Towards a Climate Data Record of Ocean Vector Winds: The Newly Reprocessed QuikSCAT

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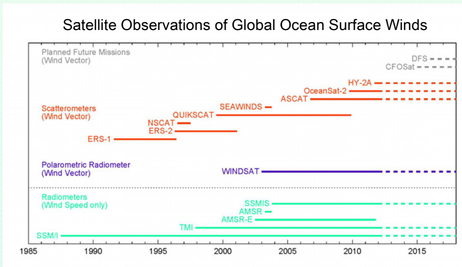
1. Introduction

A Climate Data Record of ocean surface winds is very valuable for climate research, as surface winds are key drivers of oceanic and atmospheric processes which regulate global and regional climate. However, producing a climate-quality global dataset of ocean surface winds by combining observations from different satellites is a very challenging task. Here we present our methodology for creating a Climate Data Record of ocean surface winds. Our first step has been the reprocessing of the wind vectors from the scatterometer QuikSCAT, which operated from 1999 to 2009. The QuikSCAT were reprocessed by using a new model function developed to improve retrievals at high wind speeds. QuikSCAT winds will serve as a backbone for our Climate Data Record. Our next step is to apply the same methodology and calibration method to the winds from the European scatterometer ASCAT, which started in 2007 and is planned to continue for many years. Using a consistent methodology in wind retrievals is ideal when merging different datasets to produce a Climate Data Record.

2. Global Satellite Observations of Ocean Vector Winds

Ocean winds have been observed from space since 1987. At first, observations were made only with radiometers, like those on the SSM/I platforms, which measure only the surface wind speed. Observation of global ocean wind vectors started in 1991 with the introduction of the European scatterometer ERS-1. Scatterometers are active sensors that transmit a microwave signal to the Earth surface and measure the signal that is backscattered due to ocean surface capillary waves. The backscattered signal is a function of wind speed, wind direction relative to the looking angle, and beam incidence angle. The addition of the following scatterometers allowed a continuous monitoring of global Ocean Vector Winds from space: the European ERS-2 and ASCAT; the American NSCAT, QuikSCAT, and Seawinds; OceanSat-2 (India); and recently HY-2A (China). Additionally, in 2003 a new type of polarometric radiometer (WindSat) was introduced, which is able to measure wind direction in addition to wind speed.



3. Production of a Climate Data Record of Ocean Vector Winds

<u>Motivation:</u> A scatterometer Climate Data Record (CDR) is particularly valuable for climate studies because scatterometers are inherently stable sensors, as they measure a ratio (backscatter versus transmitted radiation) rather than an absolute quantity.

<u>Approach:</u> Our efforts focus on combining all the Ocean Vector Wind satellite measurements in order to produce a climate-quality data record, starting from 1991. This is a challenging task, and it requires careful quality-control and cross-calibration of all the scatterometers. Due its decade-long operation, we decided to use QuikSCAT as a backbone for the Climate Data Record. With this focus in mind we reprocessed the complete QuikSCAT dataset (1999-2009) by using a new Geophysical Model Function (GMF) which was developed to improve QuikSCAT retrievals at high wind speeds. The GMF relates the observed backscatter ratio to a "ground truth" wind speed and direction.

<u>Quality-control:</u> The new QuikSCAT has been calibrated using WindSat as ground truth, and both have been extensively validated at all wind speed ranges using buoys, airborne measurements, and additional satellite observations.

<u>Consistency:</u> Our approach in producing a CDR for wind vector is to use a consistent methodology for all the different scatterometers which are included in the timeseries, in order to minimize differences due to observational methods. For this reason, we are now focusing on developing a GMF for ASCAT and the other scatterometers by following a very similar methodology used for QuikSCAT.

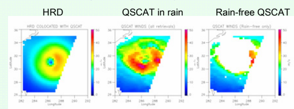
4. Challenges of High Wind Satellite Retrievals

Challenge 1: High winds often coexist with rain

- Rain signal= atmospheric attenuation + rain drops scattering + surface splash effect (Hilburn and Wentz, JAMC 2006)
- Rain signal difficult to model and to separate from surface wind signal

Challenge 2: Wind speeds > 20 m/s

- Lack of reliable ground truth (buoys, NWP) for calibration and validation at high winds.
- Scatterometer: Loss of sensitivity at high winds
- Tropical cyclones: High winds correlated with rain (challenge 1).
- Use of Hurricane Wind observations (like the NOAA Hurricane Research Division data, HRD) for Validation/Calibration of QuikSCAT is limited to rain-free regions (usually lower winds, see figure below)



5. The New QuikSCAT Geophysical Model Function Ku2011

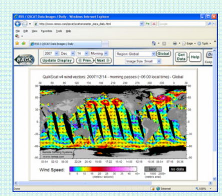
- When the methodology for QuikSCAT was developed at Remote Sensing Systems (Wentz and Smith, JGR 2001), validation data at high winds were extremely limited. Extrapolations and assumptions were made for winds > 20 m/s. Recent analyses showed that the original QuikSCAT retrievals (Ku2001) overestimated high winds.
- In April 2011, the QuikSCAT dataset has been reprocessed using a new GMF to improve retrievals at high wind speeds.
- The scatterometer QuikSCAT retrieves the radar backscatter ratio at 14 Ghz (Ku-band) that needs to be calibrated to a reliable observed ground truth for wind speed and direction.
- The Geophysical Model Function (GMF) relates the radar backscatter cross section σ_0 to wind speed w and wind direction ϕ_R relative to the satellite look angle.

$$\sigma_0 = f(w,\varphi_R)_{pol} = \sum_{i=0}^{N=5} A_i(w)\cos(i\varphi_R)$$

- The new GMF Ku2011 (Ricciardulli and Wentz, 2011, RSS tech report) uses 7 years of WindSat wind retrievals as ground truth . We used hundreds of millions of rain-free QSCAT/WindSat collocations, with about 0.2% at winds greater than 20 m/s.
- The new all-weather WindSat includes algorithms capable of measuring wind under rain or hurricane conditions (Meissner and Wentz, IEEE TGRS 2009). It has been validated at high winds using HRD. The global WindSat dataset includes many rain-free high wind cases from extra-tropical storms useful for QuikSCAT calibration .

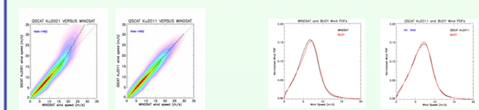
6. The Newly Reprocessed QuikSCAT Winds

Daily gridded maps of the newly reprocessed QuikSCAT winds using the Ku2011 model function for the complete dataset (1999-2009) are available at www.remss.com. Also available on the same website are the WindSat winds, together with other geophysical products.



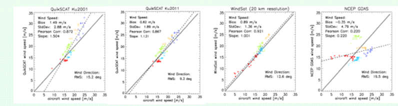
7. QuikSCAT Validation:

a) Global Wind Speed



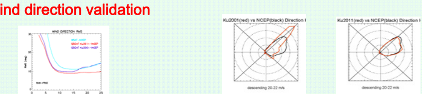
Comparison of reprocessed (Ku2011) and old QSCAT winds (Ku2001) versus WindSat (left panels, joint PDF) and versus buoys (rigth panels, linear PDF), from a 5-year statistics. QuikSCAT data are rain-free.

b) High Wind Speed Validation using aircraft data



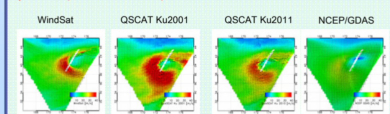
Aircraft winds for the GFDex experiment (Renfrew et al, 2009) compared to QuikSCAT Ku2001, Ku2011, WindSat, and NCEP. QSCAT Ku2011 high winds are consistent with aircraft measurements.

c) Wind direction validation



The wind direction RMS compared to NCEP as a function of wind speed is displayed on the right. The panels on the right show histograms of the old and the reprocessed QSCAT wind direction compared to NCEP, for winds 20-22 m/s. The new QSCAT Ku2011 resulted also in improved wind direction at high winds.

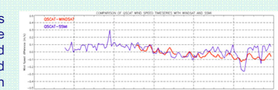
d) Example of extratropical storm



02/17/2003 08:00 UTC

e) Comparison of wind speed timeseries

Here QuikSCAT wind timeseries is compared to other satellite wind data, like WindSat and SSM/I. The global wind timeseries are consistent within 0.1 m/s.



8. Conclusions and Future Plans

A climate-quality data record of Ocean Vector Winds (OVW) requires highly accurate observations, and stability over time. Here we presented the newly reprocessed QuikSCAT wind vector dataset using a new Model Function (GMF) to improve high wind retrievals.

The QuikSCAT dataset will be used as a backbone of our OVW Climate Data Record. Our approach is to use a consistent methodology for the other scatterometers that will be included in the Climate Data Record. We are now focusing on developing a GMF for ASCAT by following a very similar methodology used for QuikSCAT. However, the two sensors operate on different frequencies and use different viewing geometry, therefore the QuikSCAT GMF cannot be applied to ASCAT in a straightforward way. Once the new ASCAT GMF is finalized, we can easily extend it to include the ERS-1 and ERS-2, which are very similar to ASCAT, and OceanSat-2, which is very similar to QuikSCAT.

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