RECENT IMPROVEMENTS OF ESA'S CCI SOIL MOISTURE PRODUCT

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ABSTRACT

In June 2012 the first version of the Climate Change Initiative (CCI) Soil Moisture data set has been released. This ESA CCI Soil Moisture product is the first data set of this kind covering a period of more than 30 years. It is generated by combination of surface soil moisture retrievals from active and passive microwave space borne instruments. The algorithm for combining level 2 data sets from multiple sensors is based on various selected methods of resampling, scaling, ranking, and blending. The advantages of the harmonized and merged product are not only the increased spatial and temporal data availability but also the integration of active and passive remotely sensed surface soil moisture data together into one consistent long term climate data record. This paper lists important improvements of the product made since its first release and discusses relevant enhancements that will be included in future releases.

1. INTRODUCTION

The CCI Soil Moisture product combines level 2 radiometer-based products from SMMR (November 1978–August 1987), SSM/I (July 1987–2002), TMI (1998–2008), and AMSR-E (July 2002–2010) with scatterometer-based products from ERS-1/2 (July 1991–May 2006) and ASCAT (2007–2010). The homogenised and merged product presents surface soil moisture with a global coverage and a spatial resolution of 0.25 degree. The time period spans the entire period covered by the individual sensors, while the temporal resolution is 1 day with its reference time set to 0:00 UTC.

The quality of a consistent long term soil moisture dataset mainly relies on data availability. From 1978 to 1991 the dataset is filled with data from SMMR (1978-1987) and SSM/I (1987-1991). SMMR has a coarse spatial (~150 km stored in a 0.25 degree grid) and temporal (1-2 observations per week) resolution, and SSM/I can only be applied in the semi-arid regions and deserts. From 1991 onwards the data is combined with other satellites resulting in a higher quality product. (As shown in ***Figure 1***)

The methodology to derive one harmonized soil moisture dataset from different independent soil moisture datasets can be summarized in 5 steps [5, 6]:

1. Resampling
   Data are read from the various archives in their original level 2 formats and transformed into time series format based on the original grid (one time series per grid point). The temporal resolution of the merged product is one day. The reference time for the merged dataset set at 0:00 UTC. For each day, the observations within the reference time of 0:00 UTC ±12 hours are considered. If more than one observation falls within this period, the observation closest in time is selected (temporal resampling). Nearest neighbour resampling is performed to convert the various grid systems into the common regular grid. For each grid point in the reference (regular grid) dataset, this resampling technique receives the value of the closest grid point in the input dataset (spatial resampling).
2. Rescaling
   Due to different observation frequencies, observation principles, and retrieval techniques, the contributing soil moisture datasets are acquired in different observation spaces. Therefore, before merging can take place at either level, the datasets need to be rescaled into a common climatology. This rescaling procedure is mainly divided into two parts: a) rescaling of the resampled active microwave soil moisture observation to the climatology of the ASCAT dataset, and b) rescaling of the resampled passive microwave soil moisture observation to the climatology of AMSR-E. All rescaling procedures are performed using the piece-wise linear CDF matching technique.
3. Merging
   This processing stage produces the merged active and the merged passive soil moisture products. For the common time period between the active and passive datasets (2007-01-01 to 2007-05-31) when merging the rescaled ASCAT with the rescaled AMI-WS dataset, the following approach is applied: AMI-WS data is used to fill ASCAT data gaps if available. The same approach is also applied when merging the passive datasets, where due to atmospheric effects SSM/I data is least preferred and ASMR-E data most preferred, if there is any

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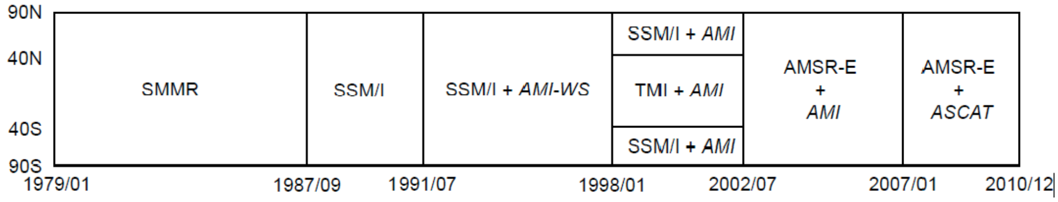

Figure 1 Spatial-temporal distribution of level 2 input products used for product generation

overlapping time period when merging SSMR, SSM/I, TMI, and ASMR-E data.

4. Rescaling
   The merged passive and active microwave products obtained in the previous sections represent volumetric soil moisture (m^3 m^{-3}) and degree of saturation (%), respectively. To combine these data, both merged microwave products need to be adjusted to a common reference. The GLDAS-Noah dataset is employed as the reference dataset. Both merged passive and active microwave products are rescaled against GLDAS-Noah using the CDF matching technique.
5. Merging
   The merged active and the merged passive dataset are fused into a combined active-passive product based on their relative sensitivity to vegetation density: over areas with a low vegetation the merged passive is used, while over areas with moderate vegetation density the merged active dataset is used. In transition areas, where both products correlate well, both products are being used in a synergistic way: on time steps where only one of the products is available, the estimate of the respective product is used, while on days where both the merged passive and merged active datasets provide an estimate, their observations are averaged. The threshold used to separate between vegetation density classes is based on the average vegetation optical depth. [2]

2. LIMITATIONS OF THE PRODUCT

Obviously the integration of active and passive remotely sensed surface soil moisture data together into one consistent long term multi decadal data record increases the temporal and spatial availability. Furthermore, Liu et al. [5] demonstrated that when passive and active microwave soil moisture products are highly correlated (i.e., higher than 0.65), combining them (i.e., taking the average when two coincident values are available, otherwise only using the one available) will increase the number of observations while minimally changing the accuracy of the merged soil moisture products. Also, it should be noted that in case where multiple input products are either in time or in space available, only the highest quality radiometer and scatterometer products are used to combine the data. (***Figure 1***)
In a study Dorigo et al. [2] identify the following three important limitations of the CCI Soil Moisture product:

A) Due to the fact that the observation time stamp is set to 0:00 UTC, a temporal mismatch against the actual observation could result a maximum error of 12 hours, because a ±12 hours time window is chosen when temporal resampling the input data sets. According to [2] the influence of this temporal mismatch is not as large as assumed, but the time difference should not be neglected, as it may introduce an extra uncertainty and of course negatively influences the performance of the product.

B) One of the primary objectives of the merging strategy is that the quality of the merged product should either be equivalent or better than the individual input products. Liu et al. [5, 6] proved that for selected regions not only the number of observation available in certain time periods increases, but also the correlation coefficients obtained are close to those of the best performing single data set. Dorigo et al. [2] revealed that this statement holds in general also at global scale, except for the last period of the merged data set, where the ASCAT product is used. A performance decrease of the merged product compared to the input product has been identified there. The authors determined that this performance drop can be ascribed to the strict data merging scheme, where a static decision rule map for each blending period based on threshold in vegetation optical depth is used. Also, the decrease in accuracy can be related to the resampling from the higher resolution ASCAT input product to a lower resolution using simple nearest neighbour search.

C) The static merging scheme implemented for data merging based on vegetation cover (vegetation optical depth) obtained from the LPRM (Land Parameter Retrieval Model) algorithm does not fill data gaps with lower quality observations. E.g. for time periods where sensor failures lead to data gaps there is no rule that make it possible to use a different data source. Using lower quality observations in this case could enhance the data coverage noticeably.

3. IMPROVEMENTS MADE SINCE THE FIRST RELEASE

The soil moisture product published in 2012 incorporates the following data attributes:

- Soil moisture value & noise
- Sensor information (SMMR, SSM/I, TMI, ASMR-E, AMI-WS, ASCAT)
- Flag (dense vegetation, snow, sub zero)
- Lat/Lon coordinates (global, at 0.25 degree resolution)
- Reference time stamp 0:00 UTC

As discussed previously and also per data user requests new data attributes have been added to the merged product:

- Original observation time stamp
- Frequency band (C-, X-, Ku-Band)
- Satellite overpass direction (ascending/descending)

4. IMPROVEMENTS UNDER DEVELOPMENT

Future releases of the CCI Soil Moisture product will address the limitations listed in section 2. Currently these enhancements are in discussion:

- **Improved CDF matching procedure** The new procedure for calculating the scaling parameters is now capable of catching exceptions. The scaling parameters slope and intercept are now verified and checked if they are valid. In case of an exception a different approach is used to calculate the parameters.
- **Enhanced merging selection scheme** [2] This point focuses on the limitation discussed in section 2 C)
  - ➢ use dynamic map depending on land cover change instead of annual average Vegetation Optical Depth (VOD)
  - ➢ fill data gaps with available data
- **Include more (meta) data characteristics** [2]
  - ➢ vegetation optical depth (passive input data)
  - ➢ land surface temperature (passive input data)
- **Include WINDSAT, AMSR-2** New soil moisture data sets produced with improved algorithms and/or derived from new satellite missions will be integrated. [4]

5. OUTLOOK

As shown in various studies, e.g. in [1, 2], the developed CCI Soil Moisture product is useful for a variety of applications, and the established methods of merging the active and passive data provide good results. The harmonization of data sets incorporates the strength of both the radiometer and the scatterometer microwave techniques [3]. The current data set is not perfect, but an increasing better understanding of its limitations and weaknesses derived from various evaluation and validation studies will help in improving the merged soil moisture product.
Although not discussed in this paper the improvements of the level 2 input data sets carried out by the data provider themselves, and research studies conducted by CCI soil moisture project members and the science community will certainly have an important positive influence on the development of the merged product, and ultimately ensure that ESA's CCI Soil Moisture product follows best practices and standards, and that the merged data set meets the requirements of the climate user community [4].

6. Acknowledgement

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