# Benchmarking Improvements in Global Agricultural Drought Monitoring using Soil Moisture Modeling and Remote Sensing Tools

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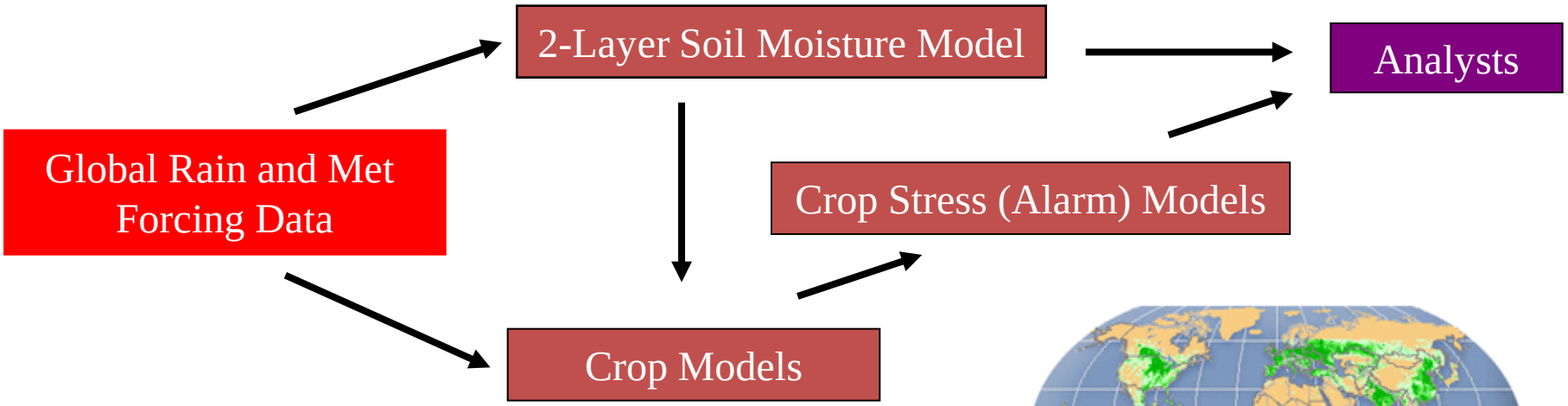
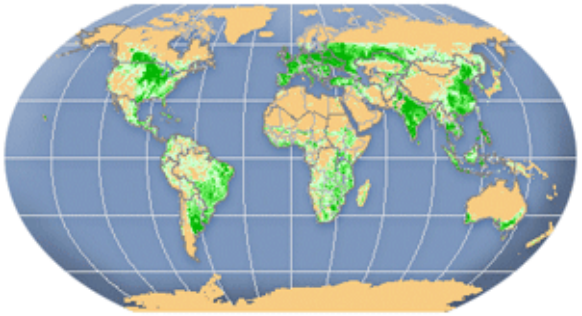
# Baseline USDA FAS Treatment of Soil Moisture

**Goal:** Use global soil moisture products (among many other things) to forecast variations in international agricultural productivity and yield.

**Baseline Approach:** Global application of a (simple) soil water balance model.

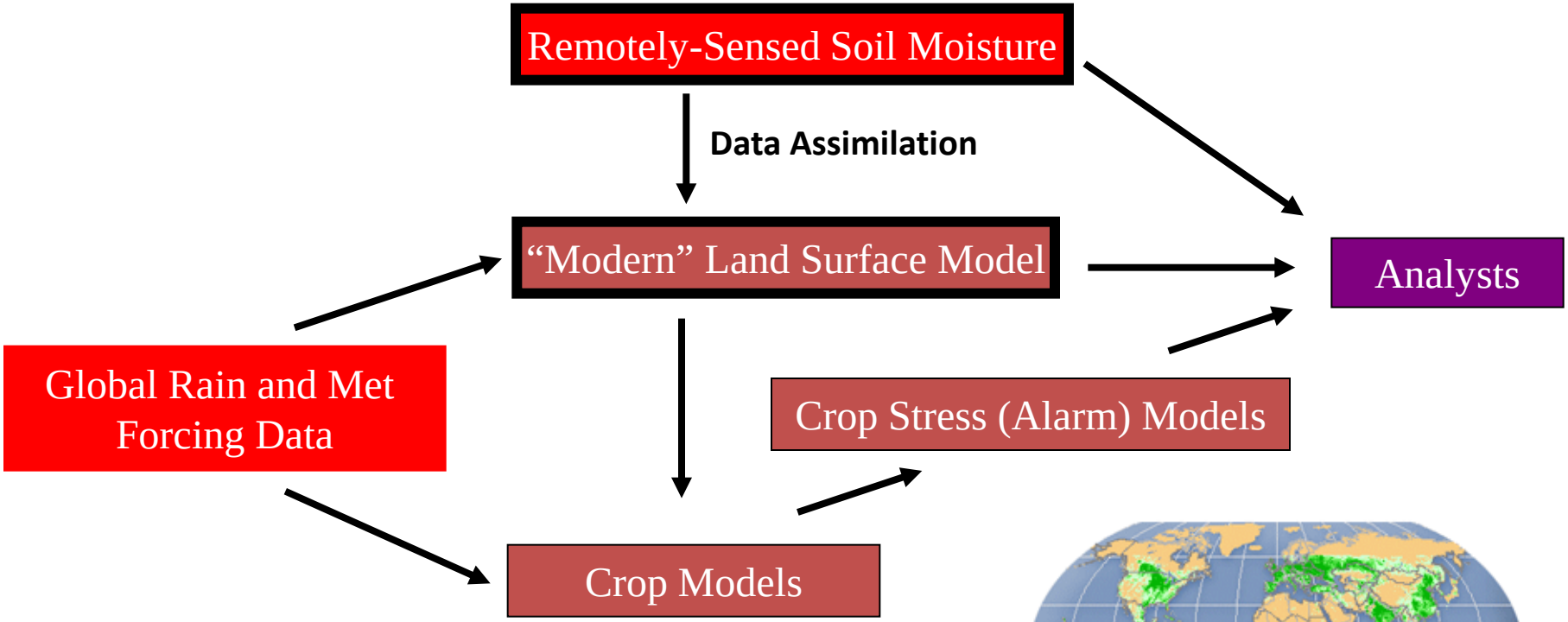


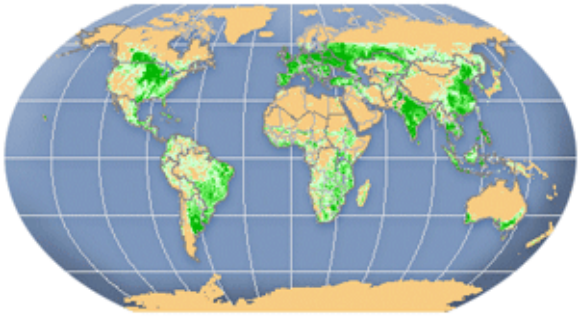



# Modifications Made by Project

What is the added value of integrating remotely-sensed soil moisture information?

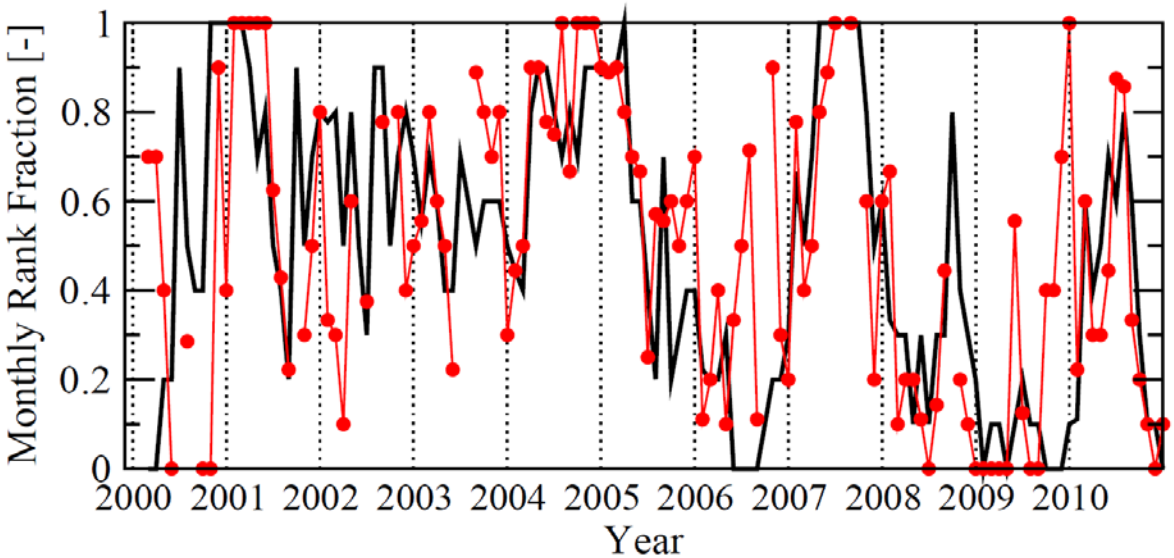
What is the added value of integrated more complex soil moisture models?



# How do We Evaluate These Modifications?

1) Obtain a multi-year, monthly, 0.25° root-zone soil moisture (SM) product.
2) Obtain a multi-year, monthly, 0.25° vegetation indices (VI) product (MYD13C2)
3) Sort both by month-of-year and rank across all years of the multi-year data set.
(e.g., count all June's in 2000-2010 that are wetter than June 2005).
4) Calculate the cross-correlation of SM/VI ranks.




For a 0.25° OK box:
Soil Moisture is black
NDVI is red.

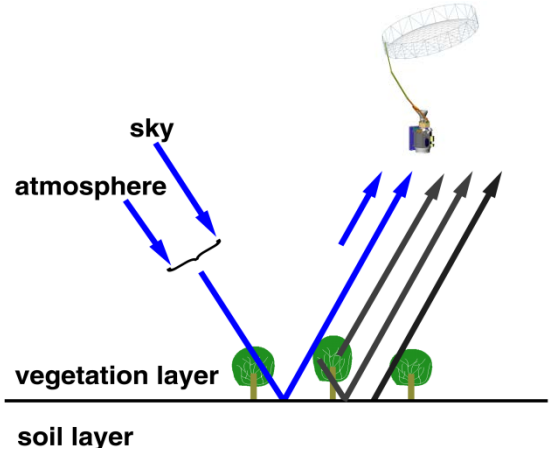
Degree of cross-correlation depends on:

1) Climate (water versus energy limited growth conditions).
2) Accuracy of the VI product.
3) Accuracy of the SM product [*Peled et al.,* 2010].

Proposed modifications:

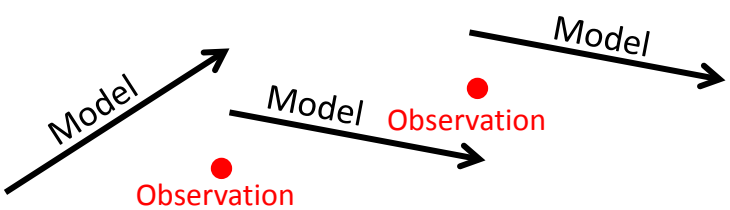
- Assimilate satellite-based surface soil moisture products into the existing USDA FAS model (2-layer Palmer).
- Apply a more complex land surface model.

Soil Moisture Remote Sensing:




- LPRM AMSR-E soil moisture product
- Passive micro., C/X-band, ~40-km resolution
- Descending orbits only, once every 2-3 days
- July 2002 to December 2010
- 0-5 cm surface soil moisture

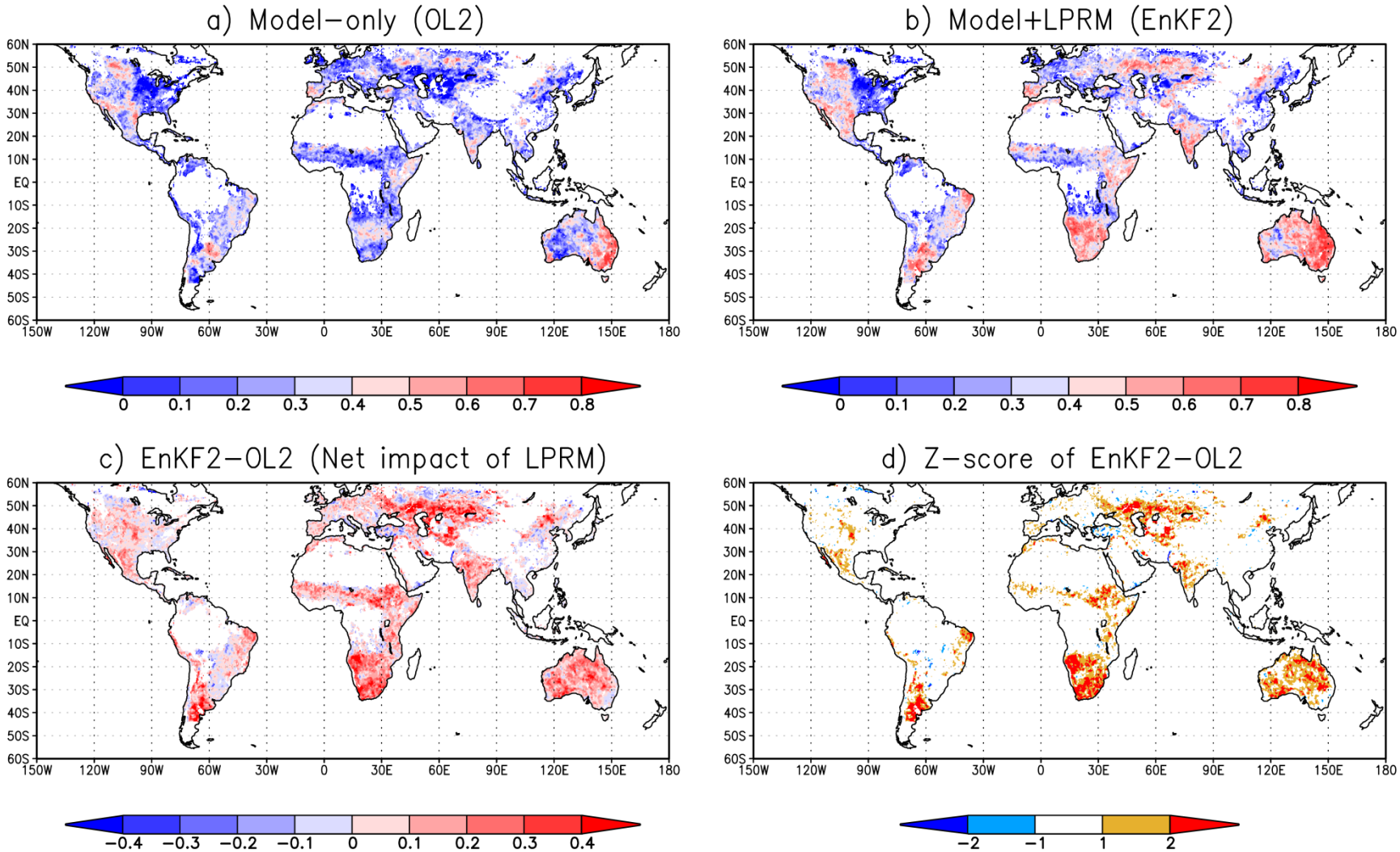
Soil Moisture Data Assimilation:




- 30-member Ensemble Kalman filter (EnKF)
- 2-layer Palmer Model
- Use EnKF to update root-zone
- Obs. error defined by climatological NDVI
- 0.25° analysis grid

# 2002 – 2010 Global Rank Correlations for Model and Data Assimilation

***Rank correlation between moisture for month i versus NDVI for month i+1***



# 2002 to 2010 Seasonality Impacts

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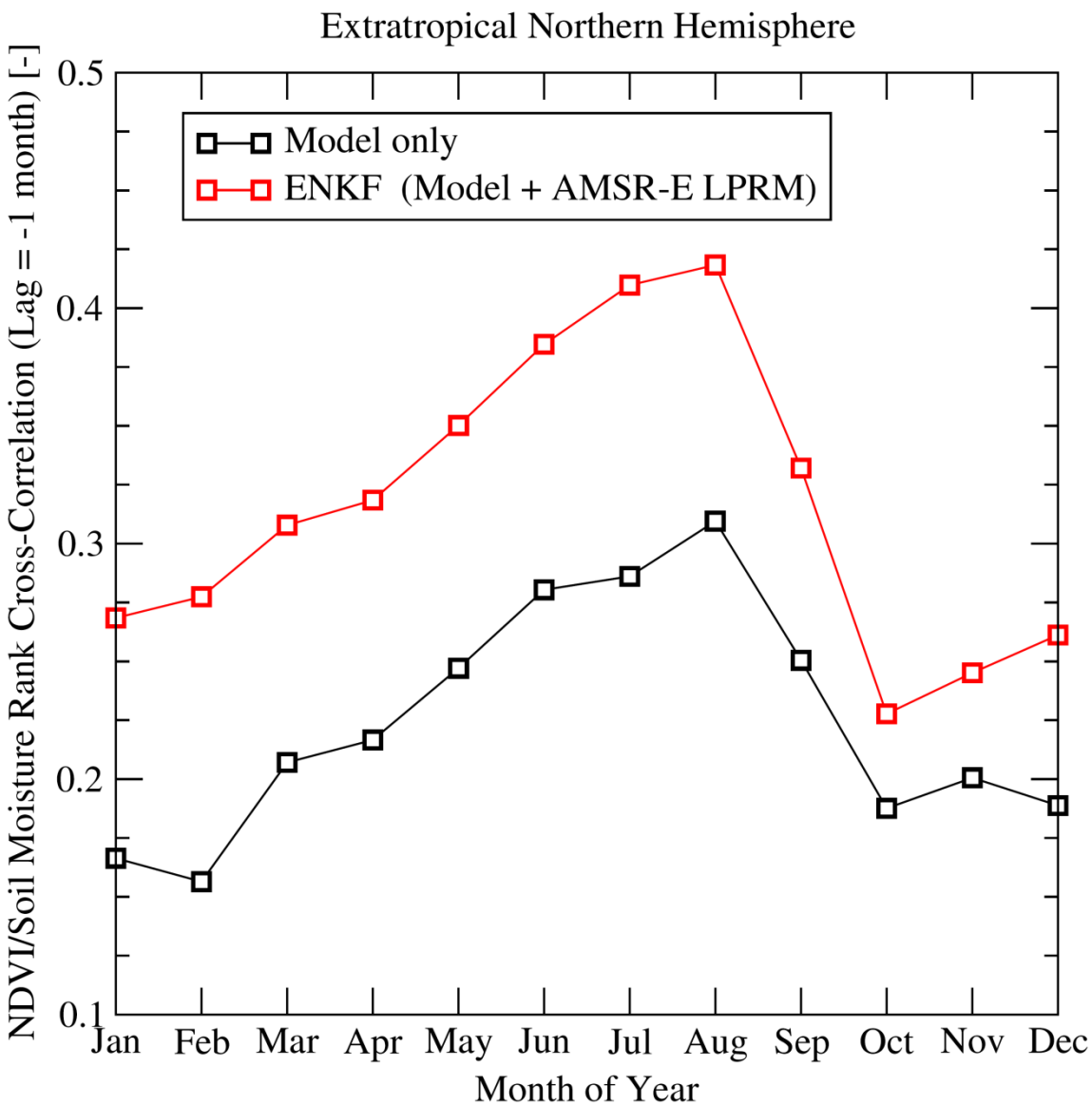

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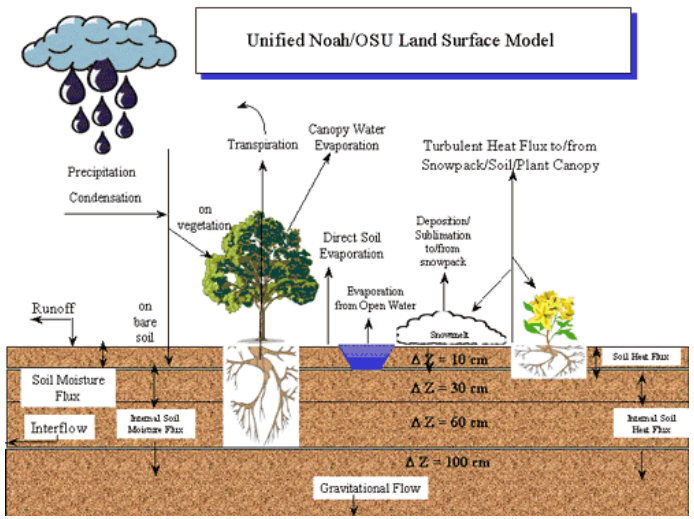



$$SM(i) = \gamma\, SM(i\text{-}1) + P(i)$$

"Modern" Land Surface Models (Noah, CLM2.0, CLSM):

1) ~10 states (profile soil moisture, snow and soil temperature)
2) ~10 dynamic inputs (precipitation, radiation and met.dat)
3) ~100 parameters (describing soil and vegetation)
4) ~10,000 lines of code

**(Global, 0.25° implementation using the NASA LIS modeling system)**

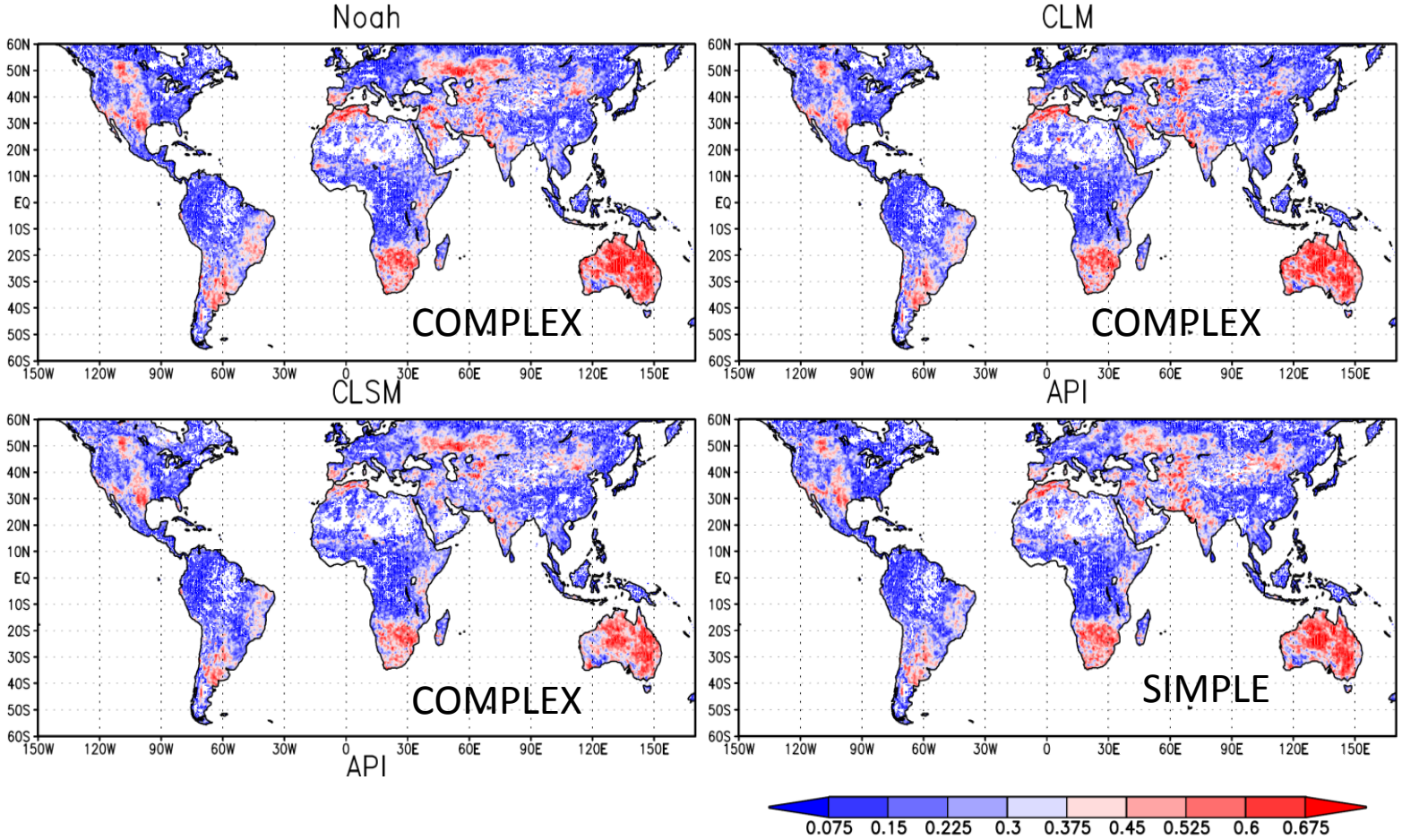
The Antecedent Precipitation Index (API):

1) 1 state
2) 1 dynamic input
3) 1 parameter
4) 1 line of code

No radiation balance, no vertical soil moisture physics, no energy balance, and no snow model.

# Global Rank Correlations for Various Models

***Rank correlation between moisture for month i versus NDVI for month i+1***



## Project Status:

• Initial benchmarking analysis suggests more value in assimilating remotely-sensed soil moisture data than increasing land surface model complexity (two papers accepted on topic).

**Designated primary delivery:** A global root-zone soil moisture product derived from the assimilation of remotely-sensed surface soil moisture imagery in the existing USDA FAS 2-layer Palmer Model (~3-day latency).

• Delivery dates to 2008 (based on NSIDC AMSR-E soil moisture retrievals).

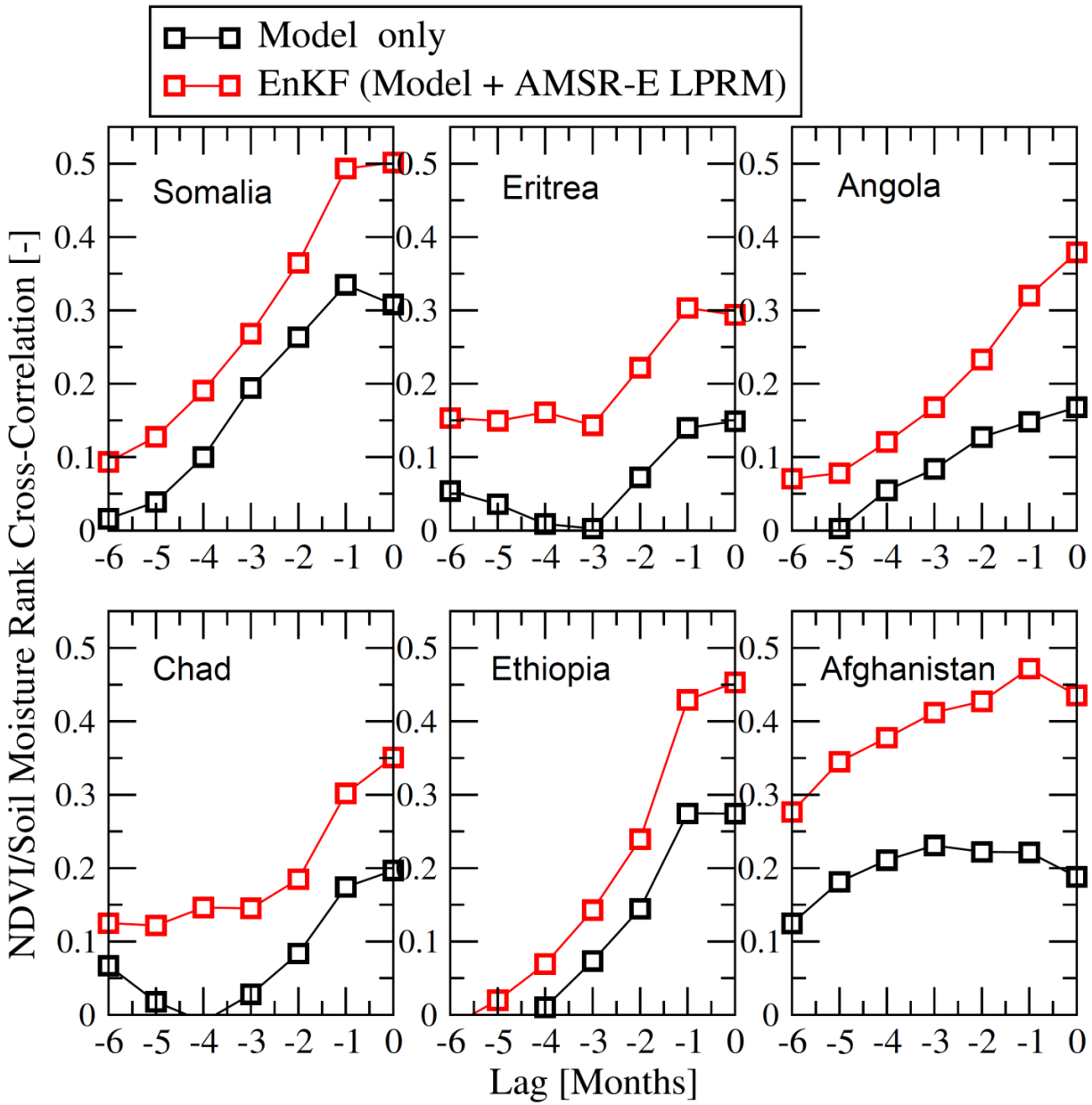
• In 2010, completed evaluation of product and found no added value. Switched to LPRM AMSR-E soil moisture retrievals (in collaboration with Bill Teng) in Summer 2011.

• Delivery was interrupted by October 2011 failure of AMSR-E.

• Re-established delivery in Spring 2012 (based on ESA SMOS surface soil moisture retrievals)…looking ahead to SMAP.

Thank you…..questions?

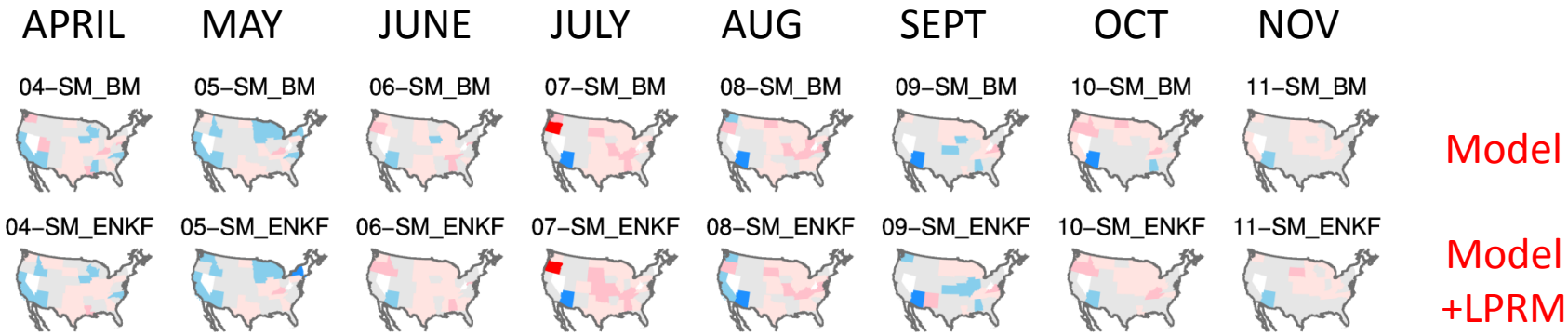
# 2002-2010 Performance in Data-Poor Regions



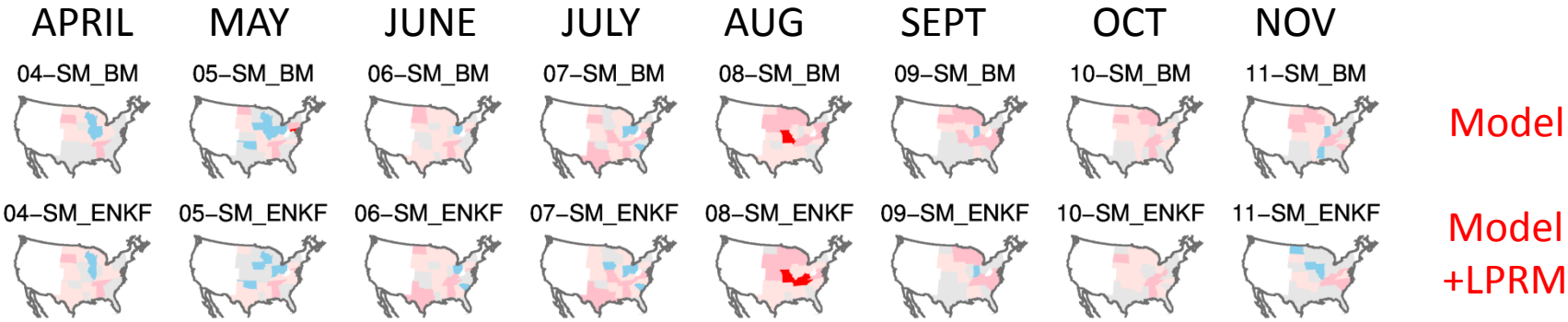

6 of the 10 most "food insecure" countries in 2011.

# Ranked SM/End-of-Season Yield Correlations

## CORN (2002 to 2010)




## SOYBEANS (2002 to 2010)




Rank Correlation