Hydrol. Earth Syst. Sci. Discuss., 8, C2608–C2619, 2011
www.hydrol-earth-syst-sci-discuss.net/8/C2608/2011/

Hydrology and Earth System Sciences Discussions

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

I. Dharssi et al.

i.dharssi@bom.gov.au

Received and published: 7 July 2011

Operational assimilation of ASCAT soil wetness Dharssi et al.

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 2 is given below.

1 General Comments

1.1 Bug in the Bare Soil Evaporation Scheme

See reply to referee 1.

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

P4315, L3-4: Maybe it can be mentioned that there is an initiative to establish such a network (http://www.ipf.tuwien.ac.at/insitu/)

We will add a reference to the International Soil Moisture Network.

P4315, L19: A more direct retrieval? compared to what?

More direct than using observations of screen level temperature and humidity to analyse soil moisture.

P4315, L22: horizontal resolution of global NWP models

We will add **global**.

P4316, L11: : : : soil moisture (Reichle

We will add the parentheses.

P4317, L2: UM is used before the shortcut is explained (see L20)

Will use **Unified Model (UM)** instead.

P4317, L4: Most Met centres : : : Is soil moisture assimilation already widely used? If so, please give some citations.

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, L24: Are there any feedback mechanism between 4DVAR and MOSES2 or are *they working totally independent (see also comment on P4326, L7-8)?*

There are likely to be feedbacks between 4DVAR and MOSES2 via the atmosphere model. 4DVAR assimilates observations of screen temperature and humidity and this is likely to increase the feedbacks.

P4318, L1: ... surface scheme (Essery : : :

We will add the parentheses.

P4319, L11 : ... ranging between 25 and 60 : : :

We will add the correction.

P4319, L12: The gap is 670km (see http://oiswww.eumetsat.org/WEBOPS/epspg/ASCAT/ASCAT-PG-4ProdOverview.htmTOC41, Fig. 4.1)

We will add the correction.

P4319, L16: Is there any reason to use the data set with higher resolution ...

We have used the 12.5 km operational ASCAT soil moisture product provided by EUMETSAT.

P4320, L9-15: Is SWI used for your experiments? If not, I see no need to mention it here.

We will move all mention of the SWI to a “Future Work" section of the paper.

P4321, L1-10: It is mentioned that ASCAT is measuring the soil moisture of the uppermost 1 cm of the soil and that this layer is subjected to more rapid drying and wetting ...

(P4318, L2), which will lead to slower response to drying and wetting ...

We accept that the use of an exponential filter could further improve results and will mention this as a source of future work.

P4322, L4: What are a and b?

The a and b are local, time-invariant matching parameters.

P4323, L6: Does that mean the parameter b is determined locally? If so, please specify the spatial and temporal resolution of this parameter.

The b parameter is determined locally using Unified Model soil texture and vegetation cover data (equation 7 of the manuscript). The b parameter is time invariant and has the same horizontal resolution as the Unified Model.

P4323, L7: Which data base is used for the vegetation cover?

The Unified Model vegetation fractions are derived from the International Geosphere Biosphere Programme (IGBP) global land cover dataset.

P4324,L23-P4325,L2: I do not understand this cross track cell number quality control ...

This simplified pseudo code, loosely based on IDL, explains how the plots in Figure 3 of the manuscript were created:

```
ascat=array of surface soil wetness measurements
lon=array of longitude positions of measurements
lat=array of latitude positions of measurements
date=array of day of measurement
xtrack=array of cross track cell numbers of measurements
simpleQC=array of simple quality control check (check for snow, frost, mountains, wetlands, ascat estimated error)

DX=0.25 (grid point spacing for longitude)
DY=0.25 (grid point spacing for lattitude)

hist=array(82 elements)
count=array(82 elements)
hist(*)=0.0
count(*)=0

for I=1 to all model grid points
     plon is longitude of grid point I
     plat is latitude of grid point I
     index=where (( plon<lon<=plon+DX) and  (plat<lat<=plat+DY) and (1/5/2009<=date<=3/5/2009) and (simpleQC=passed))
     lascat=ascat(index)
     lxtrack=xtrack(index)
     lavg=avg(lascat)
     diff=lascat-lavg
     diff2=diff*diff

     for J=1 to all elements of array lxtrack
            hist(lxtrack(J))=hist(lxtrack(J))+diff2(J)
            count(lxtrack(J))=count(lxtrack(J))+1
     endfor J
```

```
endfor I

hist=sqrt(hist/count)
plot, hist
```

P4325, L6: Which assumptions were made to use these values for observation and background errors?

We don't accurately know the values of σ_o and σ_b. The values that we have chosen are quite large and this will result in fewer ASCAT observations rejected by the background quality control check. The assumption that $\sigma_o = \sigma_b = 0.07\ m^3m^{-3}$ means that an ASCAT observation is rejected if $|y| > 0.26\ m^3m^{-3}$. For example, an alternative assumption that $\sigma_o = \sigma_b = 0.05\ m^3m^{-3}$ would mean that an ASCAT observation is rejected if $|y| > 0.20\ m^3m^{-3}$.

P4325, L19: Are results of these early trials presented in this paper? If not, skip this footnote.

We will remove the footnote.

P4326, L15: Is this assumption proven by the results of this study? For the operational run, K=0.2 (P4331, L15) is used. How was this value determined?

A study like ours cannot be used to determine the optimal value of K. The value of K=0.2 was chosen so that both the ASCAT and T/q soil moisture nudging schemes add or remove similar amounts of soil water.

P4327, L1-6: Please specify more clearly the difference between the control experiment and the test experiment. Have you performed a control run without assimilation too ...

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.

We haven't performed any experiments where the soil moisture free-wheels (no soil moisture analysis). We would expect free-wheeling to show a degradation. Our control includes the T/q soil moisture nudging scheme and so is more difficult to improve upon than a run without any soil moisture analysis. For us, the pertinent question to ask is, what is the added value of using satellite derived surface soil moisture measurements in addition to using screen level observation of temperature and humidity to analyse soil moisture. The Met Office has been operationally using the T/q soil moisture nudging scheme since 2005.

P4326, L7-8: I am not quite sure how the assimilation cycle is working. If only one forecast run is started for 12Z (P4327, L9 ? trial 1), why do you calculated 4 analyses per day? How is MOSES 2 coupled to UM?

There is full and direct two way coupling between MOSES2 and the UM.

The UM T/q soil moisture nudging only adjusts model soil moisture during daylight. Therefore, it must be performed 4 times a day to update the whole globe. The ASCAT nudging is computationally very cheap (compared to running 4DVAR and UM six day forecasts) and is also performed 4 times a day. The 4DVAR atmosphere data assimilation is also run 4 times a day.

P4327, L10: UM NWP index: I am not familiar with this 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.

P4327, L18: Figure 5 shows : : :

We will change show to **shows**.

P4327, LL19-20: ... According to Fig.5, I would say it needs 2-3 weeks until the model soil relaxed towards the ASCAT data ... Is this adjusting phase included in the verification results ...

The soil moisture analysis scheme described in this paper is computationally very cheap. However, testing is computationally very expensive (see reply to Referee 1).

Therefore, most trials are only 4-5 weeks long, this period includes any adjustment phase.

P4328, L4: Apart from snow, there is no significant change ...

There was no change in the treatment of ASCAT estimation errors. The regions covered by ASCAT data in any six hour period will vary, for example in one six hour period there may be more ASCAT data over jungles and hence more ASCAT data rejected by the ASCAT estimated error QC check. Therefore, the variations shown by Table 3 are just noise (except for snow points). We will modify table 3 to give a single summary.

P4328, L7: What is the reference data set to calculate the RMS?

The RMS is for the analysis minus background differences.

P4328, L23-P4330, L3: Does that mean the results shown here are including this bug? ...

The bug is in the land surface model code and therefore affects both the Test and Control runs. However, the bug doesn't affect the ASCAT nudging. The ASCAT nudging removes the strip of higher soil moisture from the Sahara. Fixing the bug causes a similar removal of the strip of higher soil moisture in the Sahara.

P4329, L26: zig-zag pattern: What is the reason for this pattern?

The zig-zag pattern is due to a diurnal variation in forecast skill. Such a diurnal variation should be expected. Soil moisture affects transpiration from plants and transpiration is strongly linked to photosynthesis. Therefore, we expect errors due to soil moisture to be larger during the day and smaller at night. For north America, errors are larger at 0Z than at 12Z (Figures 8 and 9). While for Europe the errors are larger at 12Z than at 0Z (Figure not shown). For example, figure 12 of Balsamo et al. (2004) also shows a diurnal variation in forecast skill. The diurnal variation in forecast skill can also be due to other sources such as errors in model clouds and surface albedo.

P4330, L2: According to table 2, the NWP index vs. ANAL is quite different for trial 3, compared to trial 2 and 4.

The differences are just statistical noise, the uncertainty in the index changes is about plus/minus 0.5 .

P4330, L22-24: Why are stations rejected if there is a low correlation/high RMS?

Very limited quality control is applied at source to measurements from USDA SCAN stations and it is thought that, at least for older measurements, there are significant problems with the data (see Reichle et al. (2007)). Therefore, we applied an objective quality control scheme to detect and remove SCAN stations where the soil moisture sensors may be malfunctioning. Our quality control of SCAN stations is rather strict and has probably removed some good stations.

Our quality control of SCAN stations does not alter the conclusions of the paper.

P4331, L23-24: Are there any ideas why there is a positive benefit for the regions mentioned, but not for other ones ...

Koster et al. (2006) suggest that both the north America and Tropics regions contain hot-spots of high land-atmosphere coupling. We might speculate that this is the reason we see a positive benefit of ASCAT assimilation in those regions.

We would also expect to see bigger improvements from ASCAT soil wetness assimilation in those regions where screen level temperature and humidity observations are sparse. Many areas of the tropics have sparse screen observation coverage and this would also explain the good results we see in the tropics. The sparse screen observation coverage in the interior of Australia might explain the good results from ASCAT soil wetness assimilation found for Australia. Europe has very dense screen observation coverage and this may explain the neutral impact from ASCAT soil wetness assimilation for Europe.

P4332, L7: ?: : : may be slightly too moist?: I would like to see more of the verification results for this argument. ...

See Table 4 of the manuscript.

P4332, L19: Maybe you can include a statement about the ASCAT data quality, usabil-

ity of the data set and improvements on the data set which could further increase its usability for data assimilation.

The ASCAT data quality and usability is very good. .

P4332, L19: As the operational assimilation of ASCAT data started more than a half year ago, I am curious if there are any evaluations of the forecasts which would be worth being mentioned in this paper.

The Met Office typically updates the operational NWP suite about 4 times every year. Therefore, it is very difficult to ascribe improvements to any particular operational change. A recent Met Office technical report has concluded that ASCAT assimilation has improved the soil moisture analysis.

```
ESCAT soil moisture climatology
Forecasting R&D Technical Report No. 551
Yaswant Pradhan, Malcolm Brooks and Roger Saunders
http://www.metoffice.gov.uk/media/pdf/i/c/FRTR5511.pdf
```

Table1: What is the meaning of these variables?

These variables are used by the van Genuchten scheme to link soil moisture to soil suction and soil hydraulic conductivity. These variables affect the soil water holding capacity, vertical flow of soil water, transpiration from plants and direct evaporation from bare soil.

Table2: Please describe the difference between trial 3 and 4 (why is the K value only affecting the NWP index vs. ANAL and not vs. OBS?). Is + or - indicating an improvement of the forecast?

+ indicates an improvement.

Table3: See comment on P4328, L4.

We will modify table 3 to give a single summary.

Table 4: The effect of the improvement stays the same no matter if stations are excluded from the comparison or not.

Yes, a very important point.

Fig. 1: The annotation of the axes is too small. Which time period was investigated for these plots? Is one dot in the plot referring to one measurement or is it the average for the whole domain for one month or something else? If these plots are valid for a longer time period, is there a yearly cycle (especially for regions with pronounced seasons and changes in vegetation like UK region)?

Each point is for one month and therefore 12 points on each graph.

Fig. 2: The annotation of the axes is too small.

Fig. 3: The annotation of the axes is too small.

Fig. 5: The annotation of the axes is too small. What is the unit of the x-axis, I cannot figure out a time period which is separating one month into 9 parts?

We will make all the figures larger.

Fig. 6: These plots are really small. What are the soil moisture nudges compared to for calculating the RMS?

The soil moisture nudges can be either negative (removal of soil water) or positive (addition of soil water). Therefore, a simple averaging may give a misleading indication of the size of the nudges. The root mean square (RMS) of the nudges gives a better indication of the absolute magnitude of the nudges.

Fig. 7: These plots are really small. Please specify in the legend if you calculated test-control or control?test. ASCAT assimilation is only affecting level 1 of MOSES2 directly; differences in level 2 are only due to propagation of soil moisture between the different levels in MOSES2?

The plots show test minus control. Differences in level 2 are due to the land surface model propagating changes into the lower soil layers.

Fig. 8: The annotation of the axes is too small. The different scales on the y-axis are confusing when trying to compare the results for different regions. Why is the zig-zag pattern not occurring for all regions? How many stations have been used for verification? I am wondering about the fact that for Australia, the forecasts with ASCAT

assimilation are even getting better for long time forecasts (hours 96+). I thought it would be the other way round: assimilation is improving the analysis, giving a positive impact on the short range forecasts.

The 4DVAR atmosphere data assimilation scheme assimilates screen level observations of temperature and humidity. Therefore errors in screen temperature and humidity are small at the start of a forecast. The land surface has a much longer memory than the atmosphere and so improvements to the soil moisture analysis often show bigger improvements at the longer forecast range.

Fig. 9: see Fig.8

Fig. 10: The annotation of the axes is too small. The different scales on the y-axis are confusing when trying to compare the results for different regions. What is the main reason for the differences (e.g. improvement for North America in trial 4, improvement for Tropics in trial 3) between Fig. 9 and Fig. 10 (e.g. different number of levels, different season)?

All the trials show a clear improvement for the tropics and Australia. All trials show a neutral or better impact for north America. All trials show a neutral impact for Europe.

Fig.11: Is there any coherence for the stations that are increasing the random error in UM?

There are more stations increasing the random error on the east coast of the US. We might speculate that the ASCAT data is less accurate in this region due to greater vegetation cover. Therefore the K value should be lowered in this region.

We may use the triple-colocation method (Dorigo et al., 2010; Scipal et al., 2008) to derive the optimal, spatially varying, value of K. This could be suggested in a "Future Work" section of the paper.

Fig.13: The annotation of the axes and the legend is too small. ...

According to the USDA SCAN site, the elevation is given in units of feet.

References

Balsamo, G., Bouyssel, F., and Noilhan, J.: A simplified bi-dimensional variational analysis of soil moisture from screen-level observations in a mesoscale numerical weather-prediction model, Quarterly Journal of the Royal Meteorological Society, 130, 895–915, 2004.

Dorigo, W. A., Scipal, K., Parinussa, R. M., Liu, Y. Y., Wagner, W., de Jeu, R. A. M., and Naeimi, V.: Error characterisation of global active and passive microwave soil moisture datasets, Hydrology and Earth System Sciences, 14, 2605–2616, doi:10.5194/hess-14-2605-2010, http://www.hydrol-earth-syst-sci.net/14/2605/2010/, 2010.

Koster, R. D., Sud, Y. C., Guo, Z., Dirmeyer, P. A., Bonan, G., Oleson, K. W., Chan, E., Verseghy, D., Cox, P., Davies, H., Kowalczyk, E., Gordon, C. T., Kanae, S., Lawrence, D., Liu, P., Mocko, D., Lu, C.-H., Mitchell, K., Malyshev, S., McAvaney, B., Oki, T., Yamada, T., Pitman, A., Taylor, C. M., Vasic, R., and Xue, Y.: GLACE: The Global LandÂŰAtmosphere Coupling Experiment. Part I: Overview, Journal of Hydrometeorology, 7, 590–610, doi:10.1175/JHM510.1, http://journals.ametsoc.org/doi/abs/10.1175/JHM510.1, 2006.

Reichle, R., Koster, R., Liu, P., Mahanama, S., Njoku, E., and Owe, M.: Comparison and assimilation of global soil moisture retrievals from the Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E) and the Scanning Multichannel Microwave Radiometer (SMMR), Journal of geophysical research, 112, D09 108, 2007.

Scipal, K., Holmes, T., De Jeu, R., Naeimi, V., and Wagner, W.: A possible solution for the problem of estimating the error structure of global soil moisture data sets, Geophysical Research Letters, 35, L24 403, 2008.