Assimilation of Satellite-Based Soil Moisture into the USDA Global Crop Production Decision Support System

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1. OBJECTIVES

1) Systematically assimilate the AMSR-E soil moisture data product into the USDA Crop Condition Data Retrieval and Evaluation (CADRE) Data Base Management System (DBMS) 2-layer water balance model

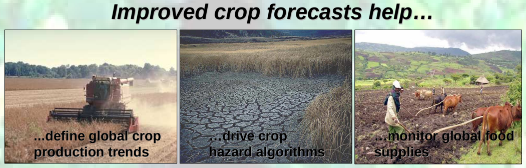
2) Provide online support of these data products for USDA-FAS CADRE DBMS

3) Evaluate the benefits of the integrated approach

2. MOTIVATION

The USDA Foreign Agricultural Service (FAS) provides information about important crops around the world. FAS crop estimates allow crucial assessment of U.S. and Global agriculture, trade policy, and food aid. The accuracy of global crop estimates are dependent on the coverage, accuracy and consistency of the data sources used, particularly soil moisture, which is a fundamental variable for the crop calendar (growth stage) and crop stress (alarm) models. Presently, soil moisture estimates being used by PECAD for crop growth are derived from spatially and temporally interpolated estimates of precipitation observations from the US Air Force Weather Agency (AFWA) and World Meteorological Organization (WMO). The addition of soil moisture observations from AMSR-E into the USDA PECAD soil moisture model is envisaged to provide soil moisture observations at greater temporal coverage and over larger spatial domains than the currently applied ground-based networks and error-prone precipitation data.

Improved crop forecasts help…



3. TWO-LAYER MODEL

PECAD utilizes a modification of the Palmer two-layer soil moisture model to calculate surface and subsurface soil moisture content from daily precipitation and temperature records. Daily potential evapotranspiration (PET) is computed from station latitude, longitude, elevation and daily temperature extremes. Moisture loss from the soil is determined by initial moisture content, PET, and soil water-holding capacity. Daily temperature and precipitation observations are taken from weather observations provided by the Air Force Weather Agency (AFWA) and World Meteorological Organization (WMO).

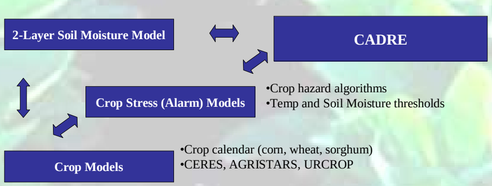


Figure 1. Schematic of the PECAD soil moisture model and decision support system

4. ADVANCED MICROWAVE SCANNING RADIOMETER

Principal to this study is the NASA EOS Advanced Microwave Scanning Radiometer (AMSR-E), which was launched in 2002 aboard the National Aeronautics and Space Administration (NASA) Aqua satellite. AMSR-E has a five year heritage of daily global soil moisture product with instrument characteristics shown in Figure 2. Our approach uses the the Level-3 product is a gridded data product at global cylindrical 25 km Equal-Area Scalable Earth Grid (EASE-Grid) cell spacing.

Center Frequencies (GHz)	6.925	10.65	18.7	23.8	36.5	89
Bandwidth (MHz)	350	100	200	400	1000	3000
Beamwidth (degrees)	2.2	1.4	0.8	0.9	0.4	0.18
Incidence Angle (degrees)	55	55	55	55	55	55
Mean Spatial Resolution (km)	56	38	21	24	12	5.4

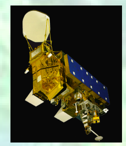


Figure 2. AMSR-E has provided a daily global soil moisture product since 2002. These soil moisture estimates are comparable to the first layer soil moisture used by PECAD.

5. ASSIMILATION METHOD

A retrospective analysis of archived AMSR-E and PECAD datasets was performed and a cumulative distribution function (CDF) matching scheme was followed to produce a transformed AMSR-E dataset comparable to the operational PECAD climatology.

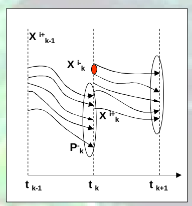


Figure 3. EnKF Schematic

The climatologically rescaled AMSR-E data were applied to an Ensemble Kalman Filter (EnKF) using sequential observations of AMSR-E, AFWA, and WMO agrometeorological input data (Figures 3,4). The EnKF generates an ensemble of randomly generated model trajectories from conditional error/covariance statistics *P*. For each time step *k*, an EnKF state estimate *x* is given by the mean of the ensemble members.

Internal filter diagnostics such as filter innovations and ensemble covariance enable calibration of the relative magnitudes of observation and model uncertainty which are essential for optimal filter performance and applied globally (Figure 5).

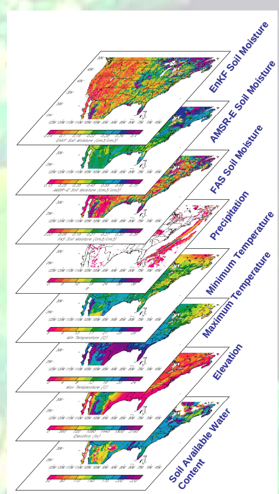


Figure 4. Model parameters and variables

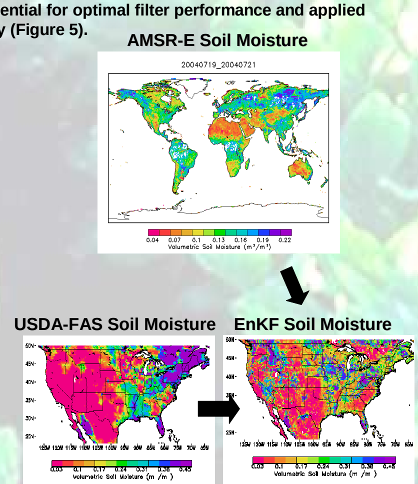


Figure 5. Three day composite of each product. Note the improved spatial heterogeneity of the EnKF product over the original USDA-FAS product

6. LIS-NOAH LAND SURFACE MODEL

With the development of the Ensemble Kalman Filter (EnKF) data assimilation capability of NASA's Land Information System (LIS), the AMSR-E soil moisture data product can be systematically assimilated into the Noah land surface model (LSM) to produce analyzed soil moisture data sets of surface layer, root-zone, and deeper soil layers. The Noah LSM with LIS could utilize the best available precipitation and other atmospheric observations, thus the Noah LSM simulated soil moisture could be more reliable than the output from the simpler Palmer water balance model currently implemented in FAS. EnKF data assimilation in LIS takes advantages of both Noah LSM simulations and microwave satellite soil moisture observations and thus is expected to produce more consistent and accurate estimates of root zone soil moisture, which in turn helps crop forecasts.

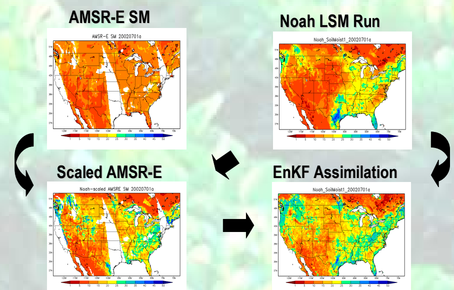


Figure 6. Application of NASA's Land Information System

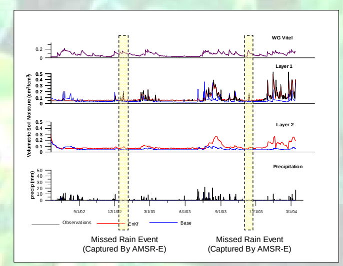


Figure 7. Time series over Walnut Gulch, AZ. The benefit of the EnKF is demonstrated here by the precipitation events that were missed by the open loop (green) being observed in both layers of the EnKF run (red).

7. CONCLUSIONS

1) Integration of soil moisture observations from AMSR-E into the current USDA PECAD soil moisture model show improved estimates of soil moisture, particularly in data-poor regions.

2) An operational quasi-global-scale AMSR-E integrated soil moisture product is being delivered to the PECAD CADRE. Evaluation of the product and improvements to the filter design are underway.

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