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SPACEBASED OBSERVATION OF GLOBAL OCEAN SURFACE WIND FIELDS

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1. INTRODUCTION

The ocean and the atmosphere are dynamically coupled by the transport of momentum which is driven by the wind shear at the sea surface. However, in situ wind measurements are relatively sparse over most of the world's ocean and are largely limited to the locations of shipping routes. They are insufficient to cover the temporal and spatial scales required to study global environmental changes. There are only two ways of providing synoptic and global surface wind fields, from spacebased observations and from numerical weather prediction (NWP) models.

The models of NWP provide dynamical interpolation and quality control to uneven data. However, where there is almost no data, like in the southern oceans, there is little dynamic interpolation can do. Furthermore, models are, of course, only as good as their parameterization scheme. A spaceborne sensor, with limited swath widths and in polar orbits to provide global coverage, can produce only irregular spatial and temporal coverage. Spacebased wind measurements have to be subjected to averaging within a certain temporal and spatial bin, or to be interpolated by an objective method, in order to be useful in many applications.

This is a report on the 0.5° latitude by 0.5° longitude and 12-hour wind vector field over the global ocean generated by objective interpolation of the observations by the National Aeronautics and Space Administration (NASA) Scatteromter (NSCAT). These wind fields are compared with those generated by simple bin-average and with NWP wind fields provided by the National Center for Environmental Prediction (NCEP) and the European Center for Medium Range Weather Forecast (ECMWF), in terms of producing monthly mean atmospheric circulation.

2. THE NASA SCATTEROMETER

NSCAT was successfully launched into a near-polar, sun-synchronous orbit on the Japanese Advanced Earth Observing Satellite (ADEOS) in August 1996. About nine months of wind data were collected over the global oceans before ADEOS' unexpected failure in June 1997. From NSCAT observations, surface (equivalent neutral) wind vectors (speed and direction) can be derived at 25 km spatial resolution, covering approximately 77% of the ocean in one day and 87% in two days, under both clear and cloudy conditions. Surface stress (momentum flux) has been derived from the scatterometer wind using the bulk aerodynamic method.

3. THE INTERPOLATION SCHEME

The objective analysis of NSCAT observations was accomplished by the method of successive corrections, proposed by Bergthorsson and Döös [1955] and modified by Cressman [1959], The interpolation scheme starts from an initial guess field (ug,vg) on the grid, which is the NSCAT monthly bin-averaged field in this case. Then one uses scatterometer observations around the grid point within the influence radius of space R_n and time T_d, to iteratively correct the value of (ug,vg). T_d was chosen to be 1.5 days, i.e., data from *one* and one-half days before and after T, are used to produce a map of time T. For each wind map, the correction process was performed five times successively. The radius of influence R_d decreases during the iteration. The contributions of observations to the correction term are weighted differently based on their positions relative to the grid point under analysis. Observations were screened out if their error E, defined as the difference between measurement and interpolated value from analyzed field, exceeding the maximum allowable error E_{max}. Emax is a decreasing function of

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iteration passes, allowing increasing confidence in the analyzed field with each successive iteration. The procedure was applied to zonal and meridional wind components separately. Computation details are given in Tang & Liu [1996]. Every twelve hours, at OZ and 12Z, a synoptical field is produced on a grid of 0.5°x0.5° resolution: it covers all ocean area from 75°S to 75°N.

4. EVALUATION

The NSCAT wind field, objectively interpolated as described in Section 3, is hereafter, referred as NSCAT-INT. It is compared with wind field computed by bin-average, NSCAT-BIN, and wind fields produced by NCEP and ECMWF. The basic resolution of these four sets of wind data are listed in Table I. Data from October 14, 1996 to November 13, 1996 were selected as the typical "month" in our comparison. These data are from an early period of satellite operation with a small amount of missing data.

4a Monthly Mean Circulation

Some major features of atmospheric circulation, such as the Intertropical Convergence Zone, the Trade Winds, and the mid latitude storm tracks are obvious in the map of monthly-mean zonal component of NSCAT-BIN (Fig. 1a). Differences in excess of 5 m/s between NSCAT-BIN and NWP zonal wind components can be found in Fig. lb and lc. They are located largely in equatorial and coastal areas. Relati ve to NSCAT data, NWP winds appear to have underestimated the eastward components in these regions. Underestimation of the southward components are found in similar regions (not shown). These are ocean upwelling regions where the surface winds have large impact on the fishing industry.

Figure ld shows the difference between NSCAT-BIN and NSCAT-INT. The differences, on the order of 1 m/s, show the patterns of satellite ground-track, indicating that the bin-averaged data, although averaged over a month, still retains the sampling pattern of the polar orbiter. Objective interpolation alleviates this errors (see also Zeng and Levy [1995]). This will be illustrated further in the spectral analysis section.

The zonal and meridional averages shown in Fig. 2 provide further evidence of the differences presented in Fig. 1. Values in the plots are obtained through averaging the absolute differences between NSCAT-BIN fields and each of NCEP, ECMWF and NSCAT-INT fields,

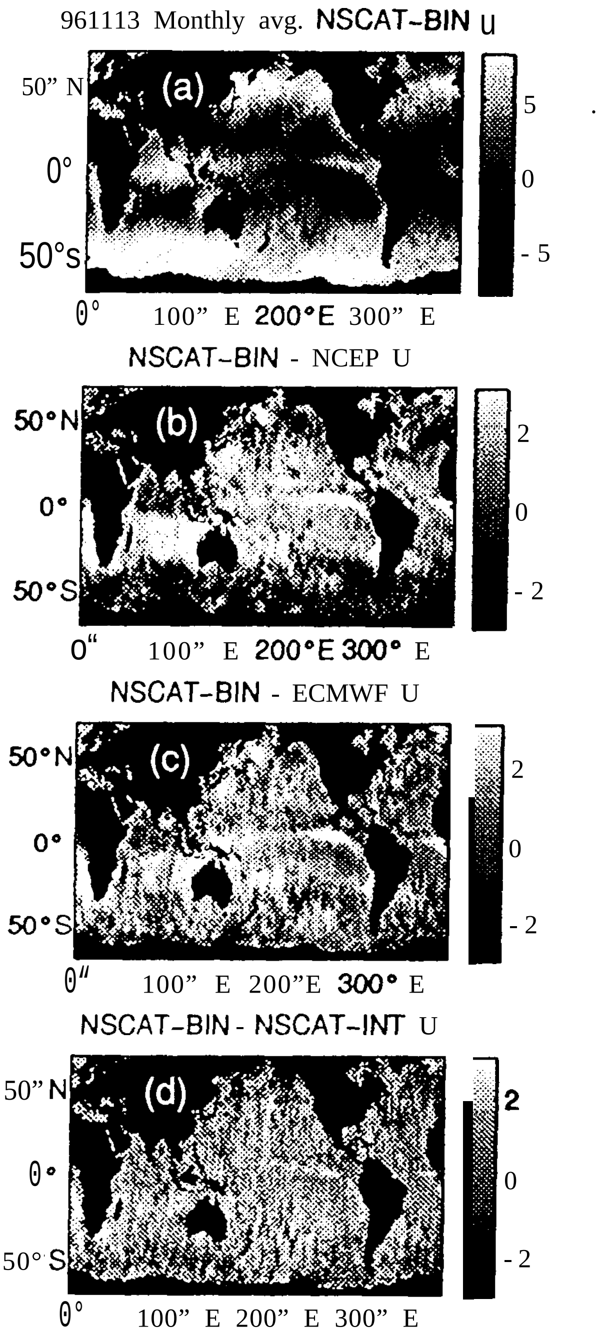

Fig 1. Monthly-mean NSCAT-BIN (a). The differences between NSCAT-BIN and NCEP (b), ECMWF (c), and NSCAT-INT (d). The data were averaged over a period of 30 days ending November 13, 1996. Only the zonal wind components are used in the figure.

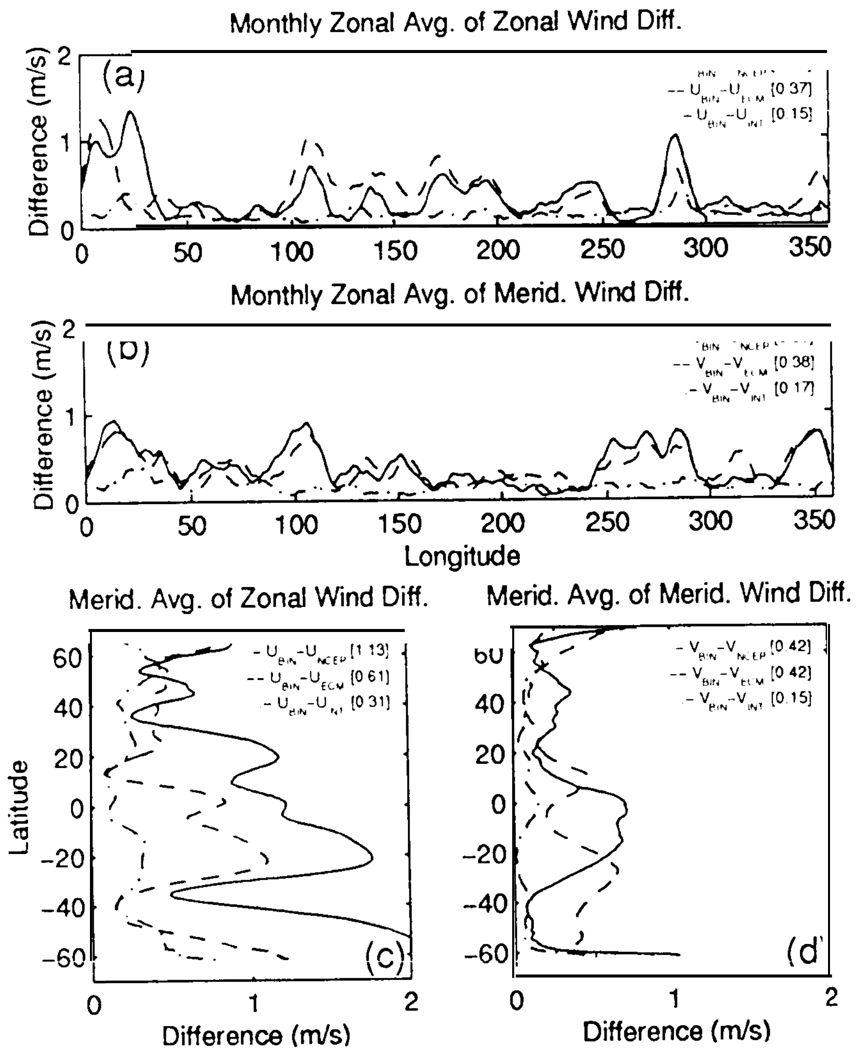

Figure 2. (a) Zonally averaged difference between the zonal wind from NSCAT-BIN and NCEP, ECMWF and NSCAT-INT. (b) Same as (a) but for meridional wind. (c) Same as (a) but for meridionally averaged zonal component. (d) Same as (c), but for meridional component.

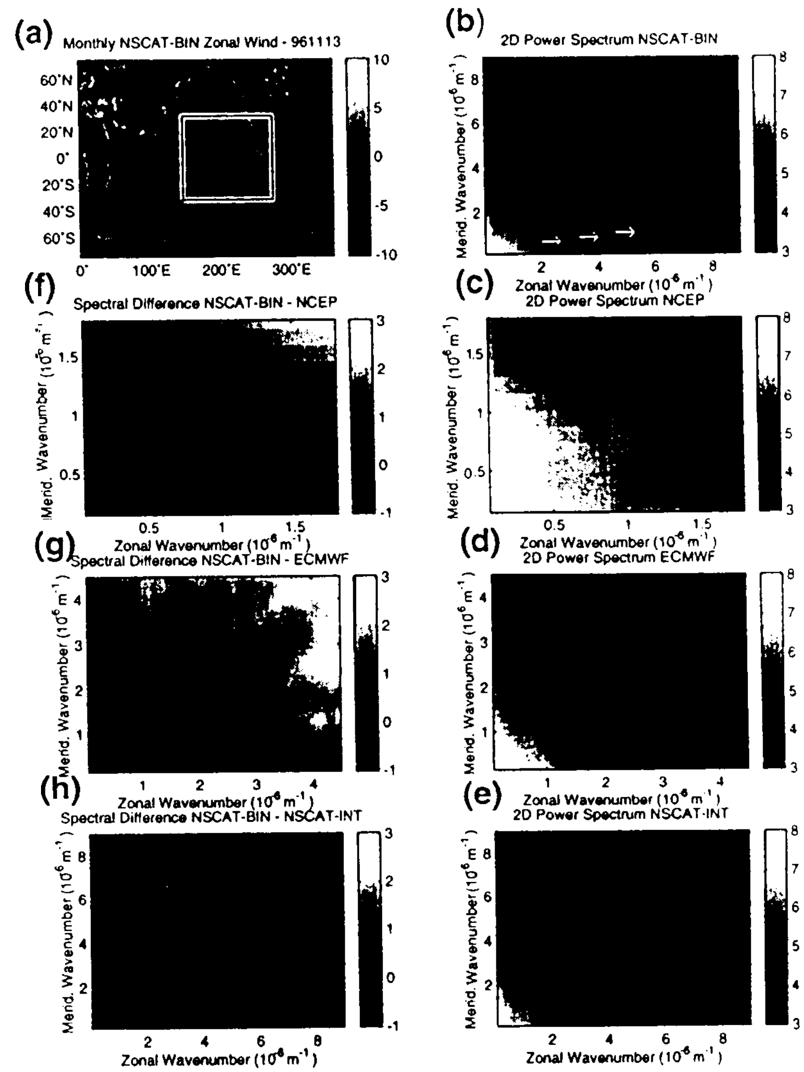

Figure 3. Area of zonal wind component used for spectral analysis (a). 2D spatial power spectrum for NSCAT-BIN (b), Arrows indicate the residual signal of the satellite ground-tracks, NCEP (c), ECMWF (d), NSCAT-INT (e). The differences of 2D spatial power spectrum between NSCAT-BIN and (f) NCEP, (g) ECMWF and (h) NSCAT-INT. Ranges in wavenumber axes reflect different resolutions for the data sets as shown in Table 1.

along a particular line of longitude or latitude. Generally speaking, the two NWP models produce winds of similar geographical distributions, NCEP wind has the largest magnitudes, especially in the high latitudes of the southern oceans. The large difference in the zonal-mean (bottom two figures) illustrated the poor performance of NWP is the data poor southern oceans.

4b Wavenumber Spectrum

The results of 2-dimensional wavenumber spectral analysis are presented in Fig. 3.

The white spots (located by arrows) in NSCAT-BIN (Fig 3b) are non-geophysical spectral peaks resulting from satellite ground-tracks. These spots disappear in the spectrum of NSCAT-INT (right bottom). This confirms the improvement of NSCAT interpolated field over simple bin-average, as we pointed out in section 4a.

The NCEP spectrum (Fig 3c) show about the same power as the NSCAT-BIN for wavenumbers below 10^{-6} m^{-1} (wavelengths - 100). For wavenumbers above this value, the power decreases significantly. Similarly, the ECMWF spectrum (Fig 3d) shows about the same power as the NSCAT-BIN for wavenumbers below $2.5x10^{-6}$ m^{-1} (wavelengths - 3.50). For wavenumbers above this value, the power decreases drastically. NSCAT-INT (Fig 3e) does not show a significant loss of small scale signal as the NWP fields. Instead, the power loss is more isotropic in wavenumber space, which indicates a general decrease in amplitude at no particular band of the spectrum.

5. CONCLUSION

The study demonstrates the advantage in the application of the objectively interpolated winds field. Objective interpolation mitigates the sampling problem caused by data gaps between ground-tracks, which is still prominent in the monthly wind fields generated by simple bin-average. The interpolated wind fields also retains more power at high wavenumber compared with bin-average wind fields and NWP wind fields. The study also shows that there are significant differences in the large scale features of atmospheric circulation exhibited by NSCAT data and NWP products.

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Table 1. Regulations for Wind Fields in Analysis

Wind Data	Spatial Res.	Temporal Res.
NSCAT-BIN	0.5X0.5	12 hour
NMC	2.5x2.5	12 hour
ECMWF	1.0x1.0	12 hour
NSCAT-INT	0.5X0.5	12 hour