

**Comparison  
between MODIS and  
AIRS/AMSU  
temperatures**

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# Comparison between MODIS and AIRS/AMSU satellite-derived surface skin temperatures

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## Abstract

Surface skin temperatures of the Version 5 Level 3 products of MODIS and AIRS/AMSU have been compared in terms of monthly anomaly trends and climatology over the globe during the period from September 2002 to August 2011. The MODIS temperatures in the 50°N–50°S region tend to systematically be  $\sim 1.7\text{K}$  colder over land and  $\sim 0.5\text{K}$  warmer over ocean than the AIRS/AMSU temperatures. Over high latitude ocean the MODIS values are  $\sim 5.5\text{K}$  warmer than the AIRS/AMSU. The discrepancies between the annual averages of the two sensors are as much as  $\sim 12\text{K}$  in the sea ice regions. Both MODIS and AIRS/AMSU show cooling trends from  $-0.05 \pm 0.06$  to  $-0.14 \pm 0.07\text{K}(9\text{yr})^{-1}$  over the globe, but warming trends ( $0.02 \pm 0.12$ – $0.15 \pm 0.19\text{K}(9\text{yr})^{-1}$ ) in the high latitude regions. The disagreement between the two sensors results mainly from the differences in ice/snow emissivity between MODIS infrared and AMSU microwave, and also in their observational local times.

## 1 Introduction

The surface skin temperature is a key variable for climate change and surface energy balance studies in order to understand the biological and environmental processes in association with the ecosystem and soil characteristics (Jin et al., 1997). Therefore, systematic observations with good temporal and spatial coverage from satellites are crucial for the analysis of the temperatures as well as for their trends for understanding the interaction between atmospheric environment and climate change (e.g. Susskind and Molnar, 2008). The MODERate resolution Imaging Spectroradiometer (MODIS) and the Atmospheric Infrared Sounder (AIRS)/the Advanced Microwave Sounding Unit-A (AMSU-A; hereafter named AMSU) instruments onboard the Earth Observing System (EOS) Aqua satellite, launched in 2002, provide an array of atmospheric and surface measurements with an unprecedented accuracy over the globe including the surface skin temperature (Wan et al., 2004; Susskind et al., 2011). MODIS has better spatial

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resolution than AIRS/AMSU, while the latter has better spectral information by taking advantage of hyperspectral IR measurements combined with microwave observations (Schreier et al., 2010). However, since the satellite-derived data include uncertainties, they need to be validated with the independent ground-based or satellite observations (e.g. Knuteson et al., 2006; Schreier et al., 2010; Armstrong et al., 2012). Furthermore it is appropriate to compare MODIS and AIRS/AMSU, loaded on the same satellite, because they match well in the observational time and space (Tobin et al., 2006).

Yoo et al. (2003) showed that the dependence of emissivity on certain surface features (e.g. sea ice and water) could lead to different surface skin temperatures and trends. Surface emissivity uncertainties of  $\sim 1\%$  can result in temperature errors of 1–2 K, based on the radiative transfer calculation for Microwave Sounding Unit (MSU) channel 1 at 50.3 GHz (Prabhakara et al., 1995). An emissivity error of 1.5% at 8.6  $\mu\text{m}$  also causes a Land Surface skin Temperature (LST) error of  $\sim 1\text{ K}$  at a temperature of 300 K (Hulley et al., 2009). Furthermore, calibration/validation studies show that the MODIS temperature over the ocean can be considered as the bulk sea surface temperature rather than the skin temperature (Yuan, 2009; Barton, 2011). The MODIS bulk temperatures tend to be  $\sim 0.2\text{ K}$  warmer than the Marine Atmospheric Emitted Radiance Interferometer (MAERI) skin temperatures for well-mixed layers at night (Donlon et al., 2002). The air-sea heat exchange can cool sea surface skin layer producing the near-surface temperature gradient (Minnett et al., 2001; Donlon et al., 2002).

Schreier et al. (2010) compared brightness temperature over the globe between MODIS and AIRS using spectrally and spatially collocated radiances on a day. The mean difference in Level 1b brightness temperatures of IR window channels between the MODIS and AIRS over the globe was within 0.1 K, based on two day observations (Tobin et al., 2006). However, the maximum differences in the regional averages of the Level 3 (L3) LST products between MODIS Version 4 (V4) and AIRS Version 3 (V3) over the United States were reported to be over 2 K depending on the season (Knuteson et al., 2006). Thus, critical assessment is needed of these products via extensive intercomparisons between the satellite datasets because each product from

the retrieval algorithm has its own pros and cons (e.g. Knuteson et al., 2006; Schreier et al., 2010). So far, the comparison between MODIS and AIRS/AMSU L3 surface skin temperatures has not been carried out with respect to different global environments (e.g. sea ice and ocean) despite their importance in environmental and climatic change studies. The primary purpose of this study is to investigate the characteristics of the differences between MODIS and AIRS/AMSU surface skin temperatures in terms of their trends and climatology over the globe during the recent nine year period.

## 2 Data and method

The Version 5 (V5) L3 gridded monthly surface skin temperature data have been obtained from MODIS and AIRS/AMSU onboard the Aqua satellite during the period from September 2002 to August 2011. The AIRS/AMSU L3 monthly mean products are available for the climate change analysis (e.g. trend) over the long-term with low systematic errors (Harris, 2007). The satellite has the local equatorial crossing time (LECT) of 01:30 (descending) and 13:30 (ascending). The AIRS/AMSU retrieval process is discussed in detail by Susskind et al. (2011). The AIRS/AMSU monthly temperature data (AIRXSTM), which have  $1^\circ \times 1^\circ$  spatial resolution over the globe, were used in this study. The AIRS has a 1650 km wide swath and 2378 channels in the 3.7–15.4  $\mu\text{m}$  wavelength range. The AIRS on-orbit radiometric and spectral calibration is consistent with preflight estimates and the instrument is stable (Pagano et al., 2002, 2006). AIRS is co-located with AMSU, which has microwave channels that are less affected by clouds (Susskind et al., 2003). AMSU has 15 microwave channels at 23–89 GHz; moreover, it consists of 12 oxygen bands (50–60 GHz) in order to retrieve the temperature profiles. Mo (2010) showed that AMSU-A operational calibration algorithms work well and meet prelaunch measured values. The AIRS/AMSU suite is used to derive cloud-cleared radiance in up to 90 % cloud cover (Susskind et al., 2006, 2011). On the other hand, the MODIS data have been retrieved only under clear sky conditions by the cloud detection method (Ackermann et al., 1998).

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The MODIS has 36 visible and infrared channels in the range of 0.4–14.4  $\mu\text{m}$  with a swath of 2330 km, and the surface information is obtained using its atmospheric window channels (Wan and Dozier, 1996). The MODIS surface skin temperature is composed of LST and SST. The V5 L3 monthly MODIS LST data (MYD11C3.5) and the standard mapped image of SST V5 data were used in this study. Compared to the V5 day/night algorithm, which has been used to derive LST, the V4 algorithm tended to overestimate LST and underestimate emissivity when compared with ground-based observations. A refined day/night algorithm was implemented for V5, but V4 was still better over the desert (<http://modis-land.gsfc.nasa.gov/temp.html>). The MODIS V5 has more spatial coverage than V4 particularly at high altitude region (Wan, 2012). The MODIS LST was retrieved from the day/night algorithm (Wan and Li, 1997), whereas MODIS SST was retrieved by the brightness temperature difference between 11  $\mu\text{m}$  and 12  $\mu\text{m}$  channels (Minnett et al., 2004). The accuracy of the MODIS LST, retrieved from the day/night algorithm was reported to be better than 1 K for the clear sky in the temperature range of  $-10^{\circ}\text{C}$ – $50^{\circ}\text{C}$  (Wan et al., 2004). The MODIS SST showed discrepancies of  $-0.03$ – $0.01^{\circ}\text{C}$  over the daily data compared to buoy measurements (Haines et al., 2007). Xiong et al. (2011) reported that MODIS could provide high quality data through on-orbit calibration. The MODIS data in this study were re-binned to a  $1^{\circ} \times 1^{\circ}$  grid in order to avoid the effect of the difference in the spatial resolution when compared to AIRS/AMSU, although the original spatial resolutions of LST and SST are  $5 \text{ km} \times 5 \text{ km}$  and  $4 \text{ km} \times 4 \text{ km}$ , respectively.

We calculated the climatology and anomaly values from the monthly mean temperatures in a  $1^{\circ} \times 1^{\circ}$  grid during the recent nine years in order to estimate temperature anomaly trends. Since these trends are likely dominated by interannual and/or decadal variations, we use the trends for convenience to describe the time rate of change for the years of MODIS and AIRS/AMSU observations. The climatology was obtained only when both MODIS and AIRS/AMSU data were available. The trends were derived only when the number of monthly data was at least 107 out of 108 whole months at each grid point. Linear interpolation was used to produce continuous time series. Area weighting

is applied to the trend analysis over the globe. The bootstrap method (Wilks, 1995) was used in the analysis to calculate the 95 % confidence interval.

### 3 Intercomparison of surface skin temperatures from MODIS and AIRS/AMSU

The climatological annual-mean surface skin temperatures from MODIS and AIRS/AMSU during the period of September 2002 to August 2011 were investigated over the globe (Fig. 1a, b). The temperature differences between the two sensors are shown in Fig. 1c: the differences over land are significant in barren areas (e.g. desert and plateau). Wan (2011) suggested that there might be large errors in the MODIS LST in the desert regions due to large uncertainties in surface emission, and further the LSTs tend to be underestimated in the bare soil areas. The MODIS temperatures over high latitude oceans are more than 4 K higher than those of AIRS/AMSU (Fig. 1c, d).

In the 50° N–50° S region, MODIS temperatures are lower by ~ 1.7K over land than those of AIRS/AMSU, but higher by ~ 0.5K over the ocean (Fig. 1c, d; see also bias values in Table 1). Overall, the MODIS values are systematically lower than those from the AIRS/AMSU over the land, but they are higher over the ocean (Fig. 1d). This MODIS tendency over land in this study is consistent with that of Wan (2011). On the other hand, Hulley et al. (2009) reported that the error in the AIRS/AMSU temperature over an arid region of the Namib Desert were ~ 1.5K due to uncertainties of Land Surface Emissivity (LSE). The error is within the difference value from –2K to –1K of our study between MODIS and AIRS/AMSU (Fig. 1c).

There are some exceptional areas to the oceanic tendency (e.g. warm ocean current extensions of Kuroshio and Gulf, Antarctic circumpolar current) (Fig. 1d). Since the number of observations in these areas is much less than 108 whole monthly values (Fig. 2), the tendency is caused by sampling issues that are related to the cloud detection/clearing processes of the sensor measurements (Ackermann et al., 1998; Susskind et al., 2003).

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The relationship between MODIS and AIRS/AMSU on the climatological annual-mean surface skin temperatures is presented in the scatter diagrams (Fig. 3). In order to analyze the effect of sea ice/snow on the high latitude temperatures from the two sensor measurements, the scatter patterns of the above relationship are examined over the globe and the 50° N–50° S region, respectively. The MODIS observed values less than 271 K are not shown over the global ocean (Fig. 3a). However, the AIRS/AMSU temperatures, which correspond to the MODIS values around 271–272 K range from 259 K to 271 K, illustrate a curved pattern.

The correlations ( $r = 0.990$ – $0.999$ ) over the two regions between MODIS and AIRS/AMSU are almost the same, however, the bias value (1.84 K) over the global ocean is much larger than that (0.51 K) over the 50° N–50° S ocean (Fig. 3a, b; Table 1). The curved shape does not appear over the 50° N–50° S ocean (Fig. 3b). This indicates that the discrepancies between the two sensors mostly occur over the high latitude oceans due to the sea ice/snow, particularly in the Arctic region rather than in the Antarctic region (Fig. 4). Thus, the discrepancies vary seasonally showing the maximum in boreal winter (January) over the ocean (Fig. 5). These discrepancies result because the AIRS/AMSU IR/microwave channels are sensitive to the surface emission (i.e. information) over the sea ice/snow, compared to the MODIS IR. As mentioned earlier, since MODIS oceanic products can also be regarded as bulk sea surface temperatures rather than skin-layer ones (Yuan, 2009; Barton, 2011), their values are expected to be higher than  $\sim 271$  K.

The global skin temperature variations (213–314 K) over land are about twice as large as those (259–304 K) over the ocean (Fig. 3a, c). In these figures the linear relationship over the global land is clearly shown without the curved pattern as seen in the global ocean. The temperature values of MODIS and AIRS/AMSU over the globe are in good agreement ( $r \geq 0.99$ ; Fig. 3 and Table 1).



#### 4 Intercomparison of surface skin temperature trends from MODIS and AIRS/AMSU

The monthly surface skin temperature anomaly trends from MODIS and AIRS/AMSU, and their differences over the globe in a grid box of  $1^\circ \times 1^\circ$  are shown in Fig. 6. There are large numbers of missing observations over the ocean compared to those over land (see also Fig. 2). Warming trends in the polar regions are detected by both instruments, particularly in the Arctic ( $0.1\text{--}0.4\text{ Kyr}^{-1}$ ) (Fig. 6a, b). Based on the spatial average temperature over a given area, warming trends ( $0.021\text{--}0.146\text{ K(9yr)}^{-1}$ ) from both measurements are observed in polar regions ( $60\text{--}90^\circ\text{ N}$ ,  $60\text{--}90^\circ\text{ S}$ ), while cooling trends from  $-0.019$  to  $-0.401\text{ K(9yr)}^{-1}$  are observed in most lower latitude regions (Table 2). In the table, the average difference (MODIS minus AIRS/AMSU) over the whole globe is  $0.086\text{ K(9yr)}^{-1}$ . This indicates that MODIS has a warming tendency compared to AIRS/AMSU, showing a positive bias of  $0.059\text{ K(9yr)}^{-1}$ , which is globally averaged from each grid value (Table 1 and Fig. 6c). The difference is the largest ( $0.261\text{ K(9yr)}^{-1}$ ) in the southern hemispheric mid-latitude region (Table 2 and Fig. 6c). Here, MODIS shows a warming trend ( $0.013\text{ K(9yr)}^{-1}$ ), while AIRS/AMSU demonstrates a cooling trend ( $-0.248\text{ K(9yr)}^{-1}$ ). Also MODIS globally presents stronger warming trends than AIRS/AMSU, except for the high latitude region in the Northern Hemisphere. Compared to the AIRS/AMSU trends, the MODIS values reveal substantial warming ( $0.1\text{--}0.4\text{ Kyr}^{-1}$ ), particularly in the barren areas (e.g. desert and plateau) (Fig. 6c). In these areas, the MODIS LST values are likely to have large uncertainties because of the problem in the classification-based emissivity (Wan, 2011). The trend estimates from the two sensor measurements are generally in agreement within  $\pm 0.1\text{ Kyr}^{-1}$ .

In order to compare the surface skin temperature trends measured from the MODIS and AIRS/AMSU, their scatter plots are shown over the globe and the  $50^\circ\text{ N}\text{--}50^\circ\text{ S}$  region, respectively (Fig. 7). The correlations between the two sensor measurements over the ocean and land regions range from 0.88 to 0.93. The correlation ( $r = 0.93$ ) over the  $50^\circ\text{ N}\text{--}50^\circ\text{ S}$  ocean is somewhat higher than that ( $r = 0.90$ ) over the global ocean

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(Fig. 7a, b). In other words, the disagreement between the two sensor measurements results from the estimates over the high latitude oceans, which lowers the correlation.

The surface skin temperature trends from MODIS at the grid of  $1^\circ \times 1^\circ$  reveal stronger warming values than those from AIRS/AMSU over the high latitude oceans where sea ice/snow exists (Fig. 7a, b). The trend variations ( $-0.77$ – $-0.48 \text{ Kyr}^{-1}$ ) over land are stronger than those ( $-0.71$ – $-0.25 \text{ Kyr}^{-1}$ ) over the ocean (Fig. 7a, c). A kink pattern is found in the scatter diagram over the global land at AIRS/AMSU ( $0.20$ – $0.33 \text{ Kyr}^{-1}$ ) and MODIS ( $0.00$ – $0.05 \text{ Kyr}^{-1}$ ) (Fig. 7c). This pattern does not occur over the  $50^\circ \text{ N}$ – $50^\circ \text{ S}$  land, implying that the disagreement of the trends between the two sensor measurements mainly appear over the high snow/ice areas (Fig. 7d). The disagreement therefore may be attributed to the fact that the AMSU microwave data are more sensitive to ice/snow than the IR data from MODIS. In addition, microwave emissivity values for sea ice can depend on the following factors: snow/ice types, composition, edge, age, thickness, surface characteristics, incidence angle, frequency, polarization, ocean currents, weather, etc. (e.g. Weeks, 1981; Kidder and Vonder Harr, 1995; Isaacs et al., 1989; Grenfell, 1992).

The MODIS surface skin temperature is retrieved from a clear sky condition, whereas the AIRS/AMSU surface skin temperature can be retrieved under a partially cloudy condition (Suskind et al., 2003). The cloud effect may influence the temperature difference between the two sensor measurements because the monthly mean products are calculated from the daily averages, which are affected by clouds. Yuan (2009) reported that MODIS might have more cloud contamination problems than AIRS/AMSU over the ocean. Thus, the effect of different observational channels (e.g. IR and microwave) can lead to a temperature difference. In order to estimate the cloud-cleared radiances, MODIS utilizes only the infrared channels, whereas the AIRS/AMSU uses both the IR and microwave channels.

The MODIS surface skin temperature over the ocean is similar to bulk sea surface temperature because MODIS oceanic products have been calibrated by in situ measurements (Yuan, 2009; Barton, 2011). On the other hand, the AIRS/AMSU surface

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skin temperature over the ocean corresponds to a skin-layer temperature of 10–100  $\mu\text{m}$  depth (Yuan, 2009). Since the skin temperature is typically lower than the bulk temperature (Donlon et al., 2002), AIRS/AMSU is expected to be lower by  $\sim 0.2\text{K}$  than MODIS.

In order to investigate the effect of the satellite Local Crossing Time (LCT) on the surface skin temperature, the tracks for MODIS and AIRS/AMSU on 1 January 2009 are displayed as a function of LCT and latitude (Fig. 8). The LCTs of MODIS and AIRS/AMSU onboard the same Aqua satellite are almost the same over the  $60^\circ\text{N}$ – $60^\circ\text{S}$  region. However, since the different scan angles from the two instruments view a different range of areas, there are substantial LCT differences between them in the high latitude regions. The MODIS LCT variations are greater than those of the AIRS/AMSU, because the MODIS swath (2330 km) is wider than that of the AIRS/AMSU (1650 km). The differences are within two hours in the low latitude regions, but can be up to several hours in high latitude regions. This LCT effect has been mentioned for MODIS/Terra (Jin and Dickinson, 2010). Thus, the disagreement in surface skin temperatures between MODIS and AIRS/AMSU may be partially due to the LCT difference.

## 5 Conclusions

The satellite-derived surface skin temperatures of the V5 L3 products of MODIS and AIRS/AMSU have been compared in terms of monthly anomaly trends and climatology over the globe during the period from September 2002 to August 2011. The MODIS temperatures in the  $50^\circ\text{N}$ – $50^\circ\text{S}$  region tend to be systematically lower than the AIRS/AMSU values by  $\sim 1.7\text{K}$  over land, but are larger by  $\sim 0.5\text{K}$  over the ocean. MODIS oceanic products are greater by  $\sim 5.5\text{K}$  over high latitude oceans than the AIRS/AMSU skin estimates. This is mainly due to the differences in ice/snow emissivity between MODIS infrared and AMSU microwave, and between the surface skin and bulk sea surface temperatures. The MODIS annual averages in the sea ice regions for the period can be up to  $\sim 12\text{K}$  larger than the AIRS/AMSU values. The MODIS

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than ~ 271 K rather than surface skin temperatures. Compared to microwave, infrared channel remote sensing fundamentally has limitations over the sea ice/snow regions.

Since AMSU channels 4 and 5 have been degraded (Fetzer and Manning, 2012), another microwave instrument (e.g. Advanced Technology Microwave Sounder; ATMS) are required for the sea-ice detection from AIRS. Algorithm developers need to analyze the systematic difference in the two instrument temperature between ocean and land over 50° N–50° S, and furthermore the large discrepancies over the sea-ice regions between AIRS/AMSU surface skin temperature and MODIS bulk sea surface temperature. It will be very useful, if the algorithm developers for the two instruments provide their users with both skin sea surface temperature and bulk sea surface temperature. Over the sea-ice regions, however, the attempt may still be possible for the AIRS/AMSU algorithm, but it would be more challenging for the MODIS algorithm, considering its current difficulty in detecting sea ice. Climatologists have to carefully use the surface skin temperature data from the two instruments, based on good understanding about the difference between the two datasets. This study can be valuable to understand the characteristics of satellite infrared and microwave data for surface skin temperature remote sensing, as well as for the climate research associated with the temperature trends.

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**Table 1.** Comparison of MODIS vs. AIRS/AMSU surface skin temperatures for their climatological annual average and monthly anomaly trends over the regions of ocean, land, and globe, respectively. Bias: MODIS minus AIRS/AMSU,  $r$ : correlation coefficient, RMSE: root mean square error. The values in parentheses indicate 50° N–50° S regions of the ocean and the land, respectively.

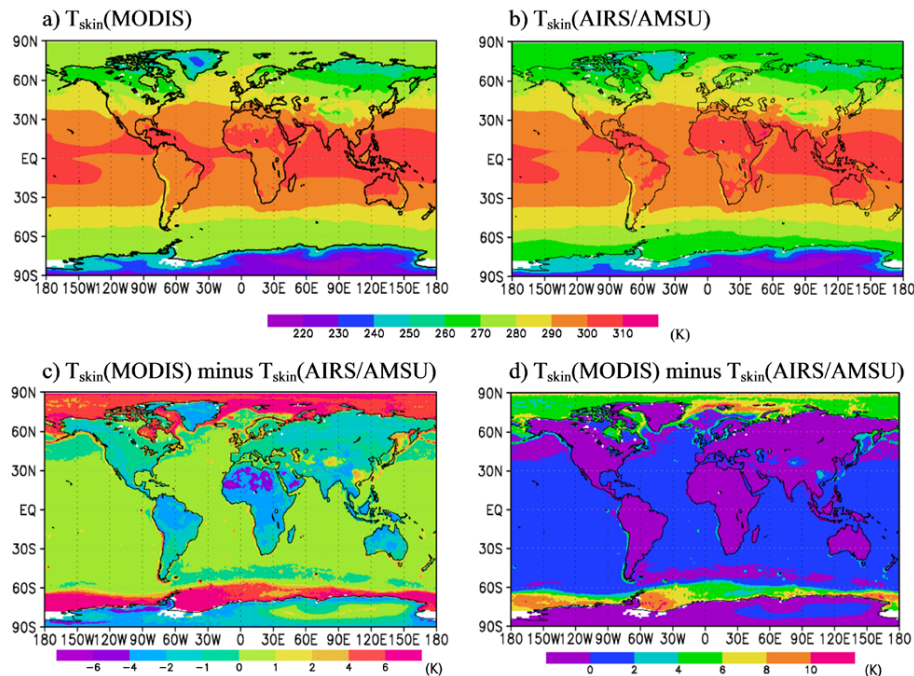
MODIS vs. AIRS/AMSU	Climatology			Trend		
	Bias (K)	$r$	RMSE (K)	Bias (Kyr <sup>-1</sup> )	$r$	RMSE (Kyr <sup>-1</sup> )
Ocean	1.841 (0.513)	0.990 (0.998)	3.133 (0.656)	$2.85 \times 10^{-5}$ $(-1.49 \times 10^{-4})$	0.898 (0.934)	$3.27 \times 10^{-2}$ $(2.44 \times 10^{-2})$
Land	-1.517 (-1.726)	0.999 (0.991)	1.991 (2.233)	$1.33 \times 10^{-2}$ $(4.72 \times 10^{-2})$	0.898 (0.882)	$6.24 \times 10^{-2}$ $(7.98 \times 10^{-2})$
Globe	0.710	0.992	2.801	$6.51 \times 10^{-3}$	0.896	$4.95 \times 10^{-2}$

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**Fig. 1.** Climatological annual surface skin temperatures (K) during the period from September 2002 to August 2011. **(a)**  $T_{\text{skin}}(\text{MODIS})$ , **(b)**  $T_{\text{skin}}(\text{AIRS/AMSU})$ , **(c)** and **(d)** the difference between  $T_{\text{skin}}(\text{MODIS})$  and  $T_{\text{skin}}(\text{AIRS/AMSU})$ . Note that color bars in **(c)** and **(d)** have the different scales.

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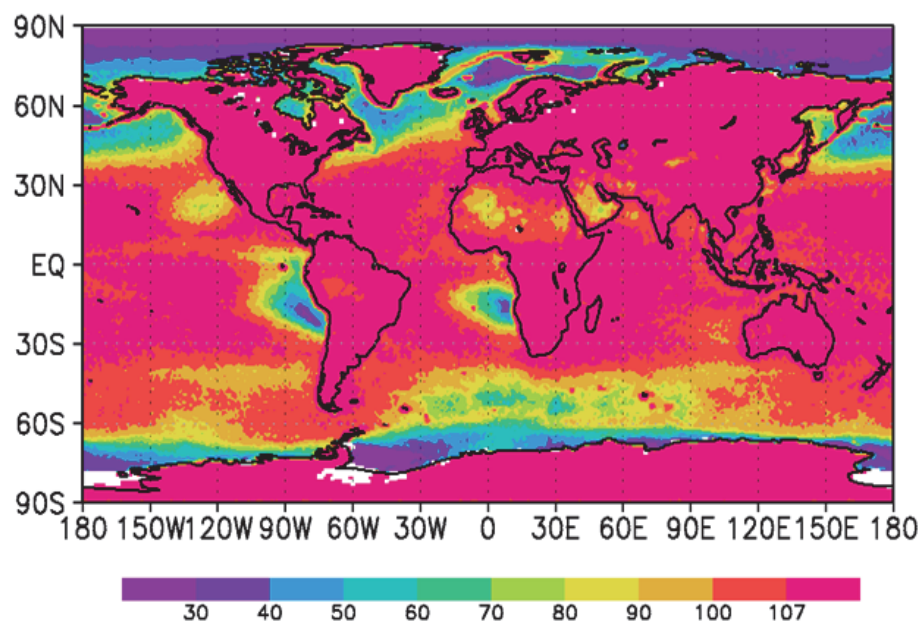
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**Fig. 2.** The number of observations of both MODIS and AIRS/AMSU data commonly available during the period from September 2022 to August 2011.

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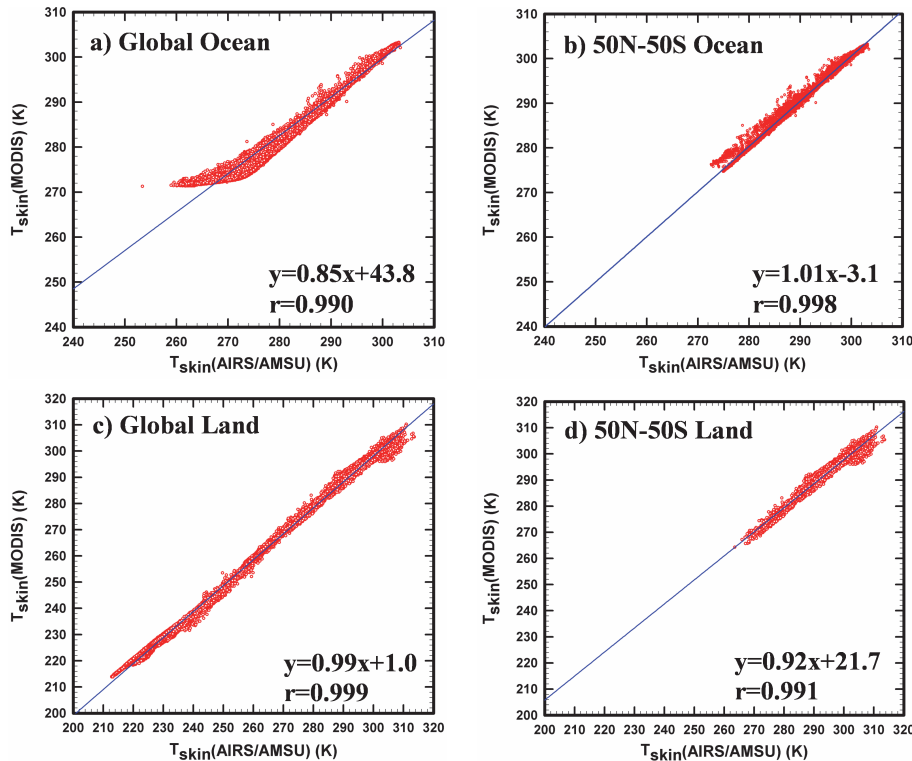
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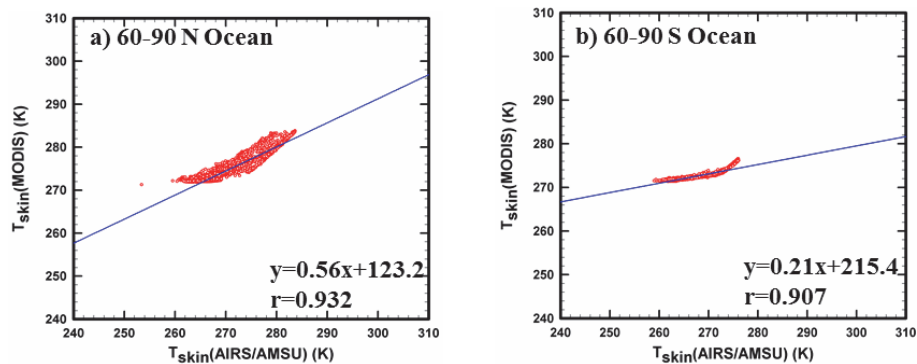
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**Fig. 3.** Scatter diagrams in climatological annual average temperature (K) of  $T_{\text{skin}}$  (MODIS) versus  $T_{\text{skin}}$  (AIRS/AMSU) during the period from September 2002 to August 2011 over the regions of (a) global ocean, (b) the 50° N–50° S ocean, (c) global land, and (d) the 50° N–50° S land. The values of AIRS/AMSU and MODIS have been compared with each other in a grid box of  $1^\circ \times 1^\circ$ .

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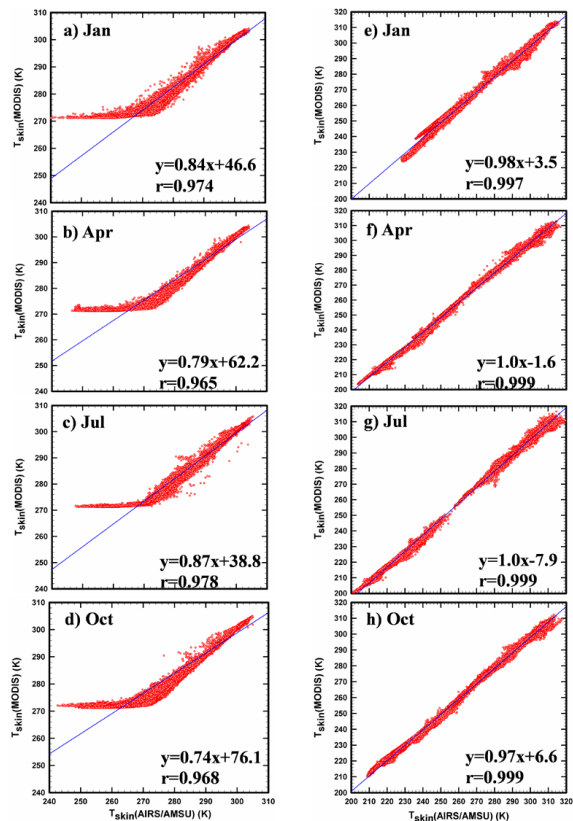
**Fig. 4.** Same as in Fig. 3, except for the oceans at **(a)** 60°–90° N and **(b)** 60°–90° S.

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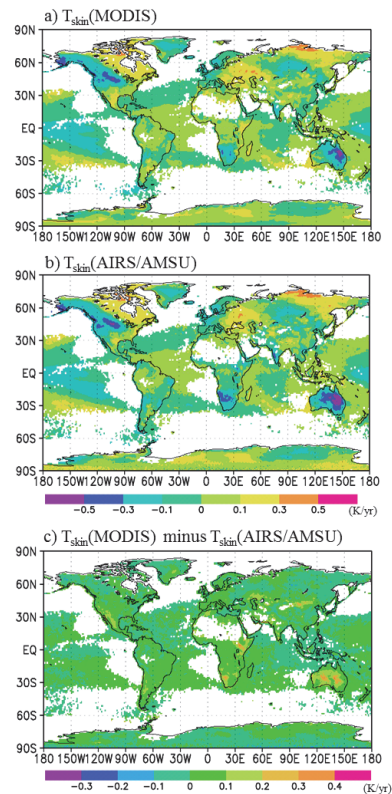


**Fig. 5.** Scatter diagrams in climatological monthly mean values (K) of  $T_{\text{skin}}$  (MODIS) versus  $T_{\text{skin}}$  (AIRS/AMSU) over the global ocean in **(a)** January, **(b)** April, **(c)** July, and **(d)** October. **(e)–(h)** are the same as **(a)–(d)**, but for global land. The values of AIRS/AMSU and MODIS have been examined in a grid box of  $1^\circ \times 1^\circ$  during the period from September 2002 to August 2011.

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**Fig. 6.** Satellite-derived monthly temperature anomaly trends ( $\text{Kyr}^{-1}$ ) in a grid box of  $1^\circ \times 1^\circ$  over the globe during the period from September 2002 to August 2011 for the **(a)**  $T_{\text{skin}}(\text{MODIS})$  and **(b)**  $T_{\text{skin}}(\text{AIRS/AMSU})$ , and **(c)** the difference in thermal trend between the two temperatures (i.e.  $T_{\text{skin}}(\text{MODIS}) - T_{\text{skin}}(\text{AIRS/AMSU})$ ).

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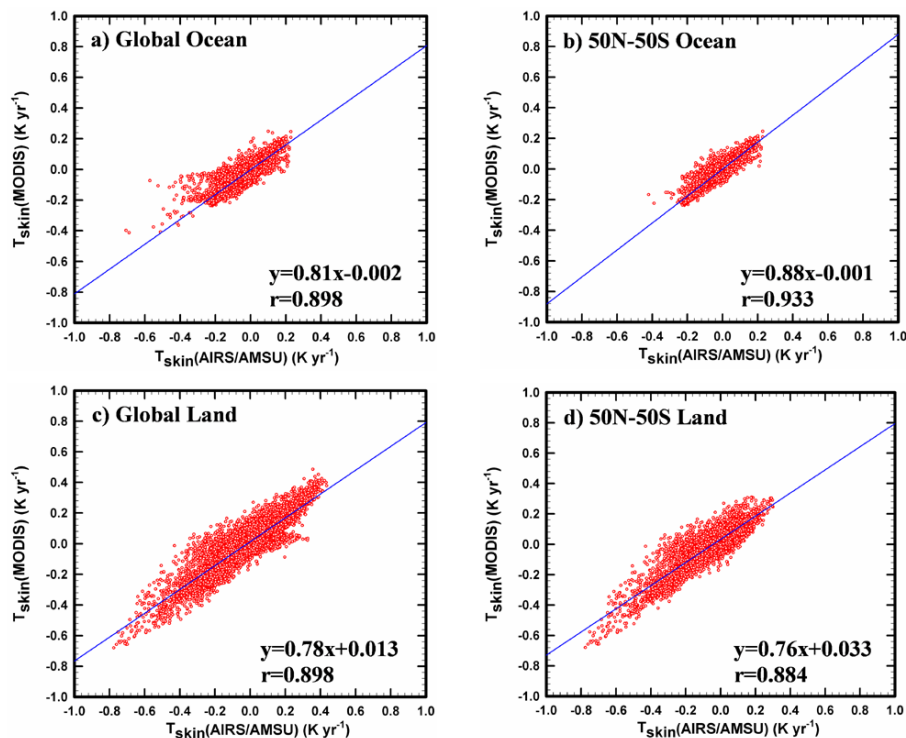
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**Fig. 7.** Scatter diagrams in the monthly temperature anomaly trends ( $\text{K yr}^{-1}$ ) of  $T_{\text{skin}}(\text{MODIS})$  versus  $T_{\text{skin}}(\text{AIRS/AMSU})$  over the regions of (a) global ocean, (b) the  $50^\circ\text{N}$ – $50^\circ\text{S}$  ocean, (c) global land, and (d) the  $50^\circ\text{N}$ – $50^\circ\text{S}$  Land. The values of AIRS/AMSU and MODIS have been compared with each other in a grid box of  $1^\circ \times 1^\circ$ .

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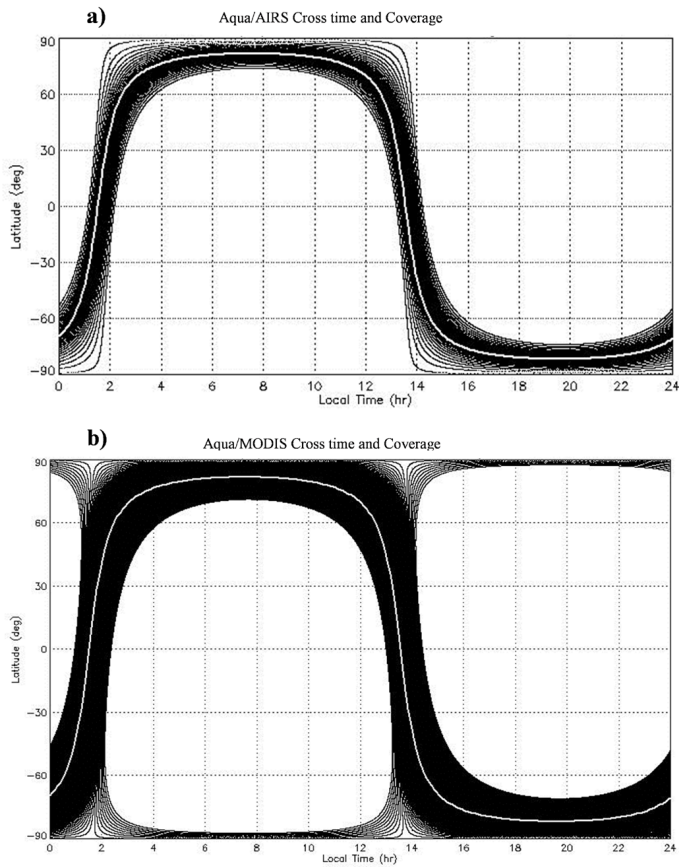
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**Fig. 8.** The latitude vs. local time plots of cross time tracks and data coverage from **(a)** AIRS/AMSU and **(b)** MODIS on 1 January 2009. The MODIS footprints cover a slightly wider area than those of AIRS/AMSU. Here, the nadir tracks are shown in white solid lines.

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