A Comparison of marine wind data sets

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1. Introduction

High-accuracy marine wind measurements are needed to understand the interaction between the atmosphere and ocean. Observational data requirements for applications in air-sea interaction are stringent. For example the calculation of heat fluxes to better than 10 W/m^2 from meteorological observations requires mean wind speed to an accuracy of ~0.2 m/s. Our goal in this study is to try to determine whether any monthly mean marine wind products meet this accuracy requirement. We note that meeting this requirement is only one part of the picture. The complex and nonlinear nature of flux parametersations mean that variability and correlations amongst a range of surface meteorological variables must also be adequately resolved.

In this study we compare ten different sources of monthly mean wind speed data, from satellite scatterometers (ERS, QuikSCAT), satellite passive microwave (SSM/I), blended satellite only products (BSW, CCMP), an in situ only product (NOC), atmospheric reanalysis (ERA-Interim, NCEP) and a blended satellite and reanalysis product (OAFlux).

We note that detailed documentation of wind speed data sets and their processing, uncertainties and data flags is a crucial requirement.

2. Data Sets

Satellite data sets:

1) ERS-1 - C-band scatterometer, 1991 - 1996
2) ERS-2 - C-band scatterometer, 1996 - 2001
3) QuikSCAT (CERSAT) - Ku-band scatterometer, 1999 - 2009
4) HOAPS3 - SSM/I (passive microwave) 1989 - 2005

In situ data sets:

5) NOC Surface Flux Dataset v. 2.0 - ship data, 1970 - 2009

Atmospheric reanalyses data sets:

6) ERA-Interim - 1989 - 2010
7) NCEP - 1948 - 2010

Blended data sets:

8) Cross-Calibrated Multi-Platform (CCMP) Ocean Surface Wind
9) Woods Hole Oceanographic Institution OAFlux (OAFlux)
10) Blended Sea Winds (BSW)

Input data (note that all sources may not be available for the entire period)

$	MNB$	Q*21BPKR$	BBC9$	BE25$	U*"3+ $	OPML$	KCBN%$	RNCCRC	MPCVWJK	MNK%<$
MNB%@$	×$	$	$	$	$	$	$	$	$	$
MNB%3$	×$	$	$	$	$	$	$	$	$	$
Q*21BPKR$	$	×$	$	$	$	$	$	$	$	$
IJKLB $	$	$	×$	$	$	$	$	$	$	$
OJP $	$	$	$	×$	$	$	$	$	$	$
MNK%D&,"!2-$	×$	×$	×$	×$	×$	$	$	$	$	$
OPML$	$	$	$	×$	×$	$	$	$	$	$
PPCL $	$	×$	×$	×$	×$	$	×$	×$	×$	×$
JKW/*X$	$	×$	×$	$	$	×$	×$	$	$	×$
UBV $	$	×$	×$	$	$	#2$	$	$	$	$

3. Atmospheric Stability

Reanalysis and in situ datasets typically contain wind speeds adjusted to a common reference level of 10 metres above sea level. Satellite and blended datasets are typically also referenced to 10 metres height above sea level but are also calibrated to neutral stability. The literature is divided about the importance of differences between stability-dependent and neutral winds. The difference is often simply accounted for by assuming that neutral wind speeds are 0.2 m/s stronger than stability dependent wind speeds. This has been justified by citing the uncertainty in the form of the adjustment and the availability of other required surface parameters including air and sea temperature and near surface humidity (*Portabella and Stoffelen*, 2009).

COARE3.0: Fairall, C., E. et al., 2003: Bulk Parameterization of Air–Sea Fluxes: Updates and Verification for the COARE Algorithm. *J. Clim.*, **16**, 571 - 591, 2003.
Portabella, M., and A. Stoffelen, On Scatterometer Ocean Stress, *J. Atmos. Oceanic Technol.*, **26**, 368-382, 2009.
Smith, S. , Wind stress and heat flux over the ocean in gale force winds. *J. Phys. Ocean.*, **10**, 709 - 726, 1980
Smith, S., Coefficients for sea surface wind stress, heat flux and wind profiles as a function of wind speed and temperature. *J. Geophys. Res.*, **93**, 15467 - 15472, 2008.

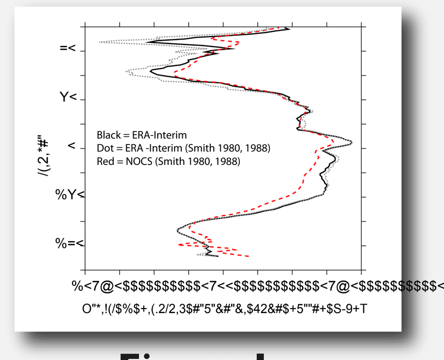

Figure 1

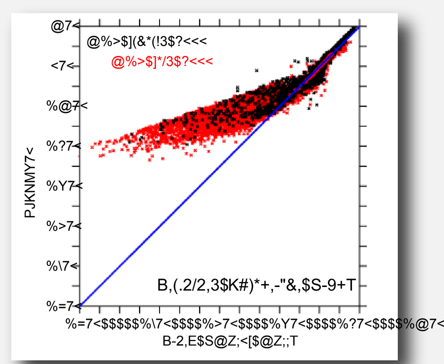

Figure 2

Figure 1 compares annual and zonal means of the stability adjustment estimated from NOC and ERA-Interim. The adjustments for ERA-Interim have also been recalculated using the same formulae as NOC. The similarities among the different estimates of the stability adjustment are greater than their differences. Figure 2 shows that there are some substantial uncertainties in the adjustment which depend on the formula chosen, but these are mostly limited to very stable conditions which are relatively uncommon over the ocean. Figure 3 shows that the differences between a stability-dependent and a neutral dataset are reduced on adjustment. We therefore choose to make the full stability adjustment and compare neutral wind speeds throughout.

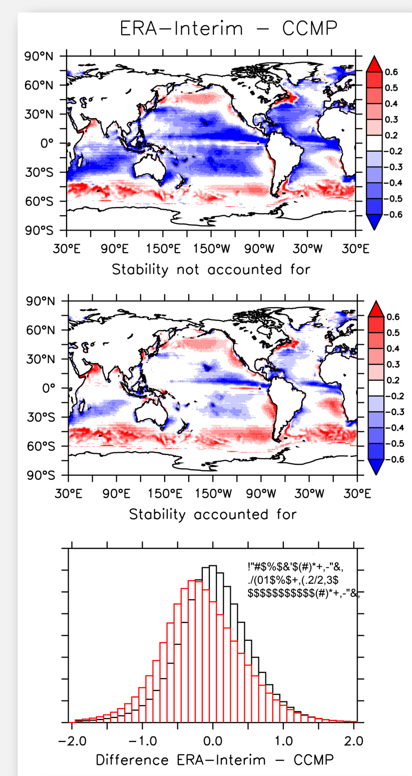

Figure 3

4. Rain Effects

Scatterometers such as QuikSCAT cannot measure wind in the presence of rain. Rain absorbs part of the radar signal in the atmosphere and causes anomalous scattering in the atmosphere and at the sea surface. The combination of these effects can cause wind speed retrievals in the presence of rain to be either erroneously high (typically at low wind speeds) or low (typically at high wind speeds). Different producers of scattermometer swath products use different rain flagging algorithms. Figure 4 shows the effect of applying various rain flags provided by Remote Sensing Systems (RSS) to QuikSCAT data in 2008. There is further room for differences if gridded datasets use different interpretations of the flags.

Ku-band scatterometers such as QuikSCAT are more susceptible to rain contamination than C-band scatterometers such as ERS-1/2. Figure 5 shows the difference between monthly mean wind speeds from QuikSCAT and ERS-2 (red/blue scale). The contour lines are estimates of precipitation. The figure shows, as expected, that QuikSCAT winds are high in the low wind speed, high precipitation regions in the Tropics. A similar pattern is seen in the differences between QuikSCAT and CCMP (Figure 6), suggesting that the blending process used by CCMP has been effective in removing the rain contaminated data. Blended Sea Winds (Figure 7) when compared with CCMP shows a less effective removal of rain-contaminated wind speeds. HOAPS (Figure 8) shows differences from CCMP which may be related to rain effects, but are of opposite sign to those in QuikSCAT and Blended Sea Winds.

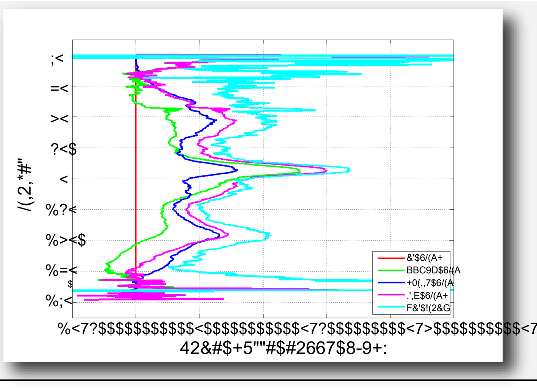

Figure 4

Reduction in mean annual wind speed as a result of rain flagging. Shown is RSS QuikSCAT data for 2008 and RSS flags derived from SSM/I data (green), scatterometer data (blue), both flags where available (pink) and only those data points where both flags are available and show rain-free conditions (light blue).

There may also be fair-weather bias in any dataset based on rain-free data only, as precipitation often occurs in regions of high wind speeds at mid to high latitudes (Figure 9).

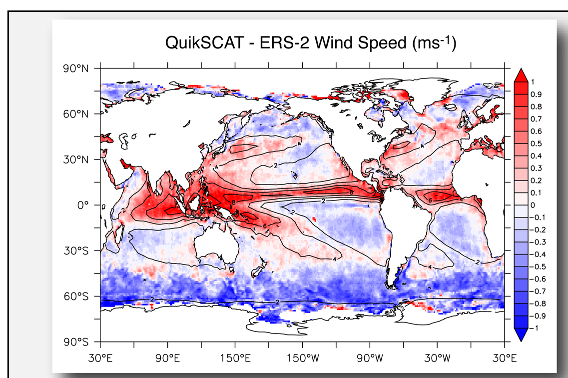

Figure 5

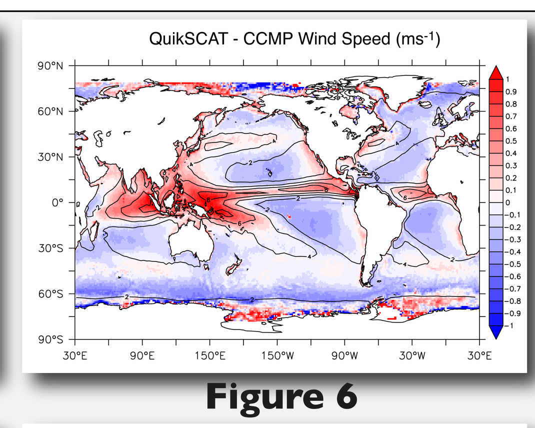

Figure 6

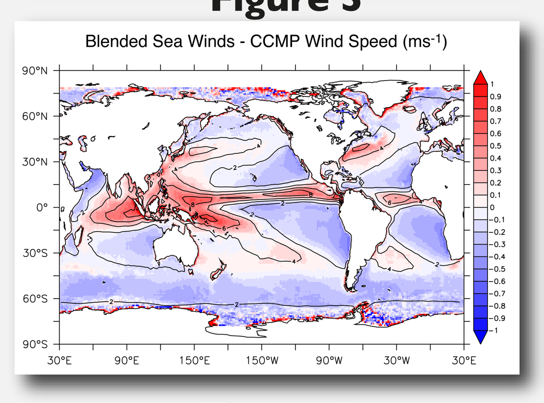

Figure 7

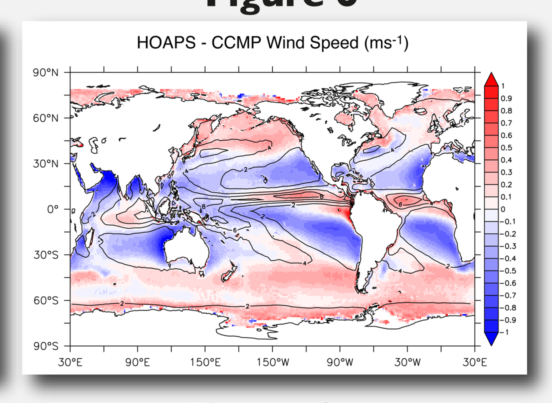

Figure 8

Figures 5-8 show the differences between monthly mean datasets from different sources over their common periods. The global mean difference has been subtracted from each comparison. The contour lines show precipitation from the Global Precipitation Climatology Project.

The differences between QuikSCAT and ERS-2 are noisy because of the short period of overlap and the relatively low sampling of the ERS-2 scatterometer.

Figure 9 shows the difference between ship wind speeds for all observations and for those observations where rain was not observed. This plot shows that if only observations in rain-free conditions are used then we can expect a fair-weather bias of a few tenths m/s in mid-to-high latitudes. It is only possible to estimate this potential fair-weather bias from ship observations in the relatively well-sampled North Atlantic.

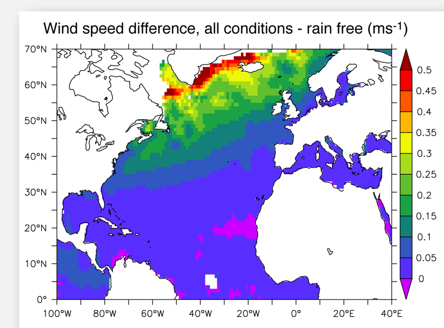

Figure 9

5. Mean Differences

Figure 10 shows monthly mean wind speed over region 75°S to 75°N from all the datasets. Out of the satellite data sets the C-band scatterometer measurements (ERS-1 & ERS-2) show the lowest mean wind speeds. Data from passive microwave measurements (HOAPS) suggest an increasing mean wind speed over its period of record 1987 to 2005. Ku-band scatterometer measurements (QuikSCAT) agree well in the large-scale monthly mean with the HOAPS winds and are substantially higher than the ERS-2 scatterometer measurements in their period of overlap. QuikSCAT wind speeds show a decreasing trend after 2005, this decrease is not seen in e.g. ERA-Interim mean wind speed. Out of the blended products, BSW shows the highest wind speeds. OAFlux and CCMP agree well and show the lowest wind speeds prior to the launch of ERS-2.

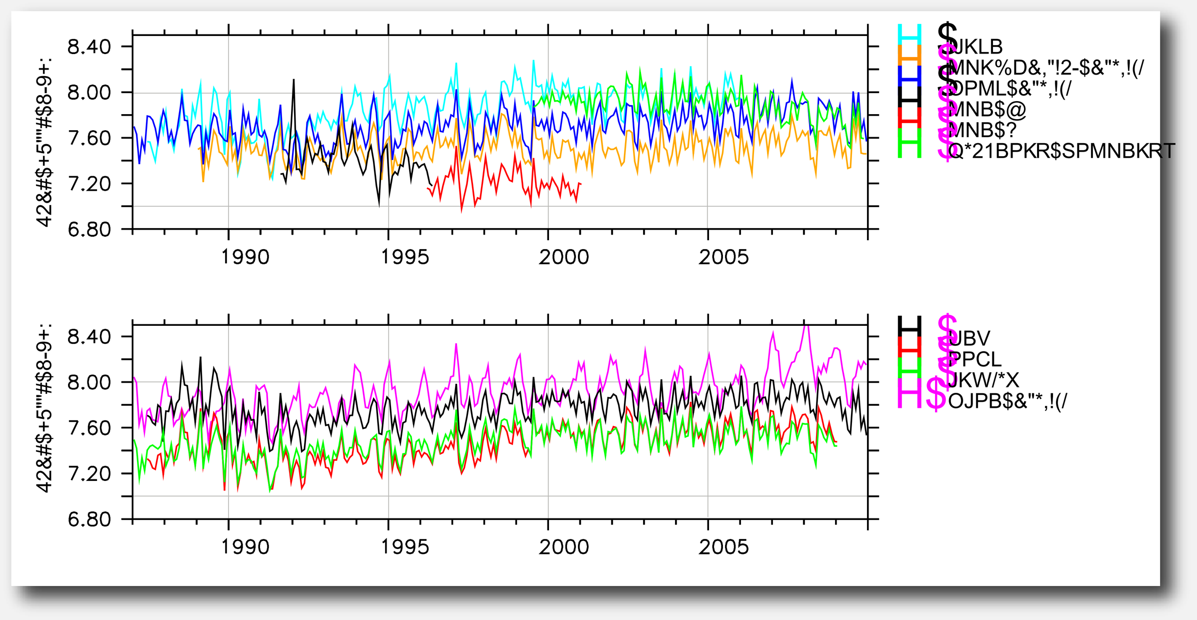

Figure 10

6. Summary and Conclusions

Out of the ten data sets studied, none shows characteristics which would enable net heat fluxes to be calculated to the target accuracy of 10 W/m^2. Adjustments for stability improve the agreement between different data sets but significant differences remain. Contamination of scatterometer and passive microwave data by rain is an issue complicated by different rain flagging methods used in different data sets. The implementation of the rain flags in blended data sets is a further source of discrepancy. Our analysis shows that wind speeds from QuikSCAT and Blended Sea Winds show the strongest overestimation of wind speed due to rain-contaminated retrievals. The CCMP dataset seems to have been fairly successful in excluding rain-contaminated wind speed data. However once rain-contaminated data are removed, the problem of fair-weather bias remains, which is on the order of a few tenths of m/s in the seasonal mean with maximum values in mid latitudes in the winter months.

There are regional and global differences among the datasets, some of which relate to atmospheric stability and precipitation as discussed. Further differences will be explained by the effects of surface currents (not shown). The remaining unexplained differences in both mean differences and trends are outside the accuracy required for accurate determination of surface heat fluxes.

Acknowledgements and Datasets

ERS-1/ERS-2 and QuikSCAT data were downloaded from CERSAT via http://cersat.ifremer.fr/data/discovery/by_parameter/ocean_wind
IFREMER/CERSAT, 2002: Mean Wind Fields (MWF) - User Manual - Volume 1 : ERS-1, ERS-2 & NSCAT; Volume 2 : QuikSCAT ftp://ftp.ifremer.fr/ifremer/cersat/documentation/gridded/
HOAPS data were downloaded from the World Data Center for Climate Hamburg via http://www.hoaps.zmaw.de/
Andersson et al., 2007: Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data - HOAPS-3, doi:10.1594/WDCC/HOAPS3_MONTHLY.
NOC data are available via http://dss.ucar.edu/datasets/ds260.3/.
Berry and Kent, 2009: A new air-sea interaction gridded dataset from ICOADS with uncertainty estimates. BAMS 90, 645-656. doi:10.1175/2008BAMS2639.1.
ERA-Interim data are produced by the European Centre for Medium-range Weather Forecasts (ECMWF) are available via http://data.ecmwf.int/data/
Uppala et al., 2008: Towards a climate data assimilation system: status update of ERA-Interim, ECMWF Newsletter, 115, pp. 12-18.
NCEP Reanalysis data were provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, via http://www.esrl.noaa.gov/psd/
Kalnay et al., 1996: The NCEP/NCAR 40-year reanalysis project. BAMS, 77, 437-471.
CCMP data were obtained via http://podaac.jpl.nasa.gov/DATA_CATALOG/ccmpinfo.html
Atlas et al., 1996: A multiyear global surface wind velocity data set using SSM/I wind observations. BAMS, 77, 869–882.
OAFlux was obtained from the Woods Hole Oceanographic Institution via http://oaflux.whoi.edu/
Yu and Weller, 2007: Objectively Analyzed Air-Sea Heat Fluxes for the Global Ice-Free Oceans (1981-2005), BAMS, 88, 527-539.
Blended Sea Winds data were obtained from http://www.ncdc.noaa.gov/oa/rsad/blendedseawinds.html
Zhang, et al., 2006: Assessment of composite global sampling: Sea surface wind speed, GRL, 33, L17714, doi:10.1029/2006GL027086.
Precipitation from the Global Precipitation Climatology Project were downloaded from http://www.gewex.org/gpcp.html
Adler et al., 2003: The Version 2 Global Precipitation Climatology Project (GPCP) Monthly Precipitation Analysis (1979-Present). J. Hydrometeor., 4,1147-1167.