ASSIMILATION OF PASSIVE AND ACTIVE MICROWAVE SOIL MOISTURE RETRIEVALS

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1. INTRODUCTION

Root-zone soil moisture is an important control over the partition of land surface energy and moisture, and the assimilation of remotely sensed near-surface soil moisture has been shown to improve model profile soil moisture [1]. To date, efforts to assimilate remotely sensed near-surface soil moisture at large scales have focused on soil moisture derived from the passive microwave Advanced Microwave Scanning Radiometer (AMSR-E) and the active Advanced Scatterometer (ASCAT; together with its predecessor on the European Remote Sensing satellites (ERS)).

The assimilation of passive and active microwave soil moisture observations has not yet been directly compared, and so this study compares the impact of assimilating ASCAT and AMSR-E soil moisture data, both separately and together. Since the soil moisture retrieval skill from active and passive microwave data is thought to differ according to surface characteristics [2], the impact of each assimilation on the model soil moisture skill is assessed according to land cover type, by comparison to in situ soil moisture observations.

2. DATA AND METHODS

The assimilation experiments were conducted with NASA's Catchment land surface model [3], run at 25 km resolution over the evaluation sites, and forced with NASA's Modern-Era Retrospective analysis for Research and Applications (MERRA) [4]. As in [1], a 1-D EnKF with 12 ensemble members and a 3 hour assimilation cycle was used for the assimilation.

The ASCAT and AMSR-E soil moisture data were assimilated over the maximum available coincident data record, from January 2007 to May 2010. ASCAT soil moisture data from the Vienna University of Technology, relating to a surface layer of $\sim$1 cm depth and at 25km resolution, have been used here. For AMSR-E, soil moisture retrieved from X-band brightness temperatures by the Free University of Amsterdam [5] have been used. The X-band observations have a resolution of 38 km and relate to a surface layer depth of slightly less than 1 cm. Prior to the assimilation, the ASCAT and AMSR-E soil moisture data were carefully quality controlled, and then rescaled to the model soil moisture climatology by matching their cumulative distribution functions [6].

The impact of assimilating each data set has been evaluated using in situ soil moisture data from the United States Department of Agriculture's Soil Climate Analysis Network (SCAN) / Snowpack Telemetry (SNOTEL) [7] network in the contiguous US, and from the Murrumbidgee Soil Moisture Monitoring Network (available at www.oznet.org.au), operated by the University of Melbourne and Monash University in southeast Australia. There were 85 grid cells with sufficient in situ, ASCAT, and AMSR-E soil moisture data for use in this experiment; 66 grid cells in the SCAN/SNOTEL network and 19 in the Murrumbidgee network. The skill of a given soil moisture estimate has been measured using the anomaly correlation-coefficient (R) with the daily in situ soil moisture time series, with the anomalies defined as the difference of the data from their 31 day moving average for that day of year (with the moving average based on data from all years).

The results of the assimilation have been reported separately for each land cover type sampled by the in situ data, based on MODIS land cover classifications from Boston University [8]. Since dense vegetation is a major source of soil moisture errors at the microwave frequencies of ASCAT and AMSR-E, all moderately vegetated land cover classifications (with 10-60% trees or woody vegetation) have been combined into 'mixed cover'.

3. RESULTS

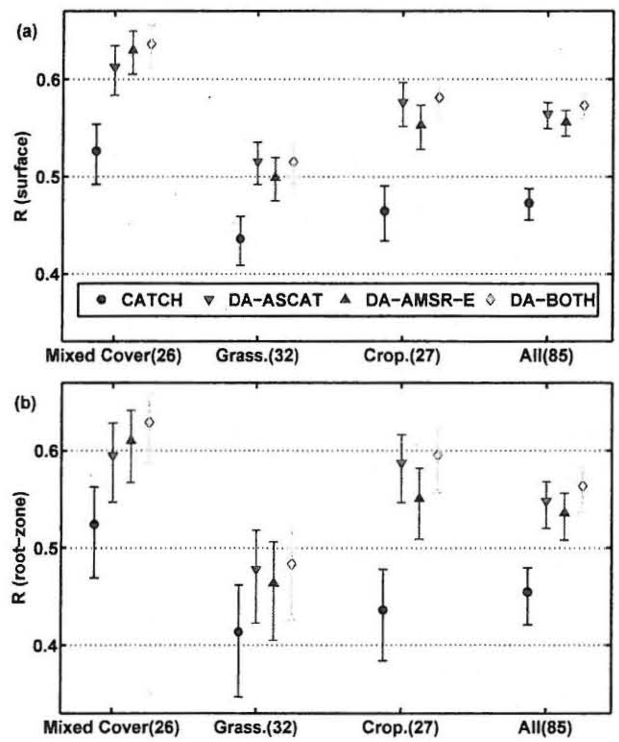

Fig. 1. Mean skill for (a) surface and (b) root-zone soil moisture from the (open-loop ensemble mean) Catchment model (CATCH), and the data assimilation (DA) of ASCAT, AMSR-E, and both, averaged across each land cover class, with 95% confidence intervals. The number of sites in each land cover type is given in the axis labels.

Figure 1 shows the estimated R values (anomaly-time series correlation-coefficient with in situ data) for the surface and root-zone soil moisture, averaged across the 85 in situ sites and across each land cover type, together with the 95% confidence intervals for the mean R. Results for the (open-loop ensemble mean) Catchment model with no assimilation, and for the assimilation of ASCAT, AMSR-E, and both, are plotted separately. Averaged across all 85 sites, the mean surface soil moisture skill was increased from 0.47 for the open-loop, to 0.56 by the assimilation of ASCAT or AMSR-E, and to 0.57 by the assimilation both. For the root-zone, the mean skill was increased from 0.45 for the open-loop, to 0.55 for the assimilation of ASCAT, 0.54 for the assimilation of AMSR-E, and 0.56 for the assimilation of both. In each case the mean skill increase from assimilating the satellite soil moisture data was statistically significant (at the 5% level).

For each land cover type, assimilating satellite soil moisture data improved the mean R, in most cases significantly. The single-sensor assimilation experiments (of ASCAT or AMSR-E) yielded very similar improvements in the mean R, while the combined assimilation (ASCAT and AMSR-E) generally matched, or slightly exceeded the mean R from the single-sensor assimilation experiments.

Prior to assimilation, the Catchment model had significantly higher skill over the more vegetated mixed cover class than over the grassland or cropland classes in Figure 1. The relatively low open-loop skill over the croplands is not surprising, given that Catchment does not account for cropping practices. In contrast, croplands are suited to soil moisture remote sensing and the observations performed well at these sites, and so the assimilation experiments significantly improved the mean R (by >0.1 in each case in Figure 1). Consequently the cropland skill after assimilation was much closer to that of the mixed cover, especially for the root-zone soil moisture.

While the assimilation did improve the mean R for the grasslands (and significantly in the surface layer), even after assimilation the mean grassland R for both soil layers was below that of the other land cover types (significantly in many cases). The mean R over the mixed cover sites was improved significantly in all cases except for root-zone soil moisture after ASCAT assimilation. Consequently, the highest mean assimilation skill was for the mixed cover.

4. CONCLUSIONS

In these experiments the mean skill for each land cover type was improved by assimilating either ASCAT and/or AMSR-E, with significant improvements for root-zone soil moisture over croplands and mixed cover (10-60% trees or wooded vegetation), and for surface soil moisture over croplands, grasslands, and mixed cover. At the frequencies observed by AMSR-E and ASCAT, dense vegetation limits the observation accuracy, and the improvements obtained over the moderately vegetated mixed cover sites are very encouraging.

The improvement in skill from assimilating ASCAT or AMSR-E was very similar when averaged over each land cover type. Following the recent malfunction of the AMSR-E instrument, applications currently assimilating AMSR-E should thus be able to switch to ASCAT data without loss of accuracy. In our experiments, assimilating both data sets consistently matched or exceeded the best results from the single-sensor assimilation experiments. Also, ASCAT soil moisture data are not available over complex terrain, such as the Rocky Mountains in the US. Consequently, for maximum accuracy and spatial coverage it is recommended that passive (AMSR-E or WindSat) and active (ASCAT) near-surface soil moisture be assimilated together if possible.

5. REFERENCES

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