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Atmospheric Measurement Techniques
Discussions

Interactive comment on "Uncertainties of satellite-derived surface skin temperatures in the polar oceans: MODIS, AIRS/AMSU, and AIRS only" *by* H.-J. Kang et al.

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Comments for referee (Dr. R. Iacovazzi, Jr.)

We thank the reviewer very much for the valuable comments. Detailed responses to the comments are given below.

Q1) Line 9 – "Department" not "Deptment". A1) Corrected (New Version; Line 9).

Q2) Lines 30-31 – Recommend the phrasing "warmer up to 1.65K" and "colder down to -2.04K" instead of "up to 1.65 K warmer" and "up to 2.04 K colder". A2) Corrected (New Version; Lines 30-31).

Q3) Line 41 – What about the Southern regions? You only give trend values for the Northern regions only here. A3) The trend values for the northern and southern hemispheric regions were presented in the lower part of the Table 3 and described in Lines 354-357 (New Version). The rates (K/decade) for the southern regions ranged between -1.944±2.271 and 0.375±0.400. However, the rates were not significant at a 95% confidence interval (New Version; Table 3 and Lines 359-362).

Q4) Line 42 – Was the temperature disagreement found to be statistically significant or not? This seems like this would be information that could be included in the Abstract. A4) The grey solid lines in Fig. 1a-b mean the 5% significance level of the differences between Tskin (MODIS) and Tskin (AA_V6), and between Tskin (AO_V6) and Tskin (AA_V6) over a possibly frozen region (poleward from 50 N and 50 S, respectively). Based on the t-test (von Storch and Zwiers, 1999) at significance level of $p<0.05$, the temperature disagreement between Tskin (MODIS) and Tskin (AA_V6) (red solid line) is significant in 50-55 N, 58-70 N, 89-90 N, 50-53 S, and 57-62 S (Fig. 1a). Considering the uncertainty of MODIS due to the conversion of spatial resolution (black dashed line), the temperature disagreement in 57-62 S can become insignificant. However, the discrepancy in 58-70 N is significant even if the uncertainty of MODIS is considered. The difference between Tskin (AO_V6) and Tskin (AA_V6) in 53-60 S is significant (Fig. 1b) (New Version; Fig. A1 and Lines 306-314).

Q5) Line 47 – Recommend to use "challenging" as opposed to "challenged". A5) Corrected (New Version; Line 47).

Q6) Line 62 – The statement "The AIRS instrument suite, with its microwave instrument. . ." leads me to think that AIRS is a suite of instruments. This is not the case. Did you mean to put "AIRS/AMSU" here, or maybe "EOS-Aqua?". A6) We mean the "AIRS/AMSU". Corrected (New Version; Line 62).

Q7) Line 69 – Recommend "Earth Observing System (EOS) Aqua" here instead of just "Aqua". A7) Corrected (New Version; Line 68).

Q8) Lines 86-87 – “The possible reasons for this include the satellite local crossing time (LCT) difference.” I don’t understand this statement, as all of the instruments are on the same platform, thus have the same LCT. Please explain. A8) According to Lee et al. (2008, AMT, 445-455, their Fig. 8), there are substantial LCT differences between MODIS and AIRS/AMSU in the high latitude regions. The LCTs of MODIS and AIRS/AMSU onboard the same Aqua satellite are almost the same over the 60 N-60 S region. However, the considerable LCT differences exist in the high latitude regions because the MODIS swath (2330 Km) has been wider than that of the AIRS/AMSU (1650 Km). The difference of LCT is within two hours in the low latitude regions but can be up to several hours in high latitude regions. Next Fig. 2 presents the footprint difference between them. The text has been revised to explain the LCT (New Version; Line 87).

Q9) Line 92 – Recommend changing “. . . different datasets” to “. . .different SST datasets” and remove the “)” after AMSU. A9) Corrected (New Version; Line 92).

Q10) Line 106 – Don’t need second “.” after “p.m.”. A10) Corrected (New Version; Line 105).

Q11) Line 115 – The question is coming up for me at this point regarding the effect of surface emissivity changes that may arise in the MODIS, AIRS, and AMSU data. How might this affect your analysis and results? A discussion of this needs to be in the paper if it is not. A11) For surface classification, the satellite observations utilize the infrared (IR) channels for MODIS and the microwave (MW) channels for AMSU, respectively. As shown in Table A1, IR and MW channels have the different values of emissivity (ε) over the various surface types, particularly over ocean/snow/ice. Compared to the MW channels, the IR channels have a weakness for the surface classification over the water/ice-mixed oceanic regions, because the IR ε ranges on three different surface types, shown in the table, are overlapped with each other. Although the MW ε ranges are also overlapped, the ε difference between different frequencies is utilized for the surface classification. The surface ε discrepancies due to different satellite-radiometric

channels, used in the MODIS, AIRS/AMSU, AIRS only algorithms, can affect the surface classification.

Table A1. The IR and MW ε values on three different surface types. IR values (Konda et al., 1994; Key et al., 1997; Hall, 2001; Wang et al., 2005), and MW values (Hewison and English, 1999; Yan et al., 2008) have been available in the previous studies. Surface type Infrared ε Microwave ε Land 0.8-0.97 0.9-1.0 Snow/ice 0.90-0.99 0.6-0.9 Water 0.96-0.98 0.5-0.7

Q12) Line 125 – Recommend “bands 31 and 32 are centered” instead of “bands 31 and 32 centered”. A12) Corrected (New Version; Line 124).

Q13) Line 126 – The question comes up for me at this point: What about the case where sea ice may cover a fraction of the radiometer pixel? Is this determined in some way? How might partial coverage of sea ice in a pixel affect your analysis and findings? If you have not discussed this impact, this needs to be added to the paper. A13) The surface condition in the IST algorithm, applied to the polar ocean pixels of MODIS, was assumed to be snow (New Version; Lines 135-136). If the estimated IST is lower than the cutoff temperature between water and ice, the MODIS algorithm categorizes all area of the pixel being ice. The various surface types in the same pixel can cause the uncertainty of SST. The problem for the surface classification can affect the AIRS data, although the AIRS L3 support data contain the number of surface type (e.g., coastline, land, ocean, sea ice, snow and glacier/snow) based on L2 data in the grid. The accuracy of AIRS/AMSU SST can be affected by surface misclassification, which is caused by the surface ε changes, the pixel mixed with the various surface types, and the ice pixel pooled with water. The text has been revised to explain the partial coverage (New Version; Lines 152-154).

Q14) Lines 142-143 – Recommend to use the wording “The AIRS/AMSU algorithm is independent of the GCM, except for the use of GCM surface pressure to determine the bottom boundary conditions” instead of “The AIRS/AMSU algorithm is independent of the GCM except for the surface pressure of the bottom boundary conditions". A14) Corrected (New Version; Lines 141- 142).

Q15) Line 148 – Does the case where water pooled on sea ice have any relevance here? For example, it may cause misclassification of sea ice. If so, is this accounted in your study? I think it at least deserves a mention in the paper, if it has not been mentioned. A15) A surface type in the case can depend on water depth where water pooled on the sea ice. If the depth is deep, the pixel is classified as ocean. The case is enough to cause misclassification. The accuracy of AIRS/AMSU SST can be affected by surface misclassification, which is caused by the surface ε changes, the pixel mixed with the various surface types, and the ice pixel pooled with water. The text has been revised to explain the ice pixel pooled with water (New Version; Lines 152-154).

Q16) Line 176 – What do you mean by random sampling? What was randomly sampled? I am assuming data, but a couple of sentences to clarify what data and at what locations may be helpful to me. Even the whole globe at 1 degree by 1 degree is less than 10,000 trends . . . and you only focus on the poles in this study. I am not sure how you create so many trends. A16) In this study, we have used the 95% confidence intervals in the trends. The confidence intervals are calculated using the bootstrap method, which operates by constructing the artificial data batches using random sampling with replacement from the original data set (Wilks, 1995). For each temperature anomaly data set used in this study, 10,000 new data sets were created by random sampling, which was conducted by drawing data out of the respective original record of temperature anomaly. The significance of a trend, and its confidence intervals, depend on the standard error of the trend estimate. The significance test is only correct if the individual data points are unrelated, or statistically independent (Wigley, 2006). This is not the case for most temperature data, where a value at a particular time usually depends on value at previous times (i.e., temporal autocorrelation). One of the trend methods which remove the effect of autocorrelation is a bootstrap method, in which 10,000 new data sets were usually generated to produce 10,000 linear trends through

random sampling.

Q17) Lines 184-185 – ". . . in the case of MODIS data present over 50% . . ." and ". . . this 50% criteria was used." What do you mean here? The number of 9-day samples for a given year at a given point is greater than or equal to 5? Or do you mean something else? I'm sorry, it is not clear to me. Can you please explain? A17) The original MODIS data has 4 km $\times$ 4 km resolution and the AIRS data has $1^\circ \times 1^\circ$ resolution. In order to compare MODIS data with AIRS data, the original MODIS data was re-gridded to $1^\circ \times 1^\circ$ grid. Near the equator, the original MODIS data are available up to 772 in a $1^\circ \times 1^\circ$ grid because 1° corresponds to about 111 km near the equator. Getting to the poleward regions, the grid area becomes reduced. The 127 original MODIS data exist in a $1^\circ \times 1^\circ$ grid near 80 N. Only if the area of the 9-day mean original MODIS data exceeds 50% of the grid area in a given latitude, the original MODIS data was re-gridded (New Version; Line 186).

Q18) Lines 188-190 – It is fine that you don't repeat the Northern Hemisphere results here, but I think it is worth simply mentioning whether or not the Northern Hemisphere results are similar in nature to the Southern Hemisphere results. A18) Uncertainties among satellite observations (Tskin (MODIS), Tskin (AA_V6), and Tskin (AO_V6)) in the sea ice region of the northern hemisphere are generally similar to those of the southern hemisphere in terms of zonal averages (discussed in Fig. 7 later). However, the systematic difference between the observations can be more clearly shown in the latter region than in the former region due to more oceanic regions in the southern hemisphere (discussed in Figs. 10-11 later) (New Version; Lines 410-414).

Q19) Line 192 – I thought for this study that you used only MODIS data when there were more than 10 samples in the 12-year period? See Line 172. A19) Corrected by removing the confusing sentence as pointed out by Referee #1 (New version; Line 193).

Q20) Line 205 – Recommend to find a uniform way of expressing cooler biases. Is it +2

K lower or -2 K lower? Can be confusing. A20) The text has been revised by using the parentheses for the cooler biases, for instance, 'about -2K' (New Version; Line 205).

Q21) Line 241 – I would not call this "inter-annual variation". I was expecting a single map figure showing a standard deviation of the annual values. I would call this instead "annual-average spatial distributions". A21) As commented by Referee #1, the single map figure with a standard deviation of the annual values would be simple and straightforward, if possible. However, since the sample numbers in a $1^\circ \times 1^\circ$ grid were interannually different due to the colocation of Tskin(MODIS) and Tskin(AA_A6) and particularly the missing Tskin(MODIS) values over the cloudy regions, Figure 5 had to be utilized. In the figure caption, the interannual variation in this study means the temporal (i.e., yearly) variation of austral springtime (9 days) spatial averages in a $1^\circ \times 1^\circ$ grid during 2003-2014. The 12 year temporal variations of the annual averages in the grid were shown in the southern hemisphere. Corrected (New Version; Lines 241 and 715, Fig. 5 caption).

Q22) Line 251 – Are there any in-situ validation data for any of these products? There is the assertion in this line ". . .which must be related to the difference in the surface type characterization." It is starting to concern me that there is no anchor point from which to discuss which of the products may be providing the most reliable results. The utility of a model study is highly limited if we don't understand the validity of the model relative to observations. Are their validation studies that can be referenced in this paper? A22) The AIRS/AMSU L2 data offer the surface type (coastline, land, ocean, two types of sea ice, two types of snow, and glacier/snow), and the AIRS/AMSU L3 data offer the number of these various surface types in a grid. The AIRS only L2 also offer the surface type (coastline, land, ocean, two types of sea ice, and snow), and its L3 data offer the number of these various surface types in a grid. Under the condition without ground truth, the direct validation has a limit because the surface classifications of AIRS/AMSU and AIRS only have some difference. Although the AIRS only has utilized the GCM forecast, there is a good agreement in SST between AIRS/AMSU

and AIRS only in most regions. However, the disagreement between them over the land regions of the Sahara desert, parts of Spain and in the US with snow cover at night has been reported (Dang et al., 2012). We present that there has been the systematic disagreement between them at the sea ice boundary locally (Fig. 1b). The text has been revised to include the validation studies additionally (New Version; Fig. A1b and Lines 473-481).

Q23) Line 254 – "types" not "ypes". A23) Corrected (New Version; Line 254).

Q24) Line 260 – Recommend "exceed" instead of the word "overestimate". A24) Corrected (New Version; Line 264).

Q25) Line 279 – Recommend to change "presented" to "presents". A25) Corrected (New Version; Line 283).

Q26) Line 290 – Recommend restructuring this sentence from "It is hard to see the systematic difference over the northern hemisphere due to the sea ice detection because of the distribution of continent if Fig. 3a." to the following: "It is hard to see in Fig. 3a the systematic difference due to sea ice detection over the northern hemisphere because of the continental distribution". A26) Corrected (New Version; Lines 294-295).

Q27) Line 292 – Recommend to remove the word "also". A27) We removed it in the text (New Version; Line 296).

Q28) Lines 292 and 293 – Instead of the words "overestimated" and "underestimated", maybe use the words "warmer than" or "cooler than" respectively. The use of the words "overestimated" and "underestimated" makes it sound like Tskin(AA_V6). A28) The text has been revised, as pointed out by Referee #1 (New Version; Lines 297-298).

Q29) Line 296 - Instead of "in broader region", needs to be "in a broader region". A29) Corrected (New Version; Line 299).

Q30) Line 298 – Choose a convention for negative biases. Here, you don't put a negative sign in front of this negative bias. In other parts of the paper you do. A30)

Corrected (New Version; Line 301 and 444).

Q31) Lines 331-332 – “MODIS IST was calculated on the snow, sea ice, and ocean assuming the surface was snow (sea ice).” Please clarify this statement, as what I am interpreting is that snow, sea ice and ocean are all assumed to be sea ice. Is this true? A31) Yes, it is. Snow, sea ice and ocean are all assumed to be sea ice (i.e., snow-covered) in calculating MODIS IST. Based on the calculated IST, the pixel in which the IST has been less than 271.5 K is classified by sea ice (Hall et al., 2004). The cutoff temperature (271.5 K) can be spatiotemporally changed (New Version; Line 342).

Q32) Line 341 – Recommend to change “2003-2014”, to “2003-2014 in the southern hemisphere”. A32) Corrected (New Version; Line 354).

Q33) Line 370 – Are there any surface based data that back up the satellite observations? A33) Over the ocean near the Korea Peninsula (34-38 N) in mid-latitude, the correlation in the monthly skin temperature anomalies between the buoy temperature and the satellite observed temperature (MODIS SST) was lower by 0.59 (Yoo et al., 2011). The reason for the low correlation is that the buoy temperature cannot represent the large-scale thermal phenomena because the temperature affected by the sea currents. The validation of the satellite observed SST uses a ship and buoy temperature as in situ SST (Hall et al., 2004). However, the ship and buoy temperatures are inadequate for the study of temperature trend because they are scattered and drifting.

Q34) Line 404 - In regards to the results of the lower section of Table 4: I am struggling to understand what the justification is for focusing the analysis only of those data that have the same sign as the temperature difference. Of course this will show that you will get a trend difference that is the same sign as the temperature difference in this case. The thought that comes to mind is that you are reducing the data set to get the answer you want to see. Please elaborate on why you subsetted the data in this way. A34) The upper section of Table 4 is shown to explain that the temperature difference has an impact on the temperature trend in the same direction. We agree with Referee #1’s

point that the data set has been reduced in the lower section of Table 4. The sample size can affect the estimated impact of ΔT on ΔTrend, but it looks like that the impact on the trends in the lower section is almost consistent with that in the upper section despite the reduced sample sizes. The text has been revised to explain the reduced samples (New Version; Lines 427-430).

Q35) Line 423 - See comment for Line 298. A35) Please see “A30”.

Q36) Line 423 – I am having trouble understanding the phrase “Tskin(MODIS) was higher by up to 1.65K than on the boundary”. Do you mean “Tskin(MODIS) was higher by up to 1.65K than Tskin(AA_V6) on the boundary”? A36) Yes, I do. Thank you for the clarification. Corrected (New Version; Line 444).

Q37) Line 424 – The term “The spatial correlation coefficient” is not clear to me here. Are you referring to the results in Table 2? Do you mean the correlation coefficient computed in latitude bands? A37) The spatial correlation coefficient between the two satellite data sets was computed in this study as follows; a) The climatological 9-day composite data of Surface Skin Temperatures (SSTs) during 2003-2014 were computed in a $1^\circ \times 1^\circ$ grid of the two data sets, respectively. b) We computed the spatial correlation coefficient between the two datasets, using their climatological values in a $1^\circ \times 1^\circ$ grid within a given latitude band. The text has been revised to explain how to calculate the spatial correlation coefficient in this study (New Version; Lines 257-261).

Q38) Line 427 – See comment for Line 298. A38) Please see “A30”.

Q39) Line 437 – See comment to Line 404. A39) Please see “A34”.

References

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Please also note the supplement to this comment:
http://www.atmos-meas-tech-discuss.net/8/C1542/2015/amtd-8-C1542-2015-

supplement.pdf

Interactive comment on Atmos. Meas. Tech. Discuss., 8, 4451, 2015.

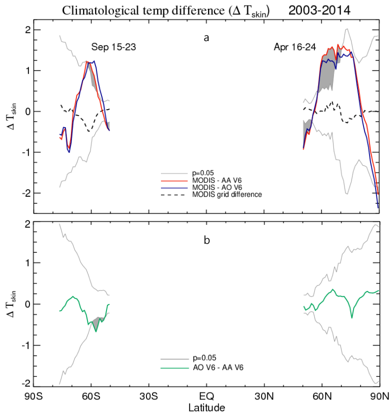

Fig. 1. The difference values (a) between Tskin (MODIS) and Tskin (AA_V6), and (b) Tskin (AA_V6) and Tskin (AO_V6) over a possibly frozen region; shown in Fig. 7. The 5% significance level is prese

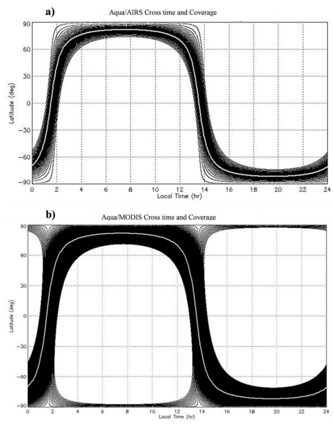

Fig. 2. The latitude vs. local time plots of cross time tracks and data coverage from a) AIRS/AMSU and b) MODIS on January 1, 2009 (after Lee at al., 2013).