An algorithm for Sea Surface Wind Speed from MWR

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Overview

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This work is a collaboration between CONAE and CFRSL. It was recently accepted for publication on IEEE JSTARS Aquarius Special Issue.

The MWR sea surface wind speed algorithm is based on Wentz’s work (1992) to estimate Wind vector from SSMI. He assumed that the TOA $T_b$:

$$
T_{b37V} = F_V(W, \tau)
$$

$$
T_{b37H} = F_H(W, \tau)
$$

$$
F(W, \tau) = T_{bU} + \tau[\varepsilon \text{ SST} + (1 - \varepsilon)(1 + \omega W)(T_{bD} + \tau T_{ex})]
$$

W: Wind Speed, $\tau$: Atmospheric transmissivity, $T_{bU}$ and $T_{bD}$ up- and downwelling $T_b$, $\varepsilon$: Sea surface emissivity, $T_{ex}$=2.73 K, SST: Sea Surface Temperature and $\omega$: diffuse scattering coeff.
For MWR:
- 36.5GHz band
- 52° (odd beams)
- 58° (even beams).

Using Newton-Raphson, $F$ can be simplified:

$$T_{b36.5V} \approx F_V(W_0, \tau_0) + \left( \frac{\partial F_V}{\partial W} \right)_{(W_0, \tau_0)} (W - W_0) + \left( \frac{\partial F_V}{\partial \tau} \right)_{(W_0, \tau_0)} (\tau - \tau_0)$$

$$T_{b36.5H} \approx F_H(W_0, \tau_0) + \left( \frac{\partial F_H}{\partial W} \right)_{(W_0, \tau_0)} (W - W_0) + \left( \frac{\partial F_H}{\partial \tau} \right)_{(W_0, \tau_0)} (\tau - \tau_0)$$

If the model function $F$ is known, this system of two equations with two unknowns ($W$ and $\tau$) can be solved using an iterative procedure.
Model function tables

Collocated data set:
- MWR $T_b$,
- NCEP environmental parameters,
- WindSat and SSMIS F17 wind speed and rain (RemSS),
- RTM (Simulated $T_{bUp}$, $T_{bDown}$ and $\tau$).

Match-up for:
- Rain free pixels
- Temporal resolution: $\pm 1h$.
- Spatial resolution: $\sim 25km$.

**Tunning period: July-December 2012**

With $N \sim 5.4 \times 10^6$ we generate 4 3D tables $T_b(WS, \tau, SST)$. H- and V-pol for Even ($58^\circ$) and Odd ($52^\circ$) beams.

Density plot of SST/$\tau$ values that exist in the match-up data.
Wind direction effect

WD is modeled as an excess of $T_b$ which is removed:

$$T_{b_{corrected}} = T_{b_{measured}} - T_{b_{Excess}}$$

$$T_{b_{Excess}} = \beta_1 \cos(\chi_{rel}) + \beta_2 \cos(2 * \chi_{rel})$$

$\beta$’s fifth order polynomial in WS. $\chi_{rel}$: relative wind direction (wind blowing toward the antenna).

Odd beams in vertical polarization for several wind speed values.

Combinations of polarizations and incidence angles, $ws=6m/s$ (top) and $ws=12m/s$ (bottom).
Wind speed retrieval: algorithm summary

- **Inputs:** MWR $T_{b36.5}$ V and Hpol. Ancillary/Auxillary: NCEP wind direction and SST, MWR azimuth angle.

- An iterative procedure is implemented using Newton-Raphson’s method until $W$ converges.

- **Outputs:** sea surface Wind Speed at 10 m height [m/s], Atmospheric transmissivity at 36.5 GHz ($\tau$).
WindSat and SSMIS comparisons

Validation data set: January-September 2013

With $N \sim 9.5 \times 10^6$ we perform a validation month by month, for even and odd beams separately.

- WindSat and SSMIS collocated dataset satisfy: WindSat wind speed $< 25 \text{m/s}$, SST $> 280\degree \text{K}$ and rain free pixels.
- Differences between both data sets:
  \[ \Delta W = W_{MWR} - W_{WS/SSMIS}. \]

- Linear regression analysis:
  \[ W_{WS/SSMIS} = aW_{MWR} + b. \]
- Statistical parameters calculated: $r^2$, $a$, $b$, Mean $\Delta W$ and STD $\Delta W$.

where $W_{WS/SSMIS}$ are RemSS WindSat and SSM/I wind speed respectively, and $W_{MWR}$ is our MWR wind speed result.
Validation results

vs WindSat (July 2013 - Odd beams)

\[ N = 298209 \]
\[ r^2 = 0.70 \]
\[ a = 1.10 \]
\[ b = -1.18 \]

Mean \( \Delta W = 0.29 \)

STD \( \Delta W = 1.89 \)
Validation results

vs SSMIS (July 2013 - Odd beams)

N=215635
r²=0.70
a=1.11
b=-1.44

Mean ΔW=0.50
STD ΔW=1.95
Conclusions

- The mean error is $< 1\text{m/s}$ and standard deviation $< 2\text{m/s}$ for all wind speed values (based on the histogram of $\Delta W$).
- Even beams show slightly better performance.
- For even beams: $0.78 < r^2 < 0.82$, error standard deviation $\leq 1.57$.
- For odd beams: $0.56 < r^2 < 0.70$, error standard deviation $\leq 2.17$.
- MWR sea surface wind speed retrieval data are quite acceptable for scientist analysis.
- Note: The presented algorithm uses $T_b$ V6.0 for tuning and validation. A preliminary study shows an improvement in the wind speed retrieval using $T_b$ V7.0 in both, tuning and validation.
References and Acknowledgment


Acknowledgment to Remote Sensing Systems, for providing WindSat and SSMIS Wind Speed data for Validation.

For more information see in the Poster Session...

*MWR SEA SURFACE WIND SPEED RETRIEVAL: ALGORITHM DESCRIPTION AND VALIDATION RESULTS.*