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Title: Quality Report: Validation of SMOS-BEC L4 high resolution soil moisture products, version 3.0 or “all-weather”

Campaign. years 2010 - 2015 dataset.

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Quality Report: Validation of SMOS-BEC L4 high resolution soil moisture products, version 3.0, years 2010 to 2015.

Abstract: This technical note focuses on the validation of the latest version (v.3.0) of Level 4 (L4) Surface Soil Moisture (SSM) products currently distributed by BEC through http://cp34-bec.cmima.csic.es. Validation results are shown for years 2010 to 2015.

1 INTRODUCTION

The aim of this note is to show the comparison of the products L4 SSM v3.0 or “all-weather” currently distributed at BEC with in-situ data from the permanent soil moisture measurement network REMEDHUS. The L4 products have a spatial resolution of 1km and cover the Iberian Peninsula, Balearic islands, Portugal, South of France, and North of Morocco (latitudes 34 N - 45 N and longitudes 10 W – 5 E). SMOS ascending orbits from year 2010 to year 2015 have been considered for this validation exercise.

This product is freely available to registered users through the BEC data distribution and visualization service (http://cp34-bec.cmima.csic.es). Detailed information about all the products generated by BEC can be found in [Barcelona Expert Center, 2014].

2 L4 HIGH RESOLUTION SOIL MOISTURE PRODUCTS

At BEC we are able to provide a Level 4 (L4) Surface Soil Moisture (SSM) product with 1 km spatial resolution that meets the requirements of land hydrology applications. To do so, we use a downscaling method that combines highly-accurate, but low-resolution, SMOS radiometric information with high resolution, but low sensitivity, visible-to-infrared imagery to SSM across spatial scales. This downscaling approach was first presented in Piles et al, 20101, along with results of its application to a set of SMOS and MODIS images acquired during SMOS commissioning phase (January to May, 2010) over the Oznet network, South-East Australia. In Piles et al., 20142, we show that the inclusion of SMOS polarimetric and multi-angular information in the downscaling method results in improved fine-scale soil moisture estimates. Using reprocessed SMOS data obtained with the latest L1 and L2 processors, we implemented this algorithms’ approach for version 2.0 L4 products. The impact of using different vegetation indices from MODIS with higher spatial and temporal resolution in the


downscaling method was explored in Sánchez-Ruiz et al, 2014\(^3\). Results from comparison to in-situ data showed that the use of more frequent (7-day vs. 15 days composites) and higher spatial-resolution (500-m vs. 1 km) vegetation information lead to more accurate soil moisture estimates, especially in spring. This may be of special interest for agricultural applications, and will be considered for future versions of the product, depending on users demands.

The latest L4 product is the version 3.0 or “all-weather”. In this version, high resolution soil moisture is estimated under all-weather conditions, greatly enhancing the potential applicability of the data. The downscaling approach is based on the one in Piles et al, 2014\(^2\) and Sánchez-Ruiz et al, 2014\(^3\), with the novelty of introducing ERA-Interim Land Surface Temperature (LST) data in the MODIS LST/NDVI space. A sample version 3.0 L4 SSM from January 8\(^{th}\), 2014 is shown in Figure 1. The version 2.0 L4 SSM for the same day is also provided to visually illustrate the differences between the different versions.

Fig. 1: L4 SSM version 3.0 (top) and version 2.0 (bottom) maps \(m^3/m^2\) from January 8\(^{th}\), 2014 (6 AM)

Fine-scale soil moisture maps over the Iberian Peninsula from years 2010 to present can be freely accessed through the SMOS-BEC data distribution and visualization service (cp34-bec.cmima.csic.es). Global SMOS data as well as MODIS data over the Iberian Peninsula are received in NRT at SMOS-BEC facilities and, since June 2012 the the downscaling algorithm is triggered twice a day, corresponding to SMOS ascending and descending passes to serve high-resolution soil moisture maps in Near Real-Time NRT (delay of < 6h). As a prime NRT application, these maps are being used by local fire prevention services in their early warning system to detect extremely dry soil and vegetation conditions posing a risk of fire. BEC has recently been chosen as an SMAP Early Adopter to foster the use of remotely sensed soil moisture data in forest fire risk prevention services.

3 RESULTS OF VALIDATION AND COMPARISON

The temporal and spatial variability of two five years (2010 to 2015) of version 3.0 L4 fine-scale (1km) SSM estimates over the Iberian Peninsula was evaluated through comparison with ground-based measurements acquired at the in situ soil moisture measurement network (REMEDHUS) located in the central part of the Duero basin, Spain.

NUMBER OF ESTIMATES

The great advantage of the new version is that it does not depend on cloud coverage. Figure 2 shows the number of L4 estimates for the year 2012 with version 3.0 (all-weather, left) and previous version 2.0 (masked by clouds, right). The different coverage in the northern cloudy regions as well as the lack of data over Pyrenees and coastal areas on both versions can clearly be distinguished.

![Fig. 2: number of L4 estimates for the year 2012 with version 3.0 (left) and previous version 2.0 (right.)](image)

CORRELATIONS

Statistical results from the 5-year comparison of L4 version 3.0 and version 2.0 remotely sensed soil moisture versus ground-based soil moisture at each REMEDHUS station are presented in Fig. 3. Further correlation and RMS errors per year and station are shown in the Annex.
Main statistics on the comparison between the two L4 versions with soil moisture measurements per year and land use are reported in Table 1. Scores confirm version 3.0 generally preserves or improves the correlation and reduces the Root Mean Squared (RMS) errors in all land uses except for forest-pasture (only represented by stations H9 and M14), where version 2.0 results in better estimates.

<table>
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<tr>
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<th>2014</th>
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<td></td>
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<td>SMOS</td>
<td>ERA-Interim</td>
<td>SMOS</td>
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<tr>
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<td>0.73</td>
<td>0.58</td>
<td>0.70</td>
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<td>R</td>
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</tr>
<tr>
<td>R</td>
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<td>0.62</td>
<td>0.58</td>
<td>0.65</td>
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</table>

*Table 1: Correlation comparison for terrain types*

**REGRESSION SLOPES**

Scatter plots of Fig. 4 display the agreement between remotely sensed and REMEDHUS in situ SSM time-series, with segments illustrating the linear fit of seasonal data. Results are shown for a representative station of rainfed cereals, the most common land-use in the area, for L4 v.3.0 (left plot) and for v.2.0 (right column). It
reflects the “all-weather” product has a higher number of SSM estimates due to clouds masking the version 2.0 product. Also, the slope of the linear correlation is improved with version 3.0 (it is closer to the 1:1 line), and the dynamic range of in situ soil moisture measurements is reproduced in the high resolution maps. In summer, the in-situ SSM measurements present no variability which hampers the agreement with remotely sensed estimates in both versions. Numeric values of the slopes are provided in Table 2. Scatter plots for the five years studied for stations with different mean soil wetness conditions and land uses are provided in the Annex.

![Graphs showing scatter plots for different seasons and comparisons between versions 3.0 and 2.0.]

*Fig. 4: Scatter plot of point-scale versus L4 remotely-sensed SSM v.3.0 (left) and v.2.0 (right) for the REMEDHUS K9 station (rainfed cereal).*

<table>
<thead>
<tr>
<th>K9 Station</th>
<th>version 3.0</th>
<th>version 2.0</th>
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</thead>
<tbody>
<tr>
<td>Summer (red)</td>
<td>-4.6740</td>
<td>-1.4947</td>
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<tr>
<td>Autumn (blue)</td>
<td>0.9555</td>
<td>1.3401</td>
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<tr>
<td>Spring (green)</td>
<td>0.9123</td>
<td>2.1016</td>
</tr>
<tr>
<td>Winter (black)</td>
<td>0.9925</td>
<td>1.0611</td>
</tr>
<tr>
<td>All (yellow)</td>
<td>1.1836</td>
<td>1.8162</td>
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</table>

*Table 2: Regression slopes comparison*

This evaluation study supports the use of the “all-weather” version, since it does not depend on cloud cover and the accuracy of the estimates with respect to in-situ data is improved or preserved.
ANNEX

CORRELATIONS AND ERRORS

2010

2011

2012
REGRESSION LINES

From left to right and up to down, years 2010 to 2014 if not specified the contrary.

E10 STATION
F6 STATION
H9 STATION

There is not in-situ data for this station during years 2013 and 2014. Results for years 2010 to 2012 are shown.
I6 STATION

[Five scatter plots showing the relationship between 1 km disaggregated soil moisture and point-scale soil moisture measurements. Each plot includes data for different seasons (SON, DJF, MAM, JJA).]
J3 STATION

[Graphs showing scatter plots with data points for different seasons (SON, DJF, MAM, JJA) and soil moisture measurements.]
J12 STATION

Multiple scatter plots showing the relationship between point-scale soil moisture measurements and 1 km disaggregated soil moisture for different seasons (SON, DJF, MAM, JJA).
K9 STATION
M9 STATION

![Five scatter plots showing the relationship between 1 km disaggregated soil moisture and point-scale soil moisture measurements for different seasons (SON, DJF, MAM, JJA). Each plot contains data points in different colors for each season, with a trend line indicating the relationship.

- Top left: SON vs. point-scale soil moisture measurements.
- Top right: DJF vs. point-scale soil moisture measurements.
- Bottom left: MAM vs. point-scale soil moisture measurements.
- Bottom right: JJA vs. point-scale soil moisture measurements.

The plots suggest a positive correlation between 1 km disaggregated soil moisture and point-scale soil moisture measurements across all seasons.
M13 STATION

Year 2013 and 2014 do not have data, so last image belongs to year 2012.
N9 STATION