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Error propagation from remotely-sensed surface soil moisture to root-zone through the exponential filter

Domenico De Santis and Daniela Biondi

Department of Informatics, Modelling, Electronics and System Engineering, University of Calabria, Arcavacata di Rende, Italy (d.desantis@dimes.unical.it)

Validation and uncertainty characterization of satellite-based soil moisture data constitute fundamental steps to support their suitability for a specific application. An estimate of the root-zone value is required in many of application fields where soil moisture plays a key role, and the exponential filter is widely used for this purpose, as the method involves only one parameter to obtain a profile soil water index (SWI) from remotely-sensed surface soil moisture (SSM) data. However, the uncertainty of SWI estimates has been poorly analysed. In this study, an error propagation (EP) approach is adapted to exponential filter and proposed to analytically compute SWI uncertainties. The EP equations are expressed in a practical recursive form and aim at estimating a SWI noise, implicitly taking into account both errors and availability of the input SSM data used for each SWI estimation.

The ASCAT surface soil moisture (SSM) dataset derived via the offline WARP processing chain, that provides SSM error estimates also computed by an EP approach, is employed to test the proposed EP scheme.

A preliminarily assessment of the computed uncertainties is carried out comparing satellite-derived SWI with root-zone in situ measurements, collected in 10 sites from different networks across Italy and available from ISMN (International Soil Moisture Network), and here used as reference datasets.

The capability of EP uncertainty estimates to detect potentially less reliable data in SWI time series, i.e. data that do not fit well in situ observations (although the observed deviations are not exclusively attributable to SWI random errors), is investigated.

Firstly, SWI time series were computed from SSM datasets, estimating the optimal parameter value that maximizes the correlation coefficient between in situ and satellite-based soil moisture observations; after linearly rescaling SWI with the mean and variance matching technique, the root-mean-square difference (RMSD) was calculated. Overall, the comparison between SWI and in situ measurements gives good results; the exponential filter generally confirmed a greater ability in capturing the seasonal soil moisture behaviour rather than short time-scale fluctuations. In parallel SWI uncertainties time series were estimated with the above mentioned EP approach.

By masking the more uncertain SWI values, performance metrics are recomputed to check how discarded data contribute to the overall agreement between the in situ and satellite-based root-zone soil moisture time series. The analysis shows a correspondence between the removing of more uncertain SWI values and the improving the observed performance metrics. Specifically, the EP uncertainty estimates assume high values at state transition, e.g. from dry to wet conditions, and thus the performance improvements can be explained by the removal of data that testify the limited skills of exponential filter in detecting short time-scale fluctuations. In this sense, the EP scheme succeeds in identifying SWI estimates that do not capture properly soil moisture state transition and deviate considerably from reference ground measurements.

Although requiring further research, the preliminary results suggest the utility of the proposed EP scheme in SWI evaluation, in the comprehension of the exponential filter shortcomings, and in providing simultaneous estimates of time-variant SWI uncertainty.