Validation Study of Gridded Product of Surface Wind/Wind-stress derived by Satellite Scatterometer Data in the Western North Pacific using Kuroshio Extension Observatory Buoy

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Abstract: Gridded products of surface wind/wind-stress over the world ocean have been constructed by using satellite scatterometer as the Japanese Ocean Flux data sets with Use of Remote-sensing Observation (J-OFURO) data. Our previous validation study in the tropical Pacific using TAO/Triton and NDBC buoys revealed high reliability of our products. In this study, the Kuroshio Extension Observatory (KEO) buoy data are used for validation of other gridded wind-stress products including the NCEP-1 and 2 in the western North Pacific region where there have been few in-situ data. Results reveal that our J-OFURO product has almost zero mean difference and smallest root-mean-square (RMS) difference, while the NCEP-1 and 2 ones significantly positive biases and relatively high RMS difference. Intercomparison between the J-OFURO and NCEP products in a wide region of the North Pacific covered by the westerly winds exhibits that the NCEPs have larger magnitudes in the wind stress than the J-OFURO's, suggesting overestimation of the NCEPs.

KEY WORDS: scatterometer, wind-stress products, KEO-buoy

1. Introduction

We have constructed gridded products of surface wind/wind-stress over the world ocean using satellite scatterometer as the Japanese Ocean Flux data sets with Use of Remote-sensing Observation (J-OFURO) data together with heat flux components. The products have been available as the J-OFURO in the web site (http://dtsv.scc.u-tokai.ac.jp/j-ofuro/), together with other heat flux components.

Our wind/wind-stress products have been persistently constructed by different scatterometer sensors (ERS-1, 2, Qscat/SeaWinds and ADEOS-II/SeaWinds) since 1992. Their reliabilities have been verified by intercomparisons with in-situ measurements mainly obtained by moored buoys on open ocean (Kasahara et al., 2003; Kutsuwada et al., 2004). They revealed that the Qscat product has higher reliability compared with numerical weather prediction (NWP) product (NCEP- 1). These were made by the Tropical Atmosphere and Ocean (TAO) and National Data Buoy Center (NDBC) buoys covering the tropical Pacific and coastal areas around the American continent, respectively. On the other hand, in the open ocean region of the mid- and high-latitudes where there had been few moored buoys, it has not been difficult to verify the reliabilities of those wind products using in-situ measurement data. The reliability of the wind-stress data in such regions of the North Pacific is considered to be one of the key factors for understanding of the dynamics of the subtropical gyre including the Kuroshio. The Kuroshio Extension Observatory(KEO) buoy, deployed on June 2004, has been supplying the surface meteorological data including the wind speed and direction continuously to us, and allowed us to validate the wind products in such a key region. Thus, we attempt to validate different gridded wind products using this buoy data, and verify their reliabilities in the subtropical region of the North Pacific.

2. Data and procedure

1) Gridded products of surface wind/wind-stress

We use two types of gridded products of surface wind/wind-stress vectors over the world ocean (Table 1). One is constructed by using swath data supplied by the scatterometer: Qscat/SeaWinds (referred to as Qscat/J-OFURO). Details of original swath data and construction procedure are described in Jet Propulsion

Laboratory (2001), Kutsuwada (1998) and Kubota et al.(2002). This product covers the almost world ocean (60°N-80°S) with spatial resolution of 1° x 1° grid and with the time resolution of one day.

The other is data set created by the Numerical Weather Prediction (NWP) model which has been supplied by the National centers for Environmental Prediction-National Center for Atmospheric Research (NCEP/NCAR) reanalysis (Kalnay et al., 1996). It has a time resolution of 6 hours and spatial ones of 2.5°x 2.5°. The wind stress is calculated from each 6-hourly wind using the drag coefficient based on Large and Pond (1981), and vector-averaged over each grid and day. Products of the 6-hourly wind stress have been supplied by NCEP and are used for our comparison. Further, a new version of wind and wind-stress products has been available even if there is a bit difference in grid size. These are referred to as NRA-2, while the old version as NRA-1(See Table 1).

2) In-situ measurement (moored buoys) data

The NOAA/Pacific Marine Environmental Laboratory (PMEL; chief scientist: Dr. Meghan Cronin) has deployed a moored buoy in the Kuroshio Extension region (144.5°E, 32.3°N) on June 2004. This has supplied time series of surface meteorological parameters including wind speed and direction. In this study, wind data on each 10 minute are converted into 10-meter winds and wind stress using the new version (LKB-3) of the procedure depending upon atmospheric stability (Liu et al., 1979), and then daily wind-stress vectors are calculated.

3. Result

We validate gridded products of wind/wind-stress by scatterometer and NWP by comparing them with KEO buoy measurement data. Time series of the zonal wind components is shown in Fig. 1, and statistical values for comparison with the KEO buoy measurements are listed in Table 2.

Significant discrepancy is found in the mean difference between the Qscat/J-OFURO and NRA-1 and 2. The Qscat/J-OFURO product is close to zero both for the wind and wind-stress meaning no bias, while the NRA-1 and 2 products have positive values of +0.3 and +0.6 m s^{-1}, respectively, for the zonal wind. Largest discrepancy is found in the mean difference for the meridional wind for the NRA-1, attaining to 1.3 m s^{-1}. These mean the overestimation of the NRA-1 and 2 wind products. Similar feature is found in the wind-stress values. In the root-mean-square (RMS) difference and correlation coefficient, there are no significant discrepancies between the Qscat/J-OFURO and NWP products. Note that there are significant differences between the Qscat/J-OFURO and KEO buoy in a few cases in which the typhoon or cyclone passed over the area near the buoy. Except these events in which short-term changes are dominant, the RMS difference for the Qscat/J-OFURO decreases until about 1.0m s^{-1} for both components.

In the next step, in order to make intercomparison among gridded products in the wide region of the North Pacific, we calculate 6-year averages of the zonal and meridional wind stresses during 2000-2005 for each product. Meridional profiles of the zonal means between 140°E and 140°W are shown in Fig. 2. Compared with little differences in the low-latitude region, noticeable discrepancies are found in the high latitudes for the zonal wind stress and in the mid-latitude (30-50°N) for the meridional wind-stress. Spatial distributions are shown in Fig.3 only for the Qscat/J-OFURO and NRA-1 products. We can find clear differences in the northern portion of the North Pacific, especially in the meridional wind-stress field. These feature, showing the NRA-1 wind-stress stronger than the Qscat's, is consistent with our validation results shown above, based on comparison with the KEO buoy measurements. This suggests that the NRA-1 and 2 products are overestimated in a wide region of the North Pacific.

4. Summary

Comparisons of the wind/wind-stress products with the KEO buoy measurements have revealed clear features in the mean differences. Namely, the Qscat/J-OFURO has no bias, while the NRA-1 and 2 have significantly positive biases. Intercomparison between the products in the North Pacific has revealed consistent feature with this validation result. The NRA-1 and 2 wind-stresses have larger magnitudes in a wide portion than the Qscat's, suggesting the overestimation in the wind stress field.

The present result allows us to verify the wind forcing function for driving the upper oceanic circulation. Meridional profile of its zonal means for wind-stress curl is shown in Fig.2c. Significant difference found around 30°N is considered to be important for wind-driven transport in the subtropical gyre (Aoki et al., 2006).

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Table 1. Data set used in this study

Name of Data set	Grid No,	Grid size (degree)	Region	
			Zonal	Meridional
QSCAT(J-OFURO)	361? 41	1.0	30°E - 390°E	80°S - 60°N
NRA1	144? 3	2.5	0°E - 2.5°W	90°S - 90°N
NRA2	192? 4	about 1.875	0°E - 1.875°W	88.542°S - 88.542°N

Table 2. Statistical values (correlation coefficient, mean difference and root-mean-square (RMS) difference) for the zonal and meridional components of wind stress between the KEO buoy and each product.

	Name of Data sets	Zonal			Meridional		
		Corr. Coeff	MeanDiff	RMSD	Corr. Coeff	MeanDiff	RMSD
Wind Speed	QSCAT(J-OFURO)	0.90	0.0	2.61	0.91	-0.2	1.8
	NRA1	0.94	0.6	1.54	0.89	1.3	1.3
	NRA2	0.93	0.3	2.20	0.93	0.5	1.6
Wind Stress	QSCAT(J-OFURO)	0.90	0.00	0.05	0.87	0.00	0.04
	NRA1/FLUX	0.90	0.01	0.05	0.89	0.03	0.02
	NRA1/WND	0.83	0.02	0.06	0.62	0.04	0.07
	NRA2/FLUX	0.91	0.02	0.04	0.89	0.03	0.03
	NRA2/WND	0.89	0.01	0.08	0.87	0.00	0.10

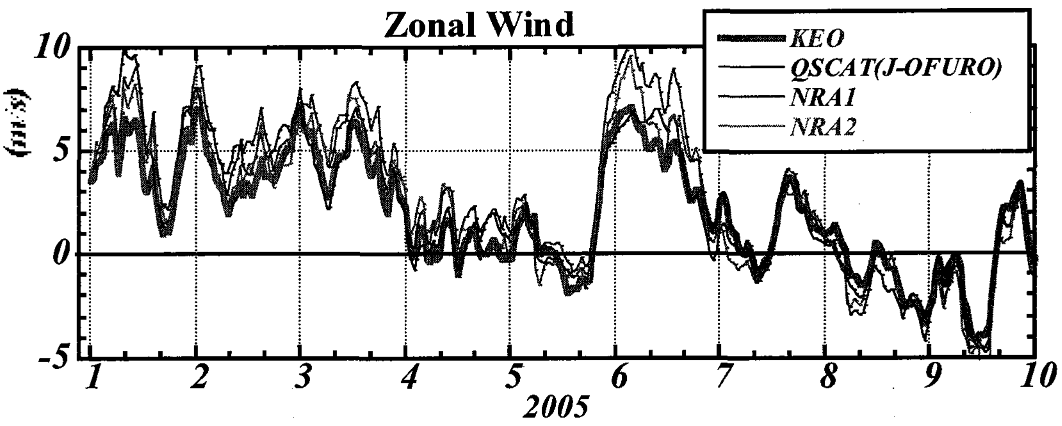


Fig 1. Time series of zonal wind components measured at KEO buoy (red) and those by wind products at its nearest grid. Qscat (J-OFURO): black, NRA-1: blue, NRA-2: green

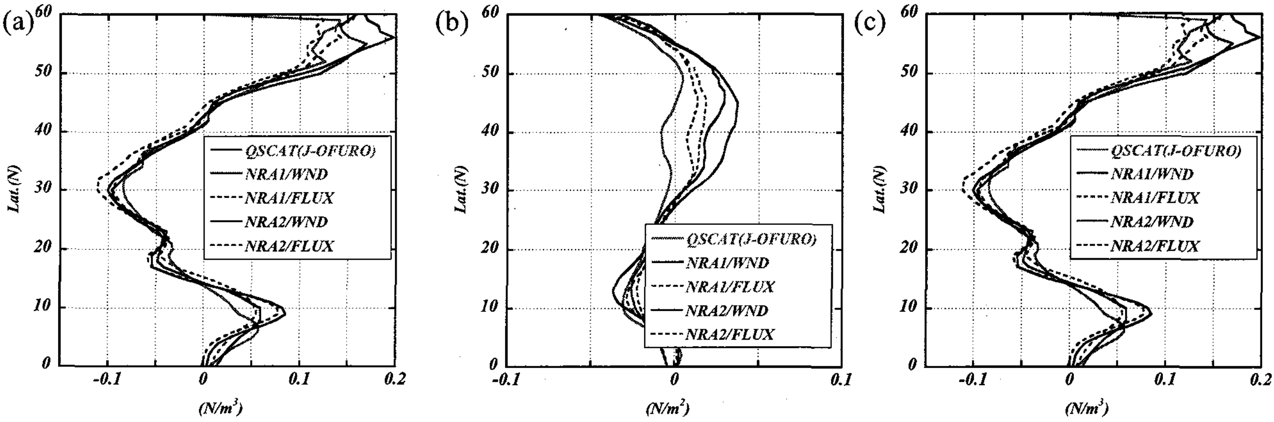
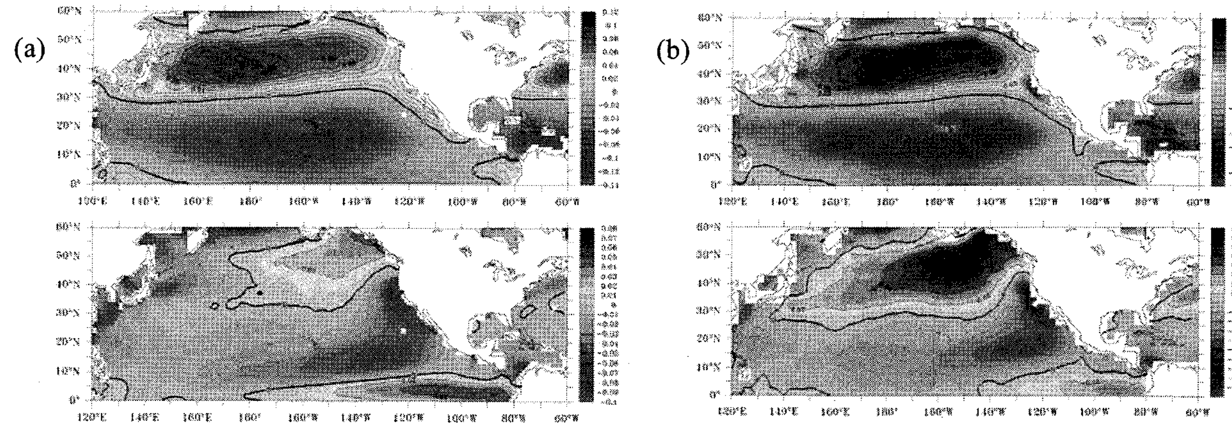


Fig.2. Meridional profiles of zonal means between 140°E and 140°W of 5-year(2000-2005) averages for the zonal(a) and meridional(b) components of wind stress and wind-stress curl(c).



QSCAT(J-OFURO)

NCEP-1

Fig. 3. 6-year mean(2000-2005) field of zonal(upper) and meridional(lower) components of wind stress derived from Qscat(J-OFURO)(a) and NCEP-1(b) wind products.