ACCURATE ESTIMATION OF GLOBAL LATENT HEAT FLUX USING MULTI-SATELLITE DATA

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ABSTRACT:

Global latent heat flux data sets are crucial for many studies such as those related to air-sea interaction and climate variation. Currently, various global latent heat flux data sets are constructed using satellite data. Japanese Ocean Flux data sets with Use of Remote sensing Observations (J-OFURO) includes one of the satellite-derived global latent heat flux data (Kubota et al., 2000). In this study, we review future development of J-OFURO global latent heat flux data set. In particular, we investigate usage of multi-satellite data for estimating accurate global latent heat flux. Accurate estimation of surface wind speeds over the global ocean is one of key factors for the improved estimation of global latent heat flux. First, we demonstrate improvement of daily wind speed estimation using multi-satellites data from microwave radiometers and scatterometers such as DMSP/SSMI, ERS/AMI, QuikSCAT/SeaWinds, Aqua/AMSR-E, ADEOS2/AMSR etc. Next, we demonstrate improvement of global latent heat flux estimation using the wind speed data derived from multi-satellite data.

KEY WORDS: global latent heat flux, satellite data, multi-satellite data

1. INTRODUCTION

Global latent heat flux data sets are cruitial for many studies such as those related to air-sea interaction or climate variation. Currently, various global latent heat flux data sets such are constructed based on satellite observation and atmospheric global circulation model. Japanese Ocean Flux data sets with Use of Remote sensing Observations (J-OFURO) is one of the satellite-derived global latent heat flux data (Kubota et al., 2000). The J-OFURO latent heat flux is calculated by the following bulk formula (Kondo, 1975);

$$QL = \rho L Ce W (Qs - Qa) \qquad (1)$$

where QL is the latent heat flux, ρ is the density of air, L is the latent heat of water, Ce is the bulk transfer coefficient, W is the scalar surface wind speed, Qs is the saturate surface air specific humidity, and Qa is surface air specific humidity.

In the equation (1), the W, Qs, and Qa are essential for estimating latent heat flux. In general, the surface wind speed is observed by a spaceborne microwave radiometer and scatterometer which are mounted on a sun-synchronous satellite. The surface air specific humidity is also observed by a spaceborne microwave radiometer on a sun-synchronous satellite. However, a sun-synchronous satellite observes wind speed or surface air specific humidity only two times per one day at same place.

Figure 1 is a schematic of sampling of wind speed by a sun-synchronous satellite. Horizontal axis shows time and the period of one day. On the other hand, the vertical axis shows wind speed.

Red line means true variation of wind speed and average value. On the other hand, blue points mean single satellite observation for one day.

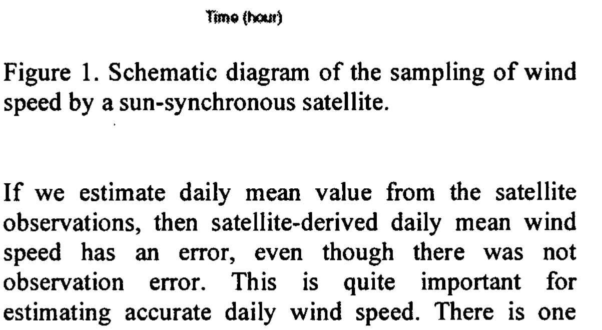

Figure 1. Schematic diagram of the sampling of wind speed by a sun-synchronous satellite.

If we estimate daily mean value from the satellite observations, then satellite-derived daily mean wind speed has an error, even though there was not observation error. This is quite important for estimating accurate daily wind speed. There is one simple method to avoid this problem, that is high frequency sampling of wind speed and surface air specific humidity. That is the use of multi-satellite data.

Fortunately, today, we can use wind speed data and surface air specific humidity obtained by many kinds of sun-synchronous satellites or sensors. If we can use multi-satellites data for estimating bulk parameters, we can obtain more reliable daily mean bulk parameters, because the high frequency sampling may reduce the sampling error.

In the present study, the improvement of daily wind speed estimation using multi-satellites data from microwave radiometers and scatterometers. In addition, the comparison with in situ data is conducted to demonstrate improvement of daily wind speed data using multi-satellite data.

2. DATA AND METHOD

In the present study, we used satellite-derived wind speed data during 2000 year. The DMSP/SSMI F13, ERS-2/AMI and QuikScat/SeaWinds are used for estimating wind speed data. These satellite-derived wind speed data are averaged on 1 degree by 1degree grids with daily time interval. In addition to these satellite-derived wind speed data, we constructed multi-satellite wind speed data by averaging all satellite-derived wind speed data as our preliminary multi-satellite product.

In order to calculate simulation value (see below) and evaluate our preliminary multi-satellite product, we used moored buoy observation data from JMA, NDBC and TAO/TRITON buoys. JMA and NDBC buoys are located in mid-latitudes region. On the other hand, TAO/TRITON buoys are located in the tropical Pacific region. Because all buoy wind speed data are not observed at 10m height, buoy wind speed values are corrected to values at 10m heigh by LKB method. The daily mean buoy wind speed data are made from three or hourly buoy wind speed data. Then, to avoid sampling error in buoy data, we made daily mean value only if hourly or three hourly buoy data are completely available for one day.

3. MULTI-SATELLITE SIMULATION

Before to explain actual multi-satellite data, an advantage of using multi-satellite data should be evaluated. We conducted simple simulation using only buoy observation data. We show results of multi-satellite simulation to explain the potential of use of multi satellite data. We made single or multi-satellite simulation data using only buoy data. The simulation data is made by averaging buoy data at each satellite observation time. So please note that satellite data is not used in simulation data.

Figure 2 shows RMS errors between daily simulation and buoy data. Horizontal axis means each single or multi-satellite simulation. On the other hand, the vertical axis shows RMS differences between simulation and buoy data. From this figure, it is clear that all multi-satellite simulations show quite small RMS error compared with other single satellite simulations. This suggests potential of use of multi-satellite data.

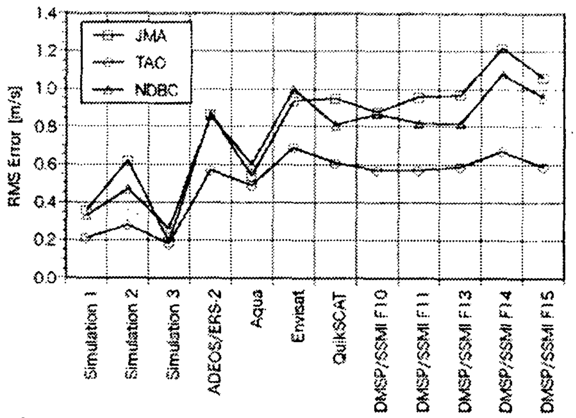

Figure 2. RMS errors between true and each simulation and satellite values for wind speed.

In order to estimate the impact of the RMS error on latent heat flux, we calculated latent heat flux using simulation data. Figure 3 is same as Fig.2 except for latent heat flux and shows for impact of rms error in wind speed on latent heat flux.

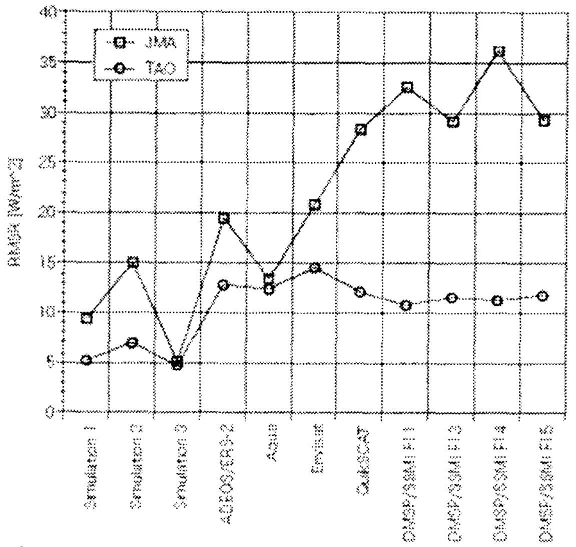

Figure 3. The RMS errors of latent heat flux between true flux value and each simulation and satellite values for wind speed.

From this figure, it is clear that there is the large differences between multi-satellite simulation and single satellite simulation. The largest differences of RMS error is 30 W/m^2. The differences for the specific humidity are small compared to the wind speed. The largest differences of RMS error is 15 W/m^2 (not shown here). From these simulation results, we can conclude that there is large possibility of improved estimation of latent heat flux using multi-satellite data, in particular for estimation of wind speed.

4. PRELIMINARY J-OFURO PRODUCT

In order to check the advantage of using multi-satellite data for estimation of global latent heat flux, we constructed preliminary J-OFURO product using actual satellite data by the method described in section 2. In order to evaluate the accuracy of our multi-satellite wind speed, the comparison with buoy data is conducted. The buoy data sets used in the present study are JMA buoy, NDBC and TAO/TRITON buoys.

Figure 4 show scatter-plots of wind speed between JMA buoy and single or multi-satellites. From Fig.4, multi-satellites product shows good agreement with buoy data compared with other single satellite data. In order to compare these products more quantitatively, the statistics between buoy and each product are shown in Table 1.

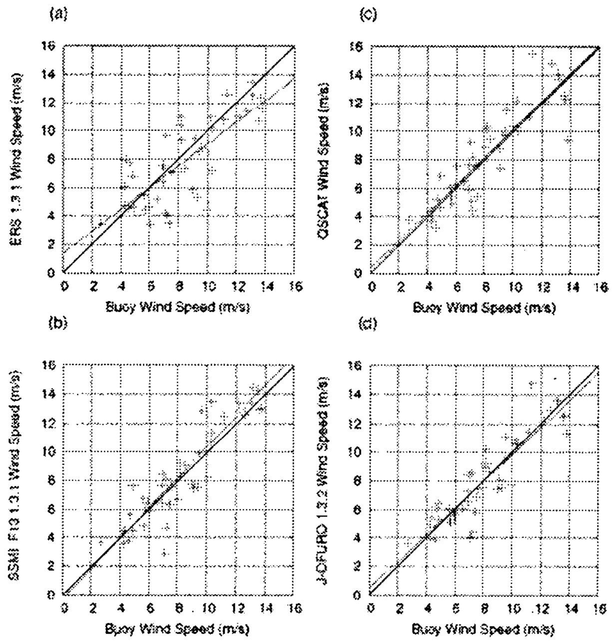

Figure 4. Scatter-plots between JMA buoy and each single- or multi-satellite wind speed. Units in m/s.(a) ERS/AMI, (b) DMSP/SSMI F13, (c) QuikScat/Seawinds, and (d) preliminary multi-satellite product (J-OFURO V1.3.2).

Table 1. Statistics between buoy and single- or multi-satellite wind speed. Units in m/s except for correlation. Bold values show highest correlation or lowest RMS error and bias values.

Buoy	Statistics	ERS/AMI	QuikScat/SeaWinds	DMSP/SSMI F13	Multi-Satellite
JMA Buoy	Correlation	0.77	0.89	0.90	***0.91***
	RMS error	1.97	1.49	1.54	***1.30***
	Bias	0.51	-0.20	-0.23	***0.03***
NDBC Buoy	Correlation	0.75	0.80	0.76	***0.85***
	RMS error	1.84	1.68	1.89	***1.39***
	Bias	***0.10***	-0.29	-0.19	-0.13
TAO/TRITON Buoy	Correlation	0.71	0.71	0.67	***0.75***
	RMS error	1.19	1.19	1.41	***1.11***
	Bias	0.71	-0.06	-0.63	***0.01***

This table shows statistics between buoy and each satellite product. Bold italic values show highest correlation, lowest RMS and lowest Bias value, respectively. From this table, the multi-satellite product is quite accurate compared with other single-satellite data at all buoy locations.

Also, we investigated the differences in improvement of RMS error. Table 2 indicates the maximum RMS error and minimum (i.e., Multi-satellite products's) RMS error for each buoy. In addition, the differences between the maximum and minimum RMS error are also shown in this table. From this table, the multi-satellite product shows good improvement in the mid-latitudes region.

Table 2. The maximum and minimum RMS error and the difference between the two RMS error.

Buoy	Max. RMS	Min. RMS	Difference
JMA	1.97	1.30	0.67
NDBC	1.89	1.39	0.50
TAO	1.41	1.11	0.30

In order to make clear the impact of the multi-satellite wind speed product on latent heat flux, we estimate latent heat flux by using multi-satellite product for wind speed and buoy data for other bulk parameter. Figure 5 is same as Fig. 4 except for latent heat flux. From this figure, the latent heat flux from the multi-satellite product is most accurate compared with other single-satellite products. For example, although the rms errors of ERS product is 45 W/m^2, the rms errors of multi-satellite product is 26.6 W/m^2.

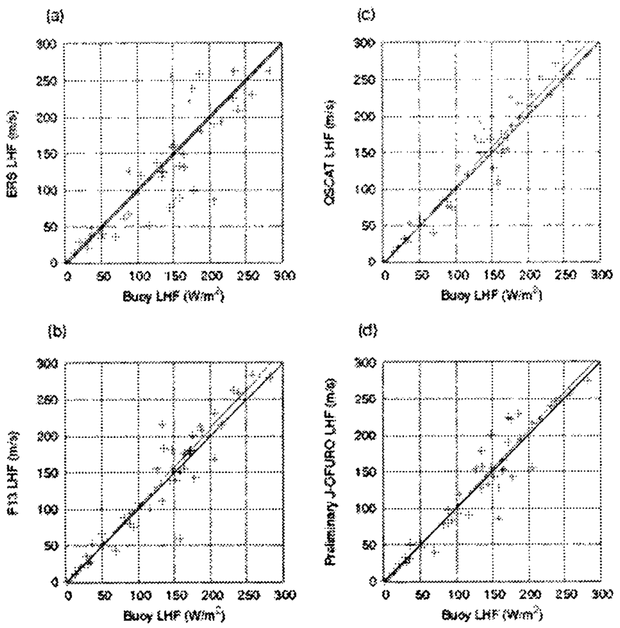

Figure 5. Scatter-plots between JMA buoy and each single- or multi-satellite latent heat flux. Units in W/m^2.(a) ERS/AMI, (b) DMSP/SSMI F13 (c) QuikScat/Seawinds, and (d) preliminary multi-satellite product.

5. SUMMARY

The present study demonstrated the advantage of using multi-satellite data for estimating global latent heat flux. From the simulation results, there is the possibility of significant improvment of accuracy in wind speed and surface specific humidity, and surface latent heat flux.

The multi-satellite product is constructed from ERS, DMSP/SSMI and QuikSCAT observations as preliminary product of new J-OFURO. The multi-satellite product is evaluated by comparison with JMA, NDBC, and TAO/TRITON buoy data. As results, the multi-satellite product shows highest accuracy (RMS: 1.1 - 1.4 m/s) compared with other single-satellite product. In particular, in the mid-latitudes region, the multi-satellite product shows good improvement. These improvements in wind speed are corresponding to the improvement of RMS: 20 W/m^2.

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