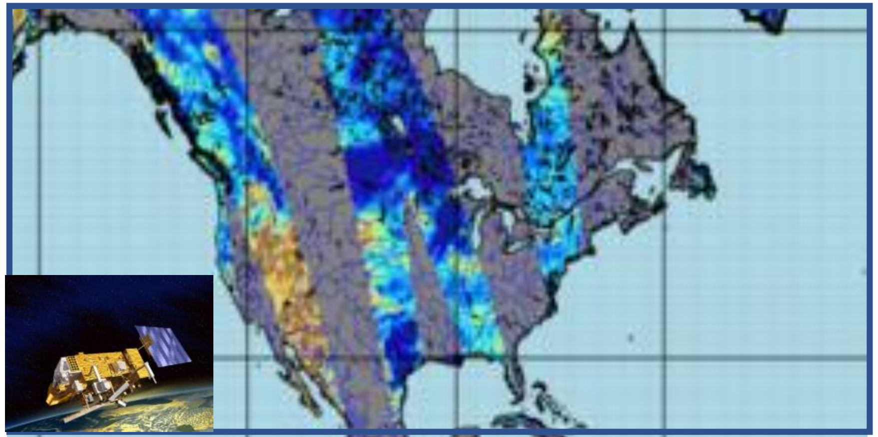
- ✓ Past decade has witnessed **global burgeoning of soil moisture datasets** from in situ networks and remote sensing platforms.
- ✓ On a daily scale, individual platforms have **limitations such as incomplete spatial coverage and errors in soil moisture retrievals.**

in situ networks

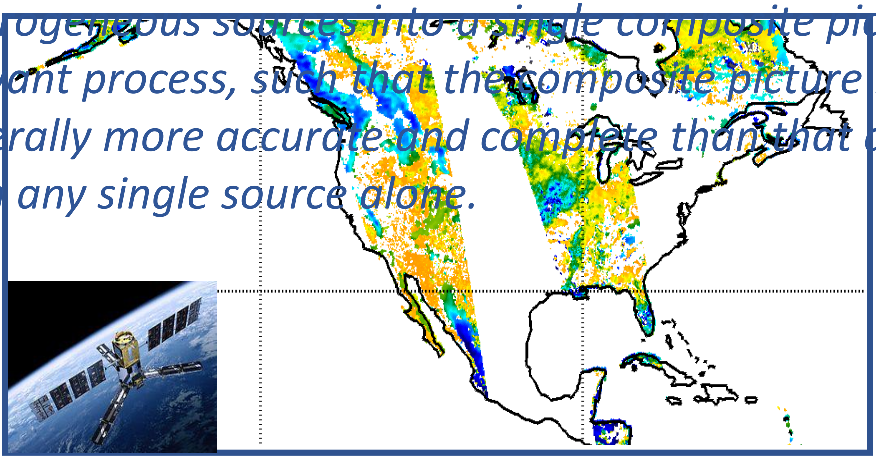


- ❑ ***Fusion of multiple soil moisture platforms*** *holds a significant potential in improving soil moisture predictions and understanding multiscale soil moisture dynamics.*
- ❑ *Data fusion is the process of combining information from heterogeneous sources into a single composite picture of the relevant process, such that the composite picture is generally more accurate and complete than that derived from any single source alone.*

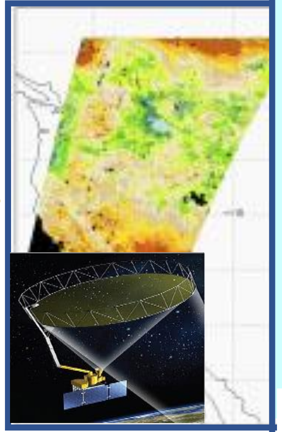
ASCAT (25 km)

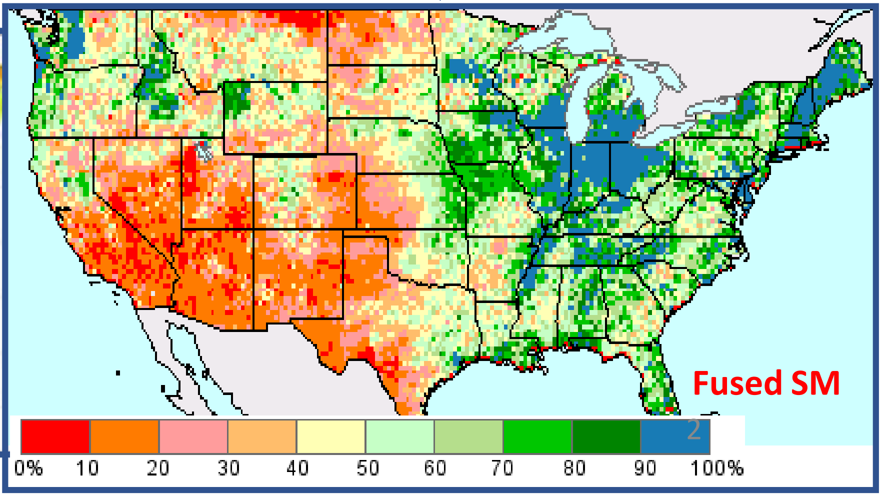


SMOS (35-50 km)

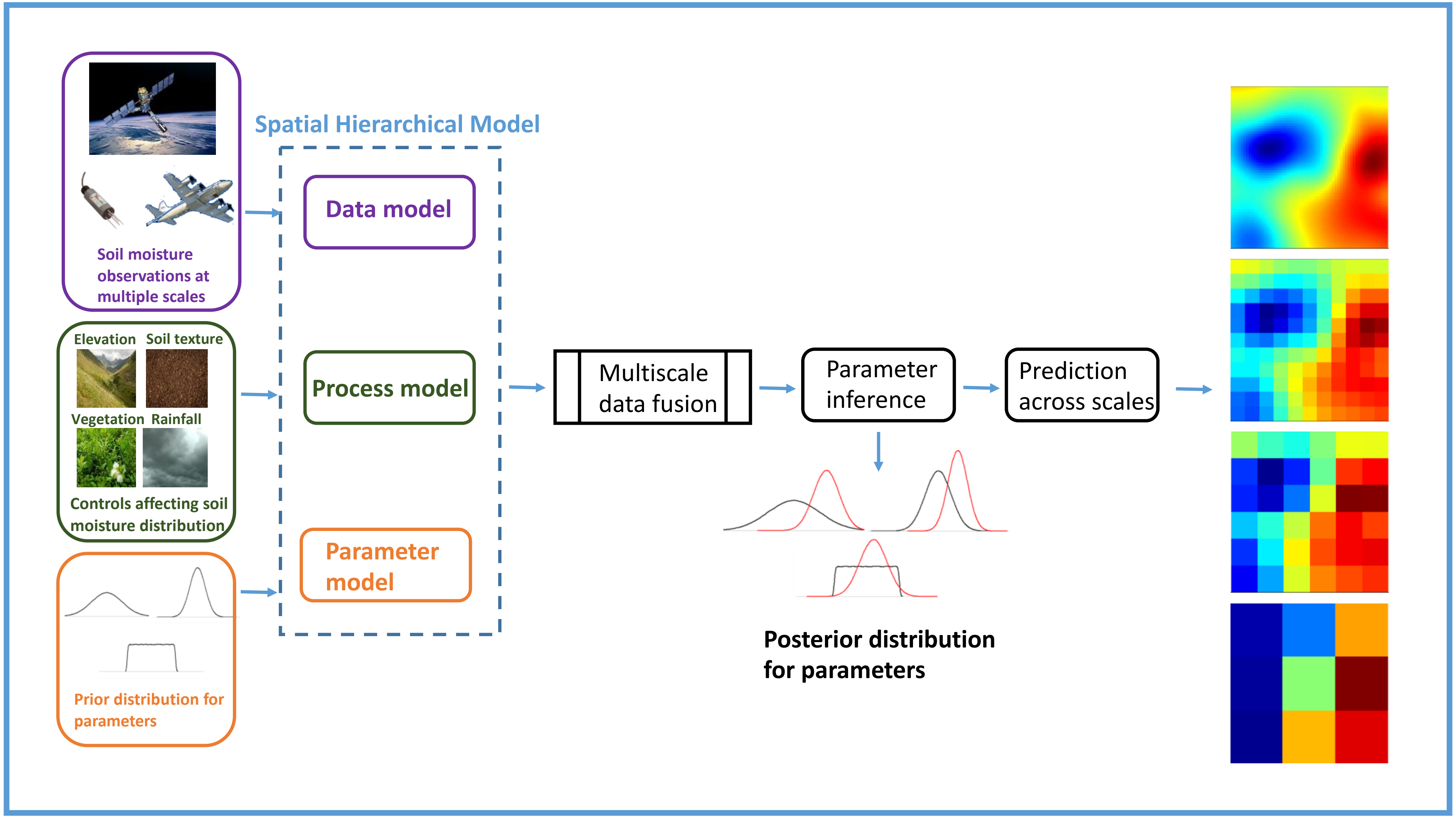


SMAP (36 km)
SMAP/ Sentinel 1 (3 km)





Multiscale data fusion: a spatial hierarchical approach



Data fusion across scales

- For the non-stationary process model at point scale we define the corresponding soil moisture distribution at a spatial support A as:

$$y(A) = \frac{1}{|A|} \int_A y(s)ds$$

- We use a numerical approximation by assuming a fine-scale grid $\mathcal{G}$ to approximate the stochastic spatial integral **resulting in a change of support matrix H** and use it to perform data fusion of multiple soil moisture platforms.

$$[\mathbf{z}|\mathbf{y}, \mathbf{P}_z] \sim \mathcal{N}(\mathbf{\Delta} + \mathbf{H}\mathbf{y}(\mathcal{G}), \mathbf{\Sigma})$$

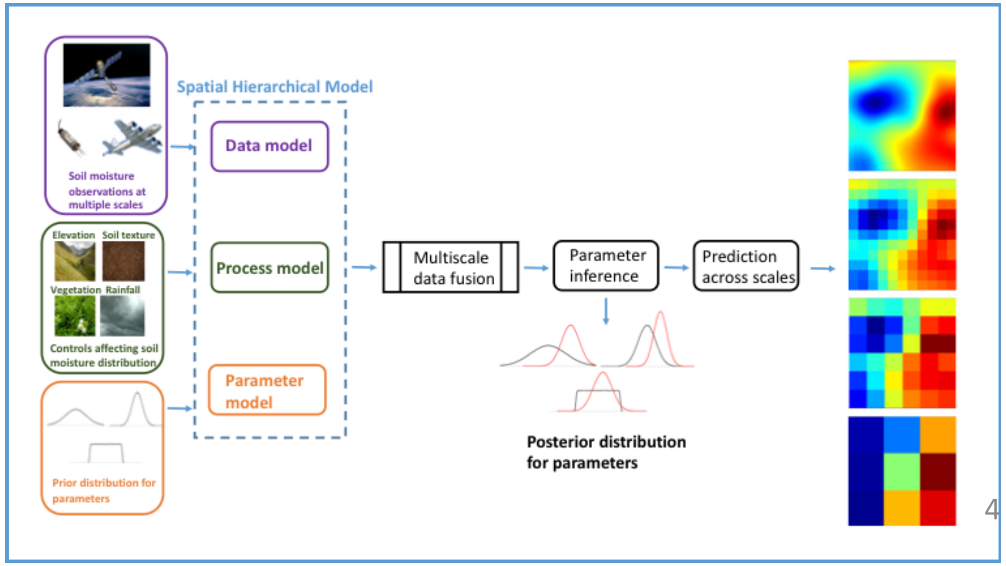
$\boldsymbol{z} = (z_{A1}, \dots, z_{An})$ represents observed SM data from all the platforms.

$\Delta = (\Delta_{A1}, \dots, \Delta_{An})$ are the biases associated with each observation.

$\boldsymbol{\Sigma}$ is the n × n error matrix.

Challenges in Multiplatform data fusion

- Inherent **spatial variability of soil moisture** caused due to precipitation and land surface controls such as vegetation, soil texture and topography.
- **Systematic and random errors** in remote sensing retrievals.
- Fusion of data platforms with **different spatial supports**.
- **Massive size** of the datasets for continental scale fusion.



Simultaneous validation at point, airborne and satellite scales

(A) (B)

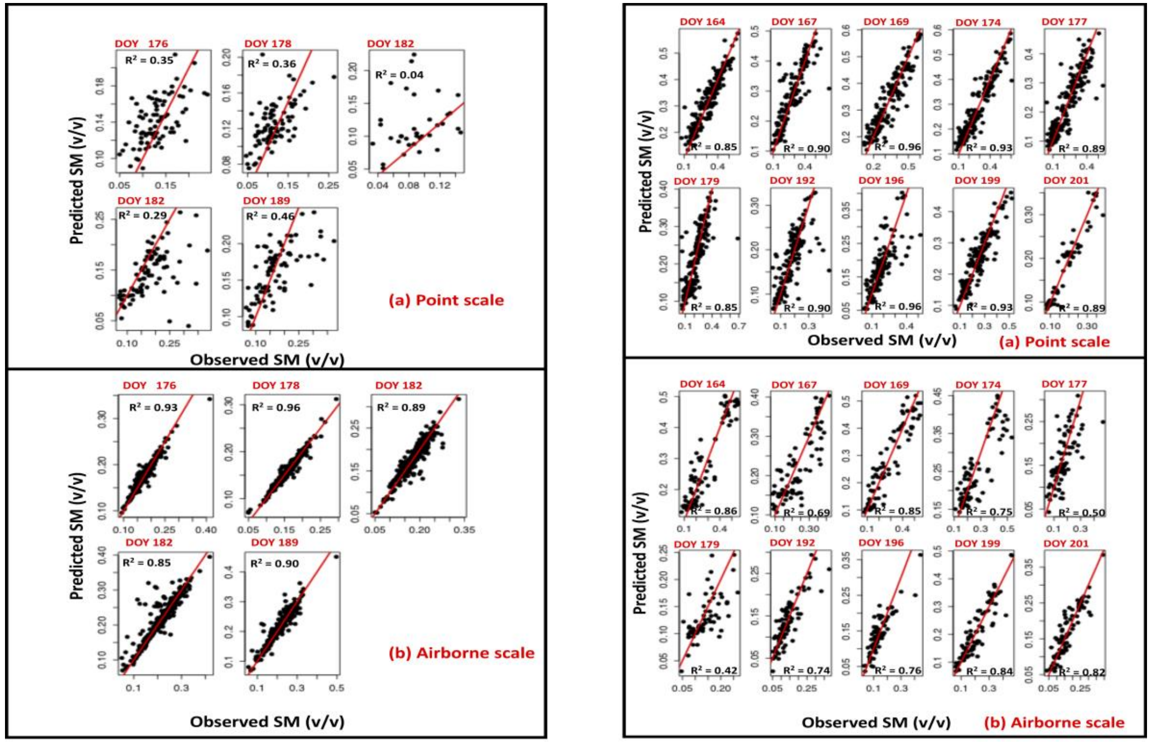


Figure 3, Validation plots for hold-out data at point and airborne scales for A) SMEX02 and B) SMAPVEX12.

- ✓ For each day, we validate the fusion framework using hold-out data at point and airborne scales and back-predicting the satellite pixels.

- ❑ The proposed scheme is applied to 5 days during SMEX02 and 10 days during SMAPVEX12.

Table 1, Root mean squared error (RMSE) values at point, airborne and satellite scales.

DOY	Fine	Airborne	Satellite
SMEX02			
176	0.033	0.007	0.004
178	0.033	0.008	0.001
182	0.051	0.012	0.003
189	0.066	0.017	0.002
190	0.054	0.014	0.005
192	0.057	0.019	0.008
SMAPVEX12			
164	0.045	0.059	0.014
167	0.057	0.053	0.023
169	0.051	0.062	0.022
174	0.045	0.062	0.024
177	0.055	0.061	0.049
179	0.058	0.045	0.037
192	0.048	0.035	0.034
196	0.059	0.039	0.028
199	0.046	0.043	0.021
201	0.026	0.031	0.018