Reconstruction and Validation of Gridded Product of Wind/Wind-stress derived by Satellite Scatterometer Data over the World Ocean and its Impact for Air-Sea Interaction Study

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Abstract: We have persistently constructed gridded products of surface wind/wind stress over the world ocean using satellite scatterometer (ERS and Qscat). They are available for users as the Japanese Ocean Flux data sets with Use of Remote sensing Observation (J-OFURO) data together with heat flux components. Recently, a new version data of the Qscat/SeaWinds based on improved algorithm for rain flag and high wind-speed range have been delivered, and allowed us to reconstruct gridded product with higher spatial resolution. These products are validated by comparisons with in-situ measurement data by mooring buoys such as TAO/TRITON, NDBC and the Kuroshio Extension Observation (KEO) buoys, together with numerical weather prediction model products such as the NCEP-1 and 2. Results reveal that the new product has almost the same magnitude in mean difference as the previous version of Qscat product and much smaller than the NCEP-1 and 2. On the other hand, it is slightly larger root-mean-square (RMS) difference than the previous one and NCEPs for the comparison using the KEO buoy data. This may be due to the deficit of high wind speed data in the buoy measurement. The high resolution product, together with sea surface temperature (SST) one, is used to examine a new type of relationship between the lower atmosphere and upper ocean in the Kuroshio Extension region.

KEY WORDS: scatterometer, wind-stress products, Kuroshio Extension

1. Introduction

Satellite scatterometer has been supplying data of surface wind vectors over the whole ocean since the beginning of 1990s. Especially, the newest one, the Sea winds on board QuikSCAT(Qscat/SeaWinds) has measured the sea surface over the almost whole ocean every day with highly spatial resolution, and has permitted us to examine the new type of air-sea interaction studies (e.g. Chelton, 2003; Xie, 2004).

Our group has supplied gridded products of surface wind/wind-stress vectors over the world ocean constructed by the scatterometer data, and they have been available as the Japanese Ocean Flux data sets with Use of Remote-sensing Observation (J-OFURO) data set, together with heat flux components, in the web site(http://dtsv.scc.u-tokai.ac.jp/j-ofuro/). Their reliabilities have been verified by comparisons with in-situ measurements mainly obtained by moored buoys on open ocean (Kasahara et al., 2003; Kutsuwada et al., 2004), and it has been revealed that the Qscat product has relatively high reliability compared with numerical weather prediction (NWP) products (NCEP-1 & 2). Validation study was also made for the open ocean region of the mid- and high-latitudes where there had been few moored buoys using the Kuroshio Extension Observatory (KEO) buoy (Kutsuwada et al., 2006).

Recently, the swath data (level 2B) of the Qscat/SeaWinds based on the new processing software has been provided by the NASA Physical Oceanography Distributed Active Archive Center (PO.DAAC) at the Jet Propulsion Laboratory. This data set involves the following three points: improvement of flagging for rain contamination, improvement of performance at high wind speeds, and supply of level 2 data with higher spatial resolution (12.5km) (See PODAAC website). Using this data set, we reconstruct a new gridded product of wind/wind-stress over the world ocean.

In the first part of this study, we will introduce a performance of this new product through validation by comparison with in-situ data. In the next part, we will focus on air-sea interaction in the Kuroshio Extension region, and examine relationship between surface wind speed and sea surface temperature (SST) using the new product.

2. Data

2.1. Gridded products of surface wind/wind-stress

We construct gridded products of surface wind/ wind-stress vectors over the world ocean. Original swath data by the Qscat/SeaWinds are referred to Jet Propulsion Laboratory (2001). In addition to the previous data, we use the new one which has delivered since 2006. These two products are called as Qscat/J-OFURO v1 and v2, respectively. Details of construction procedure are the same as those in Kutsuwada (1998) and Kubota et al.(2002). These products cover the almost world ocean (60°N-80°S) with spatial resolution of 1° x 1° grid and with the time resolution of one day.

We also use data set by the Numerical Weather Prediction (NWP) model which has been supplied by the National Center for Environmental Predic tion-National Center for Atmospheric Research (NCEP/ NCAR) reanalysis (Kalnay et al., 1996). It has temporal and spatial resolutions of 6 hours and 2.5°x 2.5°, respectively. We use two products: one is the 6-hourly wind stress supplied by NCEP, and the other is calculated from each 6-hourly wind using the drag coefficient based on Large and Pond (1981). In comparisons with other products, we calculate daily-averaged wind stress. Further, two versions of products has been available. These are referred to as NRA-2, while the old version as NRA-1.

2.2. In-situ measurement (moored buoys) data

We use time series of surface wind and other parameters at a moored buoy in the Kuroshio Extension region for validation of the products. It has deployed at 144.5°E, 32.3°N on June 2004 by the NOAA/Pacific Marine Environmental Laboratory (PMEL; chief scientist: Dr. Meghan Cronin). Using wind data on each 10 minute, we convert into 10-meter winds and calculate daily-averaged wind stress using the new version(LKB-3) of the procedure depending upon atmospheric stability (Liu et al., 1979).

3. Result

3.1. Validation of gridded products

Mean and standard deviation(SD) of surface wind and wind-stress are calculated for time series at each grid by two Qscat/J-OFURO products(V1 and V2). Even if there are little discrepancies between the two products, we can find significant difference in the SD distribution especially in the northern portion of westerly wind region (Fig.1). Distribution of the Root-Mean-Square difference (RMSD) between two products (Fig.2) exhibits values exceeding 2.0 m s^{-1} in this region. The RMSD for low-pass filtered (3-month running mean) time series are smaller than 0.4 m s^{-1} in the whole region, meaning that there are significant discrepancies in the short-period range between the two products.

We validate the products by comparing them with KEO buoy measurement data. Time series of the scalar wind speed are shown in Fig.3, and statistical values for comparison with the KEO buoy measurements including the NWPs are listed in Table 1. In some cases, the new product(v2) has stronger wind speeds than the KEO's. In fact, it has larger values in RMSD than the old one(v1)(Table 1). This does necessarily mean that the new product has lower reliability, because the KEO buoy may not measure true values in high wind speed range (personal communication, Cronin). On the other hand, the mean difference for v2 product has lower values similar to the v1's, compared with those for the NCEPs. This supports the results by Kutsuwada et al.(2006), showing the overestimation of the wind/wind-stress in the wide area of the westerly wind region in the NCEP products.

4.2. Relationship between wind speed and SST

To verify whether new type of air-sea interaction mechanism is dominant over the Kuroshio Extension region, we examine relationship between surface wind speed in our products and sea surface temperature (SST) fields. In daily SST field with the high resolution (0.25°x0.25°) by the TRMM/TMI data, anomalies are derived by removing zonal means of meridional gradient which are considered to be due to the effect of differential heating. Spatial correlation is calculated between the wind speed and SST for each month during our study period (Aug 1999–Dec 2005). Significant positive correlation area is found in the Kuroshio Extension region in many cases, and its example is shown in Fig.4 as a scatter diagram between the SST anomaly and its overlying wind speed fields.

Spatial correlation features change between seasons as well as years. This may be related to the meteorological condition with synoptic to basin-scale around the region. Further examination will be made for this problem.

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Table 1. Statistical values (correlation coefficient, mean difference and root-mean-square (RMS) difference) for the zonal and meridional components of wind/wind stress between the KEO buoy and each product.

	KEO buoy	Zonal			Meridional		
	Name of Data sets	Corr. Coeff	Mean-Diff	RMSD	Corr. Coeff	Mean-Diff	RMSD
Wind Speed	QSCAT/J-OFURO (V1)	0.90	-0.03	2.362	0.91	-0.24	2.028
	QSCAT/J-OFURO (V2)	0.87	0.32	2.719	0.85	-0.20	2.680
	NRA1	0.94	0.61	2.152	0.89	1.27	2.584
	NRA2	0.93	0.32	2.437	0.93	0.47	1.985
Wind Stress	QSCAT/J-OFURO (V1)	0.90	0.000	0.052	0.87	-0.004	0.043
	QSCAT/J-OFURO (V2)	0.83	0.005	0.082	0.79	-0.002	0.063
	NRA1/FLUX	0.90	0.009	0.054	0.89	0.034	0.019
	NRA1/WND	0.83	0.021	0.061	0.62	0.039	0.070
	NRA2/FLUX	0.91	0.024	0.044	0.89	0.031	0.033
	NRA2/WND	0.89	0.012	0.064	0.87	0.014	0.050

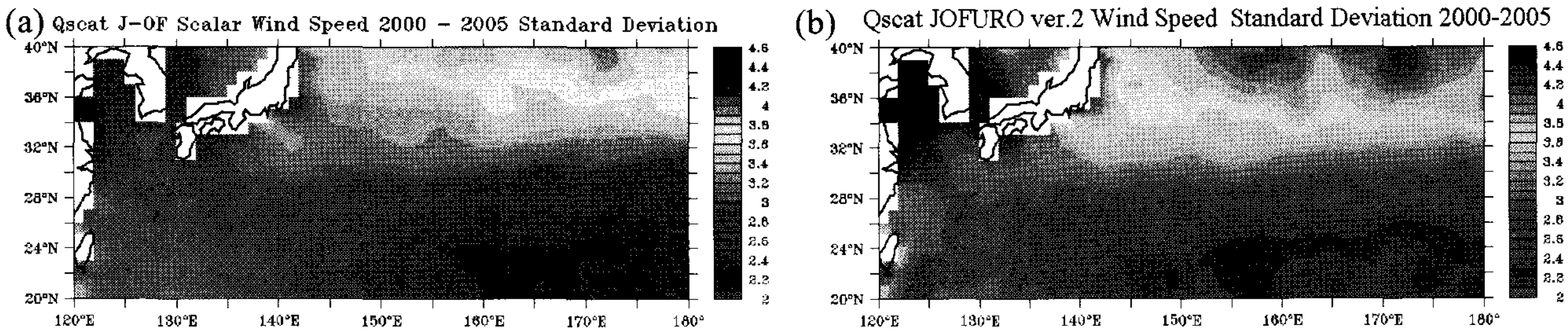

Fig 1. Distribution of standard deviations for scalar wind speeds during 2000-2005 by Qscat/J-OFURO v1(a) and v2(b) products.

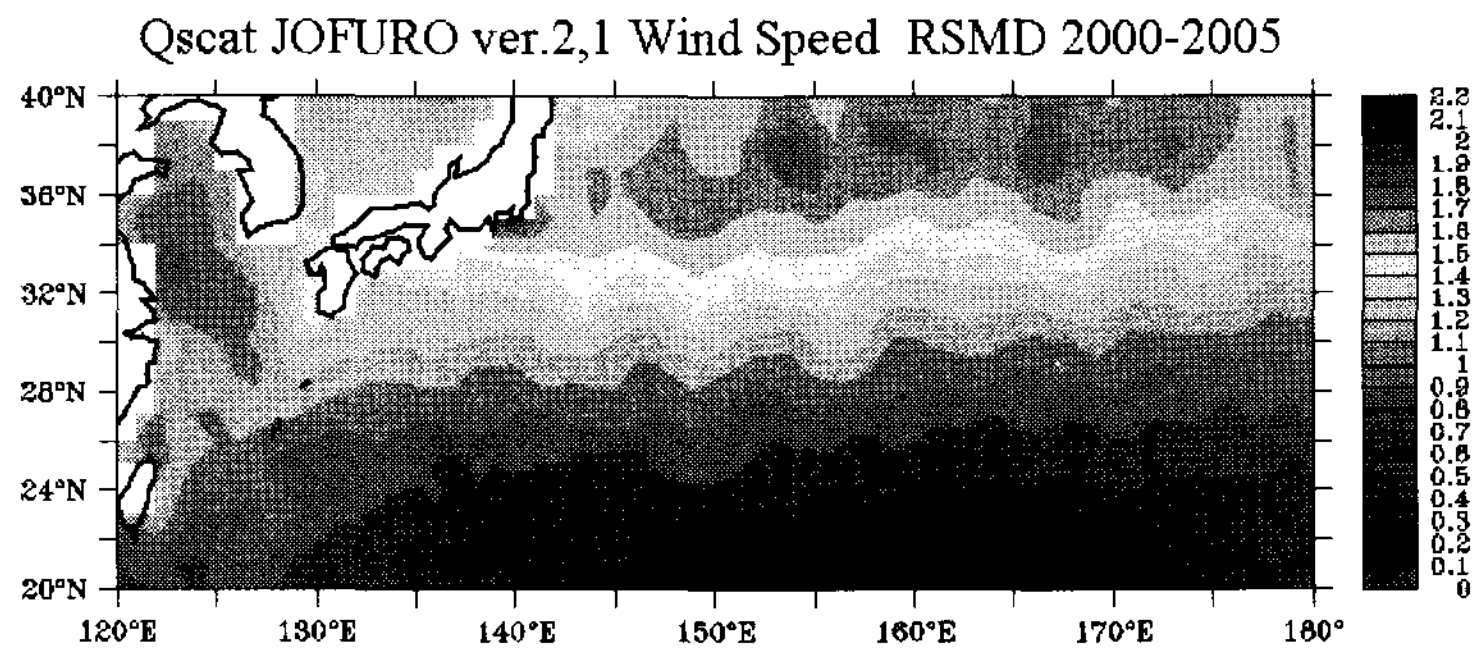

Fig 2. Distribution of root-mean-square(RMS) differences for scalar wind speeds during 2000-2005 between the Qscat/J-OFURO v1(a) and v2(b) products.

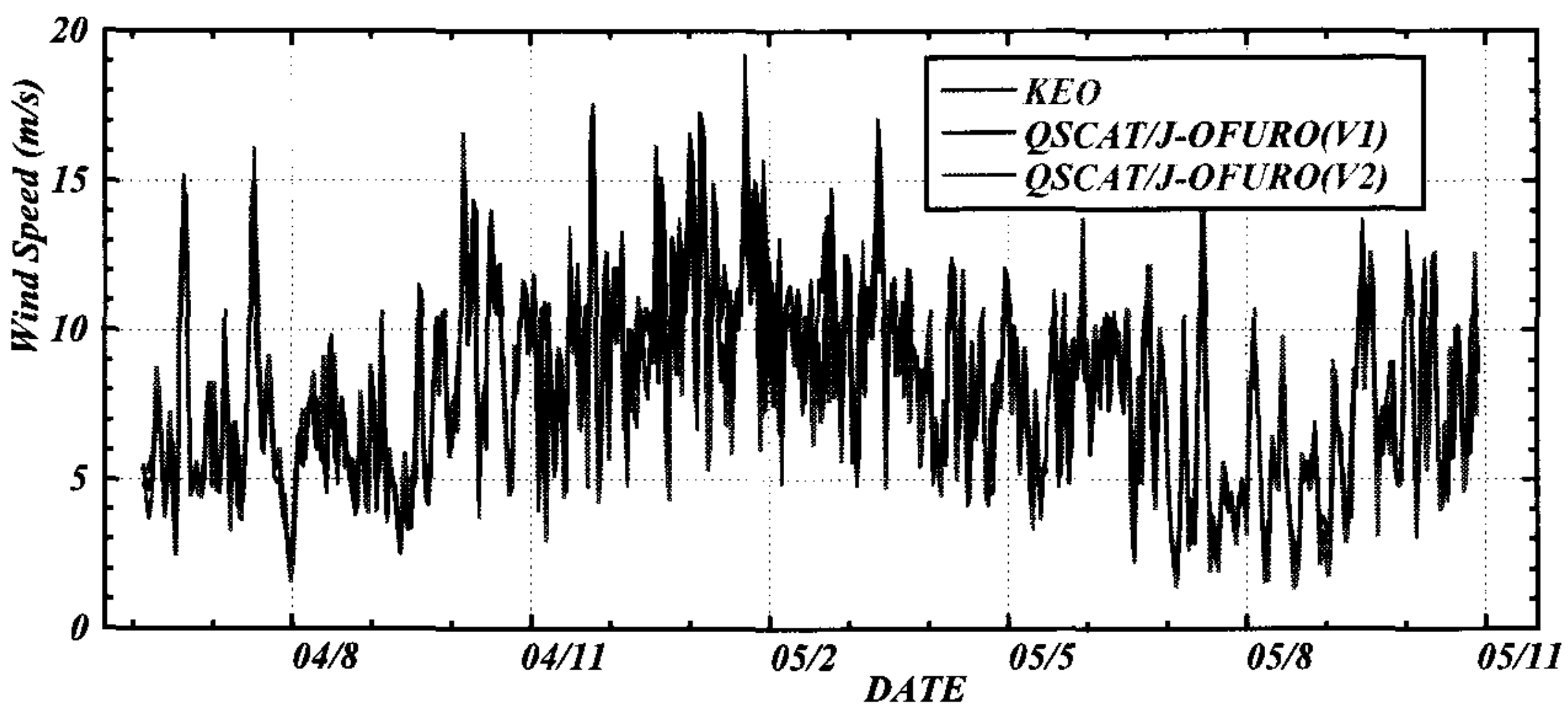

Fig.3. Time series of wind speed at KEO buoy (red line) and of old (V1: blue line) and new (V2: green line) versions at its nearest grid in the Qscat/J-OFURO products.

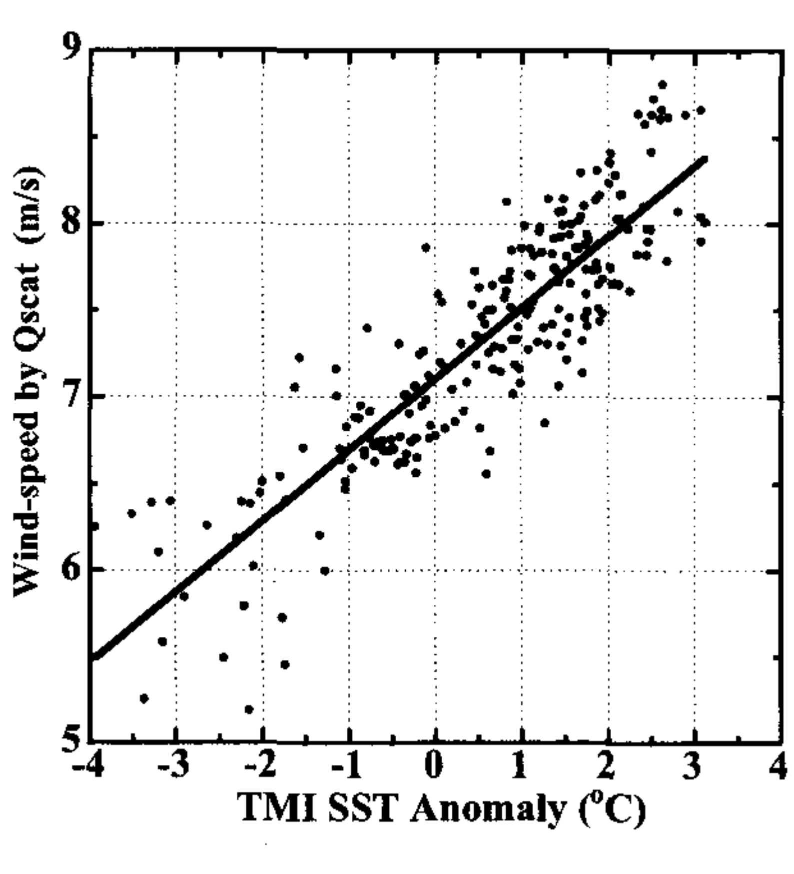

Fig.4. Scatter plot between SST anomaly by TMI product and wind speed by the Qscat/J-OFURO v2 product in the Kuroshio Extension region. A regressional line is depicted.