Advanced Algorithms for QuikScat and SeaWinds/AMSR

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Abstract-QuikScat is providing scientists and weather forecasters with an unprecedented view of ocean winds at a 25-km resolution. With a typical accuracy of 1 m/s in speed and 15° in direction, the retrieved wind vectors are being used for a number of important oceanographic and air/sea interaction studies. Here we present work on a QuikScat wind-vector retrieval algorithm that contains a number of advanced features, including: an updated geophysical model function (Ku-2001), a fully integrated stand-alone rain flag, and the capability to retrieve winds up to 70 m/s. In addition, the QuikScat data processing is done in parallel with our near-real-time operational data processing for SSM/I and TMI. In this way, an additional rain flag as well as a sea-ice flag (both based on the SSM/I and TMI observations) can be appended to the QuikScat wind vectors. We present results of two studies: 1) the capability for QuikScat to measure very high winds (>30 m/s) and 2) comparisons between scatterometer and radiometer wind speed retrievals (i.e., QuikScat versus TMI). These investigations are leading towards a combined SeaWinds-AMSR algorithm for ADEOS-2, which will ingest both scatterometer and radiometer observations to obtain more accurate wind vectors and sea-surface temperatures.

INTRODUCTION

The ADEOS-2 spacecraft will carry both the microwave scatterometer SeaWinds [1] and the microwave radiometer AMSR [2]. The SeaWinds-AMSR combination will be the first active-passive microwave conical scanners in space. Over the world's oceans, this sensor complement will be able to simultaneously image sea-surface vector winds and sea-surface temperature (through clouds) as well as atmospheric temperature and moisture (vapor, cloud, rain) to a previously unattainable accuracy. We are planning to develop algorithms and conduct research that will take full advantage of the many synergisms of these two sensors.

The scientific benefits in combining the two sensors are 1) reliable scatterometer vector wind retrievals in storms and hurricanes (and other rainy areas), 2) substantial improvement in the radiometer SST retrieval accuracy, 3) an overall improvement in the scatterometer wind vector retrieval accuracy, and 4) a more complete characterization of the marine boundary layer. An additional result is the precise determination of the dependence of brightness temperature on wind direction, which will help answer questions about future active versus passive wind vector sensors.

During the pre-launch phase of our SeaWinds-AMSR investigation, we have focused on the following three areas:
1. Improvements in the vector wind retrieval algorithm
2. Consistency in the active-passive wind speed retrievals
3. Wind retrievals in storms with high winds and rain

IMPROVEMENTS IN VECTOR WIND SELECTION ALGORITHM AND ASSOCIATED DATA SETS

We have more fully integrated the various functions in the vector wind retrieval algorithm. The minimization of the objective function $\Lambda(\sigma_o)$, the ambiguity selection, and the rain flagging processes are now done in a consistent manner and are all based on the same formulation for $\Lambda(\sigma_o)$. Anomalous observations (as indicated by a large $\Lambda(\sigma_o)$) are excluded before ambiguity selection occurs so that errors do not spatially propagate. Objective smoothing has also been implemented so that retrievals with poorly defined $\Lambda(\sigma_o)$ can benefit from the information contained in adjacent retrievals that have a sharper $\Lambda(\sigma_o)$. An improved geophysical model function (Ku-2001) has been derived. Ku-2001 more accurately represents the wind direction dependence of σ_o at low winds and has a flatter σ_o versus wind speed response at high winds.

Using the improved retrieval algorithm and model function, we have reprocessed the entire QuikScat and NSCAT data sets. These new wind products are produced in near-real time and are made available to the community at large for analysis. The scatterometer processing is done in parallel with our SSM/I-TMI processing to realize better rain and sea ice flagging. The feedback on the new products has been very positive and it does appear that the reprocessed vector winds are an improvement over the standard products. Since the same algorithm and model function are used for both QuikScat and NSCAT, a more consistent time series is obtained. In addition, these two data sets can now be directly compared to determine the relative performance of QuikScat versus NSCAT.
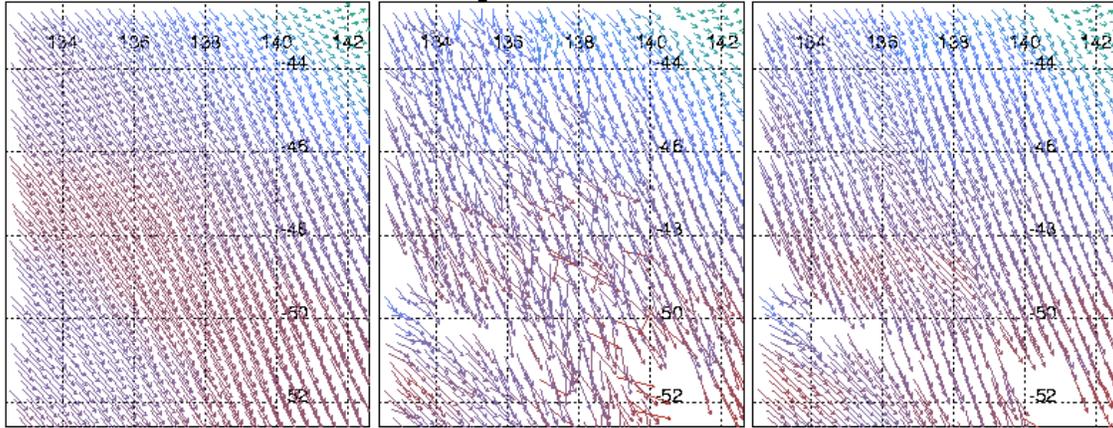
Fig 1. Example of objective smoothing for QuikScat orbit 973. This plot shows three wind fields for this center swath region, NCEP winds (left), QuikScat winds produced with no objective smoothing (center), and QuikScat winds produced using objective smoothing (right). White regions are locations identified as containing rain by the scatterometer or a collocated radiometer.

CONSISTENCY IN ACTIVE AND PASSIVE WIND SPEED RETRIEVALS

A necessary condition for combining SeaWinds and AMSR observations is that the wind speed retrievals from SeaWinds be consistent with those from AMSR. Past results comparing SSM/I and TMI wind retrievals with NSCAT and QuikScat exhibited systematic regional biases between the radiometer and scatterometer winds [2]. These regional biases were of the order of ±1.5 m/s. To correct this problem, we rederived the sea-surface emissivity model. The radiometer T_B observations are first transformed to emissivity values, and then these emissivities are stratified into SST and wind speed bins. The SST comes from Reynolds weekly values, and the wind speed comes from collocated QuikScat observations. The new wind-induced emissivity model shows more dependence on SST than did the previous model. We reprocessed the entire TMI dataset using the new emissivity model. As shown in Fig. 2, the resulting winds exhibit much smaller regional biases when compared to the
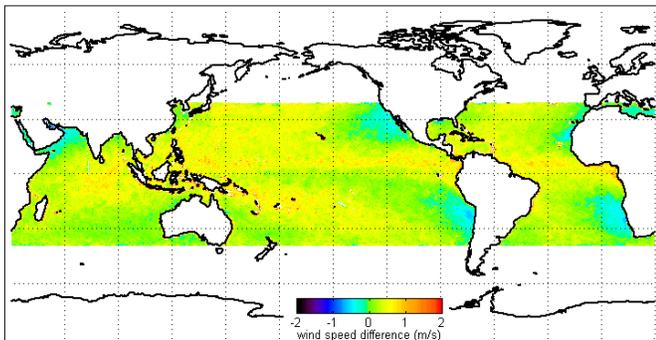

Fig 2. Wind speed difference map (TMI – QuikScat) averaged over the July 1999 to December 2000 time period. Small geographical biases (<0.5 m/s) have been vastly improved by changes in the sea surface emissivity model.

QuikScat winds. The regional biases have been reduced to the 0.5 m/s level, which is a factor of 3 improvement over the original algorithm. For individual footprints over the swath, the rms difference between the TMI wind and the QuikScat wind is 0.7 m/s. We see this consistency in wind retrievals as a major accomplishment that opens the door to combined active-passive wind/SST retrievals.

WIND RETRIEVALS IN STORMS WITH HIGH WINDS AND RAIN

The retrieval of accurate vector winds in storms is a major objective of our SeaWinds-AMSR investigation. During the pre-launch phase of our investigation, we have been doing case studies of a number of storms and hurricanes, including:
1. The December 27th 1999 coastal France storm
2. Numerous tropical cyclones from 1999 and 2000
3. North Pacific winter storms

The major focus of these case studies was to determine if QuikScat was capable of measuring high winds above 30 m/s and to assess the effect of rain on the retrievals. The data from the French storm offered the best indication that QuikScat can indeed measure very high winds. Fig. 3 shows the wind barbs in m/s for QuikScat orbit 2724 and maximum winds for 13 coastal land stations. The French coastal station data indicate a south-to-north wind gradient from 45 to 55 m/s, which agree remarkably well with the QuikScat wind measurements. In addition, the QuikScat wind speeds agree well with 1) the maximum sustainable winds reported for tropical cyclones by the Joint Typhoon Warning Center (*http://www.npmoc.navy.mil/jtwc.html*) and the National Hurricane Center (*http://www.nhc.noaa.gov/*) and 2) the winds for the northern Pacific winter storms provided by Dr. Robert Brown [3].
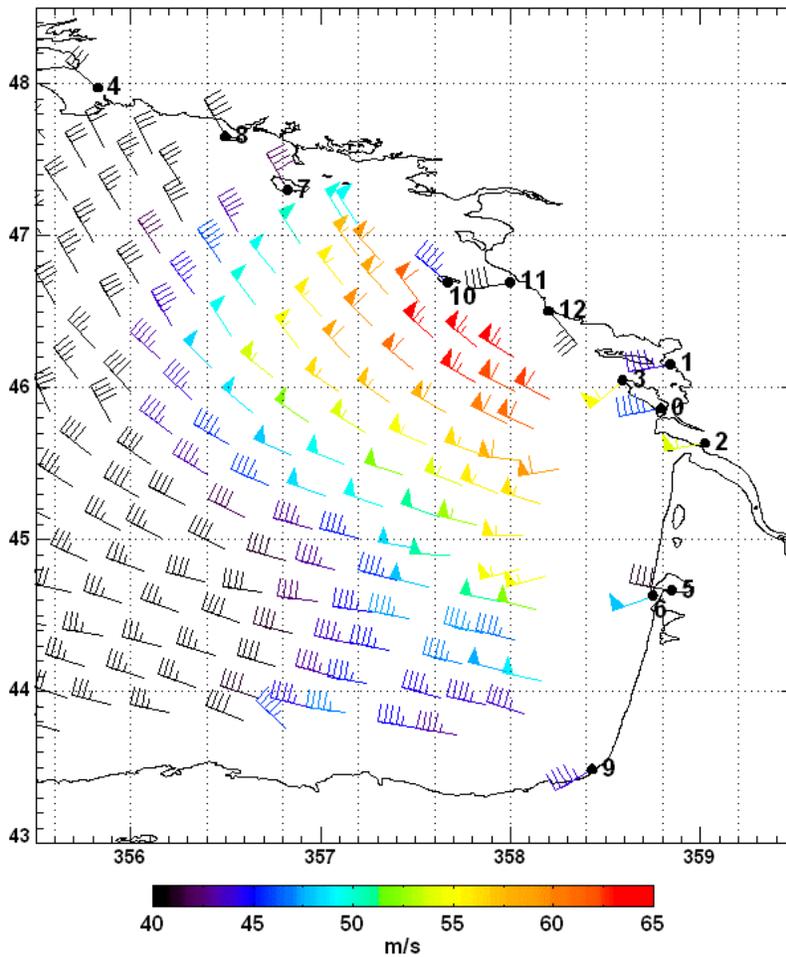
Fig. 3. QuikScat vector wind barbs in the Bay of Biscay off the coast of France on Decmeber 27th, 1999. In this plot, instantaneous (gust) winds from 13 coastal stations are plotted at the station location. Station winds have not been corrected for anemometer height since this information is unknown at this time and most stations are located at sea level. Note the close agreement between the north-south gradient of QuikScat winds and the land stations.

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