STATISTICAL MERGING OF ACTIVE AND PASSIVE MICROWAVE OBSERVATIONS INTO LONG-TERM SOIL MOISTURE CLIMATE DATA RECORDS

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ABSTRACT

Satellite observations from active and passive microwave sensors are a valuable means to measure surface soil moisture at the global scale. More than a dozen historical and currently active missions have been used for this purpose, together spanning a period from 1978 to present. Within the Climate Change Initiative (CCI) of the European Space Agency (ESA), these separate missions are systematically combined into homogenized Climate Data Records (CDRs). Currently, the operational production and the near-real-time updating of these CDRs is being transferred to the EU Copernicus Climate Changes Services (C3S). In this study, we provide an overview of the characteristics of the most recent ESA CCI and C3S soil moisture products. In particular, we focus on the new merging procedure, which optimally weighs the individual missions based on their uncertainties estimated with triple collocation analysis.

Index Terms — soil moisture, Climate Data Record, optimal merging, microwave remote sensing, radiometer, scatterometer

1. INTRODUCTION

Various soil moisture products from past and present satellite microwave missions have been developed, allowing us to study soil moisture dynamics from the late 1970s onwards. The number of suited low frequency sensors is steadily increasing and with the launch of SMOS in 2009 and the launch of SMAP in 2015 data from dedicated L-band soil moisture missions have also become available. The approved MetOp Second Generation programme guarantees that satellite soil moisture observations can be continued at least until 2042.

Combining individual Level 2 datasets into a single product gives us the opportunity to profit from the

advantages of individual missions and to obtain homogenised Climate Data Records (CDRs) with improved spatial and temporal coverage, and reduced uncertainty. Since 2012, this is being systematically done within the Climate Change Initiative (CCI) of the European Space Agency (ESA) [1-3]. The current publicly available version (v03.3) integrates eleven active and passive microwave missions. The operational production and the near-real-time updating of these CDRs is currently being transferred to the EU Copernicus Climate Changes Services (C3S; climate.copernicus.eu).

The goal of this contribution is to provide an overview of the characteristics of the most recent ESA CCI and C3S soil moisture products and, particularly, of the new merging procedure, which optimally weighs the individual missions based on their uncertainties estimated with triple collocation analysis.

2. CLIMATE DATA RECORD OVERVIEW

ESA CCI soil moisture v03.3 combines several radiometer-based products, calculated with the VUA-NASA algorithm [4], with various scatterometer-based products based on the TU Wien method [5]. Details on the input products are found in [6]. The spatial-temporal availability of input products leads to a varying combination of sensors used in space and time in the final ESA CCI combined soil moisture product (Figure 2).

3. IMPROVED STATISTICAL DATA MERGING

The construction of the multi-satellite CDR consists of a three-step merging approach (Figure 2). First, all passive and active soil moisture data sets are merged into a single radiometer-based (PASSIVE) and a single scatterometer-based (ACTIVE) product, respectively. Before merging, all observations are scaled into a common climatology, which is provided by AMSR-E for the passive observations and by

MetOp-A ASCAT for the active ones. Next, after scaling PASSIVE and ACTIVE against GLDAS-Noah land surface model soil moisture, ACTIVE and PASSIVE are merged into a COMBINED dataset.

For the production of ESA CCI SM v03.3, for the first time a new blending approach was introduced. This new approach does not only consider the highest quality observations available during a certain period (as was the case for earlier versions), but also computes a weighted average of measurements from all sensors that are available at a certain point in time [7]. This results in a merged observation whose random errors are lower than those of each individual input dataset. The blending weight attributed to each dataset is defined as the reciprocal of its random error variance [8], estimated separately for each blending period (see Figure 1) using triple collocation analysis [9]. The error variance is expressed as a signal-to-noise ratio (SNR), which relates the estimated error variance to the

signal dynamics at the given location [9]. The weights are obtained separately for each day from the SNR estimates of all datasets that provide a valid measurement on that day. If one or more datasets do not provide a valid measurement on a particular day, the decision whether or not to use the remaining datasets on that day is based on maximum error variance thresholds. This avoids degrading too severely the overall performance of the blended product by filling data gaps with input data that have too high random error variances. Spatial data gaps are filled using a decision tree based on one-tailed Pearson correlation significance between the active microwave product, the passive microwave product, and a model product (see [7] for details). The new blending scheme based on weighted averages is used to produce both the ACTIVE, PASSIVE, and COMBINED products.

Figure 1 Spatial-temporal coverage of input products used to construct ESA CCI soil moisture COMBINED v03.3. Blue colours indicate passive, red colours active microwave sensors. Modified from [6]. The periods of unique sensor combinations are referred to as ‘blending period’.

Figure 2. Schematic overview of ESA CCI SM production system. Adopted from [6].

4. RESULTS

Figure 3 shows the change in skill (expressed as signal-to-noise ratio) of the new merging approach with respect to the best performing single sensor product. It can be seen that nowhere is there a loss of skill. Skill gains are largest in areas where the input products have relatively large uncertainties, i.e. in areas with relatively dense vegetation cover.

Figure 3. Improvement in signal-to-noise (in decibel units) of the merged data set with respect to the superior single input data set, i.e., either ASCAT or AMSR-E, in the period January-October 2007. White areas masked out because less than 100 collocated measurements are available. Adopted from [7].

5. CONCLUSIONS AND OUTLOOK

The ESA CCI multi-mission soil moisture dataset presented in this contribution profits of the strengths of the individual input data sources while minimising their uncertainties. With the new merging approach introduced for the first time in v03.3, an additional gain in skill could be achieved with respect to earlier product versions. The new merging scheme potentially allows for the simultaneous merging of an infinite number of available input products, which with the increasing number of available satellites, becomes increasingly important. Upcoming products will focus on further reducing the uncertainties, e.g. by directly merging all input level 2 products into COMBINED, thus surpassing the intermediate aggregation into ACTIVE and PASSIVE. In addition, efforts are taking place to make the datasets independent of land surface model estimates by using an L-band climatology as scaling reference.

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