Blended Global High Resolution Sea Surface Forcing Parameters for Numerical Ocean Modeling

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Introduction

Advances in understanding the coupled air-sea system and numerical modeling of the ocean and atmosphere demand increasingly higher resolution data over the global ocean surface. Some applications require forcing parameters at temporal and spatial resolutions of up to 3 hours and 50 km (e.g., Curry et al. 2004). Observationally, these requirements can only be met by utilizing multiple satellite observations of sea surface wind (SSW), sea surface temperature (SST), and sea surface air temperature and humidity (Ta and Qa) for the computation of turbulent (latent and sensible) air-sea heat fluxes.

In this paper, we describe the globally gridded high resolution sea surface parameters that are blended from observations of multiple platforms (ships, buoys, satellites, etc). The integrated use of multiple-platform observations reduces both systematic bias errors and analysis errors of the blended products. A sampling study was first carried out for the feasibilities of producing various high resolution gridded products for sea surface wind speed using up to six satellite observations. Consequently, global 0.25° gridded sea surface wind speeds are produced for temporal resolutions of 6-hourly and daily. For many oceanography applications that use vector winds, wind directions are added from NCEP Reanalysis 2. The hybrid vector winds are available from July 1987 onward. The widely used NOAA/Reynolds Optimum Interpolation (OI) SST analysis has been improved from 1° and weekly to 0.25° and daily and uses both microwave and AVHRR satellite observations, together with in-situ data. The SST products are available from Jan 1985 onward. A neural network approach is used to develop the retrievals of sea surface air temperature (Ta) and humidity (Qa) from the AMSU sounder onboard the NOAA series of satellites. Blended 6-hourly and 0.5° (Qa) or 1° (Ta) gridded products are being produced and will be available from October 1998 onward. Data description and access can be found from the links at http://www.ncdc.noaa.gov/oa/satellite.html.

Sea Surface Winds

Sea surface wind speed has been observed from long-term multiple satellites, ranging from one in the mid 1987 to six or more since mid 2002 (Figure 1). Each satellite or instrument can provide rich and unique information for specific applications. For example, QuikSCAT provides observations for sea surface vector winds; addition of the wind direction to the wind speed provides opportunities for wider oceanographic applications, including those processes that are directly linked to the ecosystems, such as ocean current divergence and ocean upwelling. However, each individual satellite/instrument observations have limitations in both spatial and temporal coverage, and may have systematic bias errors (e.g., Zhang et al. 2006a, b). Such an example is shown in Figure 1 (left column). In this case, QuikSCAT only sampled Hurricane Katrina once a day (including both ascending and descending tracks), and missed important timely information in between. Significant systematic biases by single instrument observations have also been documented (e.g., Zhang et al. 2006b). For applications that need higher resolution and higher accuracy data, blended products from multiple resources are desirable. Also as equally important, the resolutions of the blended products have to be supported by the available observational data; otherwise, blended products on higher resolutions that cannot be supported by observations may include significant alias errors associated with subsampling. Our detailed sampling studies showed that on a global 0.25° grid, blended products with temporal resolutions of 6-hours, 12-hours and daily have become feasible since mid 2002, mid 1995 and January 1991, respectively (Zhang et al. 2006). Thus four times per day global 0.25° snapshots have been produced since mid 1987 using spatial and time radius of R = 62.5 km and T= +/- 6 hours, respectively. Using the above window sizes, the combined data density distribution in the 0.25° boxes is shown in Figure 2 for 1 April 2004, 12 UTC. A 3-D near Gaussian interpolation was used to minimize aliases for the 6 times per day instantaneous fields, especially when there are enough samplings since mid 2002. An example of the blended vector winds is shown in Figure 3 for 28 August 2005, 12 UTC. Since wind direction is only observed from one satellite (QuikSCAT) in Figure 1 (right), and given the high frequency variability of wind, the directions for the 6-hourly blended products are from a reanalysis (rather than a NWP) product for better climate consistency. In particular, NCEP Reanalysis 2 product is used because it is operationally updated.

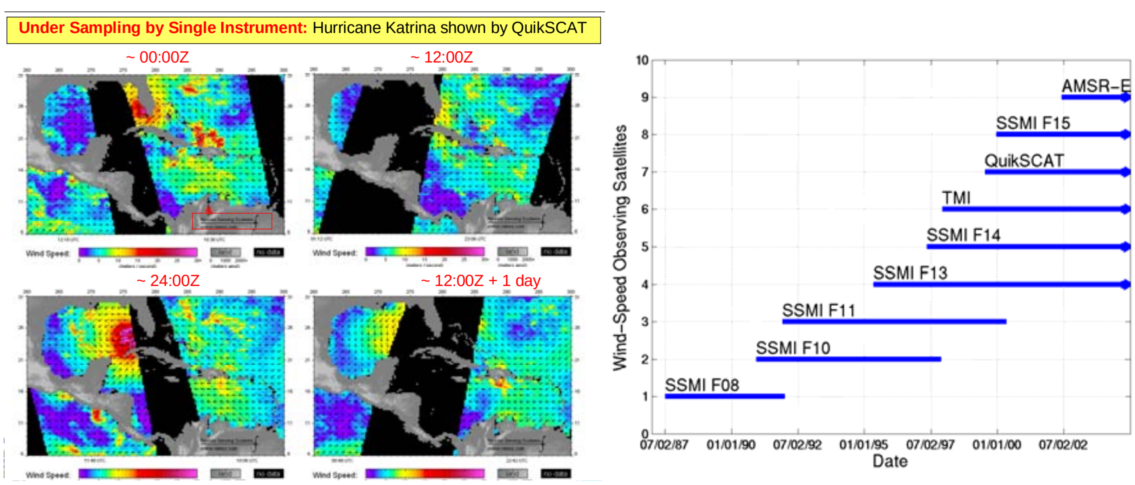

Figure 1: **Left – QuikSCAT sampling around 28 August 2005 (from Remote Sensing System, Inc, http://www.remss.com/). Note it only partially sampled Hurricane Katrina about once per day. Right - Timelines of the long-term satellites that observe sea surface wind speeds.**

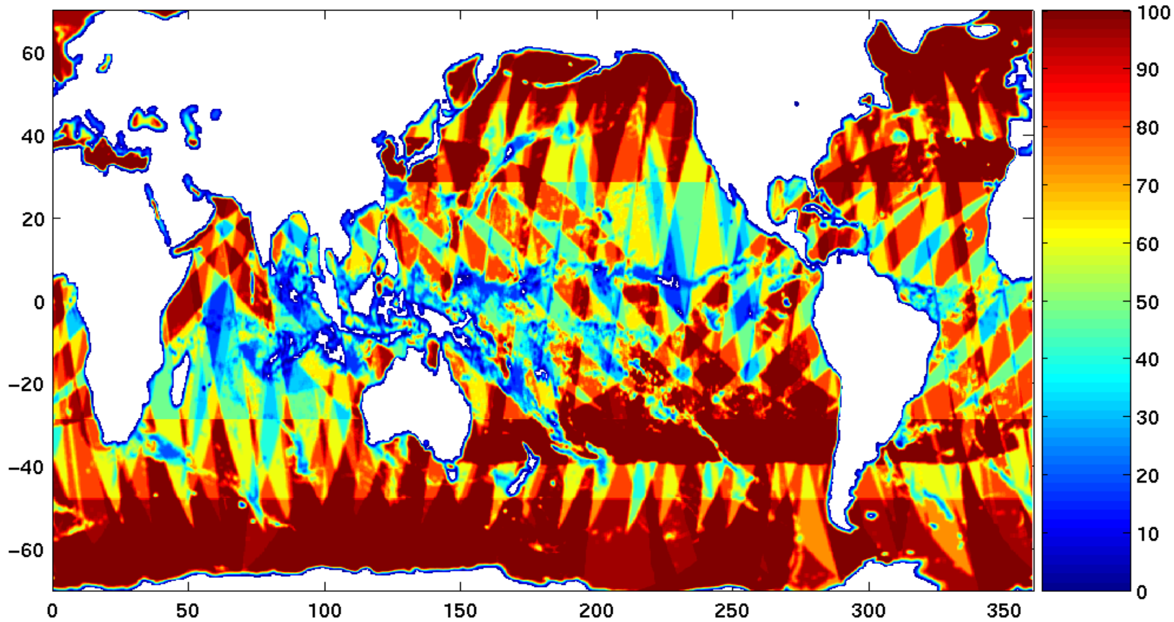

Figure 2: **The combined data density distribution in the 0.25° boxes for 1 April 2004, 12 UTC.**

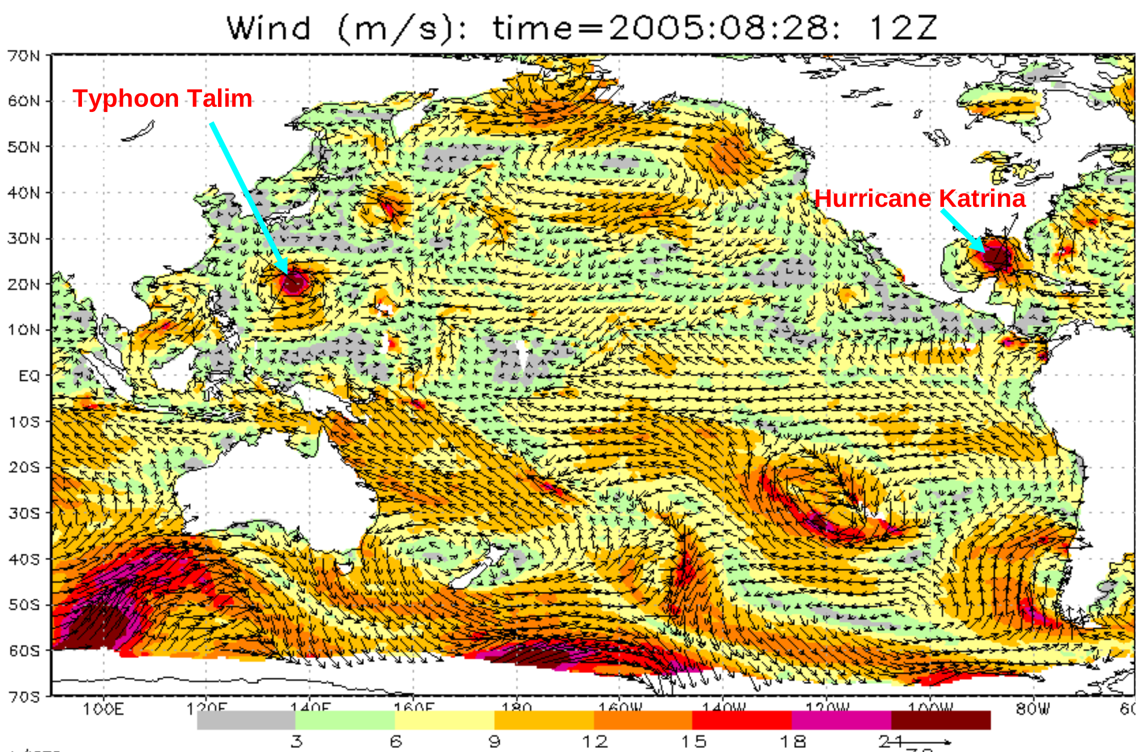

Figure 3: **An example of the blended sea winds at 6-hour intervals. Note the simultaneous Typhoon Talim and Hurricane Katrina at this particular time.**

Sea Surface Temperature (SST)

The widely used NOAA/Reynolds Optimum Interpolation (OI) SST analysis (e.g. Reynolds et al. 2004) has been improved with much higher resolutions (daily and 0.25°) and using multiple satellites (both infrared and microwave) and in-situ data. An advantage of the microwave observations (e.g., from AMSR-E) is that it can see through clouds, thus provide much more data coverage over clouded areas and time periods. The new versions (Reynolds et al. 2007) have the great improvements in term of resolving ocean features such as the meandering of the Gulf Stream, the Agulhas Current, the equatorial jets, etc (Figure 4). In all the OI SST analyses, satellite biases are corrected with regard to the in-situ observations. The satellite bias corrections are important for climate studies and monitoring. An efficient and sufficient in-situ network has been designed (Zhang et al. 2006b) and has become operational as part of the Global Ocean Observing System (GOOS; Figure 5).

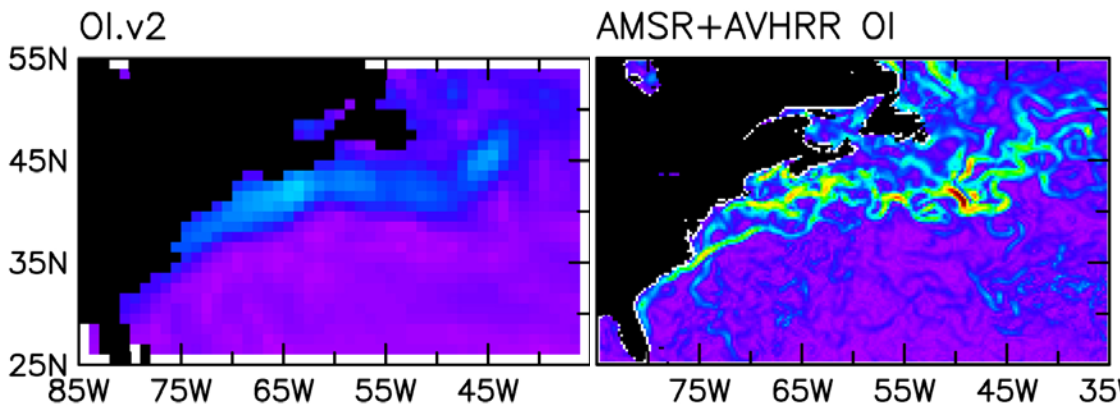

Figure 4: **A comparison of the Weekly, 1° and Daily, 0.25° Reynolds OI SST analyses. Shown are the spatial SST gradients for Jan 2003.**

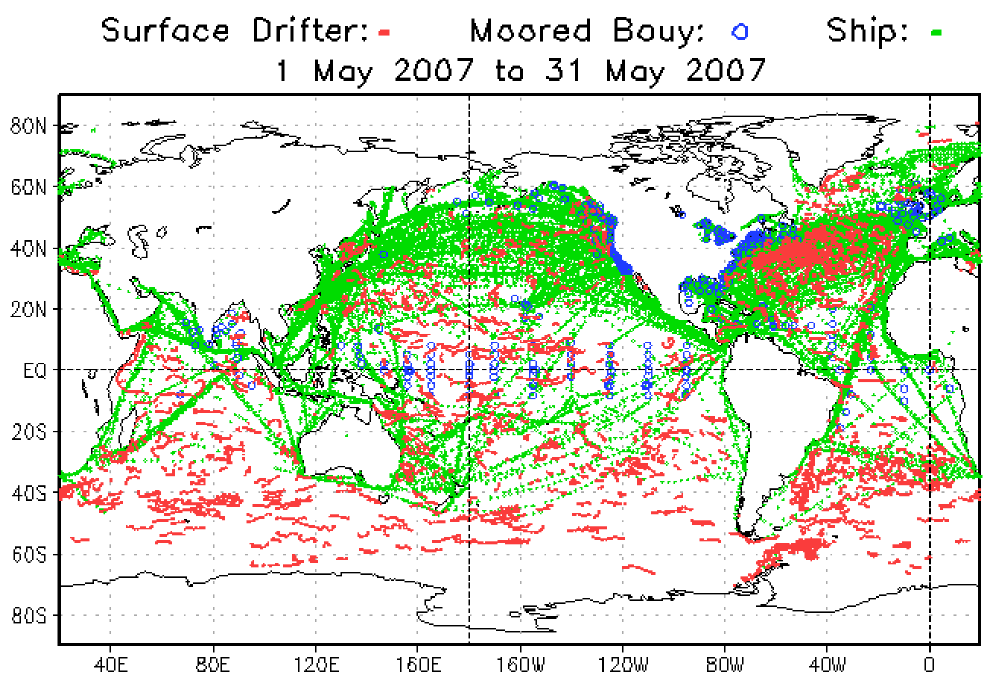

Figure 5: **One-month tracks of SST-observing ships, moored buoys and surface drifters.**

Sea Surface Air Temperature and Humidity (Ta and Qa)

The Ta and Qa retrievals are based on measurements from the AMSU sounder onboard the NOAA series of satellites. The Ta retrieval uses AMSU-A data, while the Qa retrieval uses both AMSU-A and AMSU-B observations. The Ta and Qa retrieval algorithms are developed using the neural network approach. The training datasets are constructed using co-located AMSU and buoy/ship data. The computation shows that the RMSE for Ta is 1.94°C. Adding additional SST constraints reduced the RMSE to ~ 0.94°C. However, one must note that the additional SST constraints reduce the potentially independent higher frequency variability of the air temperature. Figure 6 shows an example of the Ta retrievals from NOAA-16. Retrievals from NOAA-15 and NOAA-18 are also being developed. Then blended Ta will be produced on a global 1° grid with time resolutions of 6-hourly. Blended Qa will be 6-hourly on a global 0.5° grid.

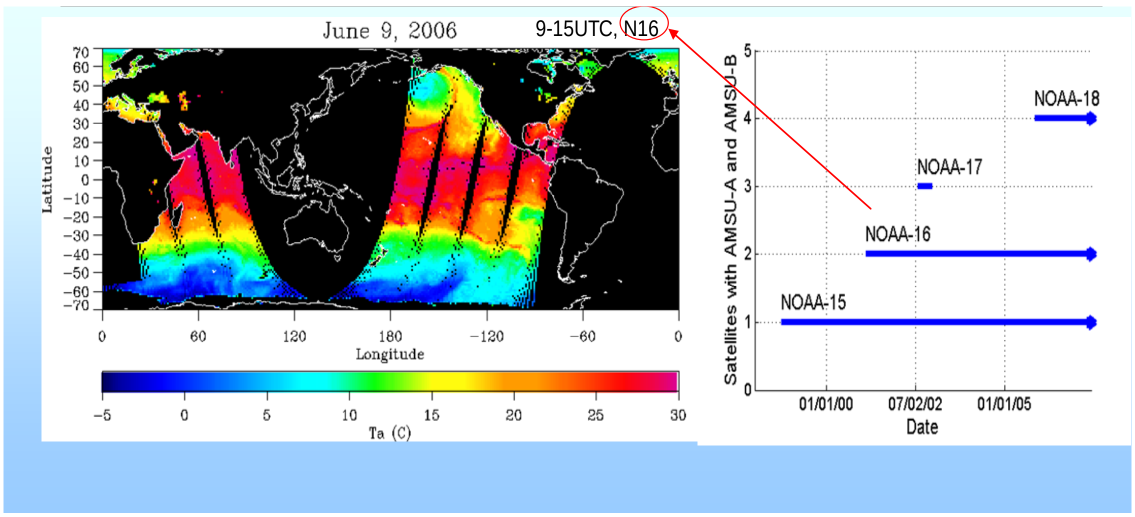

Figure 6: **Left – an example of Ta from NOAA-16. Right – timeline of the NOAA satellite series from which Ta and Qa are retrieved.**

Data Access

More detailed data descriptions and accesses can be found through the links at the NCDC Website: http://www.ncdc.noaa.gov/oa/satellite.html, then click on your desired products. Most of the datasets are accessible by multiple methods, including ftp, OPeNDAP/TDS, and interactive graphic interface such as LAS, from which one can do subsetting and downloading in one's desired formats (e.g., ascii/text, images, netCDF, IEEE binary, arcGIS, etc). Some direct links are:

ftp://eclipse.ncdc.noaa.gov/pub
http://eclipse.ncdc.noaa.gov:9090/thredds/catalog.html
http://nomads.ncdc.noaa.gov:8085/las/servlets/dataset

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