Overview of Changes To Near-Real Time 25km QuikSCAT Wind Retrievals

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Outline

• Reasons for Change
• QuikScat Measurement Technique
• Impact of Changes on QuikSCAT NRT Processing
• Validation of New NRT Wind Product
• Summary
Motivation for New Retrieval Algorithm

• Improvements based on operational and research experience with QuikSCAT data since 1999/2000
  – Retrieved wind speeds too low in high wind areas
  – Overly conservative rain flag
  – Poor retrieval quality on swath edge
  – Lack of retrievals close to coast

• NASA JPL addressed these issues by modifying retrieval algorithm
  – First for science level data
  – Now to be implemented for near-real time data
Major Changes

- Refinement of model function (backscatter-wind relationship)
- Retrieval algorithm modification
- Development of new rain impact flag
- Improved edge of swath retrievals
- Reduced land mask for 12.5-km retrieval
\[ \sigma_0 = G \frac{P_r}{P_t} \]
QuikSCAT Measurement Geometry

- Conically-scanning, dual-pencil beam Ku-band scatterometer
- Acquires global backscatter measurements at 47° (H-pol) and 55° (V-pol) incidence angles
- Measurement swath divided into 76 wind vector cells (WVCs) for 25-km retrievals (152 for 12.5-km)
- Up to four measurements in each WVC are used in retrieval algorithm
Measurement Variability Across Swath

- Far Swath
- Mid-swath
- Nadir
- Mid-swath
- Far Swath

V-pol beam
H-pol beam
Evaluation of New NRT Retrieval

• Statistical and case evaluations performed on 2003 and current datasets

• New retrievals available for evaluation in real time since June 2006
NRT QuikSCAT Processing Algorithm

Model Function
QSCAT1

Wind Retrieval
Standard Processing

Ambiguity Removal Processing
Refined Model Function
A geophysical model function (GMF) relates ocean surface wind field to the backscatter cross section measurements.

\[ \sigma_o^{\text{model}} = f(\nu, \chi, \theta, p) \]

\( \nu \): wind speed
\( \chi \): wind direction
\( \theta \): incidence angle
\( p \): polarization
Adjustment of QSCAT model function

QSCAT model function implemented in original NRT processing adjusted by Freilich and Vanhoff for wind speed 16-30m/s using collocated QuikSCAT and RSS SSM/I F13 measurements
Impact on Retrieved Wind Speed and Direction

Speed

Direction

16 m/s
Max. wind with new NRT processing 5–10 kt higher for old wind speeds > 55 kt

Examined 64 passes
Average bias of 25-km QSCAT maximum wind within 200 nm of best track

Center for 64 passes over 2003 Atlantic TCs using old and new NRT retrieval algorithm binned by NHC best track classification (tropical depression, tropical storm, Saffir-Simpson hurricane category) at time of pass.
Hurricane Force Extratropical Cyclone - Pacific Northwest

December 15, 2006

Old Algorithm max wind 62kt
Storm Force

New Algorithm max wind 67kt
Hurricane Force
NRT QuikSCAT Processing Algorithm

Model Function
QSCAT1

Wind Retrieval
Standard Processing

Ambiguity Removal
Processing

25 km

25 km
Wind vectors are retrieved for each WVC using set of collocated backscatter cross section measurements $\sigma_{o,i}^{\text{meas}}$. These are compared to the modeled cross section $\sigma_{o,i}^{\text{mod}}$ in an objective function:

$$J(v, \chi) = -\sum_{i=1}^{N} \frac{\left(\sigma_{o,i}^{\text{meas}} - \sigma_{o,i}^{\text{mod}}\right)^2}{\text{Var}(\sigma_{o,i}^{\text{meas}})}$$

Modified objective function:

$$J(v, \chi) = -\sum_{i=1}^{N} \frac{\left(\sigma_{o,i}^{\text{meas}} - \sigma_{o,i}^{\text{mod}}\right)^2}{\text{Var}(\sigma_{o,i}^{\text{meas}})} + \ln(\text{Var}(\sigma_{o,i}^{\text{meas}}))$$

Addition of term related to log of variance of measured backscatter $\rightarrow$ increased calm wind retrievals.
Increased Calm Winds
Swath Edge Retrieval Changes
Measurement Variability Across Swath

Far swath V-pol measurements divided into 2 azimuthal ranges – creating 4 looks instead of 2 for retrieval
Swath Edge Changes

- White circles represent “null” retrievals
- Wind retrievals along additional row on swath edge with new algorithm
Instrument Skill - represents percentage of the first two ranked solutions that were also correct solutions (based on GDAS wind direction)
Across Swath Statistics

- Std. Deviation of Wind Speed
- Wind Speed Bias
- Std. Dev. of Wind Direction
- Wind Direction Bias
Improved wind direction and circulation better resolved in new retrieval

Correct ambiguities chosen
New Rain Impact Flag
• The radar signal is attenuated by the rain as it travels to and from the Earth’s surface → $\sigma_0$

• The radar signal is scattered by the raindrops. Some of this scattered energy returns to the instrument → $\sigma_0$

• The roughness of the sea surface is increased because of the splashing due to raindrops → $\sigma_0$
Rain Detection
Original MUDH Flag

Original MUDH rain flag “rainy” means > 2km mm/hr SSM/I rain rate

MUDH Flag derived from 5 rain-sensitive parameters
1. Difference in return from V and H pol beams
2. Wind speed of 1st ranked ambiguity
3. Wind direction of 1st ranked ambiguity relative to satellite track
4. Variance of backscatter measurements (tight wind speed gradient)
5. Brightness temperature

Table used in flagging for each WVC by:
1) read probability from table
2) initially flag if greater than threshold T_{low}
3) remove flag if fewer than K initially flagged neighbors in an N x N window
4) flag if probability greater than T_{high}

SSM/I rain rate is not used in flagging only in training the table
Wind Rain Regimes

- Regime 1: rain dominates wind backscatter – poor quality wind estimates (10% of rain cases*)
- Regime 2: both wind and rain important – can retrieve wind and rain rate (34% of rain cases*)
- Regime 3: rain effects insignificant – wind estimates unaffected by rain (56% of rain cases*)
- * Globally, only about 4% of all QuikSCAT data adversely effected by rain

Impact Based MUDH

• “Rainy” defined by how much a cell is contaminated by rain rather than particular rain rate
• Low winds require less rain to be contaminated
• Impact defined to be > 2 m/s speed bias and >15° cross track directional bias due to rain
• Impact measure determined using AMSR rain rate data onboard ADEOS-II
• AMSR rain rate information used to train the table
• Table generated from SeaWinds/AMSR data also used to flag QuikSCAT data.
Old flag removed 4.2% of data

New Impact flags removes 1.8% of data
## Wind Speed Error

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Wind Direction Error

Both flags clear

Old flag rain – New flag clear

Both flags rain

Old flag clear – New flag rain
New Rain Impact Flag Examples
Gulf of Tehuantepec
QuikSCAT 25km
• In addition to measuring radar backscatter, QuikSCAT simultaneously measures the microwave brightness temperature of the atmosphere/surface.

• This passive microwave measurement capability is known as the QuikSCAT Radiometer (QRAD). QRAD rain rate retrieval algorithm was developed at University of Central Florida by Khalil Ahmed and Linwood Jones.

• New QuikSCAT NRT product includes these rain rate estimates. Product will be available in NAWIPS system as well.
NRT QuikSCAT Processing Algorithm

Model Function
QSCAT1

Wind Retrieval
Standard Processing

Ambiguity Removal Processing

25 km
Changes in Ambiguity Removal Processing

- Old NRT processing version utilized 3 pass medium filter ambiguity removal algorithm.
- New algorithm implements 4 pass scheme taking account coastal and ice WVC as well as rain flagged ones.
Summary of New Retrievals

- New NRT processing algorithm produces higher wind speeds
- Performance of algorithm at swath edge substantially improved
  - Additional row of retrievals on swath edge
- Number of ambiguities produced is the same for both algorithms across entire swath
- Overall retrieval error similar to old algorithm
- Sign of wind speed bias reversed
Summary of New Retrievals

- Produces higher percentage of retrievals with calm winds
- New rain flag flags ~1.8% of data instead of 4.2%
  - Accuracy of un-flagged vectors in rain areas similar to vectors in non-rainy areas
- New data files will contain QRAD rain rate estimates
Implementation

- Tentative implementation in May 2007
- Notification via email to the listed near real-time users pulling QuikSCAT data from NESDIS within the next few weeks
- Files are available for parallel testing
- Main issue from the data assimilation perspective will be additional data as a result of the rain impact flag
Additional Slides
What is the Lowest Acceptable Resolution?

User Requested

1km resolution
Max wspd 137.8 kts
True Wind Field

2km resolution
Max wspd 134.3 kts
rms 2.14 kts

13km resolution
Max wspd 120.7 kts
Rms 5.71 kts

25km resolution
Max wspd 105.9 kts
rms 7.72 kts

35km resolution
Max wspd 106.1 kts
rms 8.88 kts

70km resolution
Max wspd 91.0 kts
rms 12.50 kts

Available Today!

Likely range of NPOESS solution

Definitely Achievable

Available Today!
Number of Ambiguities across Measurement Swath
Why is Important to Check Ambiguity solutions When In Doubt?