TOWARDS A CLIMATE DATA RECORD OF SATELLITE OCEAN VECTOR WINDS

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ABSTRACT

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 a methodology ideal for merging different dataset to produce 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.

***Index Terms*—**Ocean surface winds, scatterometer, climate data record, geophysical model function

1. INTRODUCTION

Ocean winds have been observed from space since 1987 (Figure 1). 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. 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 radiometer (WindSat) was introduced, which contains polarimetric channels and is able to measure wind direction in addition to wind speed. Our goal is to combine all these ocean vector winds observations to create an intercalibrated Climate Data Record suitable for climate research. Using a consistent methodology in wind retrievals is ideal when merging different datasets to produce a Climate Data Record.

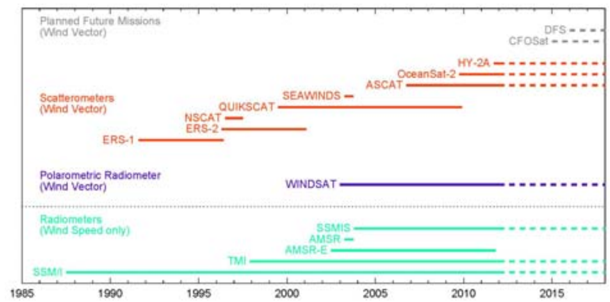

Figure 1: Satellite observations of global ocean surface winds.

2. NEWLY REPROCESSED QUIKSCAT WINDS

At Remote Sensing Systems we recently reprocessed the ocean vector winds observed with the QuikSCAT scatterometer, for the whole mission (1999-2009). One of the main reasons behind the reprocessing is to prepare QuikSCAT to serve as a backbone for a long-term climate-quality dataset for ocean winds. When the algorithm for the original Ku2001 QuikSCAT was developed [1], there was limited knowledge about what ground truth to use for calibrating high wind speeds above 20 m/s. Satellite retrievals of high winds are challenging for two reasons. First, they are often contaminated by the presence of rain, and it is difficult to separate the wind and rain signals in the retrievals. Second, validation data of winds greater than 20 m/s are scarce and therefore limit our understanding of the accuracy of the satellite-retrieved high winds. Traditionally, observed winds from buoys or winds from Numerical Weather Prediction (NWP) models are used as calibration ground truth when developing the scatterometer Geophysical Model Function (GMF), which relates the radar backscatter ratio to observed wind speed and direction. However, both buoys and NWP winds are not reliable at high winds. Therefore extrapolations were made to develop the GMF at high winds, based on feedback from the hurricane research community. Recent analyses showed that the original winds were significantly overestimated in the 20-30 m/s wind regime. We derived a new GMF, QuikSCAT Ku2011, using the complete 10 years of scatterometer observed backscatter ratio σ_0 by using as calibration target wind retrievals from the WindSat radiometer. WindSat wind speeds and directions are part of the WindSat geophysical products recently released at Remote Sensing Systems. They were developed using a new algorithm which is capable of making wind retrievals even in the presence of rain and storm conditions [2]. The WindSat retrievals are believed to be accurate for winds up to at least 30 m/s. Additionally, WindSat is able to accurately detect rain and is used to discard QuikSCAT observed backscatter ratio in the proximity of rain when developing the scatterometer GMF.

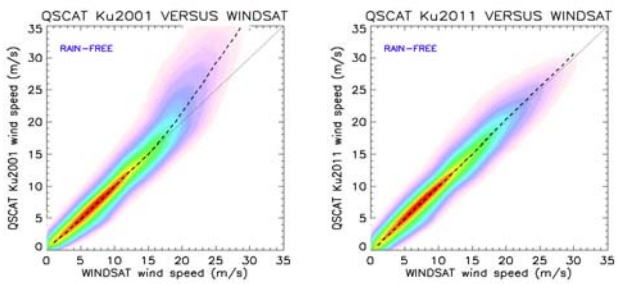

Figure 2: Joint Probability Distribution Function of reprocessed (Ku2011, right) and original QuikSCAT wind speeds (Ku2001, left) versus WindSat. The new QuikSCAT winds are intercalibrated with WindSat in the range 0-30 m/s. The statistics is based on 5 years of data.

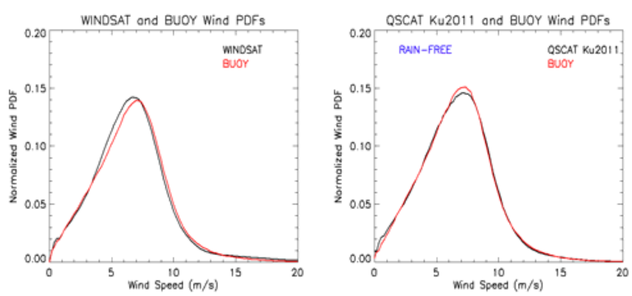

Figure 3: Wind speed Probability Distribution Function (PDF) for WindSat (left) and Ku-2011 (right) compared to buoys (200 global buoys, 5 year statistics, rain-free retrievals only).

The methodology used for Ku2011 is described in detail in Ricciardulli and Wentz [3]. The QuikSCAT and WindSat retrievals were collocated within a time-window of 90 minutes (~ hundreds of millions collocations). It is very important to exclude any possibility of rain contaminated data, as rain impacts the σ_0 and would bias the GMF. For this reason, we used WindSat rain retrievals to discard σ_0 observations in proximity of rain. We described the observed σ_0 with an harmonic decomposition as a function of wind speed and wind direction relative to the satellite look angle, separately for observations at V and H polarization. The coefficients of the expansion were calculated using WindSat wind speeds as ground truth. For wind direction, we used those from the Cross-Calibrated Multi-Platform dataset (CCMP [4]), as we found these data to have slightly lower uncertainty (noise) than NCEP.

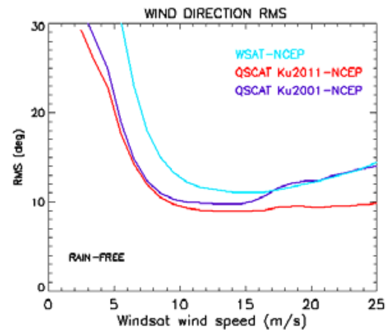

Figure 4: QuikSCAT Ku2011 (red line), QuikSCAT Ku2001 (purple), and WindSat (light blue) wind direction root-mean-square compared to NCEP wind direction, as a function of wind speed.

3. VALIDATION OF QUIKSCAT WINDS

After developing the new GMF with special attention devoted to high winds, we reprocessed the complete QuikSCAT data set (1999-2009). Swath data, and gridded 0.25 degree maps of daily, weekly, and monthly averages for Ku-2011 QuikSCAT and WindSat are available on www.remss.com. The new model function Ku-2011 has also recently been implemented in the newly reprocessed JPL QuikSCAT version V3, released in April 2012.

Figures 2-5 are examples of our validation efforts of the new QuikSCAT and WindSat wind retrievals. Figure 2 shows the joint Probability Distribution Function (PDF) of the original QuikSCAT Ku2001 winds compared to Windsat, and of the new QuikSCAT Ku2011. The new Ku2011 winds do not show any significant bias compared to Windsat in the range up to 30 m/s. Fig. 3 illustrates a comparison of the wind speed PDF for Windsat and QuikSCAT Ku2011 compared to buoys. This multi-year comparison with global buoys shows no global bias, and displays very similar probability distribution functions of wind speeds for the three datasets. Fig. 4 illustrates the improvement in wind direction retrieval with the new Ku2011 GMF versus Ku2001 when compared to NCEP wind directions. WindSat wind direction retrievals have a larger uncertainty at high wind speed compared to QuikSCAT, due to the different observing methodology (polarometric radiometer versus scatterometer). Finally, Figure 5 shows a validation at high wind speeds for the QuikSCAT wind speeds before (Ku2001) and after (Ku2011) reprocessing, compared to aircraft wind measurements taken during the GFDex experiment off the tip of Greenland [5].

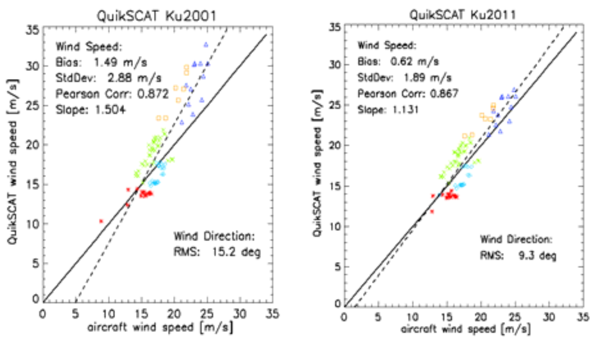

Figure 5: Aircraft winds for the GFDex experiment [5] compared to QuikSCAT Ku-2001 (left), and the new Ku-2011 (right). Each color refers to a different mission flight. Also illustrated are wind speed bias and standard deviation compared to aircraft measurements, and root-mean-square (RMS) difference in wind direction.

4. DEVELOPMENT OF THE NEW ASCAT GMF

The ASCAT vector wind retrievals started in 2007 and overlap with QuikSCAT for 2.5 years. A follow-on ASCAT is scheduled to be launched on MetOp-B in the summer 2012, providing a continuation of the ocean vector wind timeseries for years to come. ASCAT wind retrievals are processed operationally at EUMETSAT OSI-SAF. In order for the ASCAT wind retrievals to be consistent with QuikSCAT, our strategy is to reprocess them by using similar methodology and calibration targets used for our latest QuikSCAT GMF Ku2011. ASCAT and QuikSCAT need to have different model functions, as they operate on different frequencies, C-band and Ku-band, respectively. Additionally, another major difference between the two scatterometers is the viewing geometry. QuikSCAT had a conical scanner with fixed incidence angle for each polarization. ASCAT has three pencil beam antennae that each observes the earth at incidence angles between 25 and 65 degrees. Therefore, the coefficients for the ASCAT GMF need to be evaluated at all incidence angles within this range. We developed a preliminary version of our ASCAT GMF using 4 years of ASCAT backscatter ratio collocated within 120 minutes with wind retrievals from the SSM/I and WindSat radiometers. The preliminary ASCAT GMF has been recently completed, and is expressed as a three dimensional table as a function of incidence angle, wind speed and relative wind direction. We are now focusing on writing the ASCAT wind retrieval code which uses our preliminary GMF.

5. SUMMARY AND CONCLUSIONS

Using a consistent methodology in wind retrievals is ideal when merging different datasets to produce a Climate Data Record. Here we described our methodology for creating intercalibrated ocean vector wind retrievals from different satellites. Our strategy is to use a consistent method and calibration target for developing the GMFs for different scatterometer missions, starting with QuikSCAT (since 1999) and later adding ASCAT (since 2007). The Data Record can be extended back in time previous to QuikSCAT by adding two additional European scatterometers to the timeseries, ERS-1 (started in 1991) and the following ERS-2, which operate at C-band and have several similarities with ASCAT. This intercalibrated data set would then provide two decades of global ocean vector winds, suitable for climate research. This is a challenging task, because of the differences in the observing methods with each satellite, but we are moving towards it. The scatterometer data record is particularly valuable because the scatterometer is inherently a stable sensor in that it measures a ratio (backscattered radiation versus transmitted radiation) as compared to measuring an absolute quantity.
The intercalibrated QuikSCAT and WindSat wind vector retrievals are available at www.remss.com. The intercalibrated ASCAT retrievals are currently under development.

6. REFERENCES

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