

## Author comment on Anonymous Referee #2

### Interactive comment on “The effect of assimilating satellite derived soil moisture in SiBCASA on simulated carbon fluxes in Boreal Eurasia” by M.K. van der Molen et al.

#### Anonymous Referee #2

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This study's objectives are to assimilate satellite-derived soil moisture observations into a land surface model and quantify its effect on modelled carbon fluxes. The author's find that assimilations has an effect on simulated carbon fluxes, but the quality of satellite-derived soil moisture observations are highly questionable since these data do not capture major drought events.

In a close to ideal world, we have a good but imperfect model, high-quality observations and after assimilating such observations into the model, resulting simulated key fluxes agree better with independent observations. After reading this manuscript, it is clear that this study is not close to an 'ideal world' situation. I still feel that after some revisions (see below) it does provide a worthwhile contribution simply because it highlights a number of issues in regards to assimilation of a key parameter (soil moisture) in the northern high latitudes from both a modelling and observational perspective.

*Response: The referee's summary captures the essence of this study. We also think the message is important, because it may be tempting to think that assimilating satellite observations may provide valuable information in data poor regions like Boreal Eurasia. This publication shows that the quality of the satellite soil moisture data are generally lower than the simulated soil moisture, while the quality also depends on the land surface characteristics LAI, temperature and soil moisture.*

#### Major comments:

It is somewhat surprising that in this study NO comparison of simulated and observed carbon fluxes are shown. It is perhaps trivial to expect a change after assimilation but did assimilation improve the carbon fluxes (at least for specific seasons) would be the question to explore??

*Response: Fig. AC1 shows an example of a comparison of observed NEE and SiBCASA NEE without and with soil moisture assimilation. This figure may be compared with Fig. 7 in the paper, which shows the associated in-situ observed and SiBCASA soil moisture time series. Fig. AC1 shows that even though the change in soil moisture due to assimilation of ASCAT soil moisture may be substantial, particularly in the spring and in drought periods, the associated changes in NEE are usually small. The physics behind this is explained in terms of GPP and TER in section 3.2 of the paper.*

*Considering the question if soil moisture assimilation improves the NEE in SiBCASA, Figure AC1 shows that the change in NEE is usually small compared to the difference with the eddy covariance observations. The eddy covariance observations of NEE have a larger short-term variability due to micro- and meso-scale atmospheric processes which are not represented in the 1x1 degree lat/lon input weather data to SiBCASA (e.g. how the forest characteristics in the fetch change with wind direction). This may cause the sign of the difference to change from day to day. Additionally, SiBCASA underestimates NEE in the spring (the simulated NEE is less negative than the observations). This suggests that there is room for improvement of the phenology or allocation scheme.*

*The paper shows that unfortunately the four observation sites are not located in regions where ASCAT has the largest skill, and this is reflected in the uncertainty associated with the satellite observations (see also Fig. AC3). Therefore the change in soil moisture with assimilation is small at those sites (see Eq. 2). However in other regions across Boreal Eurasia (e.g. steppe) the uncertainty is smaller, resulting in a stronger effect of assimilation*

of soil moisture. There the effect of assimilation on the carbon fluxes may be larger, depending on the expression of the soil moisture response functions (Fig. 1). Concluding, this analysis shows that the NEE in SiBCASA may be subject to improvement, and that assimilation of satellite observed soil moisture is one of the target variables, along with scale issues, phenology and carbon allocation and probably others. While the paper already is of considerable length, including the comparison would further extend the paper. Whereas the referee's question is obviously valid, the paper is really about the effect of assimilating soil moisture data. Therefore we believe including a comparison would distract from the message we want to convey in the paper.

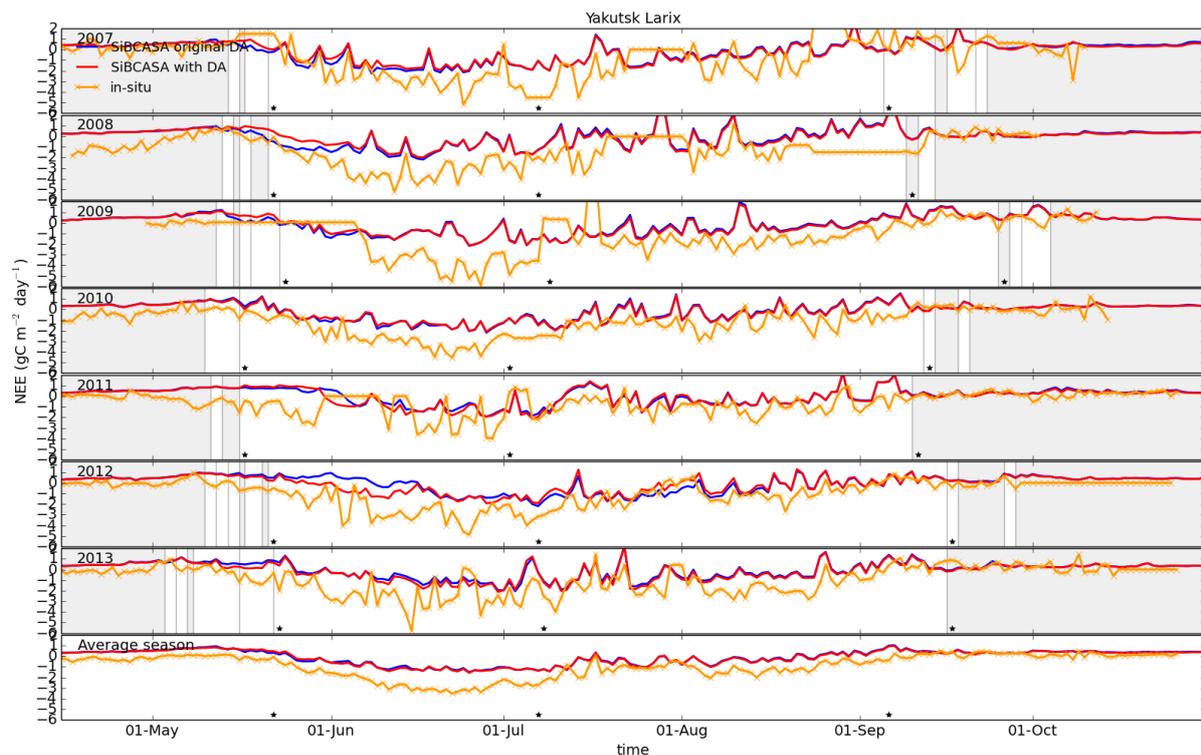


Figure AC1. Time series of daily NEE in SiBCASA original (without assimilation) (blue), and with assimilation (red), in situ soil moisture (orange), at the Yakutsk Larix site, Russia. Each panel shows one year of soil moisture. Grey-shades indicate periods when the top soil is frozen. The three asterisks indicate the date when the top soil is last frozen in the spring, 46 days after that, and the date when the top soil is first frozen again in the fall. The bottom panel shows the average seasonal cycle of the each NEE type.

### Specific comments:

Page 3, line 22 (first sentence start): I wonder if a publication has its own 'interest'? Perhaps better to start with some context and then state the goals of the study.

*Response: We will change 'interest' into 'purpose'. The context has already been introduced in the abstract, and is explained in more detail after this sentence. We like to communicate the goals right at the beginning of the introduction.*

Page 4, line 6: 'Permafrost' is mentioned, but it would be good to explain somewhere how this process is modelled in SiBCASA.

*Response: The SiBCASA model is described in section 2.1, where we refer to SiBCASA description papers Schaefer et al., 2008 and Sellers et al., 1996. These papers however do not discuss how SiBCASA deals with permafrost. A relevant discussion paper was just published: Jafarov and Schaefer (2015) The importance of a surface organic layer*

*in simulating permafrost thermal and carbon dynamics. The Cryosphere Discuss., 9, 3137–3163, 2015. [www.the-cryosphere-discuss.net/9/3137/2015](http://www.the-cryosphere-discuss.net/9/3137/2015). We will include a reference to this paper in section 2.1.*

Page 4, line 6-9: References needed

*Response: This statement is based on personal experience of the lead author, obtained during field work in Yakutsk. We are not aware of references about it, neither do we think it is one which needs particular proof.*

Page 5, line 6: Sentence starting with 'Respiration: : :' is not clear. Suggest revision.

*Response: We assume the referee means page 9007, line 2-4: "Respiration, or more specifically, heterotrophic respiration, depends on soil moisture as the substrate in which microbes and bacteria consume organic matter and release CO<sub>2</sub>."*

*We will rephrase it as:*

*"Heterotrophic respiration depends on the soil moisture content, which is the substrate in which microbes and bacteria consume organic matter and release CO<sub>2</sub>."*

Page 6, line 15: Are these 4 site soil moisture measurements really representative of a larger area? A brief discussion at appropriate location about the mismatch in spatial scale between direct observation of soil moisture and the model footprint/resolution would be good.

*Response: There is indeed a scale difference between satellite derived soil moisture and in-situ observed soil moisture. We will add the following sentence: "Although the in-situ observations have limited representability for the 1x1 degree satellite observations, we focus here on longer-term variability (e.g. droughts) which develop over larger areas. We also apply a normalisation procedure (CDF matching technique, section 2.3) which removes the impact of soil characteristics on soil moisture distributions. Therefore the most important reason for mismatch is probably the difference between grid-size average and local precipitation."*

Page 9, line 5: Sentence starting with 'Therefore: : :'. What are the implications for the boreal study area? Can it be considered sparsely vegetated?

*Response: We were not sure before we did the study, but we thought that the forests in East Siberia might be sparse enough, but this appeared not to be true. This becomes clear in the results (section 3.1) and is discussed in section 4.1.*

Page 9, line 9: Paragraph starting with 'Complementary: : :'. Add info on layer penetration depth of soil moisture retrieval (as done for passive) and add reasons why this product is less accurate for bare grounds (which is a bit counterintuitive))

*Response: We added a remark about the penetration depth:*

*"Complementary, active radar soil moisture retrievals from the Advanced Scatterometer (ASCAT, 2006–present) in combination with the change detection algorithm **and is representative for the soil moisture in the top few centimetres** (Bartalis et al., 2007; Naeimi et al., 2012b, 2009; Wagner et al., 1999) **ASCAT soil moisture retrievals are reliable for sparse and moderately vegetated areas, and less for bare soils** (Liu et al., 2012)."*

*For a detailed analysis of the relative performance of ASCAT and passive microwave of different vegetation types, we refer to Liu et al. (2012).*

Page 10, line 18: a link is provided to Section 2.2 in regards to soil data, but I could see anything along these lines in Section 2.2??

*Response: The part in brackets "(Sect. 2.2, information about absolute values comes from soil data)," has become obsolete, and we will remove it.*

Page 11, line 19: Instead of 'in Siberia' you probably mean 'across boreal Eurasia'?

*Response: in the sentence "Flux data are taken in Siberia at more locations, although predominantly in the period 1997–2005, when the ASCAT satellite was not yet launched (Dolman et al., 2012)" we actually do mean Siberia. Quite a few sites had been running as part of the projects EuroSiberian Carbon flux, TCOS Siberia and GAME Siberia and others. However, only three of these Siberian sites (Tver, Yakutsk, Elgeei) have been running during the ASCAT period of record.*

Page 12, line 10: 'Reliability' in the subsection headline: Is this the right word? As this would imply a comparison to in-situ data which comes later!

*Response: The comparison with in-situ data is part of section 3.1 (starting page 9017). We argue that 'reliability' is indeed the right word, because the entire section is aimed at studying the added value of satellite observed soil moisture over simulated soil moisture. We could also use the word 'performance', which is however less outspoken in this context.*

Page 13, line 1: check figure designation!

*Response: Thank you, this indeed refers to an earlier layout of figure 2. The designation will be changed into '(second panel in Fig. 2)'. Also for 2 other instances.*

Page 13, line 6: If you state results with no figure/table, you should at least include '(data not shown)'.

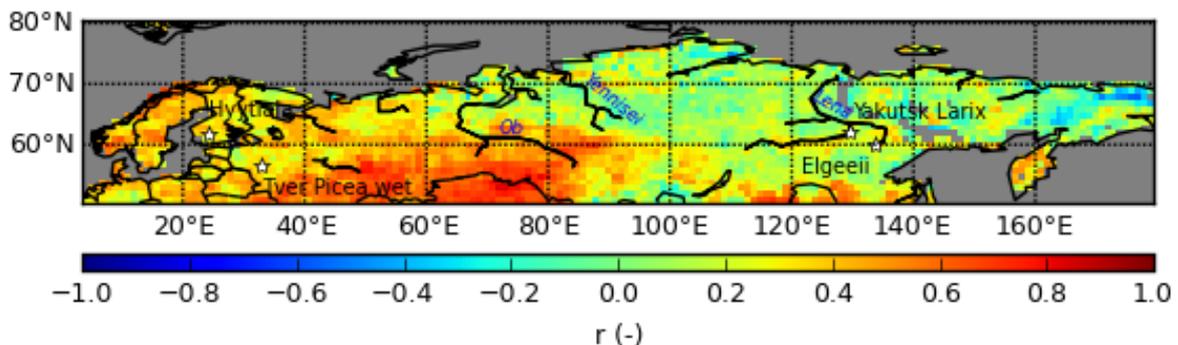
*Response: We will add '(Figure not shown)'*

Page 14, line 6: Not clear about correlations: Is the correlation based on 7 points (e.g. monthly mean August) or truly daily (30dx7year)?

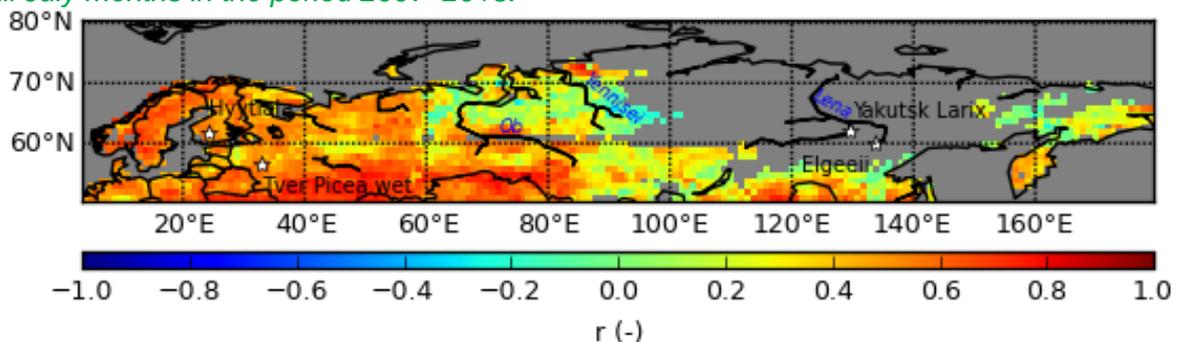
*Response: This is the daily correlation coefficient for all August days (31 days x 7 years). We will add '(31 days x 7 years)' at the end of the sentence for clarification.*

Page 14, line 14: Sentence starting with 'This pattern: : ': Again you should add at least '(data not shown)', or show it in the supplement. Otherwise we have to believe what you say and science should not be based on a 'belief' system.

*Response: The figures for the months July (Fig. AC2a) and September (Fig. AC2b) are shown below to support our statement.*



*Figure AC2a. The temporal correlation coefficient of SiBCASA and ASCAT soil moisture for all July months in the period 2007–2013.*



*Figure AC2b. The temporal correlation coefficient of SiBCASA and ASCAT soil moisture for all September months in the period 2007–2013.*

*We will add '(not shown)' behind 'This pattern is somewhat representative for July, August and September'. It would of course be good to show the figures for other months too, but realising that they merely show the same pattern, and for the sake of conciseness, we did not include them.*

Page 14, line 26: Sentence starting with ' This shows: : ': Sentence is again difficult to understand. Suggest revising.

*Response: We revised the sentence*

*'This shows that day to day noise in particularly the satellite signals are responsible for loss in short-term correlation while the match in inter-annual variation is responsible for a large part of the correlation'*

*into*

*'This shows that day-to-day noise in particularly the satellite soil moisture is responsible for the low correlation coefficients, and that the remaining correlation is dominated by inter-annual variations.'*

Page 15, line 3: Add 'temporal' prior correlation coefficients.

*Response: We will do this in the final manuscript.*

Page 15, line 12: Sentence start with 'Over the years: : :.', perhaps add here after this sentence: 'whereby the ASCAT data are also more consistent with the in-situ data'.

*Response: We will change the sentence into "Over the years ASCAT and in-situ soil moisture are larger than SiBCASA in the spring period (May to early June)."*

Page 17, line 23: After sentence starting with 'As a result: : :' more detail should be provided in regards to explanations why ASCAT does not capture the spatial footprint of the drought.

*Response: This is a valuable remark. Fig. 4 shows that the Tver and Hyytiälä sites are just outside the region with large correlations. In that sense, this result is not surprising. But why is the correlation lower there?*

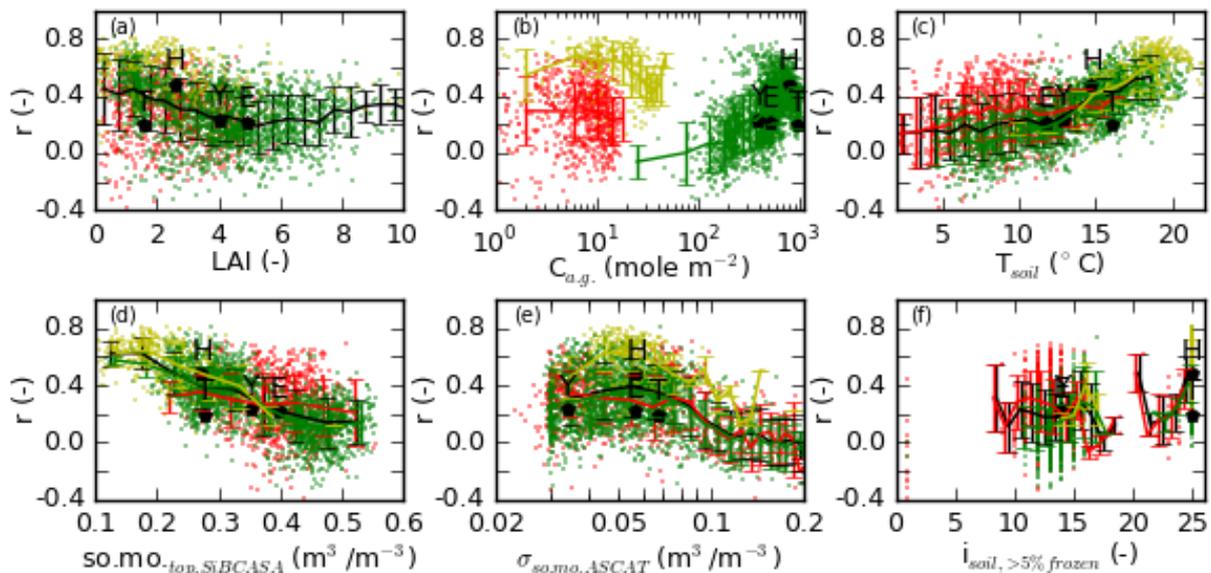
*We have modified Fig. 12 to include the characteristics of the four field sites (Fig. AC3). This shows that the Tver site is in a region with small LAI, high temperature and low soil moisture, and no frozen soil. It has characteristics comparable to the Hyytiälä site. With these characteristics a relatively good performance of the ASCAT soil moisture is expected for both sites. However, the figure also shows that the performance at the Tver site is below average, and above average at the Hyytiälä site. We can only guess what might explain these differences. The region around the Tver site is quite heterogeneous, with a mixture of Spruce and deciduous forests and peat bogs, rivers and lake Seliger. Perhaps the LAI is in reality larger than SiBCASA predicts, and the satellite retrieval is hampered by surface water.*

*We will add to page 9019, line 23:*

*'As a result the sites Hyytiälä and Tver are just outside of the drought region as observed by ASCAT and this is most likely attributable to the ASCAT soil moisture retrieval skills. Fig. 4 shows that the ASCAT performance is low around those sites. In section 5, Fig. 12 we will discuss the performance at the sites in more detail.'*

*Then on page 9026 (Discussion), after line 26 we will add:*

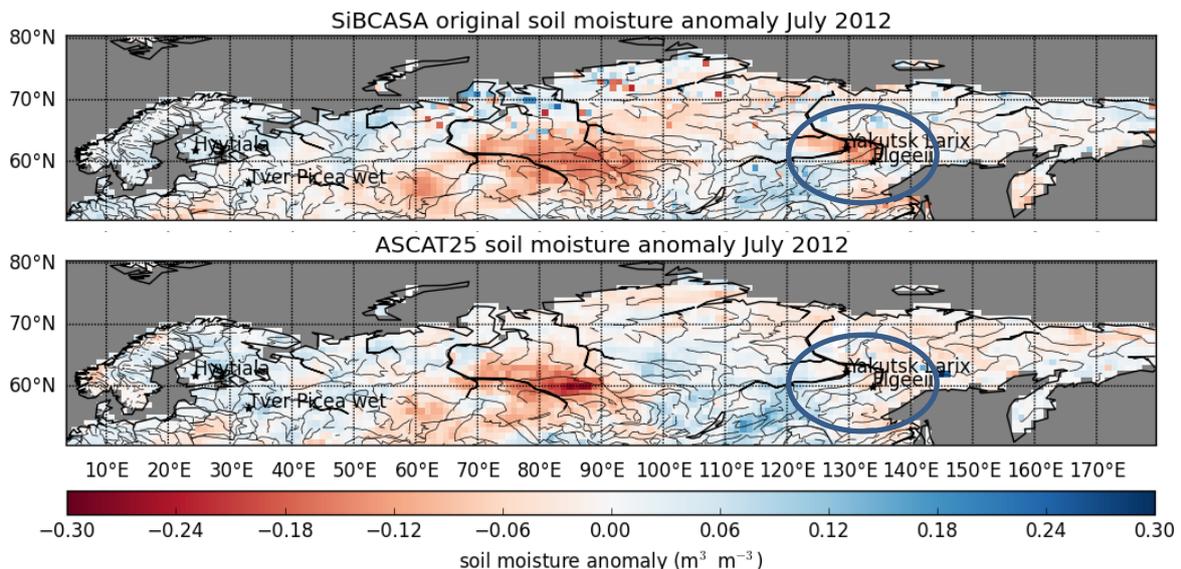
*'The characteristics of the four field sites are indicated by black marks in Fig. 12. This shows that the performance at the Yakutsk and Elgeei sites may be expected to be low, because of the large LAI, low temperatures and relatively large soil moisture. At the Tver and Hyytiälä sites, the expected performance is better, although the Tver site performs below average. We can only guess what might explain this difference. The region around the Tver site is quite heterogeneous, with a mixture of Spruce and deciduous forests and peat bogs, rivers and lake Seliger. Perhaps the LAI is in reality larger than SiBCASA predicts, and the satellite retrieval is hampered by surface water.'*



**Figure AC3.** Variables possibly explaining the temporal correlation coefficient of SibCASA and ASCAT soil moisture: (a) leaf area index; (b) aboveground carbon; (c) soil temperature; (d) top soil moisture in SiBCASA; (e) the uncertainty in ASCAT soil moisture; (f) the first soil layer with frozen fraction larger than 5 %. Red colours represent tundra pixels, green ones forest pixels, and yellow dots steppe pixels. The four black marks indicate the characteristics of the four sites Hyttiälä (H), Tver (T), Yakutsk (Y) and Elgeei (E).

Page 17, line 26-29: Without reference to any figures or tables, this becomes just story telling.

*Response:* The associated figure is show below. In order to keep the paper concise, we decided not to show this figure. We realise that there is a balance between showing evidence and the amount of evidence that can be presented. In this case we think the balance should be towards conciseness, because we already show the same figure for a different month (Fig. 9). We will add (Figure not shown) at the end of line 27.



**Figure AC4.** Monthly mean soil moisture in (a) SiBCASA and (b) ASCAT in July 2012. The ellipse shows the extent of the 2012 drought according to SiBCASA.

Page 22, line 27: By 'value' did you perhaps mean 'accuracy'?

*Response:* A matter of explainable misunderstanding: with 'value' we mean 'usefulness', 'applicability' or 'appropriateness', but in this sentence it could be misunderstood as the

*observational reading of soil moisture, i.e. the mean value as opposed to the variance. We will replace 'value' with 'applicability'.*

Page 23, line 26: Sentence starting with the 'The low soil: :...': among possibly many other factors? Right? Or is there evidence that this IS the key factor?

*Response: The preceding paragraph lists a number of possible explanations: 1) ponding occurs in reality 2) this corroborates the soil moisture retrieval accuracy 3) the amount of snow melt water and its fate is difficult to simulate and 4) overestimation of evapo-transpiration rates in the model. The true explanation is probably a complex mixture of those. Considering that evapo-transpiration rates in the cool spring are probably not large, the potential for overestimation is also small. We would therefore not expect that 4) is the key factor.*

Page 25, line 12-15: Sentence very hard to understand. Suggest revising.

*Response: We revised the sentence*

*'However, the temporal correlation coefficients were quite low for large parts of the region (Fig. 4), which implies that assimilation will have a large effect when the associated observational errors are small'*

*into*

*'However, the temporal correlation coefficients were quite low in large parts of the region (Fig. 4). This implies that simulated and observed soil moisture are quite different. Assimilation will thus have a large effect when the observational errors are small.'*

Page 25, line 23: Sentence starting with 'Furthermore' needs reference.

*Response: We change the sentence 'Furthermore, it has been shown that the drought sensitivity (Fig. 1a) only represents the potential drought sensitivity.'*

*into*

*'Furthermore, Fig. 10 shows that the drought sensitivity in Fig. 1 only represents the potential drought sensitivity.'*

Page 26, line 1: What do you mean by 'reality'? Field evidence?

*Response: Yes, the sentence is 'Furthermore, Ohta et al. (2014) show that in reality, water logging at high plant available water fractions may also reduce photosynthesis rates and affect the water use efficiency.' Ohta describes how the Yakutian forest responds to water logging, based on his field experience and observations.*

Page 26, line 19-20: Very awkward English.

*Response: We revise the sentence*

*"However, these results should be taken carefully, because the spring time conditions are not conform the ideal conditions mentioned just before"*

*into*

*"However, these results should be taken carefully, because ice and ponding occur often in the spring."*

Figure 12, caption: How is the temporal correlation coefficient calculated here???

*Response: This is the correlation coefficient between daily SiBCASA and ASCAT soil moisture for all August days in the period of record. We will add to the caption: 'r represents the correlation coefficient between SiBCASA and ASCAT in all August days in the period of record (31 days x 7 years).'*