**Hydrology and
Earth System
Sciences
Discussions**

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Interactive comment on "Operational assimilation of ASCAT surface soil wetness at the Met Office" *by* I. Dharssi et al.

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We appreciate the comments made by the three anonymous referees, the comments are fair and the suggestions made will help to significantly improve the clarity of the paper. We will modify the manuscript as suggested.

The reply to Referee 1 is given here.

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1 General Comments

1.1 NWP Index

We accept that the Global UM NWP Index will not be of great interest outside the Met Office and will remove all mention of it from the paper.

1.2 Bug in the Bare Soil Evaporation Scheme

The Bug in the bare soil evaporation scheme of the land surface model is limited in the global Unified Model to a narrow strip of the Sahara desert and causes the model bare soil evaporation to switch off at the affected land points. The bug only becomes active at a model land point if the model soil moisture at all 4 soil levels (of a land point) falls below the wilting point. Because it is rare for the soil moisture in the deeper soil levels to fall below the wilting point only a strip of points in the Sahara are affected by the bug.

Due to the bug there is a spurious strip of higher (but below wilting point) surface soil moisture in the Sahara desert. If the bug is fixed, the spurious strip of higher soil moisture quickly evaporates away. This bug does not affect the conclusions of the paper and therefore we will remove mention of it from the paper.

For anyone familiar with the MOSES2 code, the bug is in the calculation of array smct in subroutine physiol. The bug has not been formally documented.

1.3 Justification of Trials Performed

The soil moisture analysis scheme described in the paper is computationally very cheap. However, testing will be computationally very expensive. The reason is that there will be feedbacks between the soil moisture analysis, the land surface model, the atmosphere model and the 4DVAR atmosphere data assimilation. Therefore, for comprehensive testing, the full Global Unified Model (UM) numerical weather prediction

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(NWP) suite must be run. In our experience a 30 day global UM trial typically requires about 30 days of wall-clock time to complete.

Other researchers testing soil moisture analysis schemes in a numerical weather prediction context have run trials which are of similar length and also cover the northern hemisphere Spring / Summer time period. For example,

Paper	Trial Period
Draper et al. (2011)	July 2006
Mahfouf (2010)	May 2009
Scipal et al. (2008)	May to July 2005
Drusch (2007)	June to July 2002
Balsamo et al. (2004)	June 2000

Note that each trial described in Table 2 of our paper consists of two runs of the global NWP suite; a Control run and a Test run. The Control run uses the T/q soil moisture nudging to analyse soil moisture. The Test run uses both the T/q soil moisture nudging and the ASCAT nudging scheme running sequentially to analyse soil moisture. Otherwise the Control and Test of each trial are identical.

Since Trial 2 fully overlaps the time period of the longer Trial 1, mention of Trial 2 will be removed. Trial 5 covers the northern hemisphere winter period when much of the northern hemisphere land surface is frozen or snow covered. Therefore, the impact of ASCAT assimilation is small and mention of Trial 5 will be removed from the paper.

1.4 Figures and Captions

Figures will be made larger and the captions will be expanded to include all the information shown in the figures. All the original figures are in postscript format.

1.5 ASCAT Soil Moisture Product

Since we are describing a method designed for operational use it makes sense to use the operational ASCAT soil moisture product for testing. We recognise that a newer (research) version of the ASCAT soil moisture product has been released which is more accurate. A trial has already been run using the new ASCAT soil moisture product but unfortunately this trial did not take into account the change to the method of calculating the ASCAT estimated error which is provided by the ASCAT level 2 BUFR product. The new ASCAT soil moisture dataset contains much larger values of the ASCAT estimated error. Consequently, the quality control rejects a very large proportion of the ASCAT data in the new trial, therefore making the results of the new trial difficult to interpret.

1.6 Soil Water Index (SWI)

We will move all mention of the SWI to a "Future Work" section of the paper. We will flag the use of the SWI as a likely and probably very fruitful area for future investigation and mention Table 2 of Brocca et al. (2010a).

1.7 Purpose of the Paper

We will state in the Introduction the purpose of the paper and explain clearly why this work is significant. This paper is one of only a few describing the assimilation of both satellite derived soil moisture and screen level observations (temperature and humidity) for soil moisture analysis. In addition, only a few papers have looked at the impact of assimilating satellite derived soil moisture on forecast of screen temperature and relative humidity. The Met Office is the first to operationally use satellite derived soil moisture for numerical weather prediction. The comparison of our trials with Scipal et al. (2008) will be moved to the Introduction.

2 Specific Comments/ Technical Corrections (P: page, L: line or lines)

P4314, L11: Change "note" with "study".
Suggestion accepted.

P4315, L1: I agree with the authors that, usually, soil moisture measurements made within a small area are characterized by high spatial variability. ... Therefore, also the representativeness error of point measurement,reported at P4330, L10-12 and P4332, L3-5, seems to be too high (contrast with Miralles et al., 2010; Loew and Schlenz, 2011). Please revise these parts.

USDA SCAN is a low density observing network. In our paper we will reference Reichle et al. (2007), who also use USDA SCAN soil moisture observations to verify their soil moisture analysis when assimilating AMSRE derived surface soil moisture.

According to Famiglietti et al. (2008) the error of representativeness depends on the length scale of interest. " Results showed that variability generally increases with extent scale. The standard deviation increased from $0.036 \ cm^3/cm^3$ at the 2.5-m scale to $0.071 \ cm^3/cm^3$ at the 50-km scale. "

In our paper, the model grid spacing is about 40km so we would argue that an error of representativeness of about $0.06 \ m^3/m^3$ is very consistent with Famiglietti et al. (2008). We would also argue that the value of $0.06 \ m^3/m^3$ is consistent with Miralles et al. (2010) and Loew and Schlenz (2011). Figure 2 of Miralles et al. (2010) gives values for the error in point observations of between $0.01 \ m^3/m^3$ to $0.09 \ m^3/m^3$. However, Miralles et al. (2010) are considering soil moisture **anomaly** and also watersheds of areas ranging from $150 \ km^2$ (Walnut Gulch) to $611 \ km^2$ (Little Washita) [12 km to 25 km scales]. These two facts explains why the Miralles et al. (2010) errors of representativity are smaller. Loew and Schlenz (2011) report in their section 4.1, last sentence that "The standard deviation varies between 0.025 and 0.1 [m^3/m^3]."

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Therefore, we strongly believe that a value of 0.07 m^3/m^3 for the error in point observations of soil moisture is justified when the scale of interest is about 40km (i.e. we are interested in the average soil moisture in grid squares of about $40\ km \times 40\ km$).

P4315, L4-6: The International Soil Moisture Network (http://www.ipf.tuwien.ac.at/insitu/) initiative is trying to establish and maintain a global in-situ soil moisture database (Dorigo et al., 2011). Please cite it here. Moreover, other regional networks are already present (REMEDHUS, SMOSMANIA, Illinois, Oklahoma, ...).
Suggestion accepted.

P4315, L19-21: Cite also the AMSR-E (Njoku et al., 2003; Owe et al., 2008) and WINDSAT (Li et al., 2010) sensors that are currently used for soil moisture estimation. P4316, L6-7: Cite also Albergel et al., 2010; de Rosnay et al., 2010; Draper et al., 2011 as recent studies assimilating satellite soil moisture observations into meteorological models.
Suggestions accepted. For assimilation work at ECMWF we will reference de Rosnay et al. (2009).

P4316, L18-19: Basically, both Draper et al., 2009b and Rudger et al., 2009, among many others, obtained that the AMSR-E soil moisture product derived by the Land Parameter Retrieval Model, LPRM (Owe et al., 2008), provides the better agreement with in-situ observations.
It is not the purpose of this paper to say which retrieval algorithm is better. We merely wish to point out that all retrieval algorithms have deficiencies. Not everyone agrees that LPRM gives the best results, for example see Jackson et al. (2010).

P4316, L23-24: Throughout the paper it seems that the air temperature (usually measured 2m above the ground) is referred with different terms (surface temperature, screen temperature, ...). Please be consistent to avoid confusion.

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We will consistently use the phrase "screen level" to avoid confusion.

P4316, L28: Please specify the acronym T/q. Also UM at P 4317, L2, Met at P4317, L4, ... and others (MOSES, BUFR, RMS, ...).
We will explain the acronyms in the revised paper.
T/q	Temperature/Humidity
UM	Unified Model
MOSES	Met Office Surface Exchange Scheme
RMS	Root Mean Square

P4316, L4: Please add a reference for the Meteorological centres that uses bias cor- rected satellite soil moisture data. Operationally or for research purposes?
We will give a list of some of the Met centres that have used bias corrected satellite derived soil moisture for research. The UK Met Office is the first to operationally use satellite derived soil moisture for numerical weather prediction.

P4317, L12-13: Why is the bias corrected satellite soil moisture more likely to improve model surface fluxes? Please specify better.
We will add a references to Koster et al. (2009) at the end of the sentence "Conse-quently, data assimilation of the bias corrected satellite soil moisture is more likely to improve model surface fluxes and lead to better weather forecasts".

P4320, L11-15: Equation (2) has general validity. It was developed for Ukraine but also applied in other countries (e.g. Ceballos et al., 2005). However, likely it is better to remove it because the SWI is not used in the paper (see General Comments).
Suggestion Accepted, equation (2) will be removed.

P4321, L11: Please specify that the results of Naeimi et al. (2009) refers to ERSscatterometer soil moisture data and also the obtained performance (e.g. in terms of correlation coefficient).

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Will specify as suggested.

P4321, L21: Please specify here the ASCAT soil moisture product that is used in the study (operational or reprocessed?).
We have used the operational ASCAT soil moisture product provided by EUMETSAT.

P4322, L5: What does "climatology" mean? Please specify.
By climatology we mean the "monthly climatology".

P4322, L10: Please remove the reference to bufr code. Also below in the paper.
We will remove references to the BUFR code from the paper.

P4322, L24: How is it possible to compute different values for ms(t) and UM(t). Are they computed for a given area? Please specify.
There are 12 data points on each plot of Figure 1, one for each month. This will be explained in the revised paper.

P4323, L7: How is the fraction of vegetation cover computed? Which is the reference data set used for that?
The Unified Model vegetation fractions are derived from the International Geosphere Biosphere Programme (IGBP) global land cover dataset.

P4325, L12: I do not understand why is the reference to Fig.4 reported here?
This reference to Figure 4 will be removed.

P4326, L4: What is the ASCAT super-ob value? Is it θ_{scat} after the quality control?
The ASCAT super-ob value is calculated after the quality control step and conversion

to volumetric soil moisture step have both been performed. Each super-ob value is an average of several θ_{scat} values that are nearly co-located in space over a six hour time period. Since the ASCAT data has a higher spatial resolution than the model (12.5km vs 40km), a model grid square can contain several θ_{scat} values in any six hour time period.

P4326, L2-15: Please mention here Brocca et al. (2010b) because they recently applied the same nudging scheme used in this paper. Moreover, I think that a K-value equal to 0.5 is quite high. In fact, the assumption that the model and observation error is usually not correct (model error is usually lower than observation error).
We will reference Brocca et al. (2010b).

P4331, L15: "For operational use K =0.2 in Eq. (10)". The sentence should be revised.
We will revise the sentence.

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