Enhancing agricultural productivity forecasting using remotely-sensed surface soil moisture retrievals

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- Monthly global production forecasts (with 1-3 month lead time) for commodity crops.

- Vital for economic competitiveness, national security and food security applications.

- Utilizes a wide-range of satellite data sources, input databases, climate data, crop models, and data extraction routines to arrive at yield and area estimates.

- Characterizing the extent and impact of agricultural drought (i.e. root-zone soil moisture limitations) is critical.

- NASA project/ESA SMOS data grant: Quantifying enhancements in forecasting skill associated with the assimilation of remotely-sensed surface soil moisture [Key general question for all applications!].
Evaluation using MODIS EVI products

1) Monthly root-zone soil moisture anomalies (relative to climatology) calculated from a water balance model ("Model").

2) Monthly root-zone soil moisture anomalies calculated by assimilating remotely-sensed surface soil moisture retrievals into the model ("Model + AMSR-E").

3) Monthly VIS/NIR vegetation indices (i.e. EVI or NDVI) anomaly products ("EVI").

- Evaluate added value based on changes in the lagged-correlation between root-zone soil moisture and EVI anomalies.
- Requires independence between soil moisture retrievals and VIS/NIR vegetation indices.
Model, remote sensing and data assimilation approach

Soil Water Model:
• 0.25-degree, 2-Layer Modified Palmer model forced with AFWA model forcing.
• AFWA merged WMO precipitation data with TRMM-based precipitation products.

Remote Sensing:
• 0.25-degree, AMSR-E LPRM X- and C-band merged product (descending only).
• Consider both LRPM soil moisture and vegetation opacity retrievals.
• 0.25-degree MODIS MYD13C2 30-day EVI monthly anomalies.

Data Assimilation:
• 30-member Ensemble Kalman filter (EnKF).
• Model uncertainty \( Q \) is parameterized as function of average distance from nearest WMO station.
• Retrieval uncertainty \( R \) is parameterized with vegetation type.
EVI anomaly cross-correlation with soil moisture and canopy opacity

Quasi-global averaging:
- July 2002 to December 2010
- 60° S to 60° N
- Barren and forested areas removed.
- Monthly daily max. temp. > 5° C
- LPRM snow cover mask

No data assimilation…yet

LPRM soil moisture provides the most forecasting information
Soil moisture DA impact on lag = -1 month correlation

Water Balance Model Only

[Map showing soil moisture impact with a color scale ranging from 0 to 0.8]
Soil moisture DA impact on lag = -1 month correlation

EnKF (Water Balance Model + LPRM AMSR-E)
Soil moisture DA impact on lag = -1 month correlation

EnKF – Water Balance Model (Net Impact of LPRM AMSR-E)
Variation of added skill between “data-rich” and “data-poor” areas

- United States
- France
- Spain

“Data-rich” countries

- Afghanistan
- Somalia
- Ethiopia

“Data-poor” and food-insecure countries
Transition to SMOS Data

• Swap out 2002 to 2010 AMSR-E LPRM soil moisture and replace with 2010 to 2011 SMOS L2 soil moisture.

• Data assimilation procedures require a stable seasonal climatology in order to transform model background and observations into the same climatology (and to calculate anomalies).

• 20 months is too short a time period to calculate a climatology for SMOS L2 soil moisture products.

• Tried to get around this by looking at spatial correlations for “year over year” changes in soil moisture and EVI.
Transition to SMOS data - Year over Year Differences

(June 2011 soil moisture minus June 2010 soil moisture)

Examine Spatial Correlation

(July 2011 EVI minus July 2010 EVI)
Transition to SMOS data - Year over Year Differences

Quasi-global averaging:
- July 2002 to December 2010
- 60º S to 60º N
- Barren and forested areas removed.
- Monthly daily max. temp. > 5º C
- LPRM snow cover mask
- Union of areas with both AMSRE and SMOS retrievals.

• Evaluation places a premium on retrieval stability.
• Can be affected by use of NIR/VIS in soil moisture retrieval. Need to evaluate for SMOS.
Conclusions

1) Cross-correlation of lagged soil moisture/EVI anomalies is proposed as an appropriate metric for evaluation of soil moisture retrieval products for vegetation forecasting applications.

2) The assimilation of surface soil moisture retrievals significantly improves the utility of root-zone soil moisture estimates for vegetation condition/productivity forecasting.

3) Preliminary evaluations with SMOS data is positive but not yet matching skill of LPRM AMSR-E retrievals.

4) More conclusive comparisons must avoid penalizing SMOS for a relatively short historical data length.

Thank you....