SeaWinds on QuikSCAT

Multidimensional Histogram (MUDH) Rain Flag

Product Description
Version 3.0

James N. Huddleston
Bryan W. Stiles

May 1, 2000

Jet Propulsion Laboratory
California Institute of Technology

1. Overview

This section briefly describes the effects of rain on SeaWinds sigma-0 measurements.

The SeaWinds scatterometer was developed by NASA/JPL to accurately measure the normalized radar cross section (sigma-0) of the ocean surface. Such measurements are then used to infer the speed and direction of ocean surface winds. When rain is present, measurements of the ocean surface sigma-0 become contaminated for several reasons. Some of the transmitted energy is scattered back towards the scatterometer by the rain and never reaches the ocean surface. Energy backscattered from rain can constitute a significant but unknown portion of the measured echo energy. Some of the transmitted energy is scattered and/or absorbed by the rain and is never measured by the scatterometer. This has the effect of attenuating the echo energy from the ocean. Additionally, the rain roughens the ocean surface and changes its radar cross section.

The Multidimensional Histogram (MUDH) Rain Flag is designed to indicate the presence of rain on a wind vector cell by wind vector cell basis.

2. The MUDH Technique

This section outlines the MUDH rain-flagging technique.

The idea behind the MUDH algorithm is simple. Identify parameters that are sensitive to rain, estimate the probability of rain as a function of those parameters using a training set of data, and then use that rain probability estimate to flag for rain in new data.

For our training set, we chose to use an integrated rain rate estimate derived from SSM/I data. (Data was kindly provided to us by Remote Sensing Systems and was collocated with SeaWinds on QuikSCAT data by Michael Freilich and Barry Vanhoff). Our training set consisted of 953 revs taken between rev 3098 and 4066. We only included data with a less than 30-minute time difference between the SSM/I measurement and the SeaWinds on QuikSCAT measurement. For our training, we defined a wind vector cell to be rain-contaminated if the integrated rain rate for that wind vector cell was greater than 2.0 km·mm/hr.

We estimated the probability of rain by accumulating two four-dimensional histograms in which each of four rain-sensitive parameters was a histogram dimension. The first histogram was used to accumulate the total number of wind vector cells in each bin of parameter space. The second histogram was used to accumulate the number of wind vector cells that were considered to be rain-contaminated (SSM/I derived integrated rain rate > 2.0 km·mm/hr) in each bin of parameter space. Dividing the second histogram by the first gives us an estimate of the probability of rain as a function of the rain-sensitive parameters.

NB: The training data was processed using a preliminary model function. Thus, the estimated probabilities of rain are not perfectly matched to the current model function, QSCAT-1. This will have the effect of reducing the accuracy of the probability values.

The level processor simply calculates the values of the rain-sensitive parameters, converts them into table indices, and looks up the estimated probability of rain from a provided table. A threshold is applied to obtain an initial rain flag. Spatial filtering is then performed in an attempt to remove isolated rain flags.

3. Rain-sensitive Parameters

This section identifies and describes the rain-sensitive parameters used by the MUDH rain-flagging algorithm.

3.1 Normalized Beam Difference (NBD)

This parameter is a measure of the beam-to-beam bias exhibited in a wind vector cell. Rain shifts measurements away from the model function differently for the inner beam than it does for the outer beam. It turns out that rain increases the H polarization inner beam return more than the V polarization outer beam return.

This parameter can only be calculated when data from both beams is available. Furthermore, we require both fore and aft measurements from both beams to be present in order to calculate NBD.

3.2 Retrieved Wind Speed

This parameter is the wind speed of the first ranked wind vector. The presence of rain tends to increase the backscattered energy and produce higher retrieved wind speeds. Conversely, if the retrieved wind speed is low, it is extremely unlikely that it is raining in that wind vector cell.

3.3 Retrieved Wind Direction Relative to Along Track

This parameter is the angular difference between the direction of the first ranked wind vector and the along track direction. The directions are treated as streamlines so that this parameter has a value of 0° when the wind is aligned with the spacecraft ground track and has a value of 90° when the wind is blowing cross swath.

Rain is expected to be an isotropic scatterer. Thus, the presence of rain tends to equalize the forward and aft measurements of each beam. Equal energy measurements of the fore and aft beam are consistent with wind blowing cross swath.

3.4 Normalized Maximum Likelihood Estimator (MLE) Value

This parameter is the maximum likelihood estimator value normalized by the number of sigma-0 measurements. This is identical to the MLE value reported in the Level 2B product.

Rain tends to increase the variance of the sigma-0 measurements and cause the maximum likelihood estimator value to increase in magnitude.

3.5 Brightness Temperature

This parameter is the radiometric brightness temperature as calculated by the QuikSCAT instrument. The inner beam of QuikSCAT is used to calculate H polarization brightness temperatures and the outer beam is used to calculate V polarization brightness temperatures.

Rain tends to have a higher brightness temperature than the ocean.

4. Beam Availability

This section indicates which parameters are used for generating the MUDH rain flag based on the availability of data.

The NBD parameter requires measurements from both beams in order to be calculated. Therefore, it is not available in the outer swath where only measurements from the outer beam are available. Horizontally polarized brightness temperatures are also not available in the far swath. We have chosen to treat the dual-beam case and the single-beam case independently. Table 1 indicates the parameters used for the different cases; an X indicates the parameter is used, a blank indicates the parameter is not used.

Table 1. Rain-sensitive parameter usage

Parameter	Dual-Beam Case	Single-Beam Case
Speed	X	X
Direction		X
NBD	X	
MLE	X	X
Tb (H pol)	X	
Tb (V pol)		X

We use the NBD parameter to determine whether or not the dual-beam algorithm or the single-beam algorithm is to be used. If the NBD parameter can be calculated, we use the dual-beam algorithm; otherwise, the single-beam algorithm is used.

5. Spatial Filtering

This section describes the spatial filtering applied to the MUDH rain flag.

Due to the noisy nature of the rain-sensitive parameters and the probabilistic nature of the MUDH technique, there are times when the MUDH rain flag erroneously indicates rain. Often these spurious rain flags are isolated.

The idea of spatially filtering the rain flag was proposed by Remote Sensing Systems and has been implemented in the processor. First, the probability of rain is estimated for each wind vector cell using the MUDH technique. If the probability of rain is above a threshold value, T_{lower}, the wind vector cell is initially flagged for rain. Then, spatial filtering occurs. For each wind vector cell, the number of rain-contaminated cells within a centered NxN window is counted. If the number of rain-contaminated cells is less than $N_{neighbors}$, we consider there to be insufficient spatial evidence for rain. In such a case, the estimated probability of rain for that wind vector cell is then compared to a higher, more stringent, threshold: T_{upper}. If the probability of rain is higher than T_{upper}, we leave the rain flag set. Otherwise, the rain flag is cleared.

Table 2 contains the values used by the spatial filter.

NB: Although the estimated probabilities of rain were derived using a preliminary model function, the spatial filtering values were determined using a small number of orbits processed using the QSCAT-1 model function. Due to the small number of orbits available for determining the spatial filter values, we are likely to be flagging slightly more or less than 5% of the data as rain-contaminated.

Table 2. Spatial Filter Values

Parameter	**Dual-Beam Case**	**Single-Beam Case**
N	5	5
$N_{neighbors}$	4	4
T_{lower}	0.069	0.073
T_{upper}	0.263	0.274

6. Expected Performance

This section indicates the expected performance of the MUDH rain flag.

The probability and spatial filter parameters were adjusted so that approximately 5% of the data will be flagged as rain-contaminated. We have defined two metrics: the false alarm percentage and the missed rain percentage. The false alarm percentage is the percentage of the wind vector cells having an SSM/I integrated rain rate = 0.0 km·mm/hr that we flag as being rain-contaminated. The missed rain percentage is the percentage of the wind vector cells having an SSM/I integrated rain rate > 2.0 km·mm/hr that we flag as being rain-free. Table 3 indicates the expected performance of the MUDH rain flag broken into various ECMWF wind speed ranges.

NB: All performance metrics were calculated based on data processed using the preliminary model function. Thus, they are likely to differ from the performance of the rain flag on data processed using the QSCAT-1 model function.

Table 3. Estimated Rain Flag Performance

Wind Speed	% Flagged		False Alarm Percentage		Missed Rain Percentage	
	Two-Beam	Single-Beam	Two-Beam	Single-Beam	Two-Beam	Single-Beam
3 – 5 m/s	4.0	3.8	1.7	1.5	21	29
5 – 7 m/s	3.5	4.4	1.4	2.4	23	32
3 – 7 m/s	3.7	4.2	1.5	2.0	22	31
7 – 15 m/s	5.0	5.8	2.1	3.5	30	43
15 – 20 m/s	24	13	17	6.9	24	42
15 – 30 m/s	26	13	18	6.9	23	42
3 – 30 m/s	5.2	5.4	2.2	3.0	26	39

7. Customizing The Rain Flag

This section suggests a way to customize the rain flag to flag more or less data.

We have tuned the rain flag and spatial filter so that approximately 5% of the data are flagged as rain-contaminated (as indicated by the "Wind Vector Cell Rain Flag"). If your application would benefit from flagging more or less data, here is a fairly simple way for you to customize the rain flag to your needs. For each wind vector cell, do the following:

1. Check the "Rain Flag Usable" value to make sure that the rain flag information is valid. If the rain flag is not usable for a wind vector cell, we recommend not using that wind vector cell in your analysis.
2. Check the "Available Data Flag" to determine if the two-beam case (available data flag = 0) or single-beam case (available data flag = 1) applies.
3. Select threshold values to obtain the desired amount of flagging. Lower thresholds will produce higher percentages of flagged data. The two-beam and single-beam thresholds do not need to be the same in order to flag the same percentage of data.
4. If the probability of rain is greater than the threshold, consider the cell to be rain-contaminated. Otherwise, consider the cell to be rain-free.

8. Contacts

This section provides contact information in the event of questions or comments.

Questions concerning data distribution should be directed to PO.DAAC. Issues related to the quality of the MUDH rain flag and comments on this document should be directed to James Huddleston or Bryan Stiles. Specific contact information is provided below. Please note that email is always the preferred means of communication.

For data distribution issues:

JPL PO.DAAC User Services Office
Jet Propulsion Laboratory
M/S Raytheon-299
4800 Oak Grove Drive
Pasadena, CA 91109, U.S.A.

Telephone: 626.744.5508
Fax: 626.744.5506
Email: qscat@podaac.jpl.nasa.gov
Web: <http://podaac.jpl.nasa.gov/quikscat>
FTP: <ftp://podaac.jpl.nasa.gov>

For MUDH rain flag quality issues and comments on this document:

James N. Huddleston
Jet Propulsion Laboratory
M/S 300-319
4800 Oak Grove Drive
Pasadena, CA 91109, U.S.A.
Email: James.N.Huddleston@jpl.nasa.gov
Telephone: 818.354.1748
Fax: 818.393.5184

Dr. Bryan W. Stiles
Jet Propulsion Laboratory
M/S 300-319
4800 Oak Grove Drive
Pasadena, CA 91109, U.S.A.
Email: bstiles@acid.jpl.nasa.gov
Telephone: 818.354.5329
Fax: 818.393.5184