The Cryosphere Discuss., 7, C3331–C3351, 2014
www.the-cryosphere-discuss.net/7/C3331/2014/

Interactive comment on "The microwave emissivity variability of snow covered first-year sea ice from late winter to early summer: a model study" *by* S. Willmes et al.

S. Willmes et al.

willmes@uni-trier.de

Received and published: 26 February 2014

We are very grateful to Referee #2 for providing a detailed review and very good comments to our manuscript. In the following we want to respond to your comments in detail but first we address two of your general comments:

a) You summarize in the beginning that "...the conclusion of the paper appears very high, especially since the study is limited to sea ice concentration higher than 90%, for which algorithms often have the best performance."

We want to clarify, that the snow pack (and the associated microwave emission) we simulate represents a SIC of 100% and hence, our approach is valid ONLY for high-ice

concentration data. Your statement that at high SIC algorithms have the best performance is in principle correct. However, as shown by e.g. to Andersen et al. (2007) the remaining uncertainties (at high ice concentration) arise exactly from the emissivity changes that we try to address here. An inclusion of the effect of sea-ice concentrations would require a full retrieval sensitivity study, which is not subject of this paper. We will better work out the motivation for this research in the abstract, introduction and conclusions. We agree, however, that our statement "data can be used to assess the accuracies of sea-ice concentration products" leaves the final conclusions appear high as we do not directly investigate the impact on different sea-ice concentration algorithms. Hence we suggest to re-phrase this sentence to "The obtained results contribute to a better understanding of the uncertainty and variability of sea-ice concentration and snow-depth retrievals in regions of high sea-ice concentrations."

b) Accuracy of simulated brightness temperatures

We recognize that the presented approach might appear ambiguous in terms of TB accuracy, but in comparison to e.g. Montpetit et al. (2013), Brucker et al. (2011), Durand et al. (2008), this study does not intend to fully reproduce a measured TB evolution with the model output. As such, a determination of the accuracy (bias or RMSE) of our modeled TB is difficult. The sources for a deviation of modeled and SSM/I observed TB data here include ERA ambiguities (no detailed met data available) and snowpack initialization (no measured snow pack data). Additionally, an SSM/I grid point that we could compare to our modeled TB is first subject to an undetermined TB variability due to changing surface compositions (heterogeneity) and second includes open water, which certainly impacts the observed TB (for 85 GHz SSMI TB will also be influenced by atm. water vapor). We justify the use of the combined SNTHERM-MEMLS modeling approach instead by referring to the studies of Wiesmann et al. (2000) and Tonboe (2010) and state here explicitly that our approach represents an experimental study with an identical snow pack and for 100% sea-ice concentration only. With this setup however, we focus on net emissivity variations at areas with high ice concentrations as described by Andersen et al. (2007). Moreover, we do not aim at an accurate point-to-point agreement between simulations and observations. It is instead our focus to quantify the net regional effect of atmospherically driven snow metamorphism in the absence of accumulation. In our understanding, this approach and the obtained emissivity variations reveal what we call the “background emissivity variation” which we propose as a minimum emissivity variation that has to be considered for regions with high-ice concentrations in a seasonal and regional context. We therewith elaborate on the translation of atmospheric forcing into emissivity variations for an experimental snow pack and determine its regional and hemispheric characteristics.

Detailed responses

1. The snow simulations.

As SNTHERM is only a snow model and not capable of simulating ice bottom melt, we neglect the ocean heat flux and treat the sea ice as a lower boundary determining the temperature at the snow/ice interface. Similarly, a realistic computation of freeboard is not performed by the model, and therefore flooding and snow-ice formation are not treated. In our model the sea ice persists until all snow has disappeared. The main driver for snow metamorphism is provided by temperature and moisture gradients within the snow, both of which are predominantly influenced by the atmosphere. Moreover, when snow wetness begins to form in the lower snow layers, the snow-ice interface will be close to melting, independent of heat flux through the ice. Changes in the manuscript: Since the main drivers for snow metamorphism are temperature and moisture gradients within the snow, both of which are predominantly influenced by atmospheric conditions, we neglect basal (ocean) heat flux and sea-ice growth. Moreover, when the snow wettens in the lower snow layers, the snow-ice interface will be close to melting, independent of heat flux through the ice (Nicolaus et al., 2009).

Linear temperature gradients

The temperature profile adjusts itself very quickly with the only constraint that it the

temperature at the sea-ice bottom is at -1.8°C. We added a new Figure 3 (see supplement) which shows the evolution of the snow pack and sea ice temperature profiles. Figure 3 is described as follows:

The SNTHERM snow pack evolution for two locations in the Arctic and Antarctic is presented in Figure 3a and 3b, respectively. The two profiles are characteristic of the general hemispheric differences in snow pack evolution described by Nicolaus et al. (2006). In the Arctic, melting does not occur before mid June and is followed by a rapid thinning and disappearance of the snow while density changes in the pre-melt period are only small and grain sizes increase predominantly from the bottom. In contrast, in the Antarctic, the first melt event occurs already in July and is followed by multiple freeze-thaw cycles, which cause a layering of the snow, together with increasing densities and increasing grain sizes also in the upper layers.

Time series of associated simulated and observed 19H, 19H, 37H and 37V brightness temperatures are shown in Figure 3c, d together with the coincidentally retrieved sea-ice concentration at the respective grid points. The simulated data are very smooth in comparison to satellite Tb, while occasionally simulated larger peaks and excursions are also found in the observed Tb, however, superimposed to a substantially larger background variability. Especially when the snow is dry, the observed Tb variability is likely a consequence of other temporal changes of ice and snow properties at the respective grid points, e.g. due to variations in roughness, age and salinity of thin ice (e.g. Eppler et al., 1992). The largest differences between simulations and observations are found for Arctic PR values which is mainly due to the fact that the simulations overestimate 19V by approximately 5 K on average which could be an effect of the snow depth of 30 cm being overestimated in this location.

Snow scattering

We are very grateful for the provided references and added a comparison of our scaling coefficient with those of other studies to our manuscript. We suggest to add the following discussion concerning the scaling: "The use of a correlation length correction scheme for microwave modeling has also been demonstrated in previous studies. Wiesmann et al. (2000) obtained best results for the combination of SNTHERM and MEMLS when pex was calculated by scaling d0 with a value of 0.16. Durand et al. (2008) applied a linear relationship between pex and the natural logarithm of the maximum grain diameter, while Langlois et al. (2012) and Montpetit et al. (2013) used an approach similar to equation 1, while they include an additional factor of 2/3 according to Mätzler (2002) and obtained scaling coefficients of 0.1 and 1.3, respectively. In general, the calculation of correlation lengths and choice of correction factors depends on the choice of model combinations."

A fixed exponential correlation length of 0.15 mm – representative for FYI (Tonboe et al., 2006) - was used in the ice.

Figure 3 (now Figure 4)

Following your recommendation we now added a new Figure 3 (see supplement) which shows simulated snow properties and associated TB data. We chose to limit the presentation of simulations to December in the Antarctic since most of the sea ice starts to disintegrate through bottom melt in January.

2. Hemispheric differences

The general hemispheric differences in atmospheric forcing and associated differences in snow decay are described in Nicolaus et al. (2006) and our study expands upon this research in terms of associated microwave emissivity changes. Thus we would like to refer to their findings instead of specifically addressing a connection of atmospheric parameters and emissivity. We recognize, however, the need for an improved discussion in this regard and adjust our manuscript accordingly. The detailed impact of regional specifications in atmospheric forcing and an application of local snow characteristics could be implemented in a follow-up study.

Precipitation

We argue that in order to quantify the net influence of atmospheric energy fluxes we want to provide comparable snow packs in all of the presented regions and hence simulate snow metamorphism in the absence of accumulation. We try to better discuss our findings in the context of this simplification in the revised manuscript (discussion). We suggest to add the following to the introduction: Our approach represents an experimental study where we assume initial snow conditions at the start of simulations and quantify the impact of seasonal snow metamorphism in the absence of accumulation. With this setup we focus on emissivity variations in areas with high ice concentrations as described by Andersen et al. (2007) and we provide a dataset of the seasonal variability and regional specifications of the microwave emissivity variability of FYI in the 19 to 85 GHz frequency range. These data contribute to a better understanding of the uncertainty and variability of sea-ice concentration and snow-depth retrievals in regions of high sea-ice concentrations (Andersen et al., 2007; Markus et al., 2006; Comiso et al., 1997; Cavalieri, 1994).

....and to the discussion:

An assessment of the contribution of different sources for varying brightness temperatures over high-concentration sea ice goes beyond the scope of this paper. The simplification that snow fall is not considered might cause an underestimation of snow compaction which could result in a bias of mean brightness temperatures. The monthly emissivity variations due to seasonal changes will however be less affected by the missing accumulation, which is indicated by the low sensitivity of emissivity variability in SNTHERM initialization. We did not include the effect of flooding and snow ice formation and hence, the contribution of salty slush and gap layers (Ackley et al., 2008) that probably play an important role for microwave brightness temperatures found over Antarctic sea ice as well (Massom et al., 2001; Haas et al., 2001; Nicolaus et al., 2009). A completely new thermodynamic snow/ice model would be required to simulate these processes and thereby enable an assessment of combined snow and ice ambiguities and their regional characteristics.

Major comments

Abstract, emissivity expressed in %

We suggest that we add a supplementary Table (S1a and S1b, see supplement) that gives the monthly emissivity standard deviations per region, frequency and polarizations. We provide this table with emissivity values in %, the abstract is however changed now to match the range [0,1].

Path to asses SIC

The data in the supplementary Table S1 (see pdf) can be used to estimate to which degree tie points for sea-ice concentration can be accurate, depending on month, region, frequency and polarization.

One of the referee's main concern was the accuracy of the simulated data. As far as accuracy is concerned we want to argue as follows (in addition to what we stated in the beginning of this response (page 1, b):

To ensure that our model results are within the realistic ranges of observed data, we chose to plot them in PR/GR feature space in Figure 2. This figure is now changed (see supplement) and includes also a comparison of frequency distributions for simulated and modeled data. As stated correctly, the modeled data cover a more narrow range than observed TB, but here we have to keep in mind that modeled data (point-scale) represent 100% sea ice concentration, whereas observed data include also emissivity variations arising from different open water fractions (and surface heterogeneity, drift, ...). We acknowledge the referee's critics in saying that our conclusions appear high in this context and try to improve on the argumentation and changed the main outreach conclusion to: "The obtained emissivity data characterize the background emissivity variability of snow-covered first-year sea ice due to atmospheric forcing and contribute to a better understanding of sea-ice concentration and snow-depth product accuracies

at high sea-ice concentrations. The results need to be interpreted in the context of assumptions and simplifications."

The new Figure 2 (supplement) is described as follows:

With our simulations we do not aim to achieve a high point-to-point agreement between observations and simulations because we cannot properly include the effects of surface processes like snow accumulation and redistribution, flooding, snow ice formation. Moreover, the applied simplifications (equal snow pack at initialization) and the additional impact of open water and sea-ice drift on observed Tb complicate a point-to-point comparison of our results with satellite data. Instead, the objective of our study is to quantify the net effects of regionally and temporally variable atmospheric conditions on snow metamorphosis and its impact on emissivity, and to isolate these effects from those other surface processes. Figure 2 a and b show the PR and GR ratios obtained from simulated brightness temperatures for the Arctic and Antarctic, respectively. In addition, the figures show PR and GR ratios from observed brightness temperatures extracted from the daily polar gridded satellite data sets for all regions where the sea-ice concentration exceeds 90%. As expected, the simulated data are closely aligned with the 100% sea-ice concentration lines (white dotted, Cavalieri et al., 1984, 1994). However, PR and GR ratios show a larger range of variability and scatter in the Antarctic than in the Arctic, both in observations and simulations. In general, the simulated data cover a narrower range of PR/GR ratios than observed data. This is mostly due to the fact that the model results (point-scale) represent 100% sea ice concentration, whereas observed data have been extracted for sea-ice concentration >90%, and therefore are affected by emissivity variations arising from different open water fractions, surface heterogeneity and sea-ice drift. Since the simulated data represent a sea-ice concentration of 100% the presented PR/GR variability arises exclusively from changes in the snowpack. The last month of simulations (Arctic: June, Antarctic: December) is highlighted by red dots to indicate the effect of beginning melt processes. In June in the Arctic, there is a pronounced cluster of melt signals with GR values close to zero. In the Antarctic there is less change of PR and GR ratios at the beginning of summer, i.e. in December. The frequency distributions of simulated and observed PR and GR values in the bottom of Figure 2a and b indicate a small bias between observed and simulated data, and narrower distributions with less variability of the simulated data. Although the simulated values are within a realistic range of observed PR and GR, the simulations indicate on average higher PR (Arctic: +0.005; Antarctic: +0.002) and lower GR (Arctic: -0.005; Antarctic: -0.014). Possible reasons for these differences were introduced above. Notable is also a large contribution of simulated GR values close to zero especially in the Arctic, which is not found in the observed data. These GR values are caused by melting snow and result only from data in the last month of simulations (Arctic: June). We suggest that due to different open water fractions, surface heterogeneity and a lower temporal resolution this signal contribution is smoothed in the observed data. As demonstrated by the graphs, the hemispheric differences that are found in the satellite data, i.e. the frequency distribution of PR is flatter and low GR values are less frequent in the Antarctic than in the Arctic, are also present in the simulated data. Figures 2c and d show associated brightness temperatures and their frequency distributions. Modal values of observations and simulations are similar, and the distributions of simulated brightness temperatures are narrower as for the PR and GR ratios. However, in addition, simulated 19V and 37V brightness temperatures show an additional peak at high temperatures of 273 K.. In both hemispheres, Tb values of 273 K are reached in the simulations when the snow starts to melt. This behaviour is not clearly seen in the observed Tb which is probably due to the melt signal being smoothed by different open water fractions and surface heterogeneity within the sensor footprint.

p5718, l. 8: We would like to add:

“While all channels reach values up to 1 during June in the Arctic, minimum average seasonal emissivity values are as low as of 0.68 (0.65) for 85V (85H), 0.85 (0.79) for 37V (37H) and 0.94 (0.86) for 19H (19V). In the Antarctic (Figure 4b, d) the seasonal

emissivity minima are on average 0.03 and 0.01 higher than in the Arctic for 85 and 37 GHz channels respectively. The inter-annual average of maxima does not reach a value of 1 and is 0.97 (0.87) for 19V (19H), 0.94 (0.87) for 37V (37H) and 0.85 (0.79) for 85V (85H). In the Antarctic the regional differences in emissivities are more distinct than in the Arctic.”

p5718, l. 29: We re-phrase:

“It can be seen that the different regions show differences of up to 0.01, 0.04 and 0.07 in their emissivity variations (std. deviation) for 19V, 37V and 85V, respectively.”

p5719, l. 29:

We extend this description by “If an initial snow density of 270 kg/m^3 is assumed in the snow pack, the mean 19V emissivity in the WW region in October decreases from 0.946 to 0.934, while a change from 0.873 to 0.832 and from 0.738 to 0.659 is noted for 37V and 85V, respectively. The associated changes in the monthly standard deviation depend on the introduced changes in initialization. For D270 they amount to +0.01 (19V), +0.01 (37V) and +0.02 (85V) and for D370 the standard deviation decreases by -0.02 (37V) and -0.01 (85V), respectively. In general, Table 1 indicates that in thinner snow an increased microwave emissivity variability, i.e. its diurnal, regional and inter-annual standard deviation, can be expected (zs15). The same holds when snow grains are larger at the beginning of initialization (dg15). The impact of the initial sea-ice salinity (S02, S12) and the presence of ice layers (lay1) on the simulated emissivity variability is very small. As such, Table 1 provides insight into the sensitivity of our results to ambiguities in the chosen snowpack initialization. “.

p5720, l. 20:

Text is extended by the following: “We calculated the penetration depth by accumulating layer transmissivities and determining the depth at which a fraction of 1/e of the signal contributes to the emitted signal at the surface. Maximum values were constrained to the maximum snow depth of 30 cm (snow penetration depth). The mean monthly microwave snow penetration depth is lower in the Arctic than in the Antarctic during month 6 (12.5 cm vs. 20 cm). At 37 GHz the penetration depth in the Arctic starts to deviate from the Antarctic already during month 5 (May/November) with a value of 17 cm (Antarctic: 19 cm) and 10 cm (Antarctic: 17 cm) in month 6 (June/December). The rate at which the penetration depth decreases throughout the season is smaller for 19 GHz than for 37 GHz."

p5720, l. 22: See above

p5722, l. 1: We cannot quantity this proposed effect. This is speculation (text changed accordingly) and atmospheric transfer modeling would have to be applied additionally for this to be quantified.

p5715, l. 2: We changed the text in different positions to clarify that that this is an experimental study and that the use of an equally initialized snow pack is part of our experimental setup. E.g. in the Data section we add: "In defining the presented snow initialization we consider the mentioned studies addressing first-year sea ice snow properties in both hemispheres and use this as an experimental setup that combines characteristics of both hemispheres. This approach enables us to identify the net effect of atmospheric forcing on regional changes in the microwave emissivity, without strong impacts of the initial (winter) snow properties. "

p5715, ll. 19-20: We are aware of the differing frequencies between AMSR and SSMI and thus wrote "similar frequencies". As far as the incidence angle is concerned we performed some test runs checking a) the impact of the inc. angle on the emissivity and b) on the monthly emissivity standard deviation.

a) The mean emissivity is decreased by 0.02 (19H), 0.018 (37H) when we apply 55° instead of 50°. For vertical polarizations there is more or less no effect (Fig. 1, below).

b) Looking at the derivative of emissivity values (indicating the variability), we find that

a change of the incidence from 50° to 55° produces an RSME of 0.00026 (19H) and 0.000413 (37H) which is well below the range of emissivity standard deviations that we present in this study (Fig2, below).

Hence, for simplicity and with respect to the fact the our results also hold when the incidence angle is increased to 55°, we suggest to leave the original text.

p5715, ls. 24-28:

These values were chosen considering different studies that address snow characteristics in the Arctic and Antarctic to provide a useful experimental setup that as representative as possible for both hemispheres. Text change: "Although regional differences in snow depth and snow stratigraphies are documented (e.g. Warren et al., 1999, Powell et al., 2006; Massom et al., 2001; Nicolaus et al., 2009) we set this model experiment up with the same initialization profile in all considered regions. In defining the presented snow initialization we consider the mentioned studies addressing first-year sea ice snow properties in both hemispheres and use this as an experimental setup that combines characteristics of both hemispheres. This approach enables us to identify the net effect of atmospheric forcing on regional changes in the microwave emissivity, without strong impacts of the initial (winter) snow properties. "

p5715, l. 28: We here apply a sea-ice version of MEMLS (Tonboe et al., 2006) which requires the definition of a sea-ice salinity than can also be larger than 12 ppt.

p5716, l. 27: We chose to define the NT tie points as a reference to infer in how far snow property changes cause position changes in the associated feature space. As far as other studies are concerned we acknowledge the references you suggest and added the following text: "The scaling coefficient F in Equation 1 is adjusted to ensure the best alignment of our simulated Tb data with the NasaTeam FYI tie points (Cavalieri et al., 1994) after 5 days of SNTHERM spin-up time. In doing so, a value of 0.12 was obtained for F. The use of a correlation length correction scheme for microwave modeling has recently also been demonstrated by previous studies. Wiesmann et al.

(2000) obtained best results for the combination of SNTHERM and MEMLS when pex was calculated by scaling d0 with a value of 0.16. Durand et al. (2008) applied a linear relationship between pex and the natural logarithm of the maximum grain diameter, while Langlois et al. (2012) and Montpetit et al. (2013) used an approach similar to equation 1, while they include an additional factor of 2/3 according to Mätzler (2002) and obtained scaling coefficients of 0.1 and 1.3, respectively. In general, the calculation of correlation lengths and choice of correction factors depends on the applied model combinations."

p5718, l. 1: Please see the discussion on accuracies provided above....

p5719, l. 11+: This statement was probably hard to follow since the associated data were not shown. We now refer here to Table S1 (supplement) which holds the mentioned values.

p5721, l. 17: Regarding the accuracy of our simulations, please see our responses above. As far as algorithm accuracy assessment is concerned we now provide Table S1 as a basis to expand on the discussion of sea-ice concentration accuracies at high ice concentrations rather than directly assessing sea-ice concentration accuracies in general (this statement was misleading).

Minor comments

Abstract: "forcing" We would prefer to stay with this term since to adequately describes what is conveyed from ERA data to SNTHERM.

p5712, l. 21: Thank you.

p5712, l. 22: Ok, we agree, there are better ones and we now use "(e.g. Eisenman et al., 2014; Stroeve et al., 2012; Cavalieri and Parkinson, 2008; Parkinson and Cavalieri, 2008)"

p5713, l. 2: The report is removed and we added Eppler et al. (1992) instead.

p5713, l. 4: That's right, we skipped this reference at this point.

p5713, l. 13:

No, we stay now with the Markus and Cavalieri (1998) paper and changed to entire paragraph to "The temporal and spatial variability of sea ice coverage and its physical properties are operationally observed with satellite passive microwave radiometers for more than 30 years (e.g. Eisenman et al., 2014; Stroeve et al., 2012; Cavalieri and Parkinson, 2008; Parkinson and Cavalieri, 2008). Sea-ice concentration, the fractional coverage of sea ice per total area, is one of the most important parameters in an operational global monitoring of the polar oceans. It is derived daily in the Arctic and Southern Ocean (e.g. Spreen et al., 2008; Markus and Cavalieri, 2000; Comiso et al., 1997; Cavalieri et al., 1996) based on the microwave emissivity contrast of sea ice and the open ocean at microwave frequencies from 18 GHz to 90 GHz (e.g. Comiso, 1986; Eppler et al., 1992; Cavalieri et al., 1997; Lubin et al., 1997; Svendsen et al., 1987). These methods rely on emissivity proxies that are derived from the microwave brightness temperature (Tb) data at different channels and polarizations. From a comparison with field data or other ground-truth references tie points or transfer functions are deducted to allow for an inversion from microwave measurements to sea-ice concentration or also surface properties like snow thickness or ice type (Markus and Cavalieri, 1998). Critical to this inversion are, however, seasonal and regional variations in the surface microwave emissivity that are caused by differences in atmospheric forcing and associated snow processes (Meier and Notz, 2010; Markus et al., 2006; Cavalieri et al., 1995; Gloersen and Cavalieri, 1986). As shown by Andersen et al. (2007) variations in sea-ice concentration retrievals over high-concentration Arctic sea ice are dominated by variations of snow emissivities. Their study concludes that long-term trends in surface and atmospheric properties may influence computed trends in sea-ice extent and area through their undetermined impact on microwave emissivities. "

p5713, l. 16: We changed this term to "variations in snow emissivities" p5713, l. 28: In this context, “layering” adresses the presence of ice layers. We change the term to “formation of ice layers”.

p5714, l. 12: Typical means “average regional conditions” which we are confident to acquire from 10 years of ERA data.

p5716, l. 15: This is correct, and we are aware of this fact. We want to argue again with the suggested specifications that we need simplifications in this experimental approach to be able quantify the net effect of atmospheric influences on emissivity variations (see above).

p5717, l. 2: see above

p5717, l. 6: These two radiance ratios are generally used as independent variables to discriminate between ice types and ice/ocean. We will add the reference Cavalieri et al. (1984) in this place.

p5717, l. 19: We replied to this concern above, saying that this study is actually focusing on the high-ice concentration emissivity variability. The threshold of 90% is an arbitrary choice with the intention to provide enough pixels for comparison without allowing too much open water to influence the observed data.

p5718, l. 8: The emissivity is provided by an MEMLS function following Wiesmann et al. (2000)

p5718, l. 22: We just added the word “on” and think that the sentence should be ok now: “They show that the impact of melting and evaporation ON the snow cover decrease is very different between Arctic and Antarctic, e.g. the ratio of evaporated snow mass to melted snow mass per unit area amounts to approximately 4.2 in the Antarctic and only 0.75 in the Arctic, which certainly also impacts the evolution of microwave emissivities. “

p5720, l. 3: Thank you for this comment, we suggest to add sub-sections in a revised version (see supplement) to better outline the manuscript and we will change

this sentence to: “The probability distribution of the standard simulation of emissivities (compare Table 1) vs. region is indicated....”

p5720, l. 20: Penetration depth was calculated by accumulating layer transmissivities and determining the depth at which only 1/e of the signal contributes to the emitted signal at the surface. The slight reductions in penetration depth during months 1 to 4 arise from the presence of early melt events that cause a decrease in penetration depth on both frequencies. We suggest to extend the respective text by the following sentence: We calculated the penetration depth by accumulating layer transmissivities and determining the depth at which a fraction of 1/e of the signal contributes to the emitted signal at the surface. Maximum values were constrained to the maximum snow depth of 30 cm (snow penetration depth).

p5721, l. 19: We introduce some examples in the end of the sentence, which says: “...and variations in emissivity just represent one problem next to spatial inhomogenity of surfaces, the presence of thin ice (Kwok et al., 1997) and atmospheric disturbances (e.g. Cavalieri et al., 1995; Markus and Dokken, 2002; Spreen et al., 2008).”

p5721, l. 25: No, they do not, this is just hypothetical and the references are referring to the reduction of weather effects. This would probably be more clear if the references are skipped in this place.

p5721, l. 26: Thank you, this is of course correct. To state this more accurately, we change the sentence to: “Even if an algorithm would implement monthly tie points to account for seasonal variations and weather effects, this tie point would be subject to the regional, diurnal and inter-annual emissivity variations inherent to a specific region. “

p5722, l. 1: To be more specific we replace “Atmospheric effects” by “Atmospheric water-vapor, cloud liquid water and rain”

p5722, l. 2: We suggest to add that “...the weather filters are implemented to reduce to impact of the atmosphere on upwelling brightness temperatures, not to reduce the impact of surface emissivity variations due to atmospheric forcing (Gloersen and Cavalieri, 1986)..."

p5722, l. 14: We change this phrase to "satellite measurements of the surface brightness temperatures" and also add "over high-concentration sea ice" to be more precise in what our investigations refer to.

Figure1: We do not have a good argument justifying why the Sea of Okhotsk was not considered. We just focused in the Arctic Ocean, but we agree that it would be interesting to include this region in a follow-up investigation.

Figure 2: We improved the Figure and its description to clarify these questions.

Figure 4: We speculate that this relates to the local overestimation of the 30 cm snow thickness in these regions since 19H is more affected by a bias in snow depth (Eppler et al., 1992)

New references:

Ackley, S. F., Lewis, M. J., Fritsen, C. H. and Hongjie, X.: Internal melting in Antarctic sea ice: Development of "gap layers", Geophys. Res. Lett., 35, L11502, doi:10.1029/2008GL033644, 2008.

Brucker, L., Royer, A., Picard, G., Langlois, A. and Fily, M.: Hourly simulations of seasonal snow microwave brightness temperature using coupled snow evolution-emission models in Quebec, Canada, Rem. Sens. Environ., vol. 115, pp. 1966-1977, 2011.

Durand. M., Kim, E. and Margulis, S.: Quantifying uncertainty in modeling snow microwave radiance for a mountain snowpack at the point-scale, including stratigraphic effects, IEEE T. Geosci. Remote, 46(6), 1753-1767, 2008.

Montpetit, B., Royer, A., Roy, A., Langlois, A. and Derksen, C.: Snow Microwave Emission Modeling of Ice Lenses Within a Snowpack Using the Microwave Emission Model

for Layered Snowpacks, IEEE T. Geosci. Remote, 51(9) 4705-4717, 2013.

Wiesmann, A., Fierz, C. and Mätzler, C.: Simulation of microwave emission from physically modeled snowpacks, Ann. Glaciol., 31(1),397-401, 2000.

Parkinson, C. L., and Cavalieri, D. J.: Arctic sea ice variability and trends, 1979–2006, J. Geophy. Res., 113, C7, doi:10. 1029/2007JC004558, 2008.

Cavalieri, D. J., and Parkinson, C. L.: Antarctic sea ice variability and trends, 1979–2006, J. Geophy. Res., 113, C7, doi:10. 1029/2007JC004558, 2008.

Stroeve, J. C., Serreze, M. C., Holland, M. M., Kay, J. E., Maslanik, J., and Barrett, A.P.: The Arctic's rapidly shrinking sea ice cover: A research synthesis. Clim. Change, doi:10.1007/s10584-011-0101-1, 2012.

Eisenman, I., Meier, W. N., and Norris, J. R.: A spurious jump in the satellite record: is Antarctic sea ice really expanding?, The Cryosphere Discuss., 8, 273-288, doi:10.5194/tcd-8-273-2014, 2014.

removed:

Bjørgo, E., Johannessen, O. M., and Miles, M. W.: Analysis of merged SMMR-SSMI time series of Arctic and Antarctic sea ice parameters 1978-1995, Geophys. Res. Lett. , 24(4), 413-416, 1997.

Gloersen, P., Campbell, W. J., Cavalieri, D. J., Comiso, J. C., Parkinson, C. L., and Zwally, H. J.: Arctic and Antarctic Sea Ice, 1978-1987 : Satellite passive-microwave observations and analysis. NASA Special Publications, 511, 290 pages, 1992.

Comiso, J. C., and Nishio, F.: Trends in the sea ice cover using enhanced and compatible AMSR-E, SSM/I, and SMMR data, J. Geophys. Res., 113(C02S07), doi:10.1029/2007JC004257, 2008.

Comiso, J. C., Cavalieri, D. J., and Markus, T.: Sea ice concentration, ice temperature, and snow depth using AMSR-E data, IEEE T. Geosci. Remote, 41(2), 243-252, doi:

10.1109/TGRS.2002.808317, 2003.

Please also note the supplement to this comment:
http://www.the-cryosphere-discuss.net/7/C3331/2014/tcd-7-C3331-2014-supplement.pdf

Interactive comment on The Cryosphere Discuss., 7, 5711, 2013.

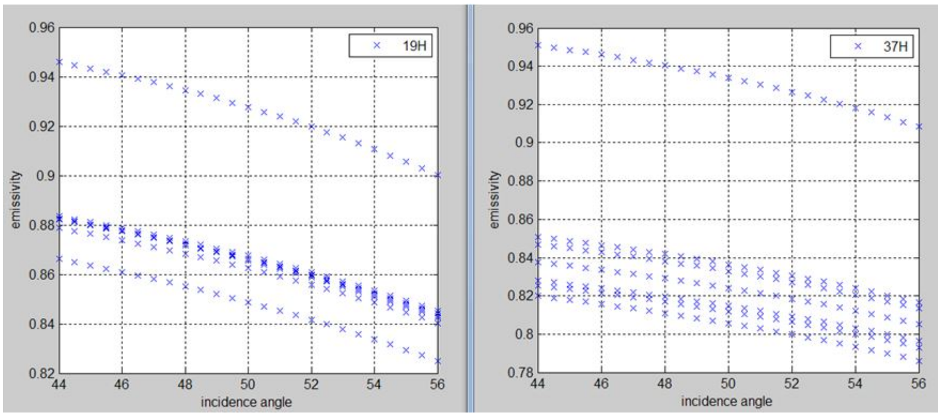

Fig. 1. 19H and 37H emissivities vs. incidence angle

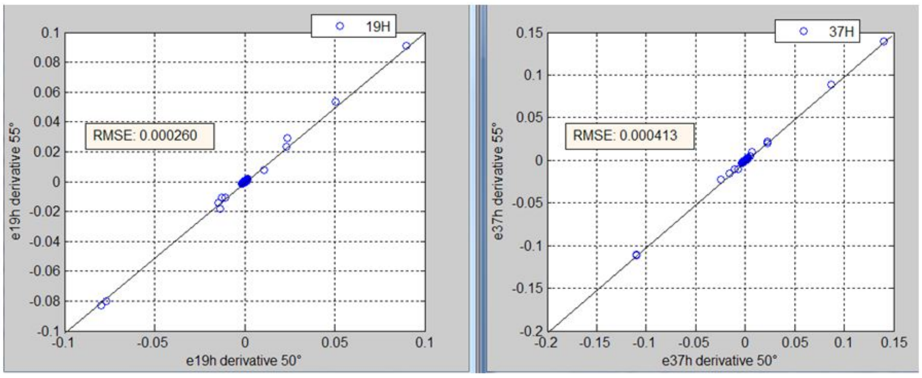

Fig. 2. daily derivative of 19H and 37H emissivities vs. incidence angle