Response to Reviewer 2 are structured as follow: (1) 2.X: comments from Reviewer 2, (2) Response to 2.X: author's response and author's changes in manuscript when any. For sake of clarity, line and page numbering from the revised version is used.

Reviewer#2

[...] This paper seems to represent a major milestone in the development of LDAS-Monde (which is in my view a very important undertaking), and hence I recommend publishing the paper after minor revisions.

Dear Reviewer#2 many thanks for reviewing the manuscript and for highlighting its relevance and interest. Your comments and suggestions led to an improved version of the manuscript. Below is a point by point answer to your specific comments, all your editorial and technical comments were accounted for in the revised version of the manuscript.

2.1 [Line 167: What do you mean by "...is bale to ..."?]

Response to 2.1

Thanks for pointing out this typo, it should read "[…] ***is able to*** [...]" it is now corrected in the revised version of the manuscript.

2.2 [Lines 188ff: The procedure described here results in an observational error field mainly related to soil properties, while the real retrieval errors are mostly dependent on vegetation density. Please discuss implications.]

Response to 2.2

You are right that vegetation has a role in ASCAT SSM observational error. The observational SSM error we use is consistent with errors typically expected for remotely sensed SSM (e.g., de Jeu et al., 2008, Gruber et al, 2016). Most of the in-situ measurements sites used in typical evaluation studies are indeed representative of grassland. Going from radar backscatter measurements (ASCAT level1 data, σ°) to SSM (ASCAT level2 data) using the change detection approach developed at TUWIEN implies a lot of assumptions in particular on vegetation variability: only seasonal variability is accounted for (e.g. Wagner et al., 1999, Bartalis et al., 2007). That is why we have an undergoing work at CNRM trying to directly assimilate σ° (Shamambo et al., 2019). Assimilating σ° also raises the question of how to specify observation, background, and model error covariance matrices. The last decade has seen the development of techniques to estimate those matrices. Approaches based on Desroziers diagnostics (Desroziers et al., 2005) are affordable for land data assimilation systems from a computational point of view and could provide insightful information on the various sources of the data assimilation system.

<u>The following paragraph has been added in the discussion and conclusion section (P.24, Lines 788-796):</u>
"CNRM is also investigating the direct assimilation of ASCAT radar backscatter (Shamambo et al., 2019), it is supposed to tackle the way vegetation is accounted for in the change detection approach used to retrieve SSM with an improved representation of its effect. Assimilating ASCAT radar backscatter also raises the question of how to specify observation, background, and model error covariance matrices, so far mainly relying on soil properties (see section 2.1.3 on data assimilation). The last decade has seen the development of techniques to estimate those matrices. Approaches based on Desroziers diagnostics (Desroziers et al., 2005) are affordable for land data assimilation

systems from a computational point of view and could provide insightful information on the various sources of the data assimilation system".

References (* denotes new references added to the manuscript):

Bartalis, Z.; Wagner, W.; Naeimi, V.; Hasenauer, S.; Scipal, K.; Bonekamp, H.; Figa, J.; Anderson, C.: Initial soil moisture retrievals from the METOP-A advanced Scatterometer (ASCAT). Geophys. Res. Lett., 34, L20401, doi: 10.1029/2007GL031088., 2007.

Desroziers, G.; Berre, L.; Chapnik, B.; Poli, P. Diagnosis of observation, background and analysis-error statistics in observation space. Q. J. Roy. Meteor. Soc. **2005**, 131, 3385–3396.

de Jeu, R.A.; Wagner, W.; Holmes, T.R.H.; Dolman, A.J.; Van De Giesen, N.C.; Friesen, J. Global soil moisture patterns observed by space borne microwave radiometers and scatterometers. Surv. Geophys., 29, 399–420, 2008.

Gruber, A.; Su, C.-H.; Zwieback, S.; Crow, W.; Dorigo, W.; Wagner, W. Recent advances in (soil moisture) triple collocation analysis. Int. J. Appl. Earth Obs. Geoinf., 45, 200–211, 2016.

Shamambo, D.C.; Bonan, B.; Calvet, J.-C.; Albergel, C.; Hahn, S. Interpretation of ASCAT Radar Scatterometer Observations Over Land: A Case Study Over Southwestern France. *Remote Sens.* 2019, *11*, 2842.

Wagner, W.; Lemoine, G.; Rott, H. A method for estimating soil moisture from ERS scatterometer and soil data. Remote Sens. Environ., 70, 191–207, 1999.

2.3 [Line 198: Is "20 %" a relative error?]

Response to 2.3

It is 20% of the LAI itself, this paragraph has been revisited to improve its understanding. Setting up the observed and modelled LAI standard deviation to 20 % of the LAI value is an empirical option coming from previous studies by Jarlan et al. (2008) and Rudiger et al. (2010), which have underlined the need for a variable LAI error definition. Barbu et al. (2011) further explored the impact of LAI model and background errors on the assimilation results by using diagnostics on model and observation errors (e.g. Desroziers and Ivanov, 2001) on different setups (see figure 2 of Barbu et al., 2011). They found that for small LAI values, it is necessary to use a fixed error standard deviation. This value was set to 0.04 m^2m^{-2} for LAI values lower than 2 m^2m^{-2} and is also used in this study.

The following sentence: "The standard deviation of errors for the observed LAI is assumed to be 20% and a similar assumption is made for the standard deviation of errors of the modelled LAI values higher than 2 m2m−2. For modelled LAI values lower than 2 m2m−2, a constant error of 0.4 m2m−2 is assumed (Barbu et al., 2011). More details can be found in Albergel et al, 2017 or Tall et al., 2019." as been reformulated and is now (P.7, Lines 220-224): "Based on previous results from Jarlan et al., 2008, Rüdiger et al., 2010, Barbu et al., 2011, observed and modelled LAI standard deviation errors are set to 20 % of the LAI value itself for values higher than 2m^2m^{-2}. For LAI values lower than 2 m^2m^{-2}, a fixed value of 0.04 m^2m^{-2} has been used. More detailed can be found in Barbu et al., 2011 (section 2.3 on data assimilation scheme and figure 2)."

Reference (not added to the manuscript):
Desroziers, D. and Ivanov, S.: Diagnosis and adaptive tuning of observation-error parameters in a variational assimilation, Q. J. Roy. Meteorol. Soc., 127, 1433–1452, 2001.
Reference (added to the manuscript):

Jarlan, L., Balsamo, G., Lafont, S., Beljaars, A., Calvet, J.-C., and Mougin, E.: Analysis of leaf area index in the ECMWF land surface model and impact on latent heat on carbon fluxes: Application to West Africa, J. Geophys. Res., 113, D24117, doi:10.1029/2007JD009370, 2008.

Reference (already in the manuscript):

Rüdiger, C.; Albergel, C.; Mahfouf, J.-F.; Calvet, J.-C.; Walker, J.P. Evaluation of Jacobians for leaf area index data assimilation with an extended Kalman filter. J. Geophys. Res. 2010.

2.4 [Section 2.2: Note that ASCAT SSM data are already assimilated in ERA5. Please discuss implications.]

Response to 2.4

Thank you for your comment. ASCAT soil moisture is indeed assimilated in the ERA5 LDAS. However, previous studies showed that its impact is confined to the soil and that it is neutral on the IFS atmospheric analysis and forecasts (de Rosnay et al 2014, Munoz-Sabater et al 2019). In our study we use the ERA5 atmospheric analysis as forcing but we do not use any of the ERA5 soil analysis variables as input of our system. So, we consider the ASCAT SM contribution to the ERA5 atmospheric forcing to be negligible.

Reference (already in the manuscript):
de Rosnay, P.; Balsamo, G.; Albergel, C.; Muñoz-Sabater, J.; Isaksen, L. Initialisation of land surface variables for numerical weather prediction. Surv. Geophys., 35, 607–621, doi: 10.1007/s10712-012-9207-x, 2014.
Reference (not added to the revised version of the manuscript):
Muñoz-Sabater, J. , Lawrence, H. , Albergel, C. , de Rosnay, P. , Isaksen, L. , Mecklenburg, S. , Kerr, Y. and Drusch, M. (2019), Assimilation of SMOS brightness temperatures in the ECMWF Integrated Forecasting System. Q J R Meteorol Soc. Accepted Author Manuscript. doi:10.1002/qj.3577

2.5 [Line 248: SWI is the Soil Water Index]

Response to 2.5

Thanks, it has been corrected accordingly

2.6 [Section 2.3: Describe also the masking of SSM]

Response to 2.6

Thanks for your comment, the following sentence has been added to section 2.3 (P.9-10, Lines 299-301): "As in Albergel et al. (2018a, 2018b), pixels whose average altitude exceeds 1500 m above sea level as well as pixels with urban land cover fractions larger than 15% were discarded as those conditions may affect the retrieval of soil moisture from space."

2.7 [Line 493: Only this sub-study focusses on severe conditions, but not "this study" overall.]

Response to 2.7

We agree with Reviewer#2 and the sentence has been corrected accordingly, it is now: "As this subsection focuses [...]"