Interactive comment on "Combined use of optical and radar satellite data for the monitoring of irrigation and soil moisture of wheat crops" by R. Fieuzal et al.

Answers to the anonymous Referee #2
Received and published: 3 December 2010

Our answers are given after each question or remark of the reviewer, the latter being in bold type.

The main novel contribution of the paper lies in the assessment of the effectiveness of Envisat ASAR data for monitoring soil moisture conditions in agricultural areas. In particular, wheat crops are investigated for which estimates of biomass water content (BWC) are retrieved employing the SAFY model where values for the green leaf area index (GLA) input parameter are derived from Formosat-2 RSI NDVI values.

The proposed methodology and results obtained are rather interesting, especially in the light of upcoming ESA Sentinel-1 and Sentinel-2 missions, which will make possible to obtain (at no costs) long time series of SAR and optical data worldwide. Indeed, the former will provide the same type of data currently available from Envisat ASAR at improved revisit frequency, whereas the latter will provide data in 13 spectral bands (guaranteeing enhanced continuity for Landsat and SPOT missions) at 10 and 20 meters resolution (plus three bands at 60 meters for atmospheric correction) with an average revisit time of 5 days.

The main limitation of the proposed work is that just a single dataset is taken into consideration under kind of ideal hypotheses (i.e., same topography, stable surface condition, common agricultural practices). In this framework, it is proved that a relationship can be established (with certain limitations) between the soil moisture estimated from radar backscattering and that retrieved with in situ measurements. Nevertheless in a standard operational case, different sources of disturbance contribute to making the problem more complex and challenging. If it is not possible to perform additional experiments on a different area, the authors should add some considerations about an effective strategy for dealing with them.

Specific Comments:

In Section 2.3.2 some details about how large geographical units (used for averaging the backscattering coefficients) have been identified should be provided. Such an approach let remove the radar speckle noise. Nevertheless, this choice does not appear to be optimal. Indeed, several advanced techniques have been presented in the literature for reducing the speckle (e.g., Gamma filter, Lee filter) while preserving geometry at the edges between different regions. The authors might properly justify their choice.

Details about the extraction of backscattering coefficient were provided in the new version in Section 2.3.2 [lines 182-189].

We agree that many techniques exist to reduce speckle, amongst which the spatial averaging we used in this study. They are applied to improve both the image appearance and the accuracy of inversion algorithm used for the retrieval of biophysical variables. In this study, the emphasis is put on the physical information contained in the radar signal at the field scale, and more specifically on its sensitivity to surface parameters. We thus took advantage of the delineation of field derived from the FORMOSAT images and the land-cover field survey to identify homogeneous areas consistent with agricultural field limits. It is obvious that the inconvenience caused by the speckle across the pixel is smoothed by considering a fairly large number of pixels. We believe that this methodology is thus appropriated in the context of our study.

In Section 3.2 the authors should clearly point out which is the formula used for approximating the Formosat-2 NDVI response to GLA and how they obtained it. Indeed, such a relationship is particularly important in the framework of the proposed work. However, it is worth noting that, despite still considered reasonable, the accuracy is about 25%. Here, I would expect that the use of advanced non-parametric regression techniques such as for instance the Support Vector Regression (SVR) approach might definitely help in improving the performances (they do not allow obtaining an explicit relationship between the NDVI and GLA quantities, but would act similarly to a black box where, once provided the NDVI value, the corresponding estimated GLA value is given).

As indicated in the Section 3.2, the empirical relationship developed between GLA and NDVI is logarithmic. We added in the new version of the article the formalism of this relationship (see the equation along with the statistical parameters R^2 and RMSE on the new Fig. 4). This relationship is established between the GLA derived from the batch processing of hemispherical photography performed on the field, and NDVI extracted from Formosat-2 images (at the coordinates corresponding to the shooting of hemispherical photography). In our study, the empirical relationship is composed by three parameters, found by minimizing the error between the simulated and the GLA derived from hemispherical photographs. The values of these parameters were indicated along with the equation in the revised version of the text.

We really agree that many other inversion techniques exist. They are more or less cumbersome to implement, and they require either an important field data set or the establishment of a radiative transfer model using an independent database for the validation. In this study, the optimization was based on minimization of the root mean square error between the GLA measured at field and the GLA derived from NDVI. The establishment and the application of this relationship should be considered as a methodological step. A lot of papers have demonstrated that the NDVI-GLA relationship is accurate and robust, amongst which the one of Duchemin et al. 2006 that was established on wheat crops in Morocco. In this paper based on measurements performed in Mexico, we found a relative error of 25%, which is comparable to the error made on the GLA indirect measurements. We consider this satisfactory for answering the main question addressed in our paper.

Details should be given on the number of parameters that needs to be set in the SAFY model and how the research of the most suitable value for each of them has been carried out during the optimization phase. Did the authors consider a grid search strategy? How long did this training phase last?

As mentioned in the Section 3.2 [lines 244-250], four parameters of the SAFY model were optimized: two parameters that controlled the wheat phenological stages (the thermal threshold corresponding to the beginning of the senescence of leaves and one parameter of the leaf partitioning function) and two others related to the agricultural practices (the day of plant emergence and the effective light-use efficiency). Firstly, the two phenological parameter values were retrieved at the scale of the study area using all wheat subfields. This provided us with a distribution of parameters for each parameter then median values are used. In a second step, values of the two others parameters are sought for each spatial units. The optimization was based on minimization of the root mean square error between simulated GLA and observed GLA.

It should be kept in mind that the SAFY model is just used as a tool to simulate the time course of Biomass Water Content. A detailed description of the SAFY model and the calibration process can be found in Duchemin et al (2008b). Furthermore, model set up on the Yaqui valley is fully presented on a paper just submitted to Remote Sensing of Environment. These papers are available to the reviewer and the editor upon request.

By analysing Figure 8, I would suggest considering the possibility that there exists a kind of bias in the simulated soil moisture (for instance due to an imprecise retrieval of Hmin). In particular, it should be properly investigated whether the lowermost samples (i.e., those where the simulated soil moisture is lower than 10%) can be considered as outliers. Under such hypothesis, it seems that the above-mentioned bias could be estimated of the order of 7-8% and, if removed, the overall agreement (independent from the vegetative period) would be definitely higher. However, the reason for a rather low agreement when samples referring to different growing phases are considered at a time might be also due to the very simple linear relationship considered between estimated soil moisture and backscattering coefficient.

We agree with the fact that the bias could be removed following this suggestion, using for instance a bilinear relationship. Additional tests will be performed to confirm this in a near future. The reviewer #2 is invited to read the answer given to reviewer #1 to justify the use of a linear relationship.

The authors should provide some details about the way they used for determining wet and dry lines depicted in Figure 7. It is important to know which samples they took into consideration, since the final value of H depends on this choice.

The method for determining of wet and dry lines has been carefully described in the new version of the text [lines 386-391].

It is worth noting that at present the proposed method could not be employed for estimating soil moisture values when no in situ information is available (due to the lack of minimal and maximal topsoil moisture values observed at field. As gathering reliable in situ information is often not possible or even feasible, some ideas should be pointed out to solve this issue.

Yes, if the extreme (absolute) values of soil moisture cannot be deduced from any field measurements, the moisture can be expressed in relative value. Thus, the range of variation can be expressed without dimension with values ranging 0 and 1 for example. As such, we retrieve a value of the SWI index for the top soil moisture which is still of strong interest, in particular for deriving the complete vertical soil moisture profile.

Technical Comments:

In Section 2.3.2 it could be useful to recall all the 6 different viewing angles of the ASAR sensor.

Precisions on the five different swaths used in the study were added in Section 2.3.2 [lines 174-176].

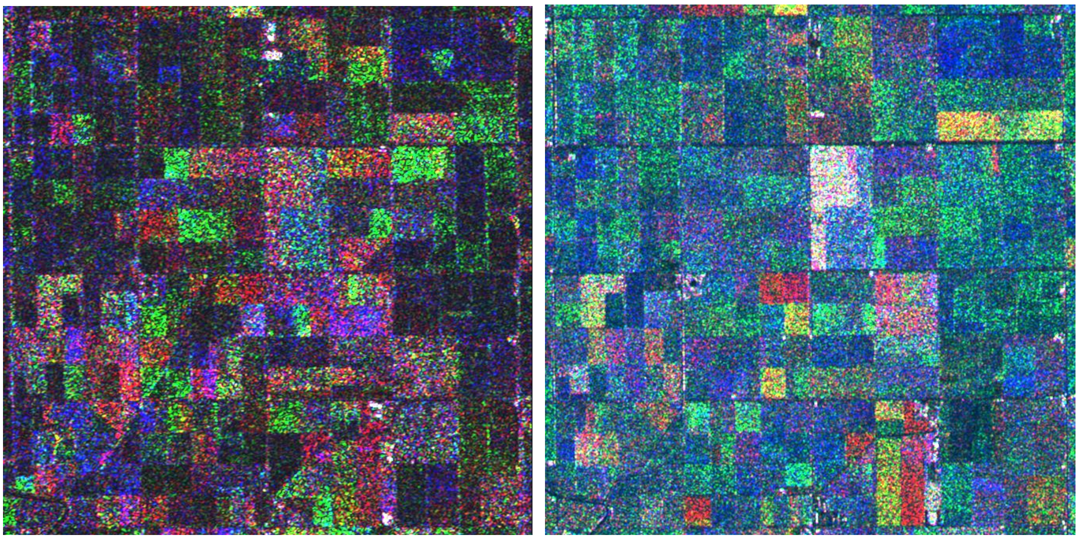
As also pointed out by Reviewer 1, equations (1) and (2) are general for processing ASAR data. Authors should provide values used for setting specific parameters.

Furthermore, it should be clarified what does the number of pixels per independent pixel represent.

The reviewer #2 is invited to read the answer given to reviewer #1 on this point and to look at the revised text [lines 191-209].

Possibly, I would suggest to insert a Figure related to one of the ASAR images used in the study. This would give a clear idea of the type of data used in the analysis.

Please find below two examples of composite color image used in this study. The whole satellite data used as well as their processing steps are detailed in the paper. We are not sure that the inclusion of an image in the paper will make the things clearer.



Color-composed images made with Envisat acquisitions. On the right, three images are displayed in red (01/01/2007), green (02/05/2007) and blue (04/15/2007); they are acquired with incidence angle IS1. On the left, three images are displayed in red (01/10/2007), green (02/14/2007) and blue (04/24/2007); they are acquired with incidence angle IS6.

At the bottom of page 6217, the authors should explicitly point out the reasons for which differences in the incidence angles between the three images considered might affect the reduction of backscattering coefficient.

The fact that the dynamics of the radar signal decrease at higher incidence angles is well known and documented since, in particular, the works of Ulaby [see in the revised version the sentence included lines 325-328]

As they are not acronym, it is more appropriate to write both “Formosat-2” and “Envisat” in lower case font.

Thanks. Each occurrence “FORMOSAT-2” and “ENVISAT” were changed to “Formosat-2” and “Envisat” in the revised version of the paper.