1. INTRODUCTION

Momentum flux through the sea surface, namely the wind stress is a major driving factor of motions in the upper ocean. Oceanographers have required detailed information on the wind stress field, because motions in the upper ocean are driven not only by the stress itself but also by its curl. Ship-measured wind data have been used to calculate surface wind stress for the last some decades, but recent studies pointed out their questionable reliability due to measurement errors such as uncertain anemometer height (e.g. Pierson, 1990). Alternatively, satellite microwave scatterometer supplies wind data with much higher resolution over the world ocean. The present study introduces gridded products of surface wind/wind-stress vectors which are constructed from scatterometer data, and illustrate examinations of their variabilities as an impact of the products. The first data sources are obtained from scatterometers on board the first European Remote-sensing Satellite (ERS-1) and the second one(ERS-2) which were both launched by the European Space Agency (ESA). These cover about 9 years since 1992, and allow us to examine variabilities on multiple time scales. Another scatterometer data are supplied by the SeaWinds on board Quikscat which was launched on June 1999 and have much higher data density than ERS-1/2.

In this study, we first validate our product by intercomparison with the Tropical Atmosphere Ocean (TAO) buoy in the equatorial Pacific. Next, we introduce two types of topics using the product; one focuses variability in the North Pacific westerly wind region. This will involve estimation of wind-driven oceanic transport in the subtropical gyre. The other topic is attributed to about intraseasonal variability(ISV) in the tropical region. This is related to the occurrence/development of El Niño event. We focus a spatial character of the ISV of the tropical wind field during the major event occurred in 1997-98.

2. DATA

The main data set is obtained from the level 2.0 ERS-1 and 2 data involving the wind speed and direction, which have been supplied by the Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) (e.g. Bentamy et al., 1994; Quilfen, 1995). Since the scatterometer data having inhomogeneous spatial distribution due to satellite orbital motion, we perform vector-averaging method using a weighting function varying with time and space, and construct wind/wind-stress vector on each 1°x 1° grid in space in the entire Pacific-Indian region (30°E-70°W, 60°S-60°N). This procedure is similar to that by Kutsuwada(1998) who constructed a data set using ADEOS/NSCAT data in 1996-97. Products of monthly and 10-day averages by ERS-1/2 are parts of a data set by the Japanese scientific group, together with heat flux components, called the Japanese Ocean Flux data sets with Use of Remote sensing Observations(J-OFURO). The data are available for any users on a web site (http://dtsv.scc.u-
tokai.ac.jp/). Another data set obtained from the SeaWinds on board the Quikscat was supplied by the Jet Propulsion Laboratory (JPL). We also construct a data set of the daily wind/wind-stress in the same domain using the same procedure.

3. VALIDATION OF PRODUCTS

Reliabilities of the products are examined by inter-comparison with TAO buoys in the equatorial Pacific. Examples for time series of the monthly zonal wind (Fig.1) by ERS-1,2 and daily one by Qscat are shown in Figure 1 and 2, respectively. Both figures exhibit good similarity between them. Comparisons are also made for the meridional components and stress ones and summarized in Table 1 and 2. These reveal that the RMS difference is smaller than 2 m s\(^{-1}\) and 0.03 N m\(^{-2}\) for the wind and wind stress, respectively. This means that our products have desirable reliability in the tropical region.

4. CHARACTER IN MID-LATITUDE REGION AND SVERDRUP TRANSPORT

A map of 8-year (1992-99) mean wind field is shown in Figure 3. When we compare it with that of the objectively analyzed data (ECMWF), we can find a clear difference between them that the ERS product has a tendency of being larger magnitude in a large portion than the ECMWF's. Similar discrepancies are found between the time series of the zonal wind in the westerly wind region persistently for the study period in 1992-99. On the other hand, comparison with the NCEP reanalysis data reveals an inverse discrepancy; our product is smaller than the NCEP's.

The Sverdrup transport is calculated from the wind stress curl of monthly product, and its mean field is shown in Figure 4. This corresponds to the stream function of volume transport in the upper ocean. Monthly value changes seasonally with maximum in winter and minimum in summer almost every year. Time series are shown in Figure 5, together with the estimates by the ECMWF product. As expected from the discrepancy between the zonal wind fields, the estimates by our ERS product are persistently larger by about 10 \(\times\) 10\(^{6}\) m\(^{3}\) s\(^{-1}\) (Sv) than the ECMWF's. This means that the wind-driven transport estimation is much sensitive to selection of the wind product. The transport values are compared with the Kuroshio transports south of Japan based on oceanic measurements and sea level obtained by satellite altimeter (Iimawaki et al., 2001). Their results reveal that the Kuroshio transport ranges between 25 and 60 Sv around its mean of about 45 Sv. Thus, the estimates by our product is closer to the mean transport by oceanic measurements than the ECMWF's.

5. INTRASEASONAL VARIABILITY OF EQUATORIAL ZONAL WIND

In a time-longitude diagram of the zonal wind along the equator obtained from the ERS-1,2 product (Figure 6), we can see persistent coverage of the westerly wind over the Indian Ocean and the western Pacific. An abnormal feature is found in the end of 1996 to 1997, corresponding to the onset of 1997-98 El Niño event. In this period, the strong westerly wind developed and extended until about 160°W, while the coverage of normal westerly wind over the Indian Ocean disappeared. Strong westerly wind over the western Pacific occurred with time scale of about 30-80 days, so that it is related to dominance of the intraseasonal variability (ISV). Detailed analysis of the ISV using our ERS product reveals that the ISV in the equatorial wind field in the period consists of two modes having their zonal features of eastward and westward, respectively, migrations (Kutsuwada and Kazama, 2001).

A similar approach is made also for the wind product by the Qscat/SeaWinds data in August 1999 to September 2000. It is suggested that the two types of intraseasonal signals having different zonal structures are prominent in the equatorial band (Figure 7).
We have an evidence that the intraseasonal signal in the upper ocean was triggered in the western equatorial Pacific and propagated to the east, probably due to the effect of internal equatorial Kelvin wave (Kutsuwada and McPhaden, 2001). Thus, it should be considered that the intensified intraseasonal signal in the western equatorial Pacific played an important role for the onset of the 1997-98 El Niño event.

Reference


Table 1. Comparison between ERS-1/2 wind and TAO wind.

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<thead>
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<th>Location</th>
<th>Component</th>
<th>Wind (m/s)</th>
<th>Wind-stress (N/m)</th>
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<td>Meridional</td>
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Table 2. Comparison between Qscat wind and TAO wind

<table>
<thead>
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<th>Location</th>
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<th>Wind-stress (N/m)</th>
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<tr>
<td></td>
<td>Meridional</td>
<td>1.06</td>
<td>0.43</td>
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</table>

Figure 1: Time series of monthly zonal wind at 0°, 180°. Solid and broken lines depict ERS-1/2 and TAO buoy data, respectively.

Figure 2: Time series of daily zonal wind at 0°, 170°W. Solid and broken lines depict Qscat and TAO buoy data, respectively.
Figure 3: Map of wind vector (arrows) and wind speed (contours) for 8 year mean (1992-99) by ERS-1,2 data. Darker shades depict strong wind speed.

Figure 4: Map of Sverdrup transport calculated from 8-year (1992-99) mean field by ERS-1,2 data. Positive values shown by darker shades depict northward volume transport in the interior region.

Figure 5: Time series (12-month running mean) of zonally integrated Sverdrup transport in a zonal band (27°-33°N). Solid and dashed lines depict estimates from ERS-1,2 and ECMWF wind products, respectively.

Figure 6: Time-longitude diagram of monthly zonal wind along the equator by ERS-1,2 product. Darker shades depict strong eastward winds.

Figure 7: Time-longitude diagram of zonal wind along the equator by QuikSCAT/SeaWinds data in Aug.1999-Sep.2000. Left: low-pass (>11-day) and Right: band-passed (20-100 days).