Progress in Understanding the Effect of Rain on Ku-band Microwaves and Refinement of the Ku-2001 Model Function

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Introduction:

During the last year the scatterometer team at Remote Sensing Systems has continued refining several important areas of research. The primary focus has been to improve scatterometer wind products. We have further refined the Ku-2001 model function to produce more accurate vector winds in active weather regions, and continue to validate the Ku-2001 winds to determine the quality of the data products. The outcomes of our efforts in each of these areas are shown in this paper.

Rain Effect on Ku-band Microwaves:

While Ku-band rain attenuation and backscattering are reasonably well understood, modification of the surface radar cross-section by rain is a poorly understood. To better understand this modification, we begin with the basic radar model:

\[ t = \frac{r - s}{r + s} \]

where \( r \) is the measured \( \sigma^0 \), \( s \) is the \( \sigma^0 \) from wind roughening alone, \( r \) is the \( \sigma^0 \) from rain roughening of the surface, \( s \) is the \( \sigma^0 \) from the two-way transmission through the rain, the transmission and backscattering for a uniformly filled beam are given by:

\[ \sigma = k (\alpha \sin \theta_0)^2 \]

where \( k \) is the attenuation coefficient, \( \alpha \) is the reflectivity, \( \theta_0 \) is the incident angle (e.g., Ulaby et al. 1982). If Rayleigh scattering is assumed, the reflectivity can be related to the reflectivity of the rain.

The coefficients \( \alpha \) depend on both wind speed and rain rate. Both \( \alpha \) and \( s \) can be related to rain rate, \( R \). Through power-law relationships:

\[ \sigma = 0.0062 (s + 0.02)^2 \]

and the \( s \) are plotted below in Fig. 3. These results were obtained by (e.g., Ulaby et al. 1982). For layers of water, we have a large number of false alarms in these regions.

Ku-2001 Model Function Validation

Composites of QuikSCAT and wind data with buoy radarometer and weather analyses continue. The most recent results are shown in Table 1. All comparisons are performed for rain-free conditions using the SSM/I (when available) and QuikSCAT winds. The wind modulus differences showed large basin trends and differences greater than \( +2 \) m/s. By using an improved sea surface emissivity model for the new retrieved SSM/I processing algorithms, we were able to reduce the target biases previously observed to less than \( +1 \) m/s. The QuikSCAT speed and direction scatter plots shown in Figures 5a and 5b show good agreement for wind speeds up to 15 m/s. Beyond that, the Ku-2001 winds appear too high, however there are few collocations in which to determine the agreement. To increase the number of high winds for validation, we have obtained, cleaned and processed the Canadian buoy data available from the Marine Environmental Data Service. This data set adds over 1 million data for our buoy validation data set including over 1000 high winds above 15 m/s. We use case studies to help determine the quality of the high winds we produce.

Over the QuikSCAT time period, the Ku-2001 winds appear to have a stronger wind effect for the Ku-band models. From our validation efforts we have determined that the Ku-2001 winds are slightly high for wind speeds above 20 m/s and more a regionally consistent model is needed for high winds regions.

Scatterometer Rain Flag Assessment

A 30-minute QuikSCAT - SSM/I collocation data was used to assess the performance of the scatterometer rain flag. At winds below 7 m/s, 66% of rain was correctly flagged with a 4% false alarm rate. The 7 - 15 m/s wind range had 63% of rain correctly identified with a 2% false alarm rate. High wind speeds, 15 m/s winds and above, we found the rain flag to be a very good method of identifying rain. For winds greater than 15 m/s, the Ku-2001 winds likely result in great variability within radar reflectivity with high rain rates. Since the rain flag is set when SSM/I values are determined threshold, we have a large number of false alarms in these regions.

References


where K is related to the index of refraction. Both k and z can be calculated for the two-way transmission through rain. The transmittance and backscattering for a uniformly filled beam are given by:

where \( \sigma \) is the incidence angle (e.g., Ulaby et al. 1982). If Rayleigh scattering is assumed, the reflectivity can be related to the reflectivity of the rain.

The coefficients \( \alpha \) depend on both wind speed and rain rate. Both \( \alpha \) and \( s \) can be related to rain rate, \( R \). Through power-law relationships:

\[ \sigma = 0.0062 (s + 0.02)^2 \]

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