Construction of Gridded Wind-stress Products over the World Ocean by Tandem Scatterometer Mission

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Abstract : Products of gridded surface wind and wind-stress vectors over the world ocean have been constructed by satellite scatterometer data with highly temporal and spatial resolutions. Even if the ADEOS-II/SeaWinds has supplied surface wind data only for short duration in Apr. to Oct. 2003 to us, it permits us to construct a product with higher resolution together with the Qscat/SeaWinds. In addition to our basic product with its resolution of 1° x 1° in space and daily in time, we try to construct products with 1/2°x 1/2° and semi- and quarter-daily resolution. These products are validated by inter-comparison with in-situ data (TAO and NDBC buoys), and also compared with numerical weather prediction(NWP) ones (NCEP reanalysis). Result reveals that our product has higher reliability in the study area than the NCEP's. For the open ocean regions in the middle and high latitudes where there are no in-situ data, we find that there are clear differences between them. Especially in the southern westerly region of 40°-60°S, the wind-stress magnitudes by the NCEP are significantly larger than the others, suggesting that they are over-estimated.

We also calculate wind-stress curl field that is an important factor for ocean dynamics and focus its spatial character in the northwestern Pacific around Japan. Positive curl areas are found to cover from southwest to northeast in our focus region and almost correspond to the Kuroshio path. It is suggested that the vorticity field in the lower atmosphere is related to the upper oceanic one, and thus an aspect of air-sea interaction process.

Keywords: Wind-stress, scatterometer, tandem mission

1. Introduction

Products of surface wind stress over the world ocean have been constructed to investigate not only variability in the lower atmosphere but its role for driving motions in the upper ocean. To understand their dynamics, we need detailed information on wind stress field, namely having high resolution in time and space. Spaceborne satellite microwave scatterometer have made such studies develop helpfully. Since the beginning of 1990's, one or two scatterometers have been operated and persistently supplied surface wind data to us. Using these data, we have constructed gridded products of wind-stress vectors (WSV) over the world ocean(Kutsuwada, 1998; Kubota et al., 2002). They have been available for users on our web site (*http://dtsv.scc.u-tokai.ac.jp/j-ofuro/*), together with heat flux components.

The first WSV product is derived from the European Remote-sensing Satellite (ERS-1, 2) and covering 9 years during 1992-2000. The second one is from the *SeaWinds*, on board QuikSCAT(hereafter Qscat), which has been operating up to the present since its launch in June 1999. Even if our ERS product requires some corrections due to its slight difference in reliability from our Qscat's (Kasahara et al., 2003), two products permit us to analyze WSV time series for a long period exceeding a decade. On the other hand, the *SeaWinds* on board the ADEOS-II had operated for about 6 months from April to October in 2004, which permit us to construct another product with much higher resolution by jointly using the Qscat's. In this study, we will introduce impact of this new product.

2. Data and procedure

The level 2B data, including individual wind speed and direction, have been provided by the NASA Physical Oceanography Distributed Active Archive Center(PO.DAAC) at the Jet Propulsion Laboratory. By taking each scatterometer wind as the value at 10-m level, we calculate WSV on each grid by the bulk formula using the drag coefficient depending only on wind speed based on Large and Pond (1981). Details of construction procedure for our gridded WSV products are described in Kutsuwada (1998) and Kubota et al., (2002). The product, called composite, constructed jointly by the Qscat and ADEOS-II covers the almost world ocean (60°N- 80°S) and have spatial resolution of 0.5° x 0.5° grid as well as 1° x 1° one and daily and semi-daily time resolution.

To examine the reliability of our products, we calculate surface winds measured at moored buoys on open ocean, consisting of the Tropical Atmosphere and Ocean (TAO) buoys covering the tropical Pacific and the National Data Buoy Center (NDBC)'s covering the mid to high-latitude in the Pacific and Atlantic Oceans. Hourly or 10-minute wind, air-temperature and humidity are used to calculate 10-m wind and wind stress by the procedure based on Large and Pond (1981). Surface wind data every 6 hours by the NCEP reanalysis are also used to calculate WSV and to be compared with ours.

3. Validation of our product

First, we compare the wind and wind-stress in our product with those calculated by the buoy winds. Statistical values for TAO buoy stations are indicated in Table 1, and time series are shown in Fig. 1. These reveal that our product has smaller mean and RMS differences and higher correlation than the NCEP's. It should be noted that the NCEP's has significant bias in the meridional component in the tropical region.

Since our composite product covers only 6 months, we need to examine the validity for our Qscat's, available for a long period of 5 years. We also construct products from each scatterometer (Qscat and ADEOS-II) and validate them together with our composite and NCEP ones. Table 2 indicates their statistical values by intercomparison at the NDBC buoy stations. We can see that our three products are better than the NCEP's and there are little significant differences among them. This means that the Qscat product has sufficient reliability and permits us to examine variabilities on various time scales from intraseasonal to interannual ones. Differences from the NCEP's are found prominently in the mid and high latitudes, especially southern westerly wind region of 40°S-60°S(Fig.2). It is suggested that the NCEP's WSV is overestimated in these regions.

4. Wind-stress curl field

Recent papers (Chelton et al., 2004; Xie, 2004), based on wind field with high resolution derived from satellite data, demonstrated that there are relationships between the wind(-stress) divergence and/or curl and underlying oceanic fields. We calculate the wind-stress curl(WSC) in our composite product and notice spatial features of the WSC field in the northwestern Pacific region covering the Kuroshio path south of Japan. Figure 3 shows a distribution of the 6-month average WSC field. We can find that there are some areas having large positive curl in the western boundary and south and east of Japan, where the Kuroshio flows. This feature suggests that the spatial feature of the surface wind field is governed by that in its underlying oceanic field, which is consistent with the results in the previous papers. These give us evidence that our composite product might be much helpful for investigation of these air-sea interaction processes.

Acknowledgements

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Table 1: Mean and Root-Mean-Square(RMS) differences and correlation coefficients in comparison between winds measured at TAO buoys and gridded winds by our composite and NCEP products. Statistical values for zonal(a) and meridional(b) wind components are indicated.

(a)

Pacific	Zonal Wind	*Mean Diff.*	*RMSD*	*RMSD (-MD)*	*Corr.*
Western	*Composite*	-0.66	2.08	1.91	0.78
	NCEP 6hr	0.25	2.45	2.25	0.69
Central	*Composite*	-0.28	1.10	0.99	0.91
	NCEP 6hr	0.13	1.66	1.52	0.76
Eastern	*Composite*	0.02	1.09	0.99	0.86
	NCEP 6hr	0.50	1.60	1.46	0.69

(b)

Pacific	Meridional Wind	*Mean Diff.*	*RMSD*	*RMSD (-MD)*	*Corr.*
Western	*Composite*	0.16	1.83	1.82	0.60
	NCEP 6hr	0.22	2.20	2.11	0.53
Central	*Composite*	0.00	1.03	0.98	0.88
	NCEP 6hr	-0.74	1.96	1.60	0.69
Eastern	*Composite*	0.22	1.02	0.95	0.88
	NCEP 6hr	-0.70	1.91	1.59	0.68

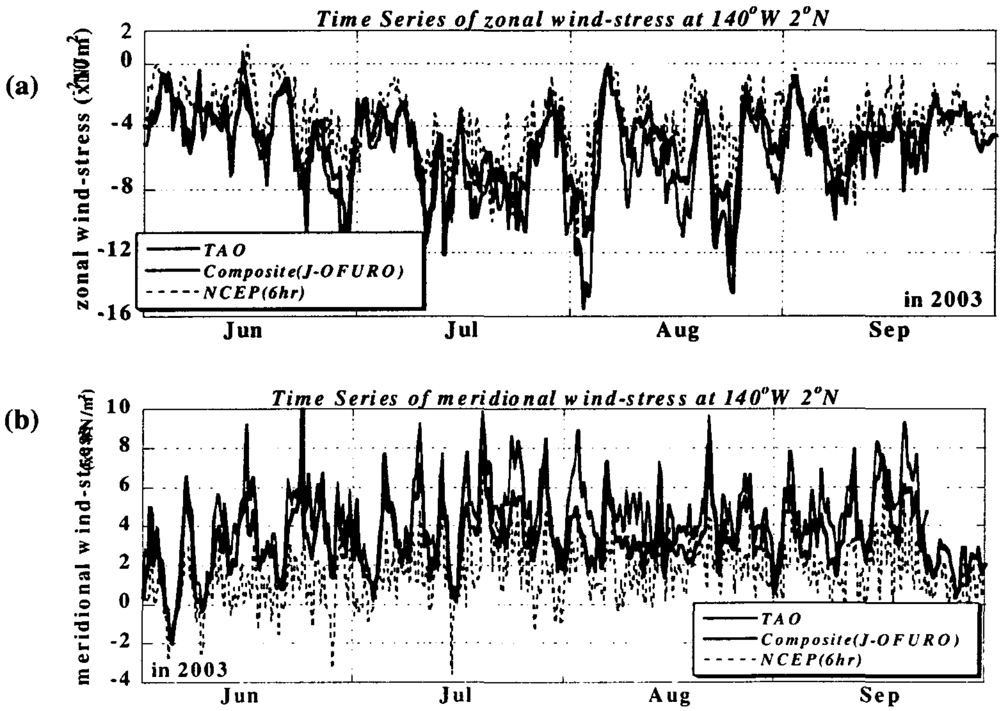

Fig. 1: Time series of zonal(a) and meridional(b) components of wind stress every 6 hours at 140°W, 2°N. Thick solid, thin solid and broken lines depict those by TAO buoy, satellite(composite) and NCEP.

Table 2: Mean and Root-Mean-Square(RMS) differences and correlation coefficients in comparison between wind-stress calculated at NDBC buoy winds and gridded wind-stress by satellite and NCEP products. Statistical values for zonal and meridional wind-stress components are indicated.

Pacific			*Mean Diff.*	*RMSD*	*RMSD(-MD)*	*Corr.*
Zonal wind-stress	40-60N	*Composite*	0.003	0.017	0.016	0.97
		QSCAT(J-OFURO)	-0.006	0.020	0.019	0.96
		ADEOS2(J-OFURO)	0.002	0.019	0.018	0.94
		NCEP 6hr	0.006	0.045	0.044	0.92
		NAR40(flux)	0.006	0.034	0.033	0.91
Meridional wind-stress	40-60N	*Composite*	-0.004	0.018	0.018	0.97
		QSCAT(J-OFURO)	-0.006	0.020	0.019	0.96
		ADEOS2(J-OFURO)	-0.001	0.019	0.019	0.96
		NCEP 6hr	-0.004	0.050	0.048	0.92
		NAR40(flux)	-0.009	0.039	0.035	0.91

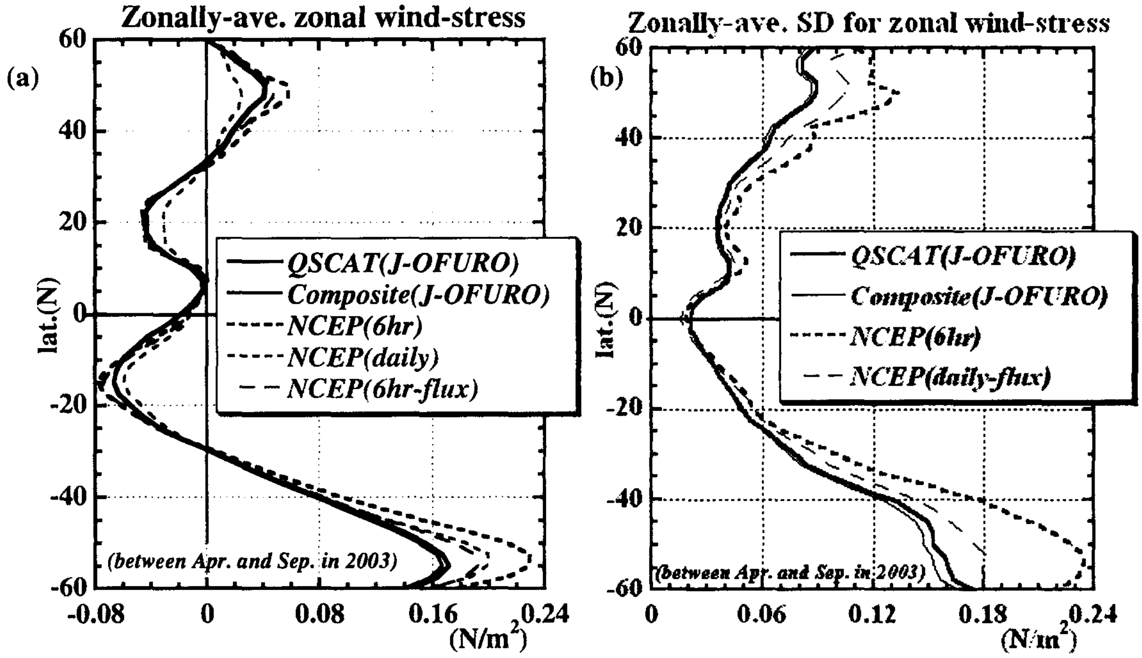

Fig. 2: Meridional profiles of zonal averages of averages(a) and standard deviations(b) for 6 months (Apr.-Sep., 2003) which are calculated from various wind-stress products.

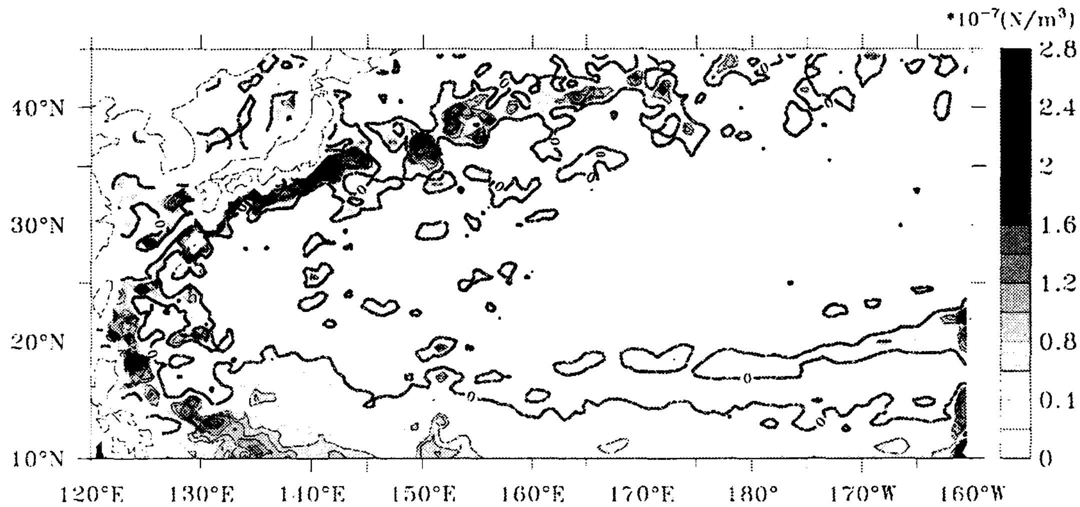

Fig. 3: Wind-stress curl field averaged over 6 months (Apr.-Sep., 2003) which is calculated by our composite products with highly time and space resolutions. Areas having strong positive curl are shadowed.