Integrating Multi-Platform Satellite Soil Moisture and Evapotranspiration Retrievals to Constrain Water and Energy Balance Coupling

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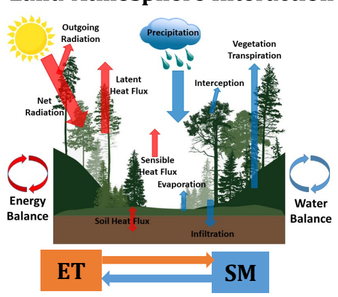
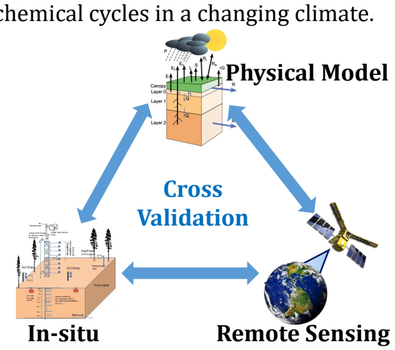
Motivation

- Soil moisture (SM), through its direct limiting effect on surface evapotranspiration (ET), modulates feedbacks between the land surface and the lower atmosphere. For regions with a strong causal relationship between SM and ET, this coupling can significantly affect terrestrial water, energy, and biochemical cycles in a changing climate.

Land-Atmosphere Interaction



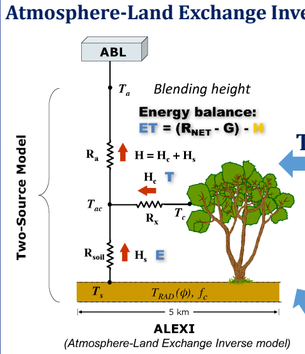


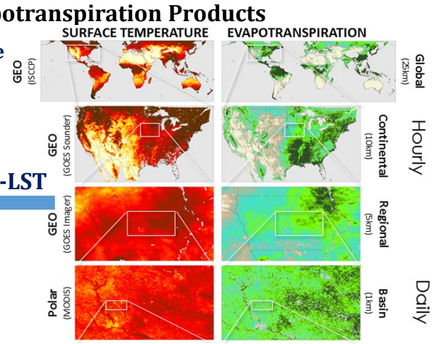
Multi-Platform Satellite-based Estimates of SM/ET Coupling → **Benchmark** → Performance of Land Surface Models

Materials

❖ **Remote Sensing-based Evapotranspiration Products**

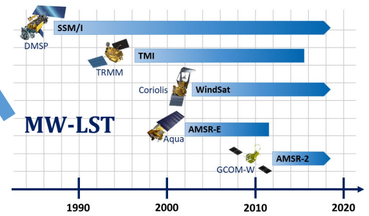
Atmosphere-Land Exchange Inverse





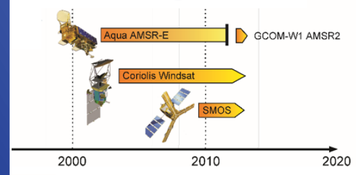
Key Inputs:

- Land Surface Temperature
- Leaf Area Index
- Meteorological Conditions
- Land Surface Characteristics

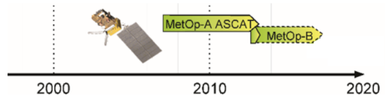


❖ **Remote Sensing-based Soil Moisture Products**

ESA CCI Merged Soil Moisture



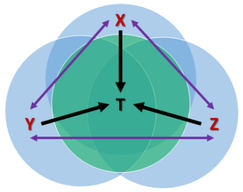
MetOp A/B ASCAT Soil Water Index



Methodology

❖ **Triple Collocation-based Coupling Strength Metric**

X	Passive Microwave		X	ALEXI TIR-LST
Y	Active Microwave		Y	ALEXI MW-LST
Z	Land Surface Model		Z	Land Surface Model



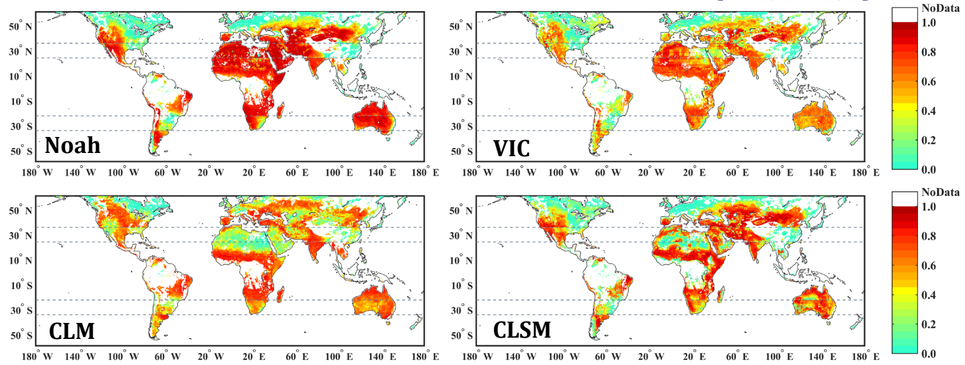
→ Linear Model and Error Orthogonality
→ Mutual Random Error Independency

Soil Moisture ⟷ Evapotranspiration: Spearman Rank Coefficient of Determination

$$R^2[SM_{True}, ET_{True}]_{X,X} \equiv \frac{Cov[SM_X, ET_X]^2 Cov[SM_Y, SM_Z] Cov[ET_Y, ET_Z]}{Cov[SM_X, SM_Y] Cov[SM_X, SM_Z] Cov[ET_X, ET_Y] Cov[ET_X, ET_Z]}$$

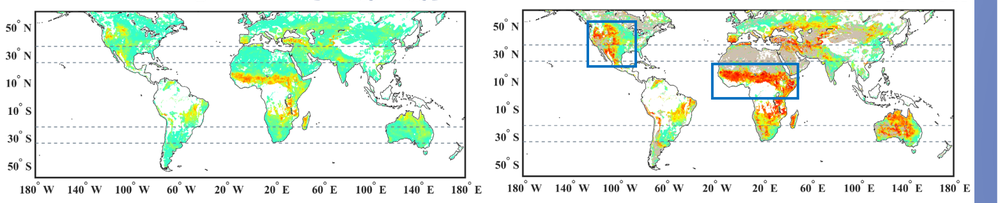
Results and Discussion

➢ **Global Land Data Assimilation System Land Surface Models** $R^2[SM_{LSM}ET_{LSM}]$



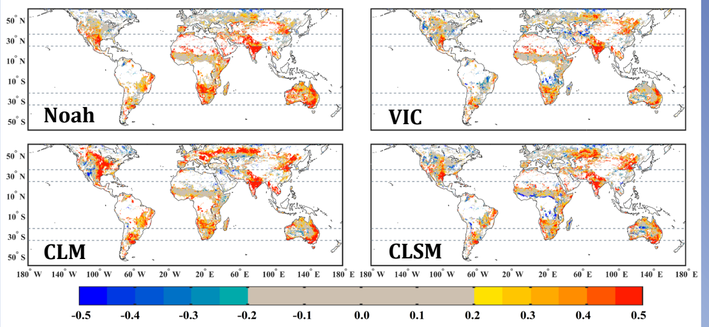
- Due to variations in the processes and parameterization schemes embedded in LSMs, different models exhibit large discrepancies in the degree of direct SM/ET coupling they predict with distinct magnitudes and spatial patterns in coupling strength.

➢ **Remote Sensing-based** $R^2[SM_{RS}ET_{RS}]$ ➢ **Our Triple Collocation-based** $R^2[SM_{TC}ET_{TC}]$



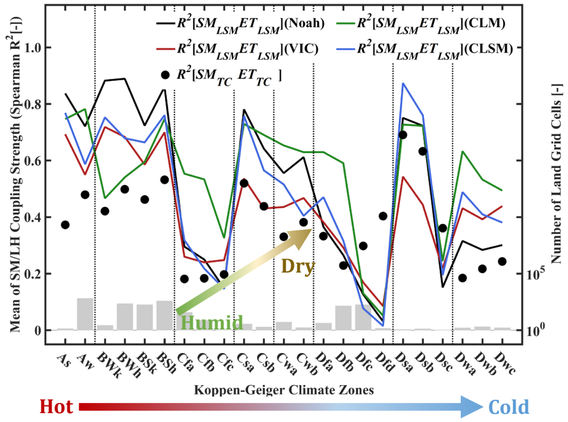
- The SM/ET coupling strength estimates sampled from remote sensing data are generally smaller, as compared to the triple collocation-based estimates.
- The TC-based approach corrects for the impact of random errors in observations and provides an unbiased estimate that is unaffected by either noise in the RS retrievals or systematic errors in LSM estimates .

➢ **Biases in LSMs with Regard to TC-based Estimates**



- Different LSMs demonstrate distinct spatial patterns of over-/under-coupling relative to our TC baseline.
- Noah appears to over-predict SM/LH coupling strength (relative to TC) over arid and low-vegetated zones

➢ **Climate Zone Analysis**



- Although LSM- and TC-based coupling estimates differ in exact absolute values, the general trends with regard to different climate zones are consistent.

Conclusions

- Quasi-global maps of unbiased SM/LH coupling strength estimates are obtained via integrating multi-platform satellite data through triple collocation;
- RS-based coupling strength estimates are prone to large negative biases and thus insufficient for directly benchmarking the true SM/LH coupling relationship;
- Regions with strong SM/LH coupling are found over western Northern America, the Sahel, Central Asia and Australia.

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