Retrieval of Air Specific Humidity over Oceans

from AMSR-E Measurements

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1. INTRODUCTION

Latent heat flux (LHF) is considered to be most important component in air-sea heat fluxes and plays a significant role in the climate system. Therefore, monitoring of LHF is important to understand the climate variation. Usually we estimate LHF by a bulk formula including wind speed, saturated specific humidity and air specific humidity. If we derive LHF from satellite data, the accuracy of air specific humidity is critical (Tomita and Kubota, 2006). DMSP/SSMI data have been generally used for estimation of air specific humidity. However, recently Advanced Microwave Scanning Radiometer for EOS (AMSR-E) data are available for this purpose. Unfortunately an algorithm for estimation of air specific humidity using AMSR-E data is not popular. Although only Zong et al. (2007) developed the algorithm using AMSR-E data, they assumed reanalysis data to be true values in the study. However, it is not considered that reanalysis data are true values. Kubota et al. (2008) pointed out reanalysis data have considerably large errors by comparing with buoy data.

Our objectives are to develop a new algorithm for accurate estimation of air specific humidity using AMSR-E data, to validate the present products by buoy data and to compare the present products with other products.

2. DATA

We used the AMSR-E Level 1B brightness temperature data, specific humidity data at each pressure level in NCEP/NCAR Reanalysis (NRA1) data and surface specific humidity (Qa) data observed by ships and buoys, included in International Comprehensive Ocean-Atmosphere Data set (ICOADS) from 2003 to 2005. Temporal and spatial resolutions of NRA1 data are 6 hours and 2.5° grid, respectively. Also ICOADS data are instantaneous data. The data in 2005 were used to develop the algorithm and the data in 2003 and 2004 were used for evaluation of new products. Moreover, Qa data observed by buoys in 2003-2005 were used to validate Qa estimated by the present algorithm. Figure 1 shows the buoy location. We use Kuroshio Extension Observatory (KEO) buoy, National (NDBC) buoys, TAO/TRITON buoys and PIRATA buoys. In addition to the above-mentioned data, we used six global Qa products given in Table 1 for comparison. These products are unified to the daily data of 1° grid.
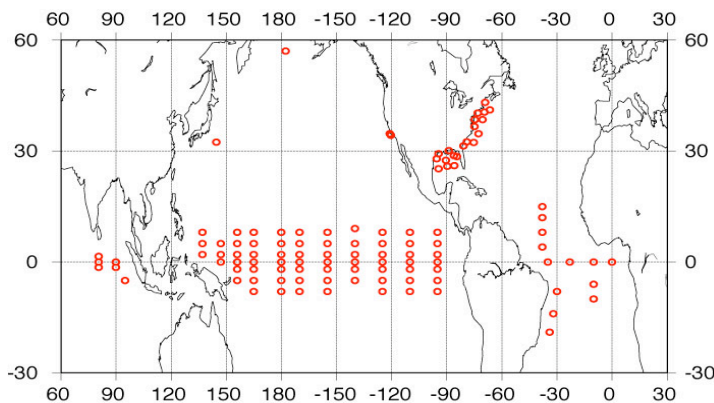

Figure 1 Buoy location

Table 1. Global products used for comparison

Product	Algorithm	Sensor
J–OFURO2	Schlüssel et al. (1995)	SSM/I
HOAPS3	Bentamy et al. (2003)	SSM/I
Zong	Zong et al. (2007)	AMSR-E
Liu	Liu (1986)	AMSR-E
NRA1	reanalysis data	
NRA2	reanalysis data	

3. Development of a new algorithm

First, ICOADS data are collocated to AMSR-E data using the criterion of the temporal and spatial differences of 30 min. and 25 km, respectively. Next, we did the multiple linear regression by using the collocation data in 2005 assuming ICOADS data to be true values. The regression equation (001) has a following form

$$Q_a = a_0 + \sum_{i=1}^{12} a_i T_i \quad (001)$$

where T_i is brightness temperatures observed by AMSR-E and a_i is a coefficient.

Also it is expected that the regression coefficients depend on a vertical structure of the water vapor over the ocean. So, we tried to make another algorithm including information of a vertical structure of the water vapor. We introduced a new parameter, the difference between specific humidity at 1000hPa and vertical average of specific humidity as a parameter reflecting the vertical humidity profile. Figure 2 shows a schematic diagram showing the definition of a profiling parameter, D. Figure 3 is a scatter diagram between ICOADS Qa and D. We can find a strong relation between them. Then we made another regression equation (002) using the brightness temperature and D.

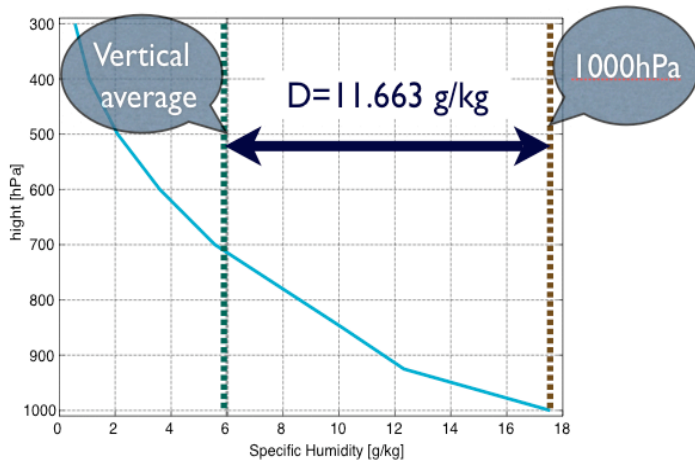$$Q_a = a_0 + \sum_{i=1}^{12} a_i T_i + a_{13} D \quad (002)$$

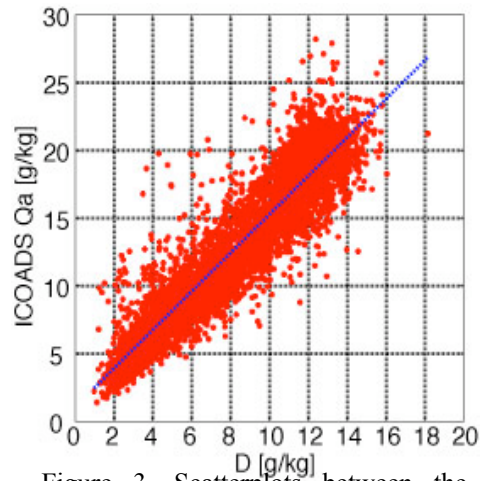Figure 2. Schematic diagram for the profile parameter.

Figure 3. Scatterplots between the profile parameter, D and ICOADS Qa.

We evaluated the performance of two algorithms using independent collocation data in 2003 and 2004. In Fig. 4, the scatterplots between ICOADS Qa and Qa estimated by 001 or 002 are shown. Additionally, Figure 4 shows scatterplots between ICOADS Qa and Qa derived from AMSR-E data by applying other algorithms, which were developed for DMSP/SSMI brightness temperature data. The statistics were listed in Table 2. We can see that the scattering for 002 is smaller than that of not only 001 but also other products. Especially, the improvement is remarkable for ICOADS Qa values smaller than 10 g/kg. The results of the algorithms of Schulz et al. (1993) or Schlussel et al. (1995) are worse than that of the new algorithms, as expected, because the algorithms were constructed for DMSP/SSMI data.

Table. 2. Statistics for each product.

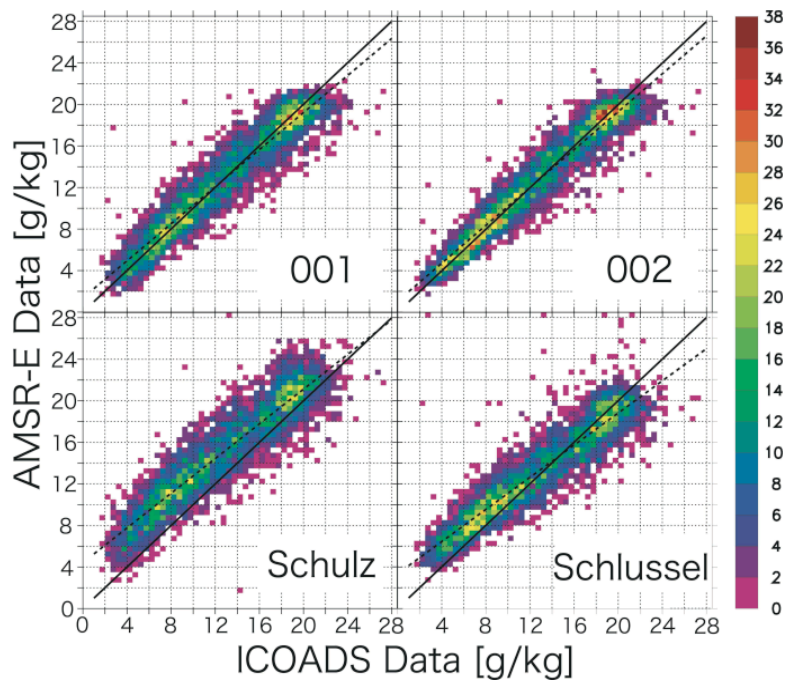|	001	002	Schulz	Schlussel
BIAS [g/kg]	−0.01	−0.04	2.32	0.45
RMSE [g/kg]	1.75	1.55	2.17	2.17
CORRERATION	0.946	0.958	0.916	0.919

Figure 4. Scatterplots of the frequency distribution between specific humidity data
in ICOADS and derived from AMSR-E data.

4. Validation by buoy data

Global products derived from AMSR-E brightness temperature using two algorithms are evaluated by buoy data. Figure 5 shows the scatterplots between Qa observed by buoys and each global product. Qa estimated by the algorithm of Liu (1986) has the biggest scattering. Clearly, Qa estimated by Zong (2007)'s algorithm is overestimated for small values and underestimated for large values. The present products have smaller scattering than J-OFURO2 or HOAPS3. The scattering of reanalysis data is smaller than that of satellite data, but reanalysis data seem to be slightly overestimated. Statistics were listed in Table 3.
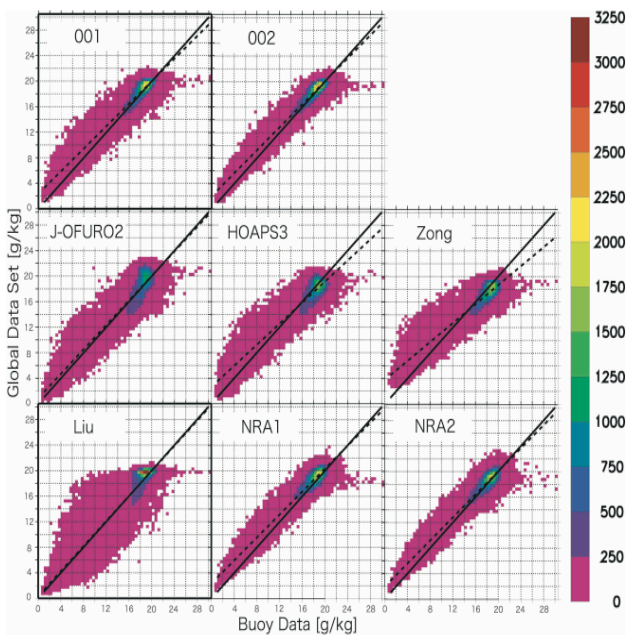

Table 3. Statistics for evaluation by buoy data.

	001	002	J−OFURO2	HOAPS3
BIAS [g/kg]	0.46	0.42	0.19	−0.21
RMSE [g/kg]	1.23	1.03	1.68	1.57
CORRERATION	0.954	0.969	0.920	0.925
	Zong	Liu	NRA1	NRA2
BIAS [g/kg]	−0.41	0.03	0.72	0.39
RMSE [g/kg]	1.65	1.88	1.13	1.16
CORRERATION	0.923	0.906	0.962	0.959

Figure 5. Same as Fig. 4, except by buoy data.

Second, we analyzed a cluster analysis using only buoys of which missing data are less than 30 days in 2004. The results are shown in Fig. 6. The number of clusters is six and there are four clusters in a tropical region and two clusters in mid- and high-latitudes. It is interesting that the buoys located in western (eastern) equatorial Atlantic are included in the same cluster as the buoys in western (eastern) equatorial Pacific.

The statistics for each cluster are shown in Fig.7 for all products. The present products give small RMSE compared with other products in all clusters. J-OFURO 2 and HOAPS3 using SSMI data shows very small correlation in the cluster 1 and cannot reproduce the variability in the western equatorial Pacific. The product of Zong et al (2007) gives small RMSE in the equatorial regions, while large RMSE in the mid-latitudes. NRA1 and NRA2 show relatively small RMSE in most clusters, but smaller correlation coefficients than satellite-products in the clusters 3 and 4.
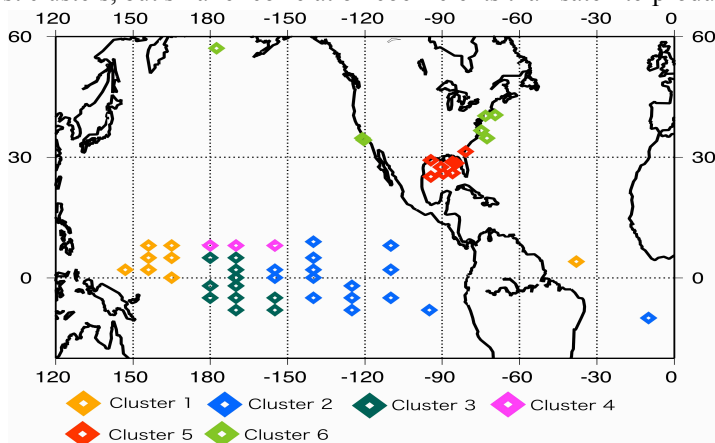

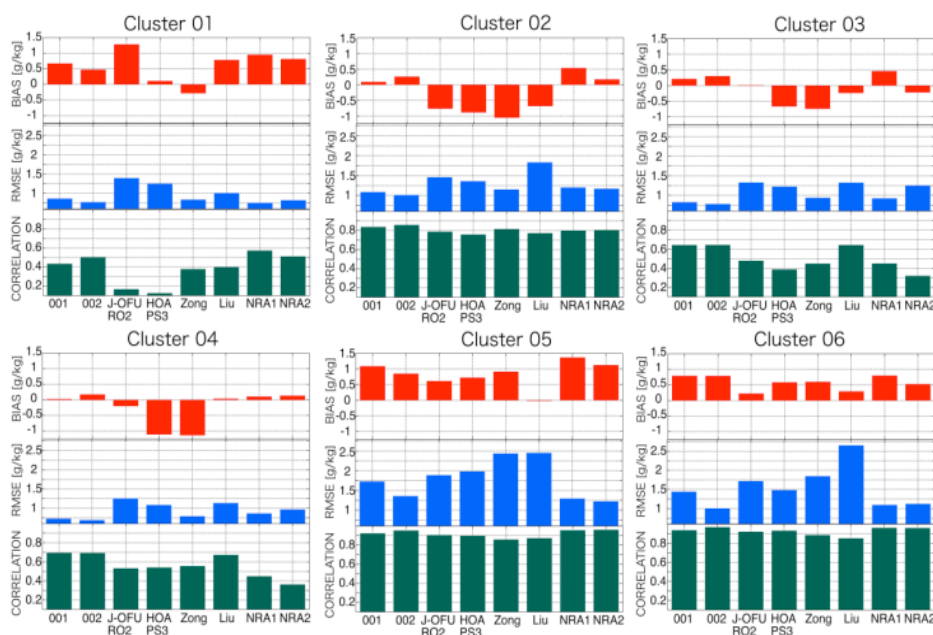Figure 6. Clustering of the data

Figure 7. Statistics for each cluster

Finally we show scatterplots between Kuroshio Extension Observation (KEO) buoy and satellite-derived surface specific humidity data (Fig.8). Time variation of specific humidity and the statistics are also shown in Fig. 9 and Table 4, respectively. The characteristics found in Fig. 8 are similar to those of global comparison. Our products give small RMSE and high correlation compared with other products. However, the bias is not so small. Zong et al. (2007) gives

a small bias. However, it should be noted that the small bias is caused by overestimation in winter and underestimation in summer.
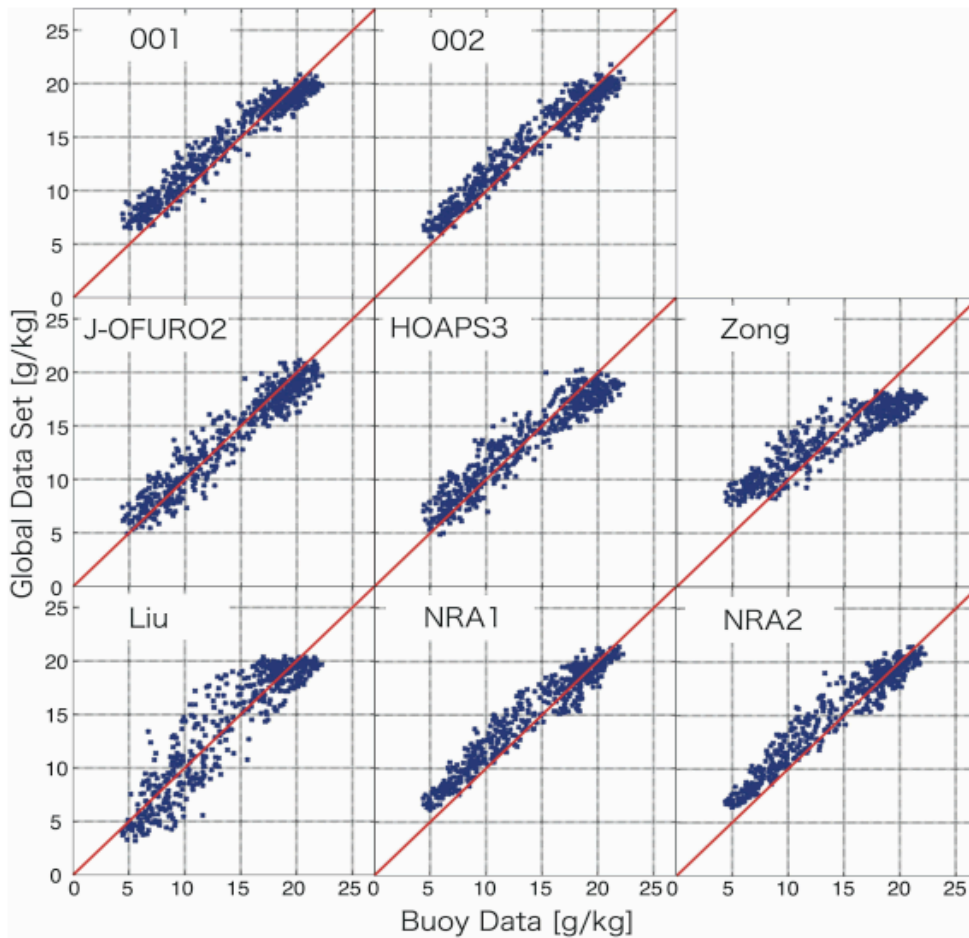

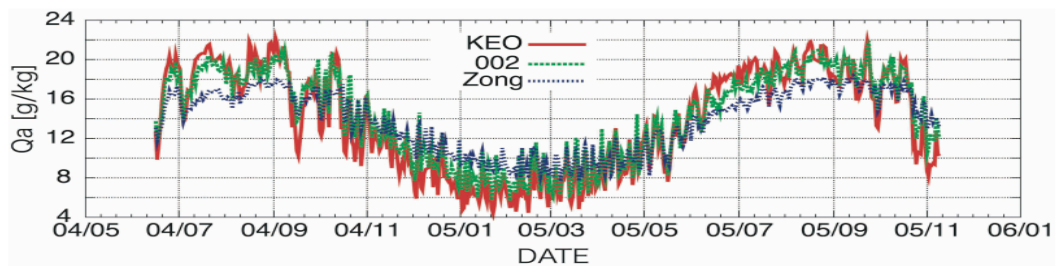Figure 8. Scatter plots of specific humidity between KEO buoy and each product.

Figure 9. Time variation of KEO Qa and Qa derived from AMSR-E data.

Table 4. Statistics for each product evaluated by KEO Qa.

	001	002	J−OFURO2	HOAPS3
BIAS [g/kg]	0.60	0.46	−0.07	−0.11
RMSE [g/kg]	1.43	1.33	1.50	1.76
CORRERATION	0.969	0.970	0.957	0.949
	Zong	Liu	NRA1	NRA2
BIAS [g/kg]	−0.06	0.02	0.90	0.88
RMSE [g/kg]	2.55	2.00	1.43	1.47
CORRERATION	0.924	0.928	0.966	0.964

5. SUMMARY

We developed new algorithms for estimation of surface specific humidity using AMSR-E brightness temperature data. The use of a profiling parameter, D can significantly reduce random errors. The daily specific humidity data estimated by the present algorithms are evaluated by buoy data. The bias is not so small compared with other products such as satellite and reanalysis products. However, the RMS error is considerably small, 1.04 g/kg compared with other products. And the correlation coefficient is the highest, 0.974.

The bias, RMS error and correlation coefficient for the present product are 0.45 g/kg, 1.32 g/kg and 0.971for KEO buoy, respectively. And those for products estimated by Zong et al. (2007)'s algorithm are -0.06 g/kg, 2.55 g/kg and 0.924. We found the small bias for products estimated by Zong et al. (2007)' algorithm is not homogenous and caused by the offset generated by overestimation for the small values and underestimation for the large values. It is concluded that the present new algorithm is much better than the algorithm by Zong et al. (2007).

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