Author response to R4

We thank the reviewer for their comments which have helped to strengthen this manuscript. Please find our responses below:

1) The reviewer shared the concerns of others with respect to the use of the CCI data and performance metrics used within the paper.

We have included extra text explaining the limitations of the used observations and have also included unbiased RMSD and correlation statistics for our experiments to show that the DA is not just acting to match the climatology of GLDAS1-Noah soil moisture. This is the same text from our response to reviewer 3's second comment, P11L8:

"Satellite soil moisture products can be subject to larger errors and biases associated with data processing. This is particularly true for the CCI level 3 combined active and passive product used in this paper, as in order to merge information from 11 different sensors data is CDF matched to the GLDAS-Noah v1 model (Rodell et al., 2004). Therefore, any bias within the GLDAS-Noah model will be included in the level 3 soil moisture product used here. To make sure we are not just correcting the bias of the JULES model to that of GLDAS-Noah we include summary statistics of unbiased root-mean squared difference (ubRMSD) and temporal correlation in table 2. In every case we find that after data assimilation we improve both ubRMSD and correlation and in the majority of cases find the best results for experiment 4 (TAMSAT v3.0 with DA). For the north of Ghana, we reduce the ubRMSD by 18% from experiment 3 (0.0622 m3 m−3) to experiment 4 (0.0508 m3 m−3). From experiment 2 to 4 we can see that, after data assimilation, using TAMSAT v3.0 rainfall over v2.0 has contributed to a 6% reduction in ubRMSD when calculating statistics over the whole period. In the south of Ghana, we reduce the ubRMSD by 21% from experiment 3 (0.0590 m3 m−3) to experiment 4 (0.0467 m3 m−3), here improved rainfall data has contributed to 10% of this reduction. We find the highest correlations in the north of Ghana for the whole period (2010 - 2014), this is mainly due to the seasonal cycle being much more pronounced in this region."

2) The reviewer asked us to explain the larger improvement and lower overall errors shown for the South in Figure 5, given that we mention the products have lower skill in the south.

In Figure 5 we are comparing our model estimates to the ESA-CCI observations which we believe will also have higher errors in the south given the denser vegetation cover and higher cloud cover. Therefore, lower errors in Figure 5 do not necessarily mean that our model estimate is closer to the truth in the south if, as expected, the CCI observations are also of poorer quality in this region. There is also a much more pronounced seasonal cycle in the north, so that the model mistiming this cycle slightly can lead to large peaks in error. We have since re-run our experiments with a 5 cm soil depth and find similar results. The new figures relating to this point are 7 and 8. We have updated the text to clarify this point.

P9L7:

"Experiments 2 and 4 have a lower RMSD in the south (Figure 8) compared to the north (Figure 7), this seems surprising given that we consider the quality of the data to be poorer in the south. However, this is in part due to the much more pronounced seasonal cycle in the north leading to peaks in RMSD when the seasonal cycle is even slightly mistimed by the model. We also have less confidence in the CCI soil moisture observations in the south so a lower RMSD in comparison to this product over this region is perhaps not indicative of a better soil moisture estimate overall."

3) The reviewer asked us to indicate the version of the ESA CCI soil moisture we are using.

We are using ESA CCI level 3 v03.2. We have included this in the manuscript in section 2.3.