Towards a QuikSCAT quality control indicator: rain detection

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ABSTRACT

A good assessment of the information content of scatterometer winds is particularly important in order to assimilate them in weather analysis. Besides retrieval problems in cases of a confused sea state, a particularly acute problem of Ku-band scatterometry is the sensitivity to rain. Elimination of poor quality data is therefore a prerequisite for the successful use of NSCAT or QuikSCAT winds. Following the Quality Control for the ERS and NSCAT scatterometers performed at KNMI, we further develop this methodology for QuikSCAT and define a quality indicator, called the normalized residual (Rn). In order to characterize and validate the normalized residual, we use collocated SSM/I rain and ECMWF wind data. The results show indeed correlation between Rn and data quality. A wind speed dependent Rn threshold is shown to be adequate in terms of rejecting poor quality data (particularly rain) and keeping fair quality data. This opens the way to a quantitative use of SeaWinds measurements in weather analysis.

Keywords: quality control, rain screening, SeaWinds scatterometer

1. INTRODUCTION

The SeaWinds instrument (onboard QuikSCAT satellite) is an active microwave radar and uses a rotating 1-meter dish antenna with two spot beams, an H-pol beam and a V-pol beam at incidence angles of 46º and 52º respectively, that sweep in a circular pattern. The antenna radiates microwave pulses at a frequency of 13.4 GHz (Ku-Band) across a 1800-km-wide swath, making ocean surface wind vector measurements. The SeaWinds swath is divided into equidistant across-track wind vector cells (WVC) numbered from left to right when looking into the satellite's propagation direction. The nominal WVC size is 25 km x 25 km, and all backscatter measurements centered in a WVC are used to derive the WVC wind solutions. For more detailed information on the QuikSCAT instrument and data we refer to [1].

The forecast of extreme weather events is not always satisfactory, while its consequences can have large human and economic impact. The lack of observations over the oceans, where many weather disturbances develop, is one of the main problems of Numerical Weather Prediction (NWP) for predicting their intensity and position. A space-borne scatterometer with extended coverage like SeaWinds is able to provide accurate winds over the ocean surface and can potentially contribute to improve the situation for tropical and extratropical cyclone prediction. In order to assimilate QuikSCAT data into NWP models, a comprehensive QC needs to be done in advance. [2] use a method to detect and reject WVCs with poor quality wind information using a Maximum-Likelihood-Estimator-based (MLE) parameter for NSCAT. Here we adapt this method for QuikSCAT.

The MLE indicates how well the backscatter measurements used in the retrieval of a particular wind vector fit the Geophysical Model Function (GMF), which is derived for fair weather wind conditions. A large inconsistency with the GMF results in a large MLE, which indicates geophysical conditions other than those modeled by the GMF, such as for example rain, confused sea state, or ice, and as such the MLE provides a good indication for the quality of the retrieved winds.

In order to characterize and validate the QC, we collocate a set of 180 orbits of QuikSCAT HDF data with ECMWF winds and SSM/I rain data.

2. METHODOLOGY

The method consists in normalizing the MLE with respect to the wind and the WVC number (or cross-track location). For a given wind and WVC number, we compute the expected MLE. Then we define the normalized residual as: Rn=MLE/<MLE>; where MLE is the maximum likelihood estimator of a particular wind solution (given by the inversion) and <MLE> is the expected MLE for that particular WVC and wind solution. The <MLE> is retrieved by computing the mean MLE value for any wind speed and WVC number using a set of 60 orbits of QuikSCAT.

We hypothesise that the MLE is very much altered in the case of rain and therefore very different from the expected MLE. A set of σ^o_m coming from a “rainy” WVC (or a WVC where some geophysical phenomena other than wind is “hiding” the wind-related information) is expected to be further away from the GMF than a set of measurements coming from a “windy” WVC (which should lie very close to the GMF). Therefore, the MLE is much higher than <MLE> and the normalized residual is high. In contrast, the MLE of a “windy” WVC is closer to the <MLE> and consequently we have low values of Rn.

3. RN CHARACTERIZATION

In this section, we study the correlation between Rn and the quality of QuikSCAT winds. Collocated ECMWF winds and SSM/I rain are used as characterization and validation tools. The vector RMS difference between the retrieved and ECMWF winds (RMS-ECMWF) is used as a quality indicator. The higher the RMS-ECMWF is, the lower the quality of the wind solution.

Characterizing Rn results in a QC procedure by finding a threshold value of Rn which separates the good quality from the low quality retrieved winds.

The ECMWF collocated winds show good correlation between the data quality and Rn. The data quality decreases with increasing Rn, and the decrease rate is increasing with retrieved wind speed; data quality is relatively poor at low Rn values when retrieved speeds are high. This suggests a Rn threshold dependent on wind speed.

Looking at the effects of rain, we found that the rain rate is proportionally increasing the retrieved wind speed and that for rain rates above 6 mm/hr the WVCs contain no valuable wind information. The latter is clearly discernible in Figure 1 which shows the two-dimensional histogram of RMS-ECMWF versus the retrieved wind speed for rain-free (plot a) and for rain rates over 6mm/hr (plot b). The contour areas are in logarithmic scale (half an order of magnitude per contour line) filled from white (unpopulated areas) to black (most populated areas). We set an arbitrary threshold at RMS=5 m/s which is roughly separating the “good” from the “bad” quality cases. The upper plot shows a generally horizontal orientation of the contour lines, where most of the data are of good quality (below 5m/s threshold). The bottom plot shows mainly a vertical orientation, where most of the data are of poor quality (above threshold).

We then define a Rn threshold which is wind speed dependent. It is a parabolic threshold with a maximum value of 4 at 5 m/s, which reaches a value of 2 at 15 m/s and then is kept constant for higher speeds.

4. VALIDATION

We test the threshold defined against the ECMWF and SSM/I collocations. The test consists of looking at the Rn of the selected solution of any WVC. If the Rn is lower or equal to the threshold, the WVC is accepted; otherwise, the WVC is rejected.

The mean RMS-ECMWF for the accepted data is 2.2 m/s while for the rejected data is 6.2 m/s showing that the Rn threshold is effective in rejecting poor quality data and keeping good quality data. In cases of SSM/I rain over 6 mm/hr, 87.3% of these data are rejected showing again the effectiveness of the Rn threshold.

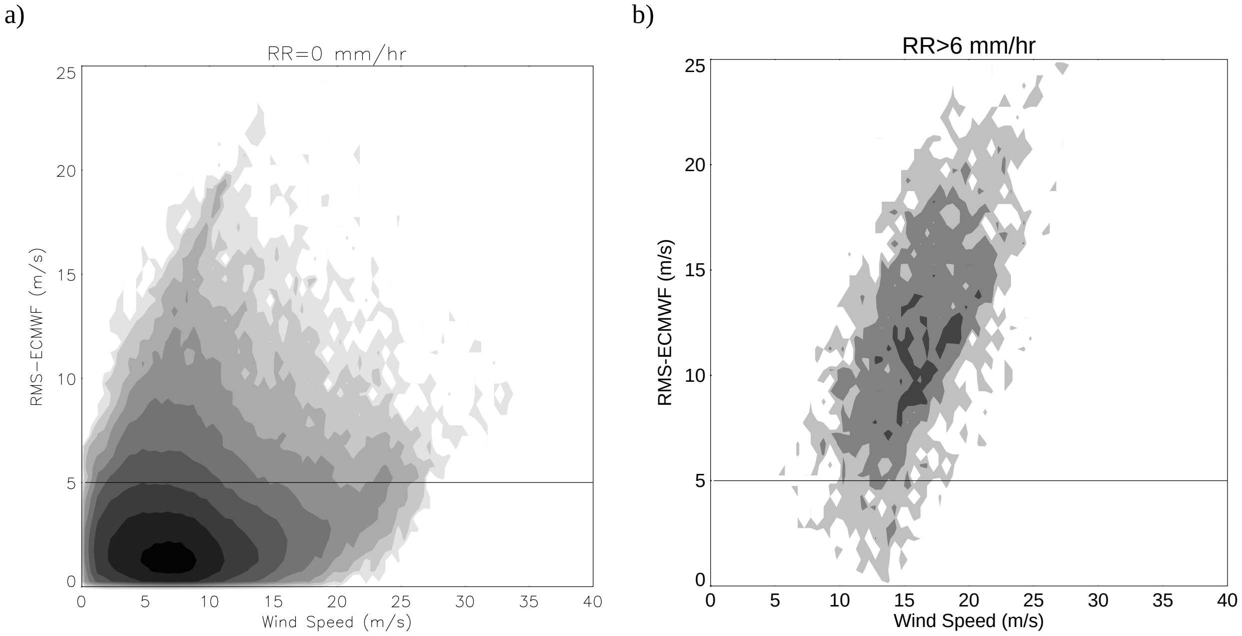

Figure 1 Two-dimensional histograms of RMS-ECMWF versus JPL-retrieved wind speed for rain-free (plot a) and for rain rates above 6 mm/hr (plot b).

Figure 2 shows triple collocated QuikSCAT-ECMWF-SSM/I data. The arrows in plot a) correspond to the QuikSCAT JPL-selected wind solutions; the grey thin arrows represent the accepted solutions and the black thick arrows the rejected solutions by the Rn threshold (QC). The squares correspond to the collocated SSM/I rain data, where the size of the squares annotates rain rates from 0 mm/hr (no square) to 25 mm/hr (the largest ones). The arrows in plot b) correspond to the collocated ECMWF winds. In plot a, the presence of a front is clearly discernible in the middle of the plot, where confused sea state (due to high temporal wind variability) and therefore poor quality winds are expected. WVCs along the front line are rejected by the QC. This is also the case for the center of the low at the bottom of the plot, where there is probably extreme temporal and spatial sea state variability or rain. At the left side of the front we see a region of significant rain (above 6 mm/hr) which has been successfully detected by the QC. The ECMWF forecast (plot b) does not accurately place the center of the low and the associated wind front is not so pronounced as in the QuikSCAT plot. This example illustrates the potential value of assimilating QuikSCAT winds into ECMWF after using our QC.

For more detailed information about this paper, see [3, 4].

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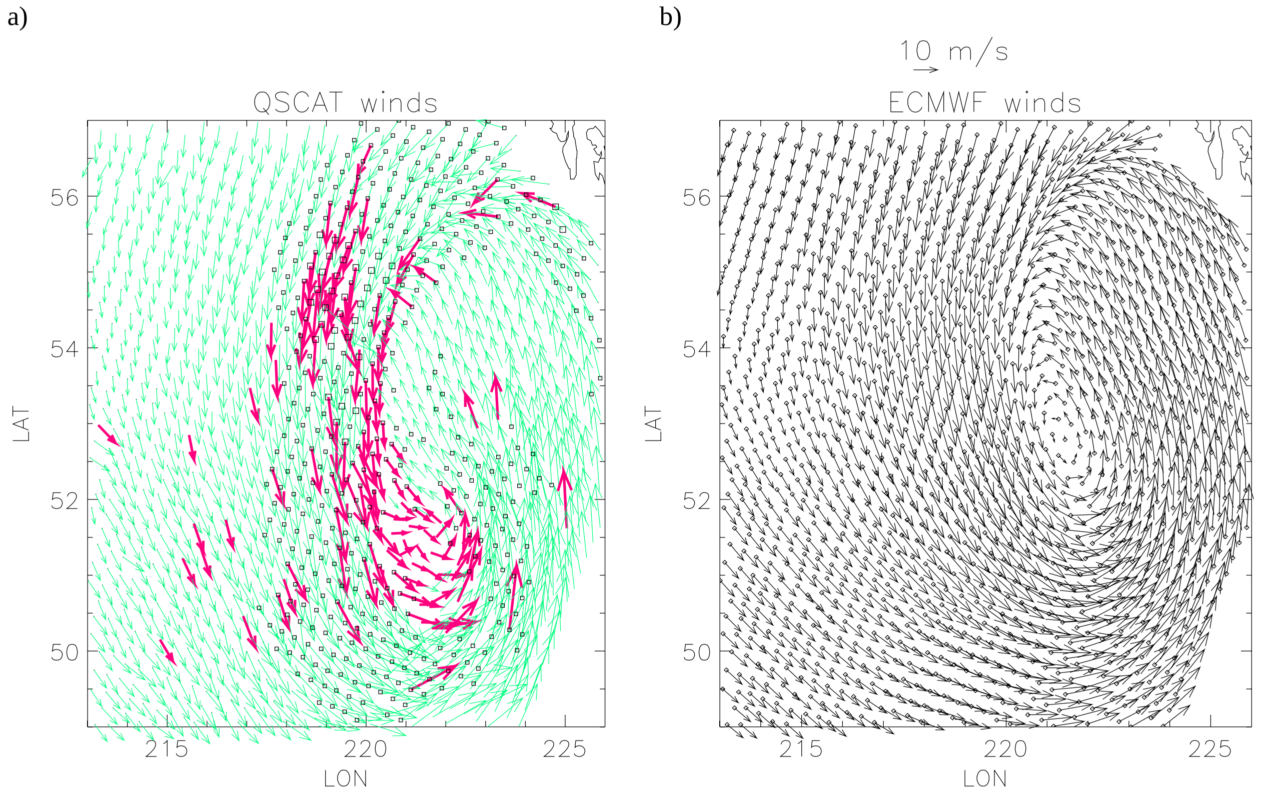

Figure 2 Collocated QuikSCAT-ECMWF-SSM/I data. Plot a shows QuikSCAT wind arrows (JPL-selected winds) and plot b the collocated ECMWF winds.

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