DATA ASSIMILATION APPROACH FOR MERGING OF SOIL TEMPERATURE OBSERVATIONS FROM MULTIPLE SATELLITES

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1. INTRODUCTION

It is well known that microwave soil moisture retrieval algorithms must account for the physical temperature of the emitting surface. Solutions to this include: difference, or ratio indices; forecast model products; thermal infrared satellite observations; and high frequency passive microwave estimates. The availability of multifrequency observations in the same data stream has made the use of high frequency temperature estimates, specifically 37 GHz (Ka-band), an attractive option.

The two L-band soil moisture missions, Soil Moisture and Ocean Salinity (SMOS) and Soil Moisture Active Passive (SMAP), will not include a 37 GHz (Ka-band) microwave radiometer. Therefore, alternative algorithms and data sources must be utilized. This temperature estimate will need to closely match the spatial resolution and the overpass time these missions (between 6 and 7 am/pm local time). The current approach is to use the temperature output from numerical weather prediction (NWP) models. In a recent study, the accuracy of NWP analysis data was analyzed in terms of land surface temperature [1]. Of the sources considered, the Modern Era Retrospective-analysis for Research and Applications (MERRA), was found to have the best performance with an absolute accuracy of 2.0 K (RMS error) in the morning, with a bias removed error of 1.5 K.

The relationship between the error in soil temperature data and the requirements of the radiative transfer and soil moisture retrieval algorithm temperature requirements are assessed in [2]. For a single channel soil moisture retrieval, a 1.5 K error in temperature results in an error of up to 0.03 m^3m^{-3} in soil moisture (at the highest vegetation level within the SMAP requirements). Therefore, the level of accuracy of a single NWP temperature product is not likely to be high enough to achieve the stated goals of 0.04 m^3m^{-3} for the retrieved soil moisture products from SMAP and SMOS.

The goal of this study is to combine a single NWP soil temperature product with observations from multiple satellites in an attempt to increase the accuracy of the combined product to a level that is suitable with the SMAP mission requirements.

2. MATERIALS

All the data for this study were selected based on the limitations of a real world application for the SMAP soil moisture retrieval, which will require an estimate of soil temperature 24 hours after the observation time (t=~06:00). Initially NWP-like data from MERRA will be used, to be replaced by NWP data when available. It is expected that the NWP forecast data will be available with a delay of 6 hours. This means that at t+24, there will be analysis data for 00:00, 06:00, 12:00, 18:00, together with 3 hour forecast data for 03:00, 09:00, 15:00 and 21:00.

Microwave Ka-band observations are currently available from advanced microwave scanning radiometer on EOS (AMSR-E), the special sensor microwave and imager (SSM/I) and the TRMM microwave imager (TMI). The AMSR-E radiometer with a Ka-band radiometer (36.5 GHz) is on the Aqua satellite with a sun synchronous orbit that passes over the equator at 01:30 and 13:30 [3]. Preliminary AMSR-E brightness temperature data (AE_L2A) are available with a delay of ~24 hours. The SSM/I instrument includes a Ka-band radiometer (37 GHz) and is currently part of the DMSP F15 satellite with a sun synchronous orbit that passes over the equator at 08:40 and 20:40 hours [4]. SSM/I swath data are available with a delay of 2 days. The TMI brightness temperatures are available with a delay of 2 days [5].

For the analysis at t+24 hours the most recent satellite observation is likely to be the 01:00 hour descending overpass of AMSR-E, however, the data in the preceding two or three days will be available to adjust the daily mean and amplitude of the NWP temperature. This group of satellites is available for the recently launched SMOS satellite. For SMAP, projected to be launched in 2015, it is anticipated that versions of these instruments will continue in operation as part of GCOM-W [6], SSMIS and the global precipitation measurement mission (GPM).

The combined temperature product is validated at 6AM and 6PM local times for the year 2004 (or most recent possible), and against *in situ* data from the Oklahoma Mesonet (at 5 cm).

3. METHODS

The microwave Ka-band data are converted into land surface temperature according to [7]. Error in the NWP soil temperature time series (created by merging analysis and forecast data) will be modeled as a first-order autoregressive process and an ensemble Kalman smoother [8] will be applied to estimate the magnitude of 6 am and 6 pm NWP soil temperature errors based on recent satellite retrievals. Estimated error values can then be used to adaptively correct NWP soil temperature predictions prior to their use in soil moisture retrieval algorithms. In a later stage the smoother will be replaced by a filter to reflect the data availability at the time of the operational soil moisture analysis.

4. RESULTS AND CONCLUSIONS

An example of the filter results for a synthetic analysis is given in Figure 1. This example assumes a NWP temperature (T_{NWP}) with an RMS error of 2 K, and two Ka-band satellites with twice daily observations and an RMS error in derived temperature of 3 K (T_{amsr-e} and $T_{ssm/i}$). The resulting accuracy of the combined temperature (T_{comb}) is 1.4 K instead of the original 1.8 K, at 6 AM.

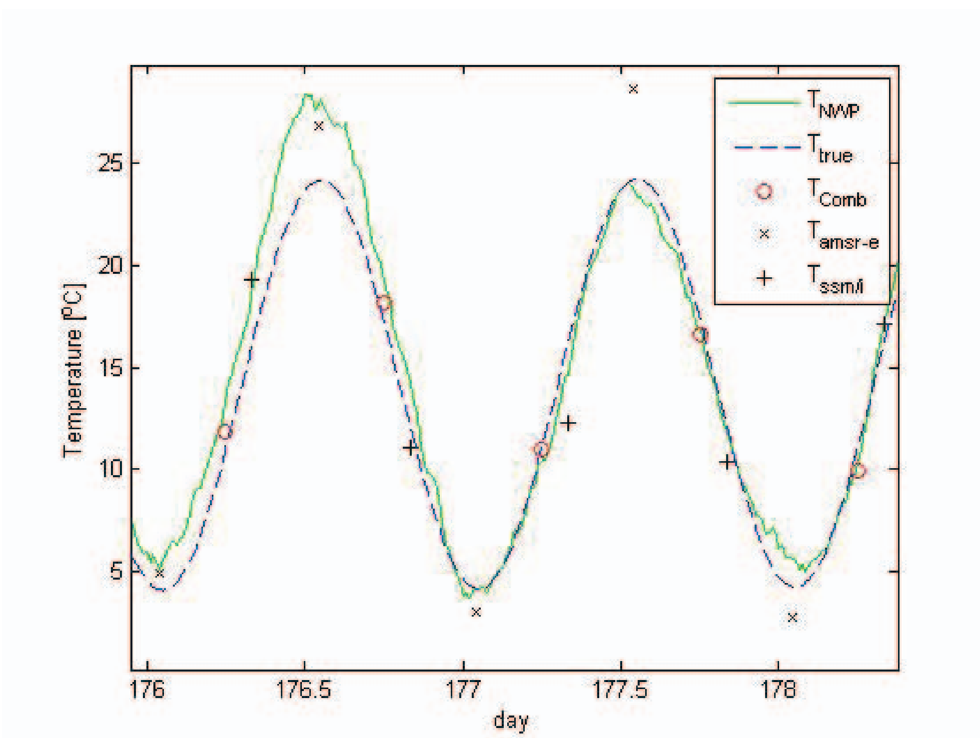

Fig 1. Example of Kalman filter results for a synthetic case.

Based on previous research into the accuracy of soil temperature products the effect of adding the Ka-band observations is expected to be largest in terms of adjusting the daily mean temperature and the amplitude of the daily temperature cycle. The resulting accuracy is expected to be in the range of 1-1.5 K, depending on vegetation density, accuracy of NWP temperature and availability of satellite observations.

5. REFERENCES

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