TOWARDS A BETTER MONITORING OF SOIL MOISTURE USING A COMBINATION OF ESTIMATES FROM PASSIVE MICROWAVE AND THERMAL OBSERVATIONS

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ABSTRACT

Soil moisture is a key variable in hydrological and meteorological processes. It exhibits significant temporal and spatial variation. Therefore, the use of satellite imagery to monitor its variability is crucial. The main objective of this work is to implement a multi-satellite approach which combines soil moisture estimates from passive microwave and thermal observations to improve the monitoring of soil wetness on a continental scale. Soil moisture estimates are obtained from passive microwave data from the AMSR-E NASA product and from thermal and near infrared observations using the ALEXI model. Ultimately, a statistical combination of these two products would overcome their individual limitations, allowing for better monitoring of soil moisture. The main limitation of passive microwave based products is their coarse spatial resolution. Their main advantage however, is their capability to penetrate clouds. On the other hand, the main advantage of the ALEXI based product is its higher spatial resolution and deeper sampling into the root zone. Clouds blockage is its main limitation. The prospective product, result of the combination, would have a better spatial resolution than the passive microwave based product and a better temporal coverage than the ALEXI based product. Several locations with different land cover conditions were chosen to compare and analyze the difference between the two products. These areas are located in Washington State, California, Texas, Alabama, Florida and New York. The Atmosphere-Land Exchange (ALEXI) model mainly uses GOES data to calculate soil moisture in clear sky days on a continental scale. On cloudy days, when visual imagery is affected by clouds, a gap filling technique is adopted to continue inferring soil moisture. A preliminary visualization of the soil moisture products from ALEXI and AMSR-E has been conducted including daily evaluations for the different combinations of data in different regions. A reasonable agreement has been noticed between the two products. The consistency between the two products suggests that they can be combined for better monitoring of soil wetness.

Key Words: *ALEXI, soil moisture, AMSR-E, evapotranspiration, passive microwave*

METHODOLOGY

The proposed methodology makes use of two soil moisture products for an improved monitoring of soil moisture in the U.S. The two distinct products used in this study are based on two different types of observations. The first is the NASA AMSR-E soil moisture product obtained from passive microwave observation[D]. The second product is obtained from the Atmosphere-Land Exchange Inverse (ALEXI) model, which makes use of observations in the thermal infrared channels[A]. Further details about these products are presented in the following sections.

Passive Microwave Data: AMSR-E

The Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E) is a passive microwave instrument onboard NASA Earth Observing System (EOS) Aqua satellite. AMSR-E measures brightness temperatures at the following frequencies 6.9, 10.7, 19, 37 and 89 GHz and many products are derived from these observations. In this study, we are particularly interested in the soil moisture product because soil moisture is a key variable in modeling surface hydrology and atmospheric behaviors[D].

In this project, we use the gridded Level-3 land surface product (AE_Land3) of the EOS AMSR-E data made available by the National Snow and Ice Data Center (NSIDC). These data includes surface soil moisture, vegetation/roughness water content interpretive information, brightness temperatures and quality control variables. The data are available twice a day from a descending (night) and ascending (day) overpasses. Descending overpasses were chosen in this study. Data are stored in HDF-EOS format and re-sampled into global cylindrical 25 km Equal-Area Scalable Earth Grid (EASE-Grid) cell spacing. AMSR-E data and products are available from 19 June 2002 to the present. However, at this stage of the project, only images acquired in July of 2003 have been used to test the proposed approach (Figure 1).

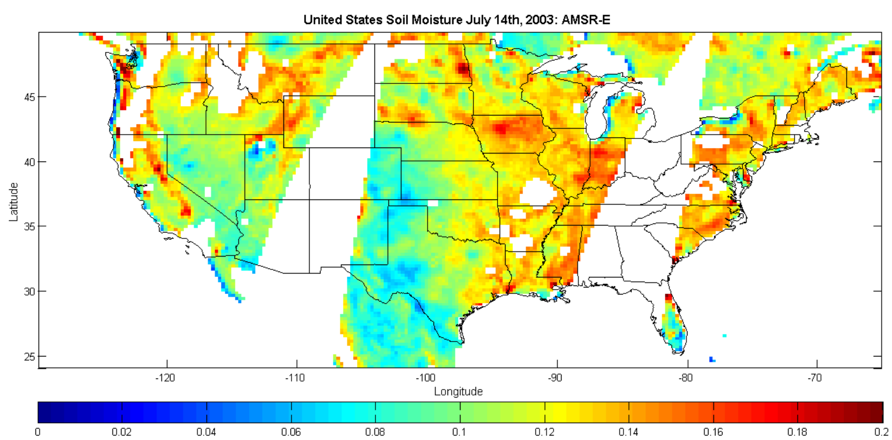

Figure 1: An example of a NASA AMSR-E soil moisture map for July 14th, 2010; less cloudy day of the month.

ALEXI Model

The ALEXI model is a two-source land surface model that uses time changes in surface temperature, available from geostationary satellites, to retrieve daily information on evapotranspiration, surface moisture stress, and soil moisture in the root zone [A].

ALEXI models daily evapotranspiration and surface moisture stress over a 10-km resolution grid covering the continental United States[B]. ALEXI has a better resolution than passive microwave (25 km). However, ALEXI cannot calculate directly the evapotranspiration in cloudy days (Figure 2). Instead, it estimates soil moisture through the implementation of gap filling technique, assuming a systematic depletion of root zone and surface soil water as long as cloudy conditions persist. Our main goal is to improve the current gap filling technique through the use of inputs from the passive microwave based products, which are not sensitive to cloudy conditions. ALEXI depends on the vegetation cover for the evapotranspiration retrieval, making these calculations challenging when there is not enough vegetation cover. In these cases, ALEXI is estimated based on the evapotranspiration of the closest areas.

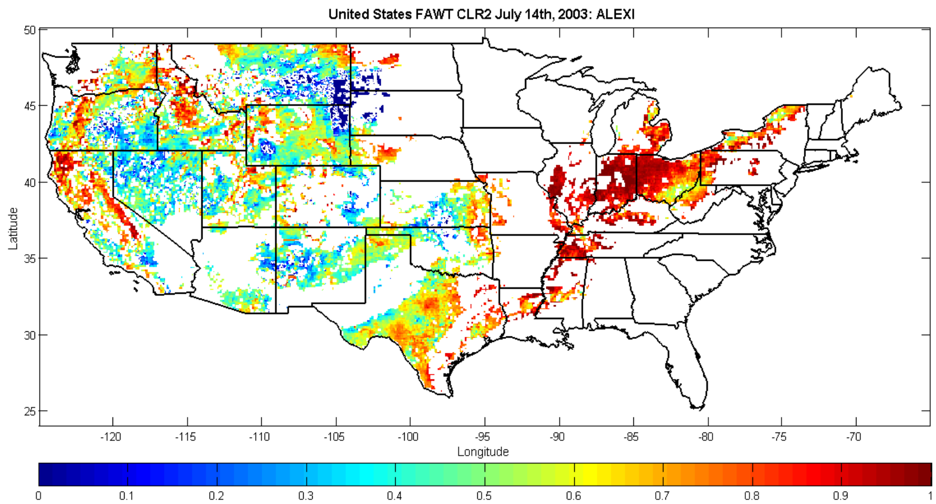

Figure 2: An example of an instantaneous ALEXI map showing the ratio of actual to potential ET, a proxy measurement of available soil water.

Combination of Soil Moisture Products

A cloud mask which was created using GOES observations[B] was used to identify cloudy scenes. Cloudy pixels in the ALEXI based soil moisture product were replaced with their corresponding pixels in the AMSR-E based products. AMSR-E soil moisture estimate were resampled to coincide with the higher spatial resolution of the ALEXI based product. Two new products were generated; the first is a daily combined soil moisture product based on one day estimates of soil moisture from ALEXI and AMSR-E. The second product is a monthly composite which includes cloud free estimates across the entire U.S.

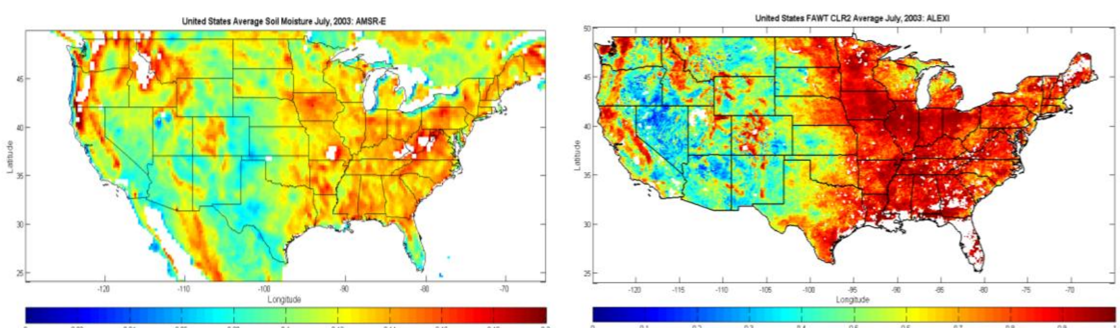

Figure 3: An example of the composites of a) AMSR-E showing soil moisture and b) ALEXI showing the fraction of total available water.

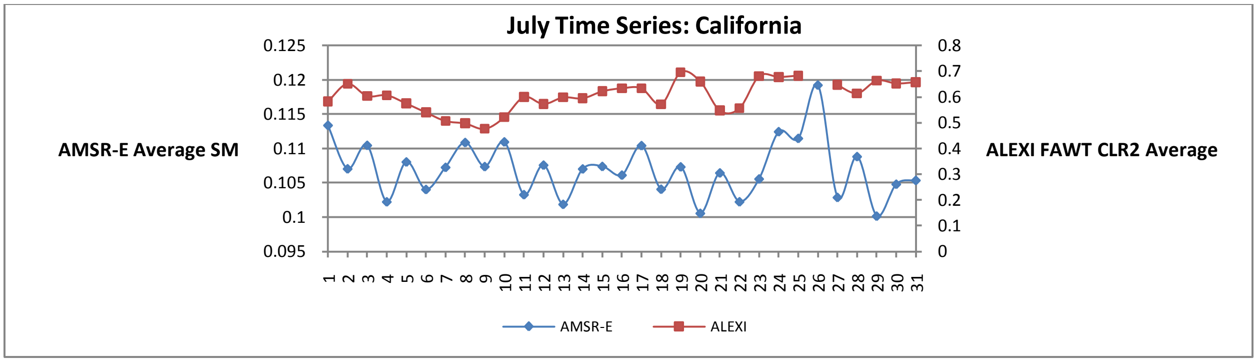

Figure 4: Daily comparison between AMSR-E and ALEXI average products through July 2003

CONCLUSION AND FUTURE WORK

The analysis made in this work aims to describe the contribution of incorporating AMSR-E soil moisture retrievals into the ALEXI model. The comparison between the two products reflects that soil moisture values from AMSR-E are in agreement with ALEXI based estimates, especially over the selected study areas in California, Florida and Texas. In the study areas of Washington and New York, the patterns are different. This means that further investigations are needed to accurately infer the potential of merging the two products for a better monitoring of soil moisture across the U.S.

As future work, we want to pursue the cloudy days filling in the ALEXI data with the AMSR-E over an extended time frame and analyze the consistency between the two precuts throughout the year..Bearing in mind that AMSR-E provides a relatively accurate estimate of soil moisture available under cloudy conditions, we expect that passive microwave data will increase the temporal coverage in the ALEXI mode. Also, we intend to include soil moisture retrievals over areas with dense vegetation cover where the sensitivity of the two products is affected. In addition, we would like to use other soil moisture products like SMOS (mission already operational) as well as future missions like SMAP and AQURIUS.

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