Release of SMOS level 2 soil moisture (SM) products to general users

Authors: ESLs (CESBIO, INRA, University of Tor Vergata, IPSL/SA) and ARRAY

SMOS is performing according to expectations and level 1 brightness temperatures have reached a quality that allows the distribution of level 2 soil moisture data as well. Hence, as of beginning of October 2010, SMOS soil moisture products are being distributed to all science users. Since the end of the commissioning phase in May 2010 the instrument acquisition mode is set to full polarization.

Version 3.09 of the SM level 2 processor, which includes substantial corrections and improvements as a result of the Commissioning Phase data analysis, is now ready to deliver the best SM products available, although still not reaching the expected quality. There are still areas for improvements under study by the development team and feedback from the users is most appreciated (feedback to the project and to ESL via yann.kerr@cesbio.cnes.fr) so that all issues, errors, inaccuracies, mistakes anomalies etc can be identified and, possibly, corrected. For all issues related to data access, formats and read/write, processors, go directly to ESA's HelpDesk: EOhelp@eo.esa.int. Suggestions to improve the algorithm will also be most welcome. Important findings will be posted on the SMOS blog (http://www.cesbio.ups-tlse.fr/SMOS_blog/). Details on the processing algorithms can be found in the Algorithm Theoretical Baseline Document (ATBD), and on the L2SM products structure in the SMOS Level 2 and Auxiliary Data Products Specifications (SO-TN-IDR-GS-0006, Issue 5.2, August 30, 2010), both available from ESA (all documents available on www.earth.esa.int/smos).

The following comments have to be taken into account for a proper understanding, interpretation and assessment of the present SM products.

1 Overall remarks

The products released are far from perfect: they are *NOT validated* and hence *for assessment only*. As they are not final, in case of problems, please provide us with feedback on flaws and issues you may identify.

⇨ ***Note that the SMOS SM products are not produced as are many others similar products so read carefully the ATBD to see exactly what is being done (as it is not always standard practice) so as to take advantage of SMOS characteristics***

The ultimate **SMOS L1 product** (L1c) consists of brightness temperatures reconstructed from interferometric data in the frame of reference of the SMOS antenna plane. Hence these radiometric data are associated to upwelling Stokes parameters through a transformation combining the Faraday effect and geometrical factors.

⇨ ***SMOS brightness temperatures are NOT TBH, TBV, ST3 or ST4 and CANNOT be compared directly with Earth surface observation or modelling.***

Soil moisture retrieval efficiency: at L2 level, SMOS soil moisture retrieval is based on matching measured and modelled (surface emission) brightness temperatures, with the modelled values varying as a function of the incidence angle and depending on soil moisture as well as other physical parameters. There is definitely, for a very large fraction of nodes of the

SMOS grid, a robust ability of the radiative model to match the angular signature of brightness temperature while producing realistic values of retrieved parameters.

Polarisation mode: According to End of Commissioning review decisions, the **full polarization acquisition mode has been selected** for the operational phase, accounting for the potential information provided by this mode. However, until full understanding of Stokes 3 & 4 parameters has been achieved,» pseudo dual pol" retrieval will be used over land surfaces; that is, only the antenna level brightness temperatures corresponding to Stokes 1 and 2 will be used in the retrieval.

> ⇨ ***Note that brightness temperature polarisations are always given in the antenna and can only be transformed into ground values (i.e., H and V) through a transformation related to the instantaneous view angles. Only points located on the satellite subtract are (almost) in H and V*.**

2 Brightness temperatures

Two main areas where progress is needed concern the correction of biases and the detection/mitigation of spurious signals.

2.1 Biases

Beyond the average biases which are brought down to satisfactory levels though calibration procedures, there are still imperfectly corrected biases which depend on the location within the instantaneous field of view. Such errors may be generated during the reconstruction process in case the detailed instrument properties (e.g. element antenna pattern) are not perfectly known,

Several such problems (across swath spurious trends, pixel biases, so called land contamination) have been detected, identified, and sometimes empirically mitigated by the ocean team; although these errors are less prominent over lands due to the much larger sensitivity of brightness temperatures to physical properties, they are present all the same. A clue to their presence is that the quality of fit is not down to expectations, as illustrated by the fact that the normalized cost function (χ^2-CHI square) is substantially higher than the theoretically expected value of 1

2.2 Spurious signals

On one hand, no significant impact of sun contamination (glint) has been detected, so far, over land.

On the other hand, spurious signals due to radiofrequency interference (RFI) are much larger and more frequent than expected when knowing that the SMOS bandwidth is in theory fully protected.

The most efficient mitigation technique consists in requesting trespassers to stop transmitting in the protected 1400 -1427MHz band. Indeed this is under way and meets encouraging results. Meanwhile, other mitigation techniques are explored.

Several detection algorithms are being used in the L2 codes. The most robust have been used to build maps which depict, for each SMOS grid node, the measured frequency of occurrence of RFI detection over a sizable SMOS observation period.

The following map shows this probability for descending orbits. Unfortunately, small RFI contributions (for example 20K or less) often go undetected over land.

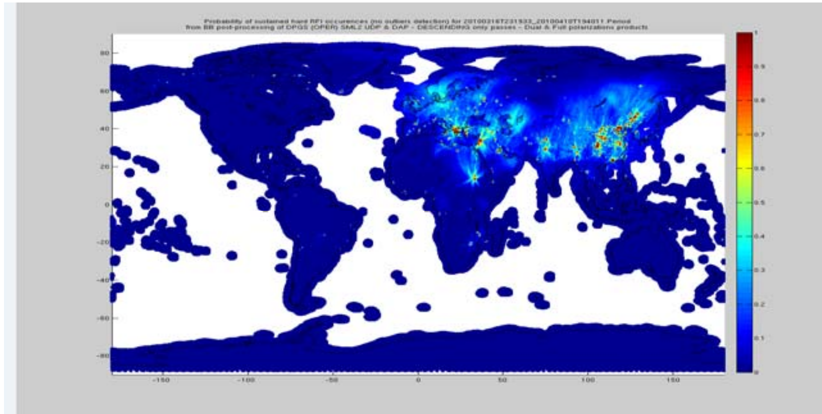

Figure 1 Probability of RFI occurrence between March 16 and April 10 2010.

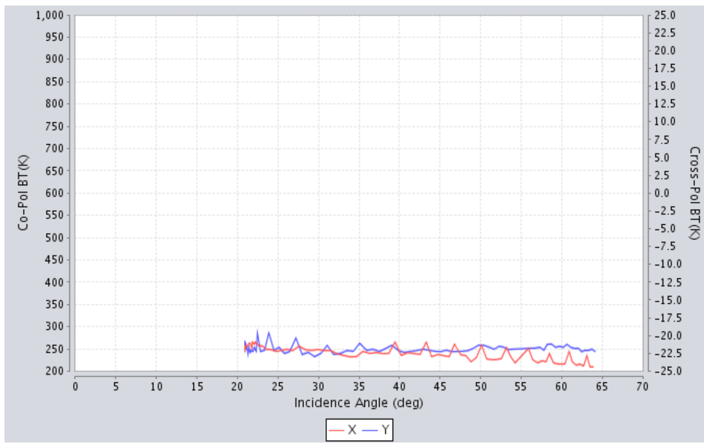

Figure 2: example of RFI of low amplitude

3. L2 SM algorithm

3.1 Primary decision tree

As described in the ATBD, the L2 algorithm is somewhat complicated. This is due to the land surface being very inhomogeneous. Some basic information is given below.

For each node of the SMOS grid, the concerned area (the **working area**: 123 km x 123 km box when including the minor contributions) is described as including several fractions: vegetated soil of course, but also ice, forest, open water and the like.

Then, the first decision tree (17 branches) selects which of the fraction(s) will carry the retrieval. This depends on the respective weights of the various land use types, including also consideration on topography.

Let us for example assume part of the scene consists of vegetated soil while another fraction consists of open sea. Since the sea fraction is not relevant for retrieving soil moisture, the radiometric contribution due to sea is computed using auxiliary data and it is considered as a default contribution. This is only an example; indeed, the forward modelled brightness temperatures used in the retrieval will integrate most of the time default contributions.

⇨ ***Note that the retrieved soil moisture corresponds only to the area where the dominant land use is present***

3.2 Radiative models

There are basically 3 radiative models in the L2 algorithm, depending on how the dielectric constant of the surface is computed. They can be used either in the retrieval iterative loop, or simply in order to build default contributions.

- The **nominal** model is the standard soil vegetation radiative transfer model and includes soil moisture;
- The **water surface** model is used for sea in coastal pixels, wetland and lakes
- The so-called **cardioid** model is used for retrieval whenever it can only aim at providing information about the dielectric constant itself (e.g ice, barren surfaces).

The nominal model will be used over vegetated soil and forest. While these cases are the only ones of direct interest as far as soil moisture is concerned, it may be mentioned that preliminary results using the cardioids model suggest there is indeed physical meaning in them.

> ⇨ ***It is important to note that for the time being only the soil moisture and vegetation opacity fields are worth using routinely. As we all progress and improve the algorithm, other fields will become interesting but for the time being they are very seldom retrieved. So please note that a value of -999 for a geophysical parameter and its associated DQX in the UDP implies either the retrieval for that parameter failed or was not attempted. When all retrieval attempts fail for a node the FL_NOPROD is set to 1, otherwise it is set to 0.***

3.3 Secondary decision tree

Depending on the content of the working area, one of 3 radiative models is used for retrieval. For each of them, one must then define which parameters are to be retrieved, and what are the constraints assigned to the initial values.

The secondary decision tree lists, for each of the 3 models, 3 options depending on the expected vegetation optical thickness and 3 options depending on the "information richness" expected from the data, which is estimated from the incidence angle coverage.

As expected the commissioning phase made clear that this scheme with 27 options was too complicated and it will be simplified during the operational phase. The original idea was to cover all possible cases and adapt and reduce after the commissioning phase as a function of what the real data looks and behaves.

4 Quality of the results

Some caveats are already identified and work is in progress (but help is appreciated)

1. The quality figures DQX (theoretical retrieval uncertainty) and GQX (overall quality) can only be considered as indicative so far.
2. Actually these quality figures do not reflect the poor quality of the fit (see possible explanations for above) resulting in χ^2 too large.

3. Concerning the radiative nominal model, some weaknesses have been detected. The behaviour of the model for very small soil moisture values produces too optimistic DQX in these regions.

4. Moreover, the retrieval performance over the forests is poor (about 40% instead of about 75% elsewhere); what happens is that the model tends to converge on a secondary minimum for negative SM values, which are finally rejected. This will be dealt with at the first major update of the L2 algorithm.

5. In too many cases the retrieved soil moisture is negative. Several causes are identified and under consideration: .i) The dielectric constant model used for soil is not adapted to dry sandy soils → an alternative model is being tested/ validated; ii) the contributions from the areas surrounding the area of interest where the retrieval is done are estimated using ECMWF soil moisture which very often over estimates soil moisture → this will be improved by matching the ECMWF range to the real one.

5 Conclusions

The data is now yours to evaluate. Please let us know the issues encountered (on scientific points! – for technical queries please contact the ESA helpdesk: EOhelp@eo.esa.int) so that we can try to fix them for the next – general - release.

We are looking forward to collaborating with you on these topics and make SMOS products even better....

Yann, Philippe and Philippe, Ali,

Ahmad, Arnaud, Cecilia, Claire, Delphine, Elsa, François

Jean Pierre, Nathalie, Olivier, Paolo, Rachid, Silvia, Steven