Development of a retrieval algorithm of water vapor and cloud liquid water for GCOM-W1/AMSR2

3rd GCOM RA
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Research Report

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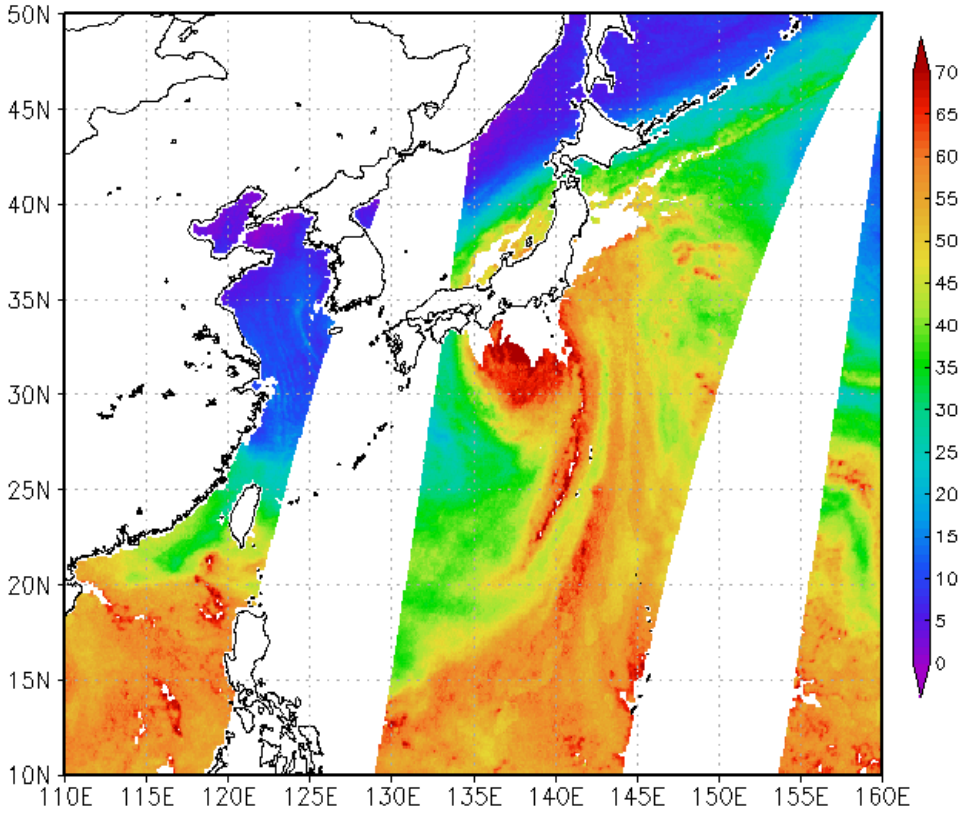
Atmospheric Water Vapor

Atmospheric water vapor is one of the important geophysical parameters and plays a dominant role in severe weather events.

Accurate estimation of water vapor from microwave imager measurements is necessary for operational weather forecasting and climate change study.

The information of atmospheric water vapor is necessary for initial condition of numerical weather predictions. GCOM-W1/AMSR2 can provide the information.

Atmospheric Water Vapor from GCOMW1/AMSR2 L2 product



Typhoon Wipha (2013)
15 October 2013

Cloud Liquid Water

Cloud liquid water information from microwave imagers is a crucial data source for climate change study. The data is used for developments and verifications of cloud schemes in numerical weather prediction models.

Cloud liquid water products from microwave imagers have wide coverage. Long time data record are available for the studies not only diurnal variations but also seasonal variations.

GCOM-W1/AMSR2 can provide the information.

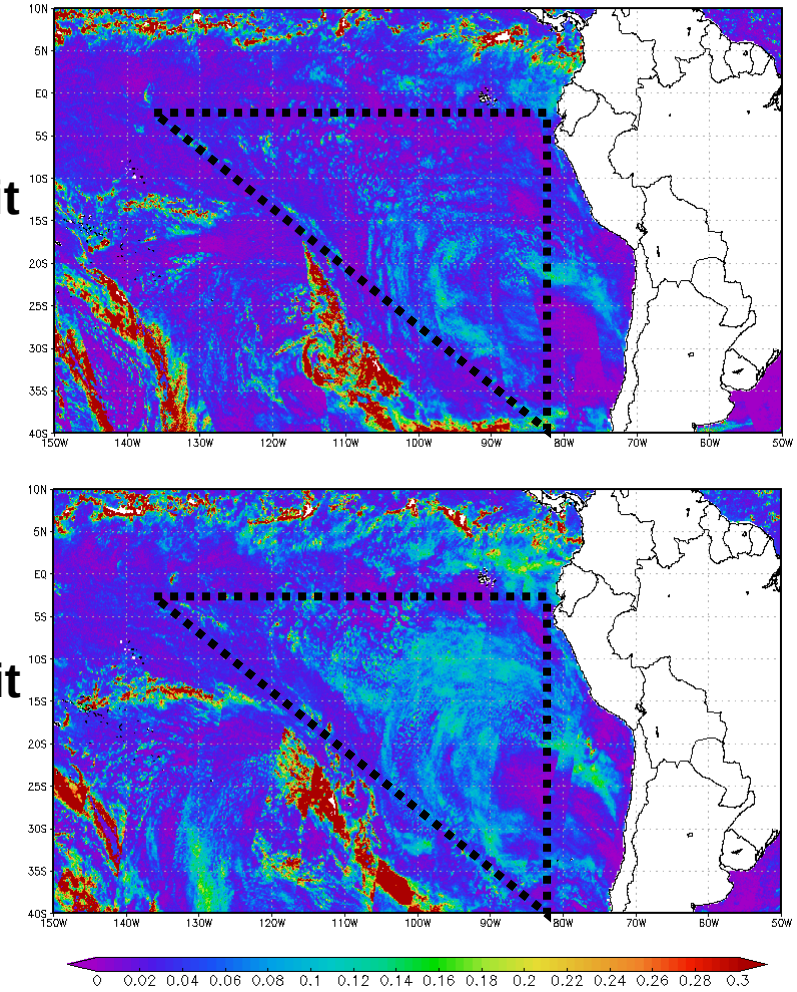
Cloud Liquid Water
from GCOMW1/AMSR2 L2 product

A-Orbit

13:30

D-Orbit

1:30



South East Pacific
stratocumulus area, 15 - 16 July 2013

Algorithm development

The algorithm retrieves Total Precipitable Water (**TPW**) and Cloud Liquid Water (**CLW**) from microwave radiometer data (Tb) over ocean.

Microwave Brightness Temperature Equation

$$T_b = (1-Tr)T_a + Tr\,\varepsilon_s T_s + Tr\,(1-\varepsilon_s)(1-Tr)T_a$$

Simplified

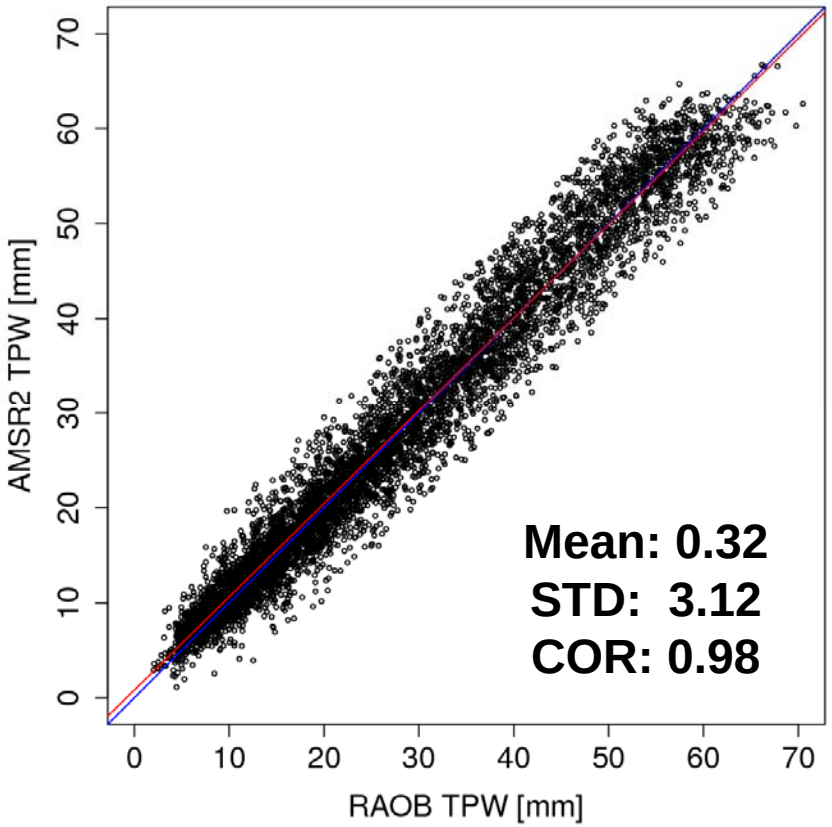
$$\begin{cases} T_b = \alpha\left\{1-(1-\varepsilon_s)Tr^2\right\} \\ Tr^2 = \dfrac{1-T_b/\alpha}{1-\varepsilon_s}, \alpha \equiv \left\{T_a + \dfrac{(T_s-T_a)Tr\,\varepsilon_s}{1-(1-\varepsilon_s)Tr^2}\right\} \end{cases}$$

Assumption:
A single-layer atmosphere above the ocean
Vertically homogeneous and isothermal and no precipitation condition

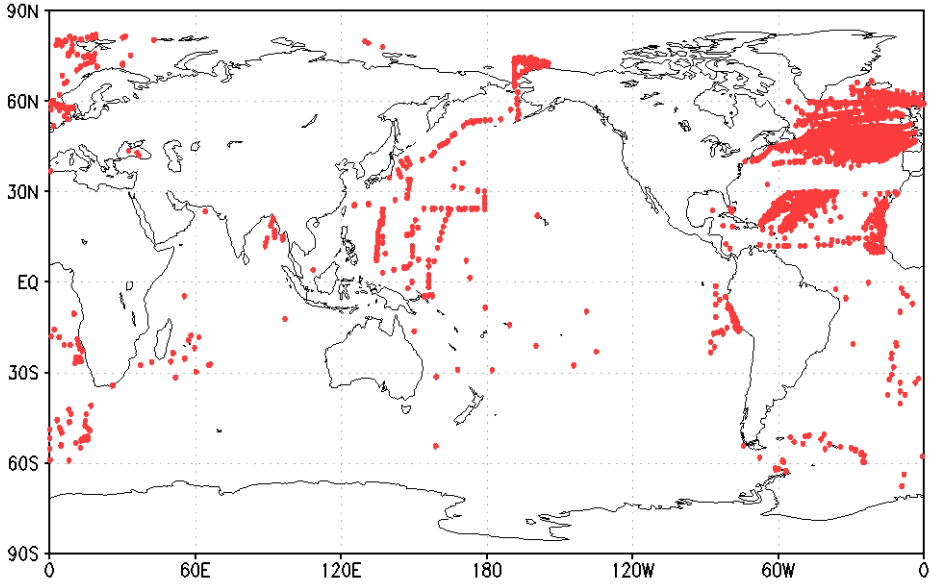
Input observation: AMSR2 Tb (19, 23, 37,89 GHz both pol.)
Index parameters (PWI, CWI) :
Combination of transmittances monotonically increasing with TPW and CLW
Ancillary data:
SST, SSW and temperature at 850 hPa from JMA Global Analysis
Look up Tables:
SST, SSW⇒Ocean emissivity
Transmittance, Temperature at 850hPa ⇒Mean Atmospheric Temperature (α)
PWI⇒TPW, CWI⇒CLW with tuned coefficients to fit RAOB TPW.

Current accuracy of the algorithm (TPW)

Verification against RAOB



RAOB coverage

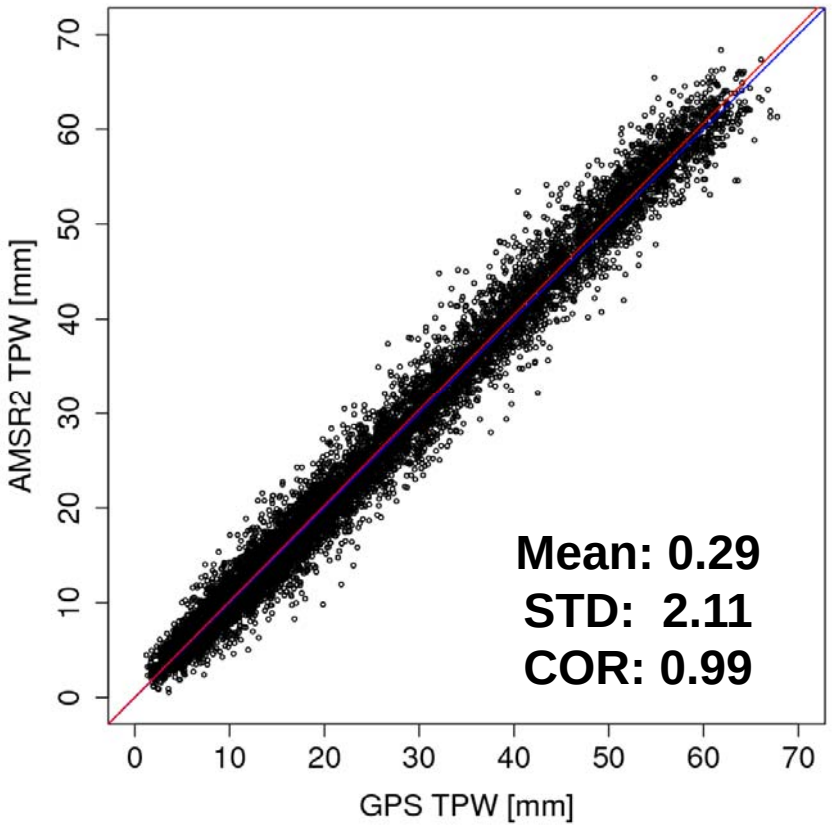


Period: 24 July 2012 – 12 December 2013, # of locations: 7278

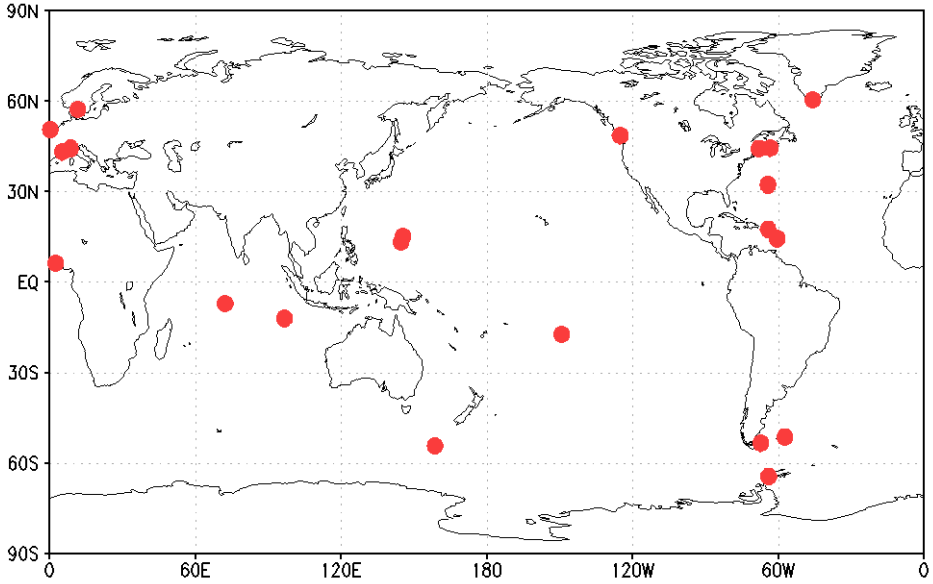
Collocation criteria: distance < 150km, time difference < 6 hr

Current accuracy of the algorithm (TPW)

Verification against GPS



GPS coverage

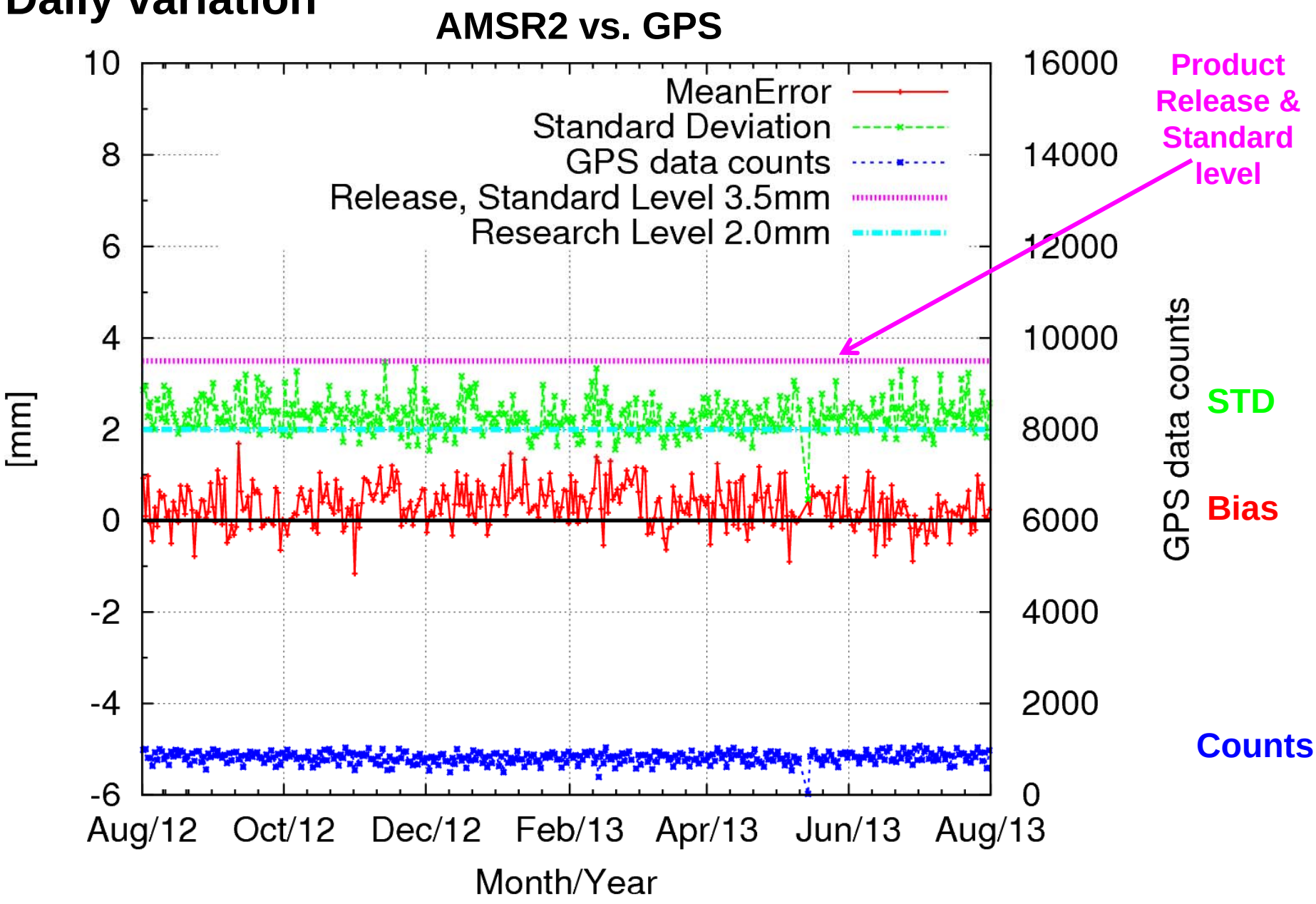


Period: 24 July 2012 – 31 July 2013 # of locations: 24

Collocation criteria: distance < 30km, time difference < 3 min.

Verification of TPW retrievals

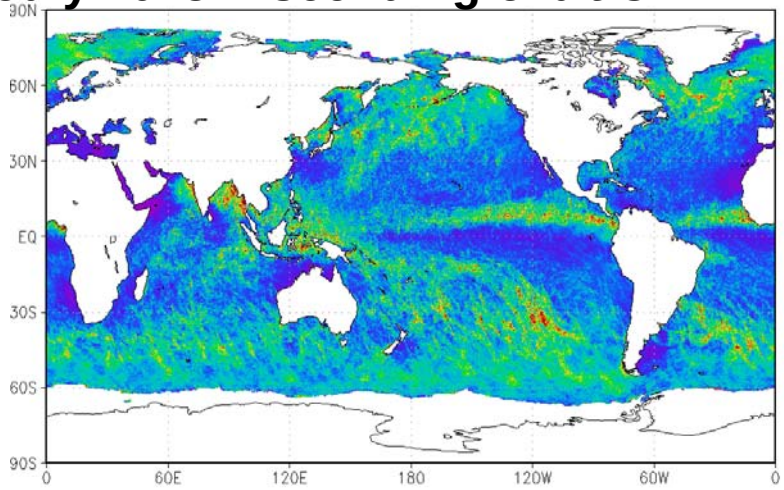
Daily variation



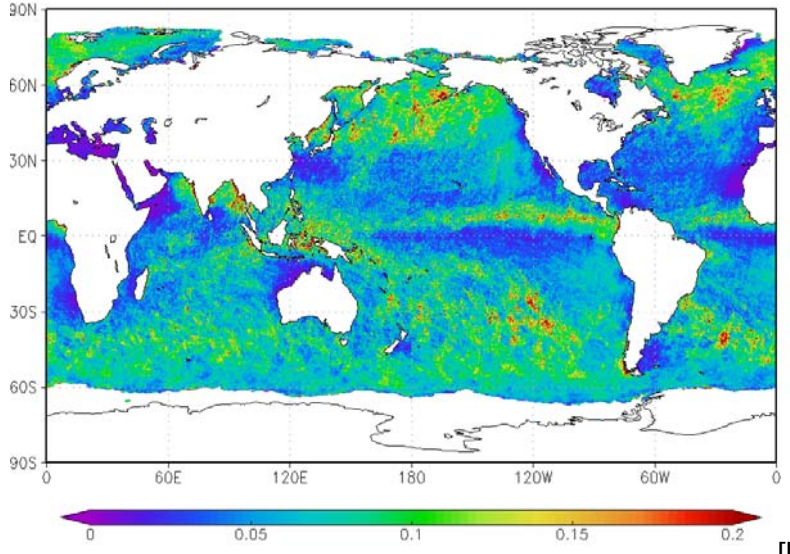
Current accuracy of the algorithm (CLW)

It is hard to verify CLW product because of few direct CLW measurement. And CLW has diurnal and seasonal variations.

July 2013: Ascending orbit CLW



July 2013: Descending orbit CLW



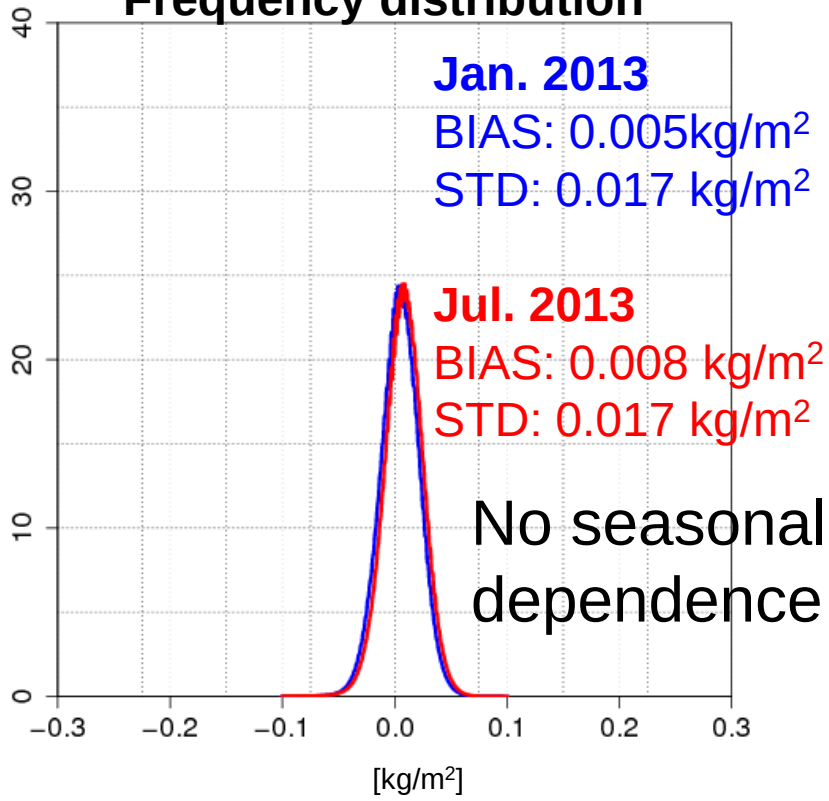
[kg/m^2]

Ideally, clear scene CLW should be zero.

This is a measure to validate the algorithm.

It gives the best accuracy of CLW and a bias in cloud-free situation.

Frequency distribution



Verification of CLW retrievals

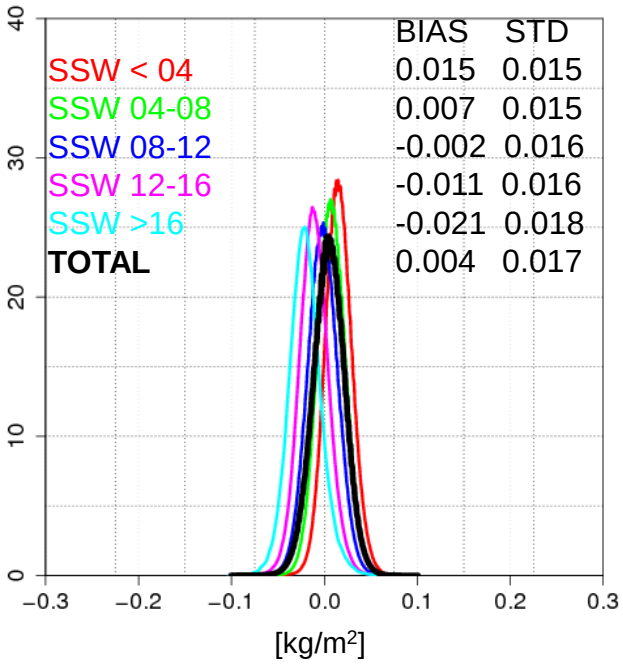
Comparison under clear sky condition can show a minimum retrieval error.
MODIS cloud cover product was used to select the AMSR2 clear sky data.
The CLW retrievals were stratified using SSW, SST from JMA global Analysis and our TPW retrievals.

AMSR2 CLW

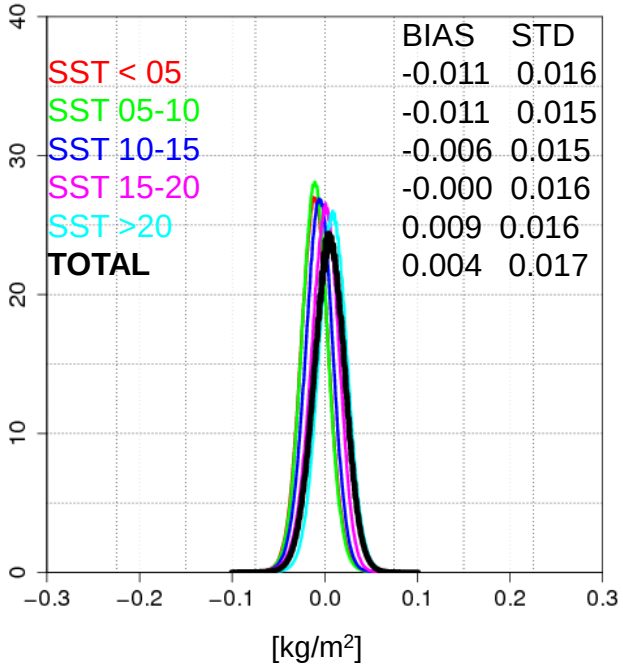
Probability Density Function (PDF)

January 2013

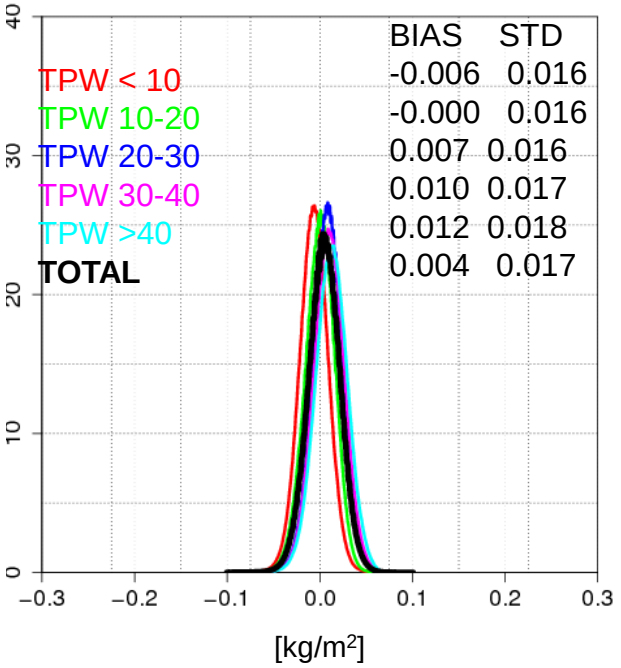
SSW dependency



SST dependency



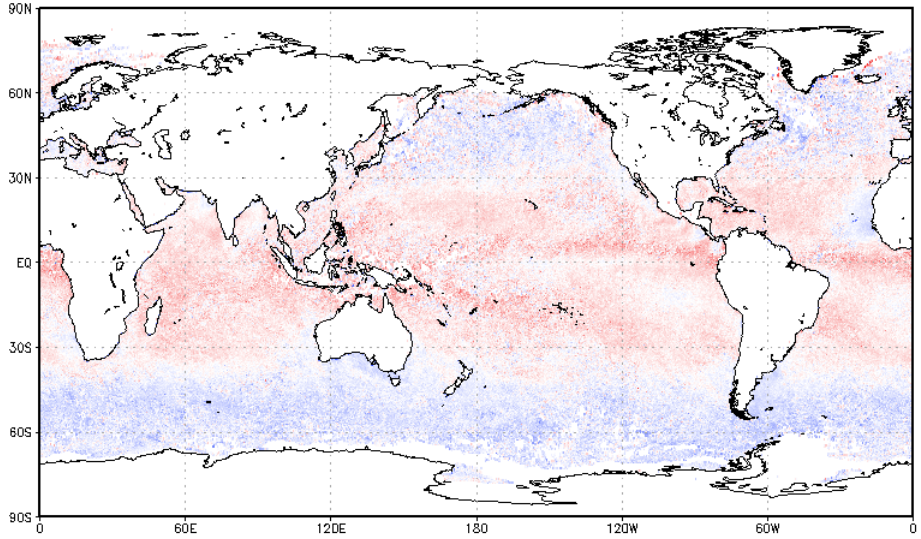
TPW dependency



AMSR2 CLW's minimum error is about 0.02[kg/m^2], but slightly depend on SSW and SST

CLW error map in clear sky condition

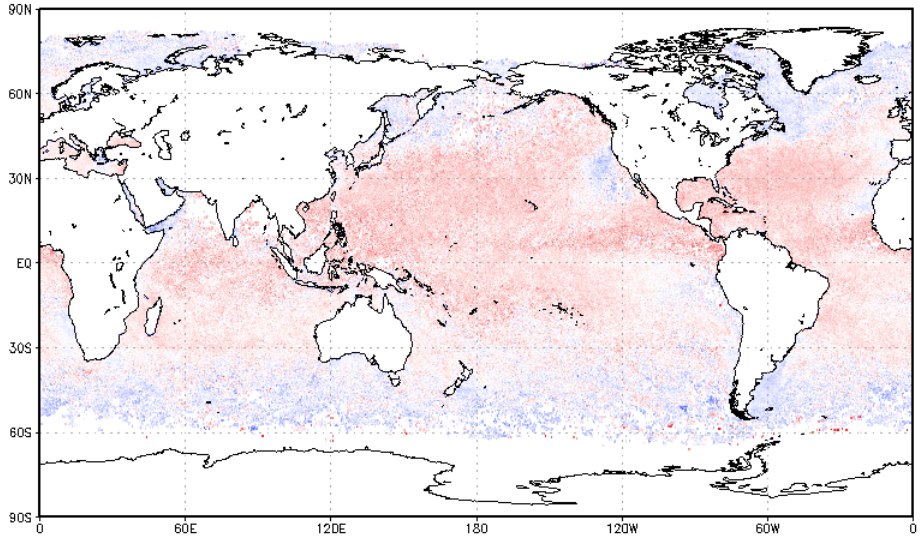
January 2013



The error distribution shows SST and SSW dependency.

JMA analyzed SST and SSW were used as truth data (inputs for algorithm) .

July 2013



JMA's analyzed SSW may have negative biases in high wind condition.

It might be better to use AMSR2 L2 SSW and SST as the algorithm input.

Research for algorithm updates

Oceanic microwave brightness temperatures (Tb) have azimuthal variations. (i.e., RWD dependent). RWD is surface wind direction relative to satellite azimuth angle. The RWD dependency appears under high wind situation.

Current algorithm does not include these effects. The variations could be an error source of TPW and CLW products. Removals of the Tb variation in the algorithm can improve the accuracy of AMSR2 TPW and CLW products.

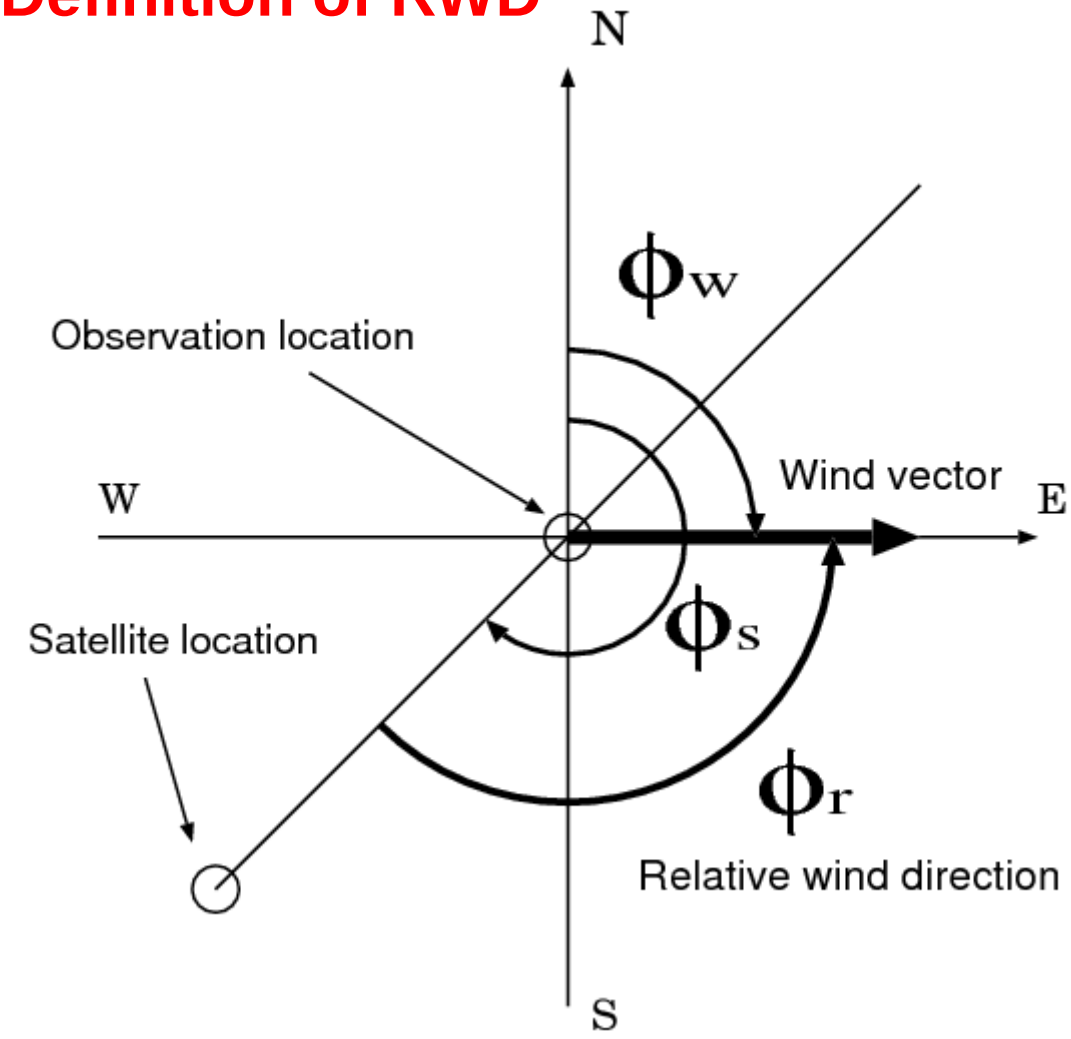
We estimated the Tb variations from the difference of observed and simulated AMSR2 Tb in ECMWF all-sky radiance assimilation system.

RTM: RTTOV-10

Emissivity model: FASTEM-5 (w/o azimuth model function)

Relative Wind Direction (RWD)

Definition of RWD



Westerly Wind case

ϕ_s **Satellite azimuth angle**

ϕ_w **Wind vector azimuth**

ϕ_r **Relative wind direction**

RWD: 0 or 360 degree

upwind direction

RWD: 180 degree

downwind direction

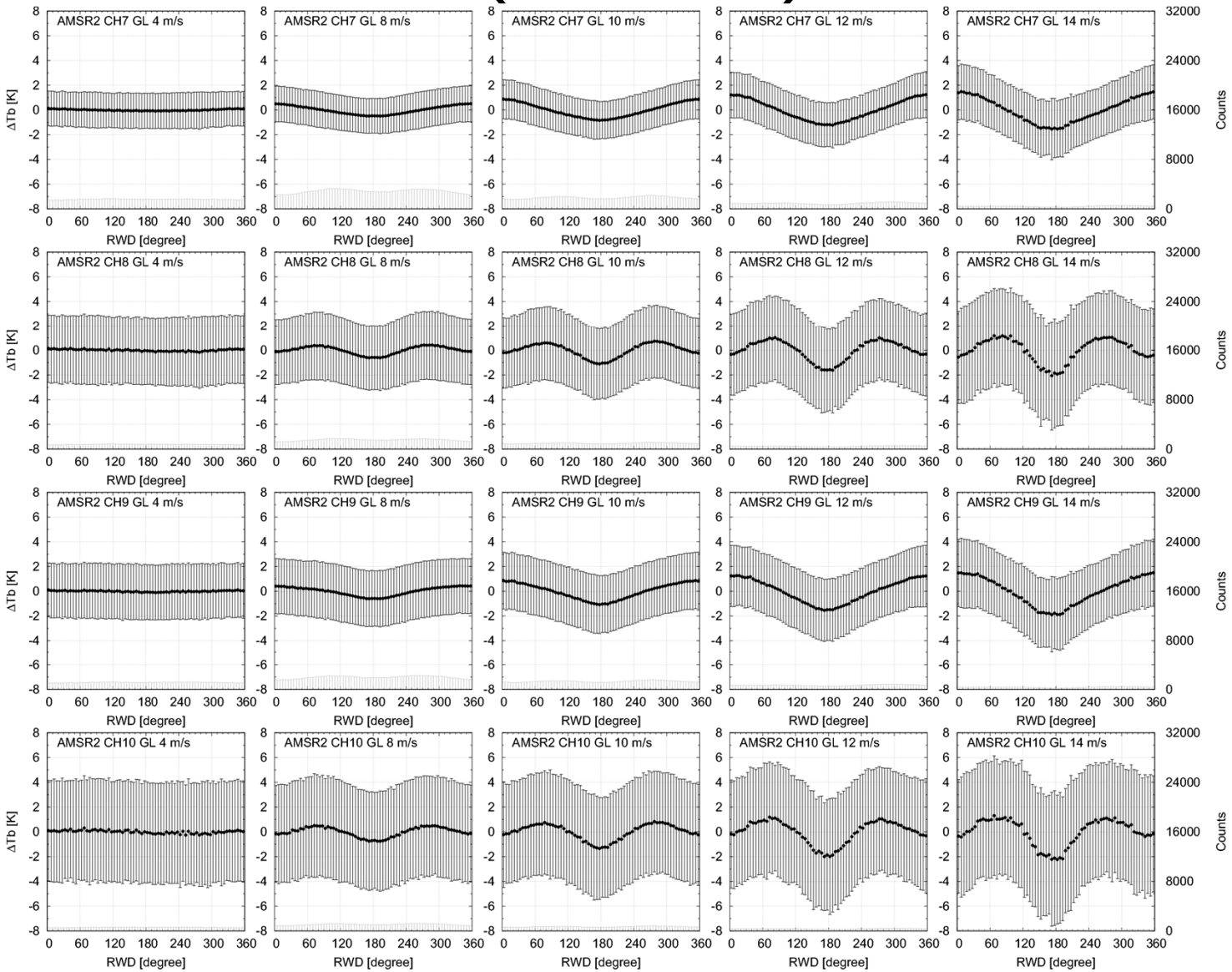
Tb variation (AMSR2)

19GHz V-pol.

19GHz H-pol.

23GHz V-pol.

23GHz H-pol.



NWP model's surface wind vector has sufficient accuracy to detect the Tb variation.

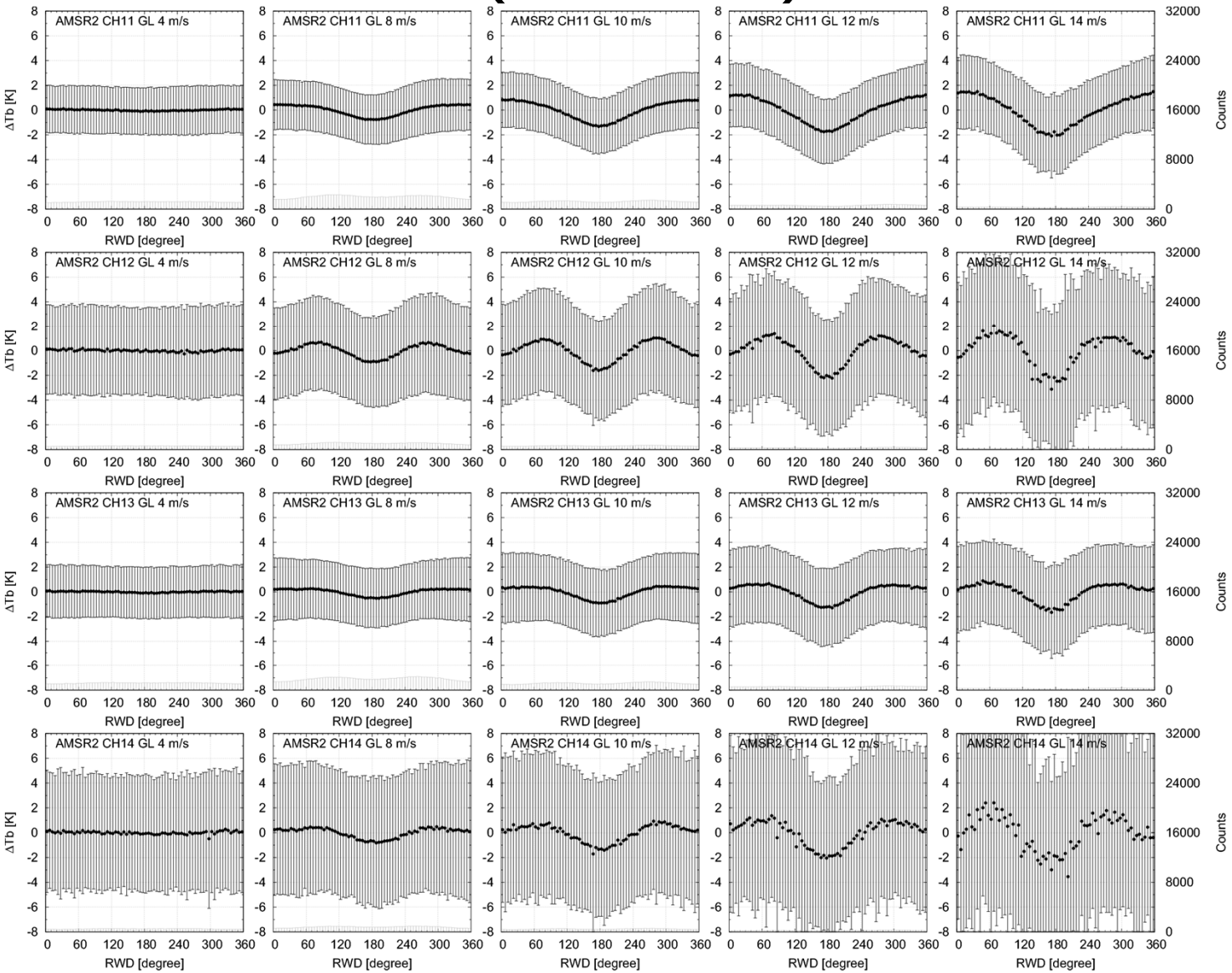
Tb variation (AMSR2)

37GHz V-pol.

37GHz H-pol.

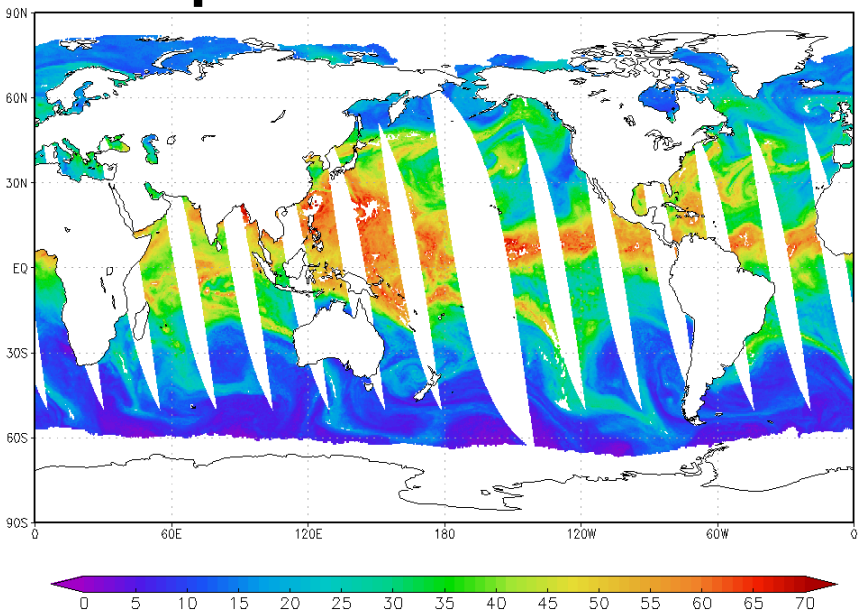
89GHz V-pol.

89GHz H-pol.



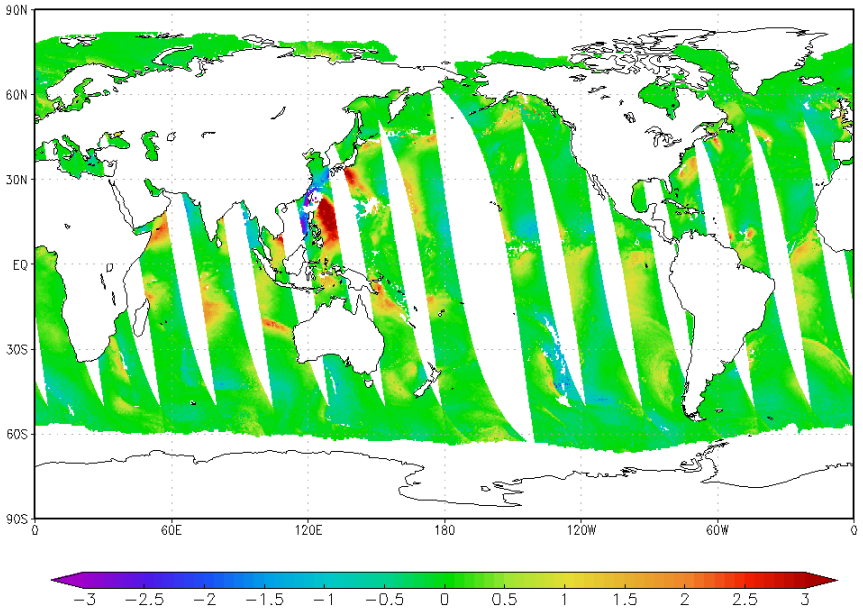
Tb variation can be represent with a second order harmonic functions.

Impacts of RWD correction on TPW



TPW algorithm with RWD correction

01 August 2012, Ascending data



TPW difference between WITH and WITHOUT RWD correction

The impacts depend on surface wind and satellite azimuth angle

Summary

A retrieval algorithm of water vapor (**TPW**, total precipitable water) and cloud liquid water (**CLW**) for GCOM-W1/AMSR2 was developed.
The algorithm is operationally used as one of the standard algorithms for AMSR2 L2 products at JAXA.

The current accuracy of the algorithm meets GCOM-W1 product requirement.

TPW : 3.12 [mm] (vs. RAOB), 2.11 [mm] (vs. GPS)
CLW : 0.02 [mm] in clear sky condition

From cross-talk checks on other geophysical parameters, dependences on SSW and SST were found in CLW product. (Necessary to be investigate further)

Further tuning with real AMSR2 measurement is necessary. Inclusion of RWD dependent Tb variation in the algorithm could provide better accuracy for TPW and CLW products.

Thank you for your attention.