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AN INTERCOMPARISON OF NEAR-SURFACE WIND PRODUCTS OVER THE OCEAN ON MONTHLY MEAN AND LONGER TIME SCALES, 1985–1995

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CONTENTS

An Intercomparison of Near-Surface Wind Products over the Ocean on Monthly Mean and Longer Time Scales, 1985–1995

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Abstract. This study presents a comparison of near-surface winds from three global wind products on monthly mean and longer time scales. The three products are: U.S. Navy, European Centre for Medium-Range Weather Forecasts (ECMWF), and U.S. National Centers for Environmental Prediction (NCEP). Vector winds, wind speed, divergence, pseudo-stress, and curl of pseudo-stress are compared for the period of 1985–1995. There is good agreement between the products in the Northern Hemisphere extra-tropics. In the tropics, along the west coast of the Americas, and over poorly observed regions of the Southern Hemisphere, the agreement between products can be very limited, especially for derived quantities like divergence or curl of pseudo-stress. There are large differences in the divergence within the Pacific Intertropical Convergence Zone, and in zonal winds in the Southern Hemisphere westerlies. Climatologies of 1985–1995 compare much better than do anomalies, as expected. To assess whether modifications during this period to the data assimilation techniques and models used to generate the wind products resulted in better agreement between the products, the first and last 5 years are compared separately. The agreement between products during the last 5 years is improved in some areas, but is worse in others.

1. Introduction

We present here an atlas of comparisons between operational analyses that produce near-surface winds over the global oceans. There are now several high-quality, high-resolution wind products available that yield near surface winds over the ocean, each, presumably, with its own relative merits and drawbacks. We have conducted an intercomparison of these global wind products in an attempt to determine where the different analyses give similar results and where they are most different. We focus our comparison on monthly mean and longer time scales.

Where the products compare well with each other it is tempting to believe that our knowledge of the winds is very good. We caution that the three global analyses all rely substantially on the same observations and that their atmospheric models have many similarities; similar results do not imply accurate representation of the actual in situ wind. Although comparisons with observations are beyond the scope of this document, we note that the companion paper to this work, Harrison *et al.* (1997), does present an effort to compare the wind products with observations.

We are motivated to compare the wind products themselves by the many applications in which these winds are used. For example, wind speed is used to calculate air-sea fluxes, and surface stress derived from these winds is used to drive ocean circulation models. To the extent that we are uncertain about the wind products themselves, even on monthly and longer time scales, we lack confidence in the results of their application in these and other uses. Thus, knowing how the wind products compare provides useful information for those seeking to use a wind product in their research.

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In addition to the wind vectors themselves, we compare several geophysically useful quantities derived from the wind fields. The most straightforward of these are the speed and divergence of the wind. We also compute the pseudo-stress and the curl of pseudo-stress from the raw wind data. We do not compare surface stress, because of the additional assumptions required to go from pseudo-stress to stress. For the wind products and the derived quantities, we have compared the following: means, standard deviations, and correlations. Where applicable we have assessed these quantities for the full, climatological, and anomaly values, as well as the differences between products.

We begin by comparing the most basic measure of the products, the long-term mean, for each quantity—wind vectors (U,V), wind speed (SPEED), wind divergence (DIVERGENCE), pseudo-stress vectors (PTX, PTY), and pseudo-stress curl (CURL). We then present the monthly climatological means of each quantity. Several measures of the variability are then presented to give a more complete comparison of the wind products. We compare standard deviations of the products and differences between products for the full fields, climatologies, and anomalies from climatology. We also present correlation coefficients between products for the full, climatological, and anomaly fields. Finally, we compute pair-wise signal-to-noise ratios for full, climatological, and anomaly fields.

In addition, we examine the extent to which the wind fields are coming into closer agreement by comparing the first and last 5-year periods, 1985–1989 and 1991–1995, for the vector wind components (U, V).

Table 1 presents a chart of all of the figures cross-listed by the quantity in question (U,V, etc.) and the type of comparison (Long-term mean, etc.).

2. Data

We make use of three global near-surface wind products: U.S. Navy (NAVY), European Center for Medium Range Weather Forecasting (ECMWF), and U.S. National Centers for Environmental Prediction (NCEP). The data from the NCEP are the result of recent reanalysis efforts (Kalnay *et al.*, 1996), so the wind product is identified as NCEPR. A summary of the wind products used in this study is given in Table 2.

The three global wind products (NCEPR, ECMWF, NAVY) combine observations and model results. The exact models, parameters, and procedures for incorporating data vary between these three organizations, and have also changed over time. Numerous changes in the ECMWF model and data assimilation occurred during the period covered by this paper; many of the changes in the system are presented in a technical note (ECMWF, 1994). The NAVY surface wind product is derived from their NOGAPS model (Hogan and Rosmond, 1991), and the procedures for generating near-surface winds from the model's boundary layer winds also changed with time. The NCEP reanalysis (NCEPR) wind product used here, however, is the result of a reanalysis effort to recalculate the product using constant procedures and model parameters throughout. A reanalysis effort is also underway at the ECMWF but was unavailable at the time of this study.

Table 1. A guide to the figures.

	Winds (U,V)	Wind Speed	Divergence	Pseudo-Stress (Ptx, Pty)	Pseudo-Curl
Long-term mean:					
1985–1995	3.1.1	3.2.1	3.3.1	3.4.1	3.5.1
1985–1989	8.1				
1991–1995	8.2				
Long-term mean differences:					
1985–1995	3.1.2	3.2.2	3.3.2	3.4.2	3.5.2
1985–1989	8.3				
1991–1995	8.4				
Monthly means	4.1.1.1–12	4.2.1.1–12	4.3.1.1–12	4.4.1.1–12	4.5.1.1–12
Monthly mean differences	4.1.2.1–4	4.2.2.1–4	4.3.2.1–4	4.4.2.1–4	4.5.2.1–4
Climatology field:					
standard deviation	4.1.3	4.2.3	4.3.3	4.4.3	4.5.3
standard deviation difference	4.1.4	4.2.4	4.3.4	4.4.4	4.5.4
correlation coefficient	4.1.5	4.2.5	4.3.5	4.4.5	4.5.5
Full field:					
standard deviation	5.1.1	5.2.1	5.3.1	5.4.1	5.5.1
standard deviation difference					
1985–1995	5.1.2	5.2.2	5.3.2	5.4.2	5.5.2
1985–1989	8.5				
1991–1995	8.6				
correlation coefficient	5.1.3	5.2.3	5.4.3	5.4.3	5.5.3
Anomaly field:					
standard deviation	6.1.1	6.2.1	6.3.1	6.4.1	6.5.1
standard deviation difference	6.1.2	6.2.2	6.3.2	6.4.2	6.5.2
correlation coefficient	6.1.3	6.2.3	6.3.3	6.4.3	6.5.3
Signal-to-noise ratios:					
full fields	7.1.1	7.2.1	7.3.1	7.4.1	7.5.1
climatology fields	7.1.2	7.2.2	7.3.2	7.4.2	7.5.2
anomaly fields	7.1.3	7.2.3	7.3.3	7.4.3	7.5.3

Table 2. A summary of the data sets used in this study.

Data set	X extent	Y extent	T extent	X grid	Y grid	T grid
NCEPR (reanalysis)	global	global	1979–1995	~1.9°	~1.9°	6 hourly
ECMWF	global	global	1985–1996	2.5°	2.5°	12 hourly
NAVY	global	global	1982–1995	2.5°	2.5°	6 hourly

We note that the NAVY winds used here are specified at 19-m height, while the ECMWF and NCEPR winds are at 10 m. We convert the NAVY winds from 19 to 10 m by assuming neutral stability. This leads to a constant conversion factor by log-layer theory of 10-m winds = 0.948*19-m winds.

Other conversions were also done to the wind products to make them uniform for comparison purposes. The various products have different temporal coverage and use different spatial grids as detailed in Table 2. The common time period for all three products is 1985–1995 and we limit our study to this period. All the products were converted from their disparate grids to a $2^\circ \times 2^\circ$ grid using linear interpolation. Monthly means were computed by binning (simple averaging) each month.

We compute a monthly mean climatology for each of the data sets by averaging the monthly means over the period 1985–1995. Eleven years is a rather short period for determining a climatology, but by using only the years for which all of the products were available, the climatologies can be consistently compared. Anomalies are defined for each data set as the departure of a given monthly mean from the monthly mean climatology.

3. Means

In Figs. 3.1.1–3.5.2 we present the long-term means of the wind fields (U,V) and various derived quantities (SPEED, DIVERGENCE, PTX, PTY, CURL) for each of the three wind products. We also present the pair-wise differences between the long-term means of the three wind products.

4. Climatology

In Figs. 4.1.1.1–4.5.5 we present the climatology of the wind fields and derived quantities for each of the three wind products. The climatology was calculated for the period 1985–1995. We present the standard deviation of the climatology fields for each of the products, the standard deviation of the difference between product climatologies, and the correlation coefficient for each pair-wise combination of wind product climatologies.

5. Full Fields

In Figs. 5.1.1–5.5.3 we present several measures of the variability of the full fields. We present the standard deviation of the full fields for each of the products, the standard deviation of the difference between products, and the correlation coefficient for each pair-wise combination of wind products.

6. Anomalies

In Figs. 6.1.1–6.5.3 we present the anomalies from climatology of the wind fields and derived quantities for each of the three wind products. We present the standard deviation of the anomaly fields for each of the products, the standard deviation of the difference between product anomalies, and the correlation coefficient for each pair-wise combination of wind product anomalies.

7. Signal-to-Noise

In Figs. 7.1.1–7.5.3 we present signal-to-noise ratios for the wind products as a measure of how well we know the winds and derived products. We define signal-to-noise for pair-wise combinations of two wind products as follows: the signal is defined as the average of the standard deviations of the two products, and the noise is defined as the standard deviation of the difference between the two products. For presentation here, the signal-to-noise maps have been smoothed after computation by a 3-point by 3-point triangle filter. The 3-point triangle filter has a half-power wavelength of 11 degrees. The triangle shape is used rather than the running mean because of its superior spectral characteristics (Dudley and Chelton, 1981).

8. Change Within the 1985–1995 Period

In Figs. 8.1–8.6 we compare the results of the first 5 years with the results of the last 5 years, in order to see if there are obvious changes. We present the mean winds, difference in the mean winds, and the standard deviation of the winds for the periods 1985–1989 and 1991–1995.

9. References

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FIGURES

(Three figures are shown here as examples:
please consult the printed report for the
remainder of the figures.)

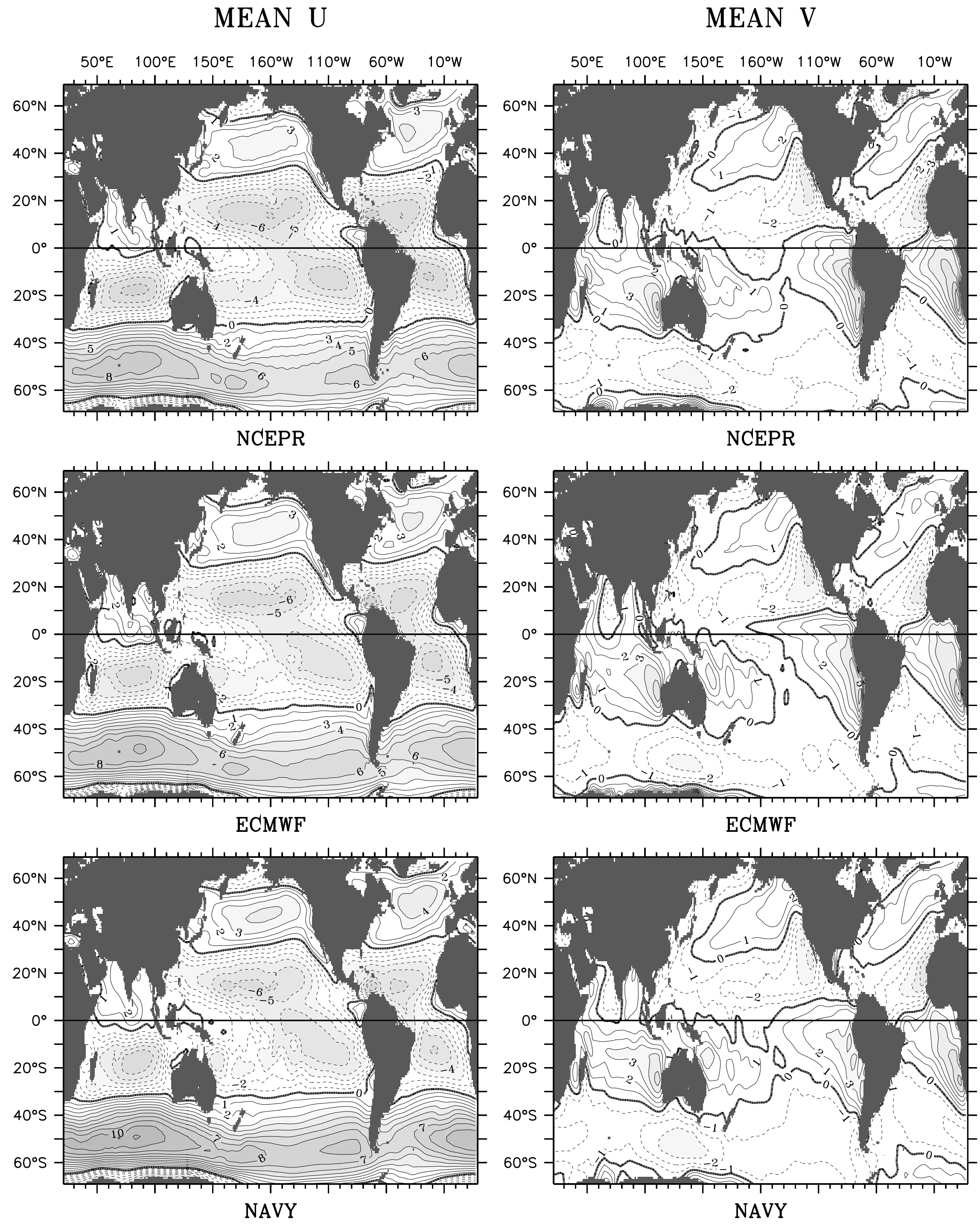

Fig. 3.1.1. Mean zonal and meridional wind components: a,b) NCEPR, c,d) ECMWF, and e,f) NAVY. Contour interval is 1 m s^{-1}.

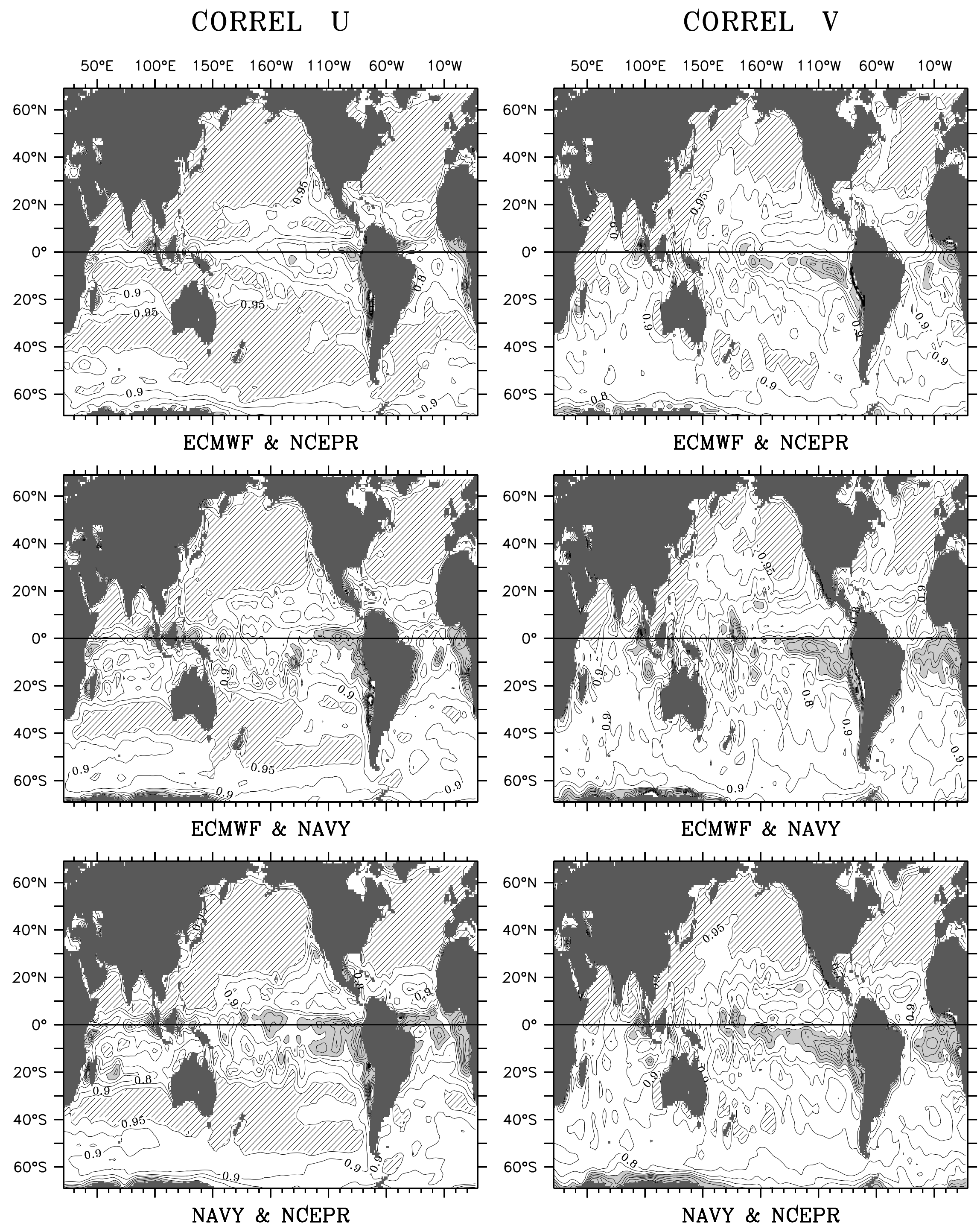

Fig. 5.1.3. Interproduct correlation coefficients of the zonal and meridional wind components: a,b) NCEPR-ECMWF, c,d) ECMWF-NAVY, and e,f) NAVY-NCEPR. Contour interval is 0.1, with additional contour for 0.95. Cross-hatching indicates a correlation coefficient above 0.95, shading indicates a correlation coefficient below 0.6.

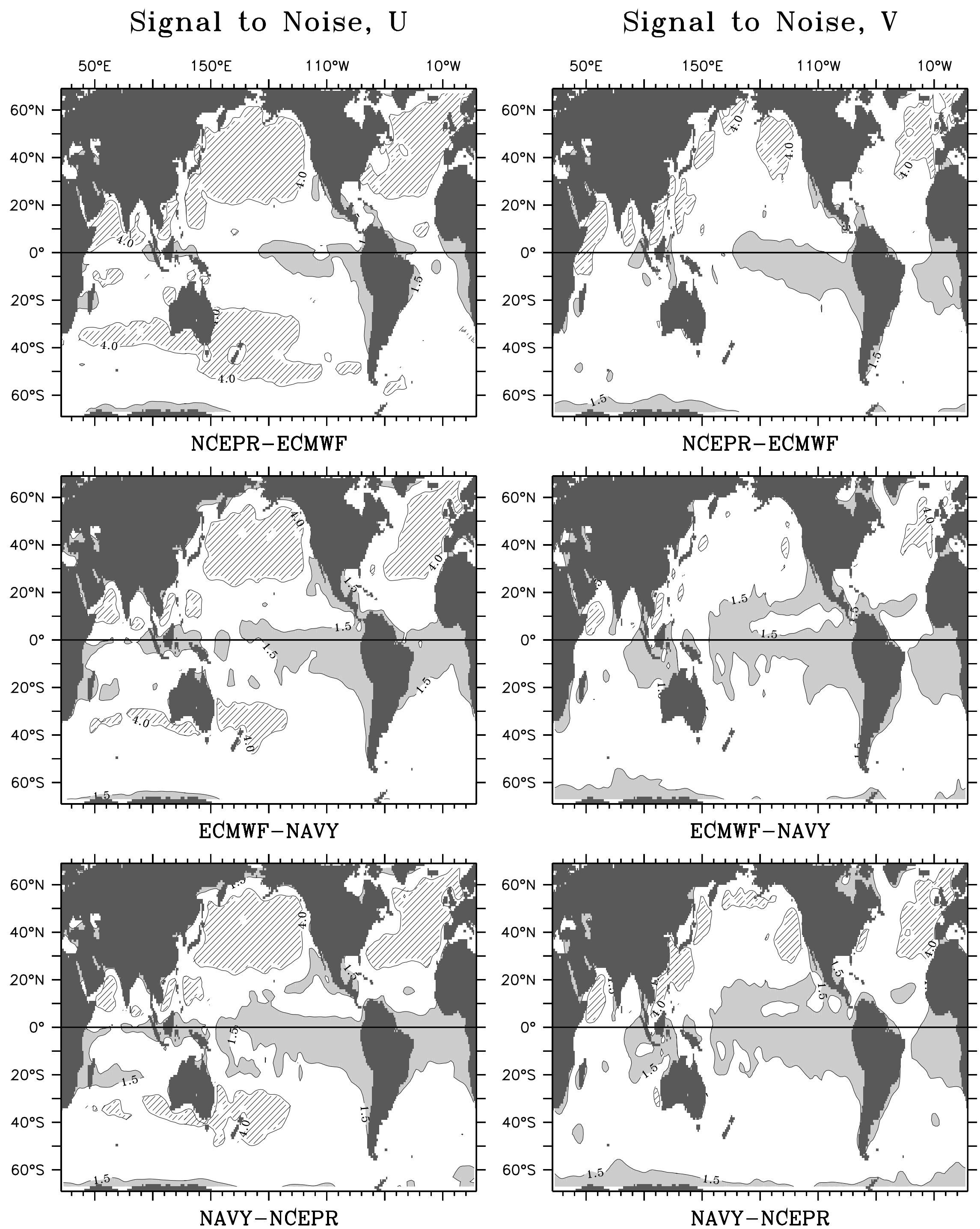

Fig. 7.1.1. Signal-to-noise for zonal and meridional wind components: a,b) NCEPR-ECMWF, c,d) ECMWF-NAVY, and e,f) NAVY-NCEPR. Cross-hatching indicates a signal-to-noise ratio above 4.0, shading indicates a signal-to-noise ratio below 1.5.