Hydrol. Earth Syst. Sci. Discuss., 9, C1068–C1081, 2012
www.hydrol-earth-syst-sci-discuss.net/9/C1068/2012/

Hydrology and Earth System Sciences Discussions

Interactive comment on "Spatial and temporal variability of biophysical variables in Southwestern France from airborne L-band radiometry" *by* E. Zakharova et al.

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Received and published: 23 April 2012

Reviewer #1

The authors thank the anonymous reviewer #1 for his/her review of the manuscript and for the fruitful comments.

1.1 [There is a lack of rational and logic in the introduction, esp. the first paragraph of the intro contains quite a few redundancies. The 2nd, 3rd and 4th paragraph in the introduction took lots of efforts in emulating the past work and campaigns, but it is better for the authors to synthesize the historical research and give your insights on

the existing problems in different soil moisture retrievals from different bands (e.g. C, L), as well as from active or passive sensors. I am eager to know what we learned from all these campaigns: this would also provide a better context for your work. I also recommend you to have a separate paragraph for VOD. There are various definitions for VOD (Owe et al., IEEE-TGRS, 2001; Njoku and Chan, RSE, 2006; Shi et al., RSE, 2008; Jones et al., IEEE-JSTAR 2009), and it is always good to clarify this at the beginning.]

RESPONSE 1.1

Yes, the Introduction Section needs to be reorganised.

The sentence of P. 897, L. 11-14 could be simplified as: "This remote sensing study investigates the joint soil moisture and vegetation growth dynamics using the L-band Cooperative Airborne Radiometer for Ocean and Land Studies (CAROLS).".

The campaign part of the Introduction could be rephrased as:

"A number of field experiments (CoSMOS, SMOSREX, VAS, MELBEX-1, ELBARA-ETH) (Saleh et al., 2007, 2009; Cano et al., 2010) were carried out in order to prepare the first Soil Moisture and Ocean Salinity (SMOS) mission that operates in L-band. The SMOS SSM retrieval algorithm is based on the inversion of the L-band Microwave Emission of the Biosphere model (L-MEB), which simulates the L-band emission of the soil-plant system (Wigneron et al., 2007). The L-MEB SSM retrieval capability was extensively tested in homogeneous vegetation cover conditions (Grant et al., 2007; Saleh et al., 2007; Wigneron et al., 2007; Guglielmetti et al., 2008). In addition, several airborne campaigns were performed to assess SSM retrieval over large areas: EuroSTARRS in France and Spain (Saleh et al., 2004), NAFE/CoSMOS in Australia (Panciera et al., 2008), EAGLE2006 in Germany (Su et al., 2009), HOBE in Denmark (Bircher et al., 2012). These studies showed that the response of L-band brightness temperatures to SSM is affected by biomass conditions (Saleh et al., 2004). They also showed the importance of specific biome calibration of L-MEB parameters (Bircher et al., 2012). Panciera et al. (2008, 2009) found that after site-specific calibration of the vegetation and roughness parameters, the SSM retrieval accuracy can be better than 0.048 m3m-3 for crops and grasslands. However, there is still a need to assess the accuracy of SSM retrievals for large regions with various ground properties and variable proportion of high/low vegetation types, in dry and wet conditions.".

We agree that more insight is needed regarding the vegetation optical thickness (VOD) retrieval at L-band.

In this study, VOD is defined as the effective zenith (i.e. nadir) opacity of the vegetation ("Tau", dimensionless) in the microwave domain. This quantity can be produced by the inversion of the simplified "Tau-Omega" approach used in the L-MEB model (Wigneron et al., 2007). When VOD = 0, there is no vegetation attenuation of the soil microwave emission. The VOD value tends to increase with the vegetation water content (VWC, in kg m-2). From L-band to X-band, VOD is proportional to VWC and to frequency (f) (Jackson and Schmugge, 1991 ; Schmugge and Jackson, 1992 ; Kerr and Wigneron, 1995 ; Njoku and Chan, 2006). The VOD value is often expressed as VOD = b.VWC, with b = A.epss.f (Kirdyashev et al., 1979), where the value of A is related to the canopy structure, and epss is the imaginary part of the dielectric constant of saline water in the vegetation. The latter depends only slightly on temperature, at the low salinity levels generally observed in plants. At low frequencies, it is often assumed that the A.epss product does not vary much from one vegetation type to another and across frequency values, and that b is proportional to f. For example, the frequency used by the SMOS radiometer is 1.42 GHz (L-band) and the C-band and X-band channels of AMSR-E correspond to 6.925 GHZ and 10.65 GHz, respectively. Therefore, if one assumes that f dominates the VOD response to VWC, VOD is about 5 times more sensitive to VWC at C-band than at L-band, even more at X-band.

Using ground multi-frequency passive microwave observations, Calvet et al. (2011) have shown that C-band and X-band are more appropriate than L-band to monitor the VWC of a wheat field, with VWC values close to 3 kg m-2 at the end of May. This is

consistent with the lower sensitivity of VOD to changes in VWC (i.e. the lower b value) at L-band. A number of studies have shown the usefulness of VOD values retrieved from C-band or X-band satellite microwave brightness temperatures (Liu et al., 2007, 2011 ; Jones et al., 2011 ; Miralles et al., 2011).

This study tends to confirm that the L-band VOD relationship with vegetation characteristics is less straightforward than at C-band or X-band. In addition to the reduced sensitivity to VWC, the L-band b value is found to present a seasonal variability for low vegetation canopies. This finding is consistent with the microwave observations over a wheat field analysed by Wigneron et al. (1996) and could be explained by changes in the value of the A coefficient.

ADDITIONAL REFERENCES

Jackson, T. J. and Schmugge, T. J.: Vegetation effects on the microwave emission of soils, Remote Sensing of Environment, 36, 203– 212, 1991.

Kerr, Y.H. and Wigneron, J.-P.: Vegetation models and observations, a review, in Passive Microwave Remote Sensing of Land-Atmosphere Interactions, Eds. Choudhury, B.J., Kerr, Y.H., Njoku, E.G., and Pampaloni, P., VSP, Utrecht, the Netherlands, 317-344, 1995.

Kirdyashev, K.P., Chukhlantsev, A.A., and Shutko, A.M.: Microwave radiation of the Earth's surface in the presence of vegetation cover, Radio Eng. Electron. Phys., 24, 256-264, 1979.

Liu, Y., De Jeu, R.A.M., McCabe, M.F., Evans, J.P., and Van Dijk, A.I.J.M.: Global long-term passive microwave satellite based retrievals of vegetation optical depth, Geophys. Res. Lett., 38, L18402, doi: 10.1029/2011GL048684, 2012.

Liu, Y., De Jeu, R.A.M., Van Dijk, A.I.J.M., and Owe, M.: TRMM-TMI satellite observed soil moisture and vegetation density (1998–2005) show strong connection with El Nino in eastern Australia, Geophys. Res. Lett., 34, L15401, doi:10.1029/2007GL030311, 2007.

Miralles, D.G., Holmes, T.R.H., De Jeu, R.A.M., Gash, J.H., Meesters, A.G.C.A., and Dolman, A.J.: Global land-surface evaporation estimated from satellite-based observations, Hydrol. Earth Syst. Sci, 15, 453-469, doi:10.5194/hess-15-453-2011, 2011.

Njoku, E.G. and Chan, S.K.: Vegetation and surface roughness effects on AMSR-E land observations, Remote Sensing of Environment, 100, 190-199, 2006.

Panciera, R., Walker, J.P., Kalma, J.D., Kim, E.J., Saleh, K., and Wigneron, J.-P.: Evaluation of the SMOS L-MEB passive microwave soil moisture retrieval algorithm, Remote Sensing of Environment, 113(2), 435–444, 2009.

Schmugge, T.J. and Jackson, T.J.: A dielectric model of the vegetation effects on the microwave emission from soils, IEEE Transactions on Geoscience and Remote Sensing, 30(4), 757-760, doi:10.1109/36.158870, 1992.

1.2 [I feel the current results in your paper reflect a major defect in CAROLS campaign design. If spatial heterogeneity plays such an important role in validating soil moisture, more ground points should be deployed in the same station such that more spatial heterogeneity could be captured. I feel we could learn more from this CAROLS campaign, and if not, we should identify the existing problems and provide directions/suggestions for future campaigns. This kind of discussion could make your unique contribution among all these validation works.]

RESPONSE 1.2

The CAROLS transect is very long (385km), and sampling soil moisture using ground observations over the whole transect was not feasible. This is why sparse automatic ground observations were associated to simulated SSM values in this study. However, during the campaign, an effort was made to perform additional manual SSM observations at three contrasting sites (Le Mona, Lahage and Berat) close to the Lahas SMOSMANIA station, for nine CAROLS flights (3 in 2009 and 6 in 2010). These data were

compared with the CAROLS Tb by Albergel et al. (2011). They found that the average SSM at each site correlated well with CAROLS retrievals based on semi-empirical statistical relationships, except for the Berat agricultural site. Indeed, this site is less representative of the area where distributed in situ measurements were taken, as it consisted of large flat maize fields with mainly bare soil in April and May, and rapidly growing maize in June.

More research is needed to analyse the CAROLS observations over these sites.

1.3 [From my personal experiences, the VOD retrieved from AMSR-E has a time lag after LAI, with longest lags in wood-dominated land-cover, and shortest lags in grassland. VOD is related to canopy water content and theoretically should lag behind the LAI. In other words, use LAI as a predictor of VOD may not be true in most cases except low leaf biomass plants, i.e. grass. So it is worthy attention in your analysis and result interpretation.]

RESPONSE 1.3

Indeed, forest VOD values are generally not correlated with LAI (e.g. Grant et al., 2008). In this study, the use of the ECOCLIMAP-II land cover information permits the representation of the sub-grid heterogeneity (Sect. 2.3) and the simulation of separate contributions of low vegetation and forests to the simulated VOD (Figs. 8-9). In particular, the simulated forest VOD does not depend on LAI (Eqs. 3b, 4b) and does not present seasonal variations. It must be noted that the ISBA-A-gs model simulates the green LAI, and that Eq. (3a) was derived by Pellarin et al. (2003b) from field data over a variety of crops, with a VWC to LAI ratio of 0.5 kg/m2. For the SMOSREX grassland, de Rosnay et al. (2006) and Saleh et al. (2006b) found very good correlations between the green vegetation VWC and the green LAI (R2 close to 0.9), with VWC to LAI ratio values ranging between 0.3 and 0.4 LAI kg/m2. An attempt was made (not shown) to use such values for grasslands in deriving VOD estimates from ISBA-A-gs simulations. This tended to degrade the scores presented in Table 2 for the VOD spatial correlation.

Therefore, the same value of 0.5 kg/m2 (Eq. 3a) was used for both grasslands and crops.

The presence of dead vegetation residues may affect VWC and tends to reduce the correlation of VWC with LAI (de Rosnay et al., 2006). In this study, we focus on the plant growing period, and it can be assumed that most low vegetation covers consist of green vegetation.

ADDITIONAL REFERENCES

Pellarin, T., Wigneron, J.-P., Calvet, J.-C., Berger, M., Douville, H., Ferrazzoli, P., Kerr, Y.H., Lopez-Baeza, E., Pulliainen, J., Simmonds, L.P., and Waldteufel, P.: Two-year global simulation of L-band brightness temperatures over land, IEEE Trans. Geosc. Remote Sens., 41(9), 2135-2139, 2003b.

Saleh, K., Wigneron, J.-P., de Rosnay, P., Calvet, J.-C., Kerr, Y., Waldteufel, P., Escorihuela, M.J. : Impact of rain interception by vegetation and mulch on the L-band emission of natural grass, Remote Sens. Env., 101(1), 127-139, 2006b.

1.4 [Language: the authors used many commas in an inappropriate way.]

RESPONSE 1.4

Yes, we will check the English throughout the text.

1.5 [Page 897, line 25: rewrite the sentence.]

RESPONSE 1.5

The sentence could be reworded as:

"Microwave sensors operating at low frequencies (1–10GHz) are particularly useful for SSM monitoring. Compared to higher frequencies, low frequencies are able to sample thicker surface soil layers. Moreover, the vegetation masking effect are less pronounced, and atmospheric effects are weaker (Wagner et al., 2007)."

1.6 [Page 900, line 18: does "the along track spatial resolution" mean swath width?]

RESPONSE 1.6

No. The sentence could be reworded as:

"The areas observed by the two antennas formed a swath with a mean width of about 3km. The high acquisition rate of the instrument permitted the over-sampling of the swath, with an along-track spatial resolution of about 5 m.".

1.8 [Page 900, line 24: ": : :,only" -> "only covered the Toulouse-: : :"]

RESPONSE 1.8

The sentence could be reworded as:

"While half of them (28 April, 15 and 27 May) covered the whole transect, the others (18, 20 and 26 May) only covered the Toulouse-Atlantic coast transect (225 km long)."

1.9 [Page 901, line 1-3: rewrite this sentence]

RESPONSE 1.9

The sentence could be reworded as:

"Four flights (18 and 27 May 2009, 4 and 22 June 2010) were performed in the late afternoon (between 18:00 UTC and 20:00 UTC). All the other flights were performed in the morning (between 05:00 UTC and 08:00 UTC)."

1.10 [Page 901, line 5: a.s.l. -> you should define these acronyms in your first use.]

RESPONSE 1.10

Yes. P. 900, L. 16 could be replaced by: "They were performed at an altitude of 2000 m above sea level (a.s.l.), and the ground footprint sizes of the nadir and side looking antennas were about 1.4 km and 2.1 km, respectively (Albergel et al., 2011).".

1.11 [Page 901, line 23: delete "As,"]

RESPONSE 1.11

The sentence could be reworded as:

"According to the Fresnel law, TbV and TbH values are confounded at nadir, and only three independent Tb values are used in the inversion: Tb at nadir, and slant (33.5 degree) TbV and TbH.".

1.12 [Page 902, line 8: add reference for "assumed to be close to zero"]

RESPONSE 1.12

A possible reference is Wigneron et al. (2007).

1.13 [Page 903, line 17: Could you provide some references for your cluster method? I am also wondering whether these noises could also be a big problem for SMOS data? How general is your filtering approach for passive L-band data?]

RESPONSE 1.13

Basically, two methods were used. A physical method based on the fact that TbH and TbV should be close at nadir, and a statistical method using 2D histograms. The physical method cannot be applied to SMOS since valid SMOS observations close to nadir are scarce. The statistical approach could be used for SMOS Tb filtering provided specific threshold curves are developed. Indeed, the threshold curve of Fig. 3 is valid for an incidence angle of 33.5 degree and cannot be used at other incidence angles. Also, the threshold line is valid for southwestern France and it is likely that performing the same exercise in other regions of the globe would give different results.

The statistical clustering method is described in Jain et al. (1999).

ADDITIONAL REFERENCE

Jain, A. K., Murty, M.N., and Flynn, P.J.: Data clustering: a review, ACM Computing Surveys, 31(3), 264-323, 1999.

1.14 [Page 904, line 9: ",also" <- not the right English]

RESPONSE 1.14

The sentence could be reworded as:

"It is based on the existing automatic weather station network of Meteo-France, and soil moisture profiles are monitored, in addition to standard hydrometeorological observations (precipitation, air temperature, air humidity, wind speed).".

1.15 [Page 905, line 21-25: rewrite the sentence.]

RESPONSE 1.15

The paragraph could be reworded as:

"The LAI simulations of ISBA-A-gs can be used, to some extent, to estimate the VWC affecting the L-band land emission. In a study at a global scale, Pellarin et al. (2003) assumed that the VWC of low vegetation (grasslands and crops), could be estimated as VWClow = 0.5xLAI, in units of kgm-2. For high (forest) canopies they set constant values of VWChigh, as at L-band this quantity depends mostly on the water content of the branches. The latter was estimated by Pellarin et al. (2003) as 3 kgm-2 and 4 kgm-2 for coniferous and deciduous trees, respectively. As lower branch water content values were reported by Grant et al. (2008) for European forests, the values 1.5 kgm-2 and 3 kgm-2 are used in this study, for coniferous and deciduous trees, respectively. Using the LAI simulated by ISBA-A-gs for low vegetation, and the ECOCLIMAP-II forest fraction, the vegetation water content affecting the L-band land emission for low and high vegetation (in kgm-2) are estimated along the aircraft transect as:"

1.16 [Page 907, line 2-3: not sure what you mean by "with anther : : :by remote sensing"]

RESPONSE 1.16

The sentence could be reworded as:

“In this study, the CAROLS-derived VOD was compared with the Collection 5 version of the MODIS LAI product.”.

1.17 [Page 907, line 24: “,only”]

RESPONSE 1.17

The sentence could be reworded as:

“Therefore, only eleven stations are considered.”.

1.18 [Page 908, line 14: what kind of correlation did you use? Pearson, Kendall or Spearman? Please clarify it.]

RESPONSE 1.18

The Pearson correlation coefficient was used.

1.19 [Page 909, section 3.2 Not sure why you did not compare ISBA LAI simulation with MODIS LAI. Based on your results, I am not sure how well ISBA captures the LAI temporal evolution. I recommend to add MODIS LAI analysis in this section.]

RESPONSE 1.19

Yes, time series can be plotted in Fig. 5 instead of the present Hovmoller diagram, for the Atlantic, Garonne, and Mediterranean regions described at the end of Sect. 2.1.2. A new Fig. 5 could also include the MODIS climatology.

1.20 [Page 910, line 11-12: rewrite the sentence.]

RESPONSE 1.20

The sentence could be reworded as:

“The same differences between 2010 and 2009 can be observed in Fig. 6 for the simulated SSM.”.

1.21 [Page 911, line 6: it is hard to tell that Fig 7 show a similar spatial pattern be-

tween CAROLS VOD and ISBA LAI (say Fig 7A and Fig 7C have very different spatial patterns).]

RESPONSE 1.21

The sentence could be reworded as:

“In spite of the lack of temporal correlation between the CAROLS VOD and the ISBA-A-gs LAI, the spatial correlation between the two quantities is significant for nineteen flights, with Pearson correlation coefficients ranging from 0.34 to 0.85.”.

1.22 [Page 912, line 25-26: rewrite the sentence.]

RESPONSE 1.22

The sentence could be reworded as:

“On the other hand, a positive bias of about 0.05 m3 m-3 is observed over the Garonne river valley at the centre of the transect, between 1 degree E and 1.5 degree E.”.

1.23 [Page 913, line 9-12: rewrite the sentence.]

RESPONSE 1.23

The sentence could be reworded as:

“To some extent, the large scale spatial patterns in the CAROLS/ISBA-A-gs SSM bias (Fig. 10) can be explained by uncertainties related to the L-MEB inversion process.”.

1.24 [Page 913, line 16: -> “it is difficult to represent litters in L-MEB”]

RESPONSE 1.24

The sentence could be reworded as:

“Also, a number of studies have shown that it is difficult to represent litters in L-MEB (Saleh et al., 2006, 2007).”.

1.25 [Page 913, line 19: -> “and also vary within a given vegetation type”]

RESPONSE 1.25

The sentence could be reworded as:

“Finally, soil roughness may vary from one vegetation type to another, and also within a given vegetation type.”.

1.26 [Page 913, line 20: -> “The same kind of problem may exist in the ISBA simulation”]

RESPONSE 1.26

Yes, the sentence could be reworded as:

“The same kind of problem may exist in the ISBA-A-gs simulations.”.

1.27 [Page 913, line 25: “,also”]

RESPONSE 1.27

The sentence could be reworded as:

“The model uses a map of soil properties and represents the interception of rain by the vegetation.”.

1.28 [Page 914, line 4.2: this is not a complete sub-title]

RESPONSE 1.28

The 4.2 sub-title could be replaced by :

“L-band b values through time and vegetation covers”

1.29 [Page 915, line 3-4: too many commas]

RESPONSE 1.29

The sentence could be reworded as:

“In this paper we have presented an analysis of the data acquired during the CAROLS flights that took place in Southwestern France between the Atlantic and the Mediterranean coasts, in April-May 2009 and in April-July 2010.”

1.30 [Page 923, Table 1: clarify what correlation you used.]

RESPONSE 1.30

The Pearson correlation coefficient was used.

1.31 [Page 930, Fig 5: recommend to add MODIS LAI]

RESPONSE 1.31

Yes, time series can be plotted in Fig. 5 instead of the present Hovmuller presentation, for the Atlantic, Garonne, and Mediterranean regions described at the end of Sect. 2.1.2. A new Fig. 5 could also include the MODIS climatology.

1.32 [Page 931, 932: “Along flight interannual variability of ” -> “Flight transect of”]

RESPONSE 1.32

Yes, the captions of Figs. 6-7 will be changed accordingly.

1.33 [Page 935: Please spell out all the acronyms.]

RESPONSE 1.33

Yes, Fig. 10 will be redrawn with more explicit acronyms, and the acronyms will be spelled out.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 9, 895, 2012.