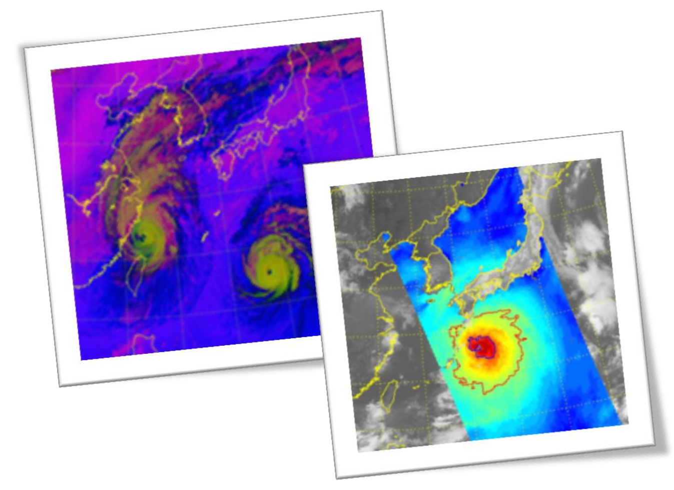
Physical retrieval of ocean surface wind speed and its application to Typhoon analysis using microwave satellite remote sensing



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Introduction

- Sea surface wind speed (W_S) plays a key role in global air-sea interactions, numerical forecasting models, and typhoon analysis.
- Microwave remote sensors have an advantage in estimating W_S because the increase of sea surface emissivity, due to roughness and foam effects driven by W_S, is related physically to the observed brightness temperature (T_B).
- Under the non-raining condition at low microwave frequencies (<10 GHz), the atmospheric contributions to the brightness temperature in the satellite observations are negligible (Yan and Weng, 2008; Uhlhorn and Black, 2003).
- In this presentation, we introduce an unique and useful algorithm and its application for retrieving sea surface wind speed with high accuracy and analyze TCs properties including typhoon analysis.

Theoretical Background and method

(1) Surface reflectivities

- Surface reflectivity = Specular + roughness+ foam effects
- Specular Reflectivity (Fresnel's Equation)

$$R_{S,V} = \left|\frac{\cos\theta - \sqrt{\hat{n}^2 - \sin^2\theta}}{\cos\theta + \sqrt{\hat{n}^2 - \sin^2\theta}}\right|^2 \quad R_{S,H} = \left|\frac{\hat{n}^2\cos\theta - \sqrt{\hat{n}^2 - \sin^2\theta}}{\hat{n}^2\cos\theta + \sqrt{\hat{n}^2 - \sin^2\theta}}\right|^2 \qquad (1)$$

(2) Surface roughness

- Relationship between specular and rough surface reflectivities (Wu and Fung, 1972; Choudhury at al. 1979).

$$R_R = R_S \cdot \exp[-(4\pi\sigma\lambda^{-1}\cos\theta)^2] \qquad (2)$$

- Characteristics of vertically (V) and Horizontally (H) polarized surface reflectivity around the Brewster's angle (Hong, 2010).

$$R_{S,H} > R_{R,H} \qquad R_{S,V} \approx R_{R,V} \qquad (3)$$

- A relationship between V and H-polarized specular reflectivity (Hong approximation) (Hong, 2009; Hong, 2013).

$$R_{S,H} = R_{R,V}^{\cos^2\theta} \qquad (4)$$

- Using eqs. (2), (3), and (4), a small-scale surface roughness (σ) is estimated as follows (Hong's roughness equation)(Hong, 2010):

$$\sigma \approx \frac{\lambda}{4\pi\cos\theta}\sqrt{\ln\left(\frac{R_{R,V}^{\cos^2\theta}}{R_{R,H}}\right)} \qquad (5)$$

- W_S is estimated using the following relationship between σ and W_S:

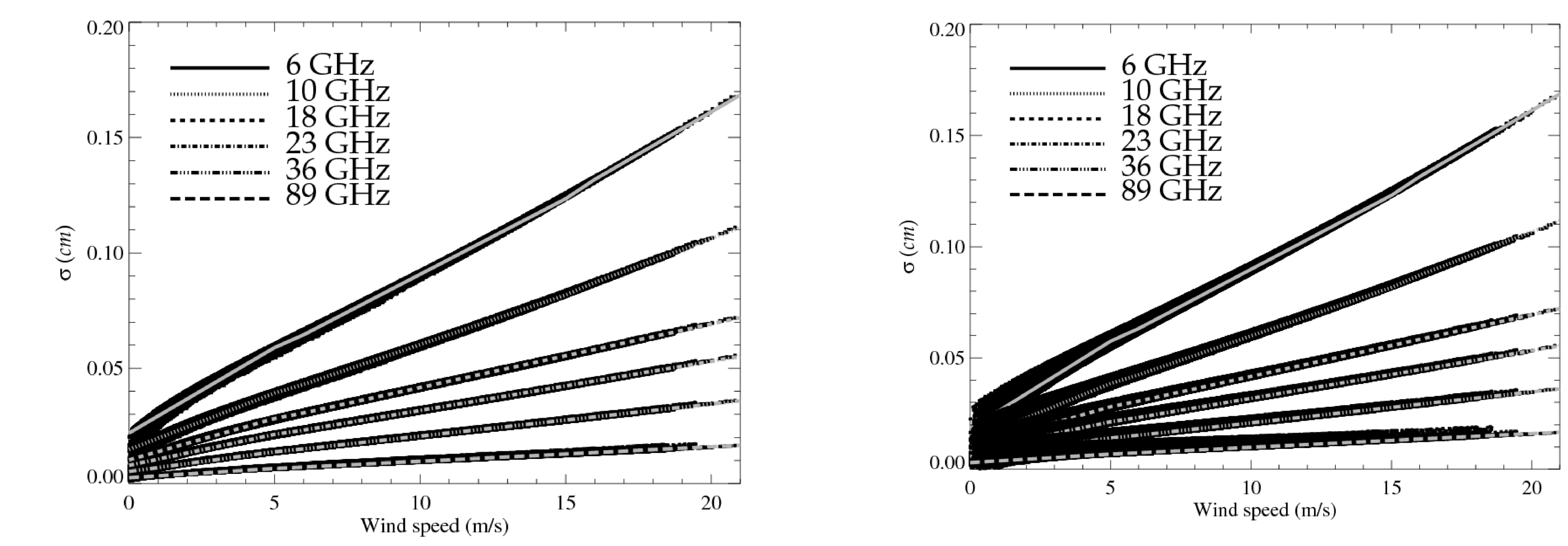


Fig. 1. Relationship between retrieved roughness and W_S calculated using (a) a radiative transfer model (FASTEM-3) and (b) Hong approximation (Retrieval) for AMSR-E channels from 6.9 to 89 GHz channels .

Data(AQUA/AMSR-E & GCOM-W1/AMSR-2)

Table 1. Frequency channels and resolution of the AMSR-2 instrument.

Band[GHz]	Polarization	Spatial Resolution [km x km]	Sample interval [km]
6.93	V & H	62 x 35	10
7.3	V & H	62 x 35	
10.65	V & H	42 x 24	
18.7	V & H	22 x 14	
23.8	V & H	19 x 11	
36.5	V & H	12 x 7	
89.0	V & H	5 x 3	5

Procedure

- T_B(O) : T_B observed at AMSR-2 6 GHz
- T_B(S) : T_B simulated using RTTOV with GDAS or ECMWF

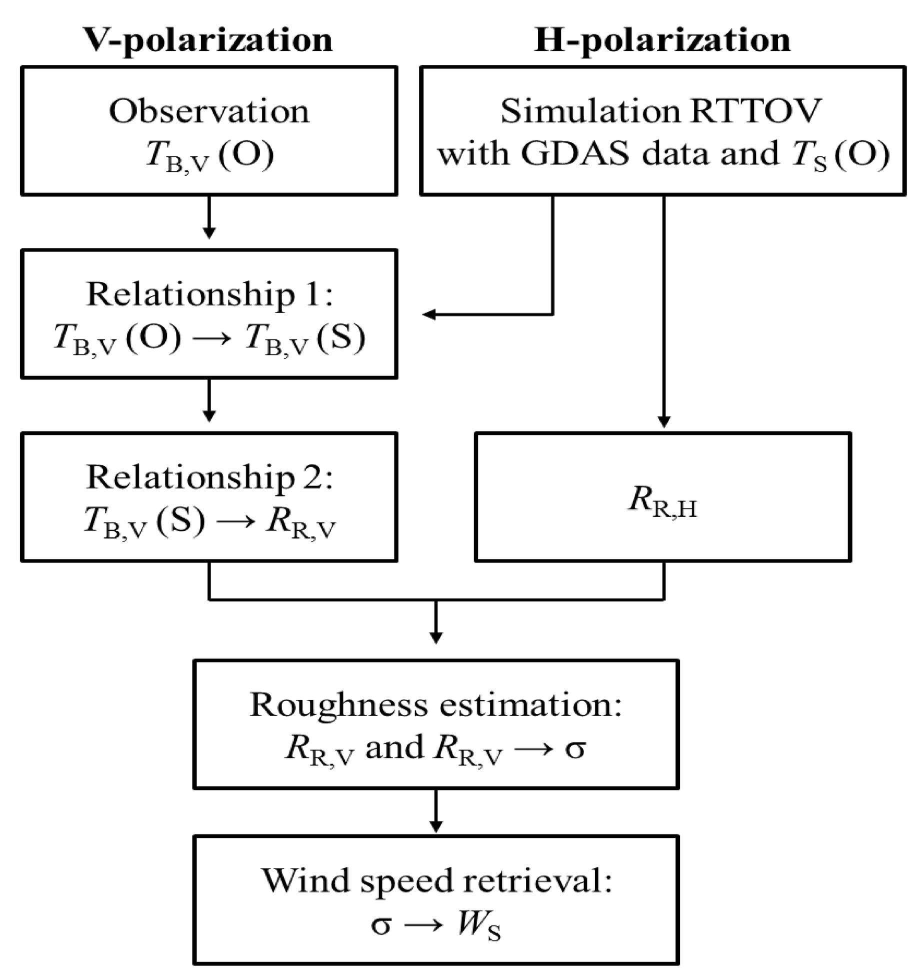
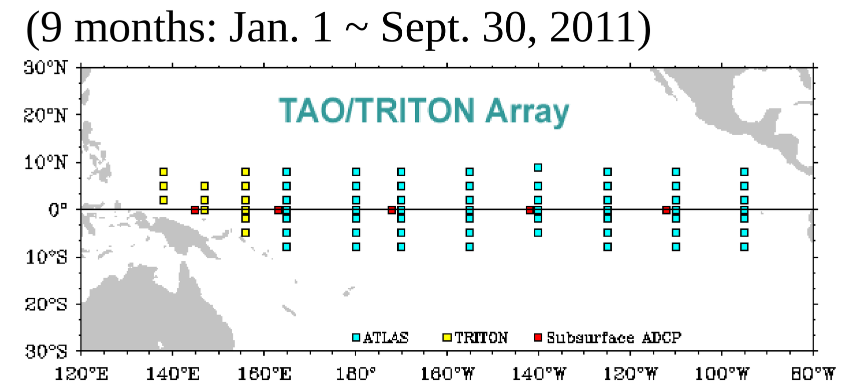


Fig. 2. Wind speed retrieval algorithm

- For rain-free and RFI-free conditions, AMSR2 SST was used
- For rainy condition, model SST(ECMWF, GDAS, UM, etc.) was used

Validation

- TAO/TRITON buoy Ws data (9 months: Jan. 1 ~ Sept. 30, 2011)



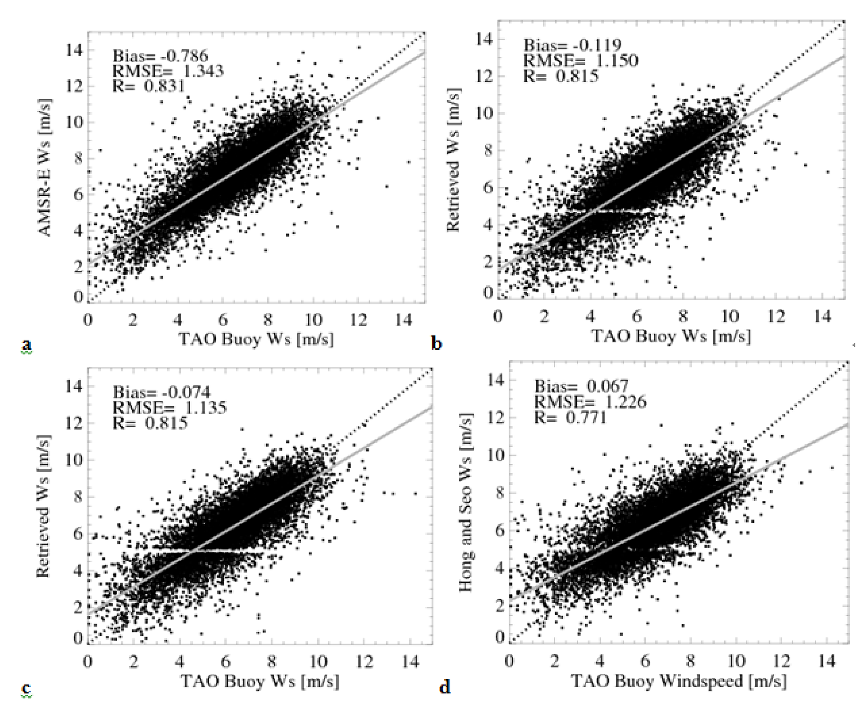


Fig.3. Scatterplots for (a) TAO Ws (observation) vs. AMSR-E Ws, and TAO Ws vs. retrieved Ws(estimation) from the observed for the AMSR-E (b) 6.9 GHz, (c) 10.7 GHz, and (d) 18.7 GHz channels.

Results

(1) Typhoon size and center locations(Typhoon Bolaven in 2013)

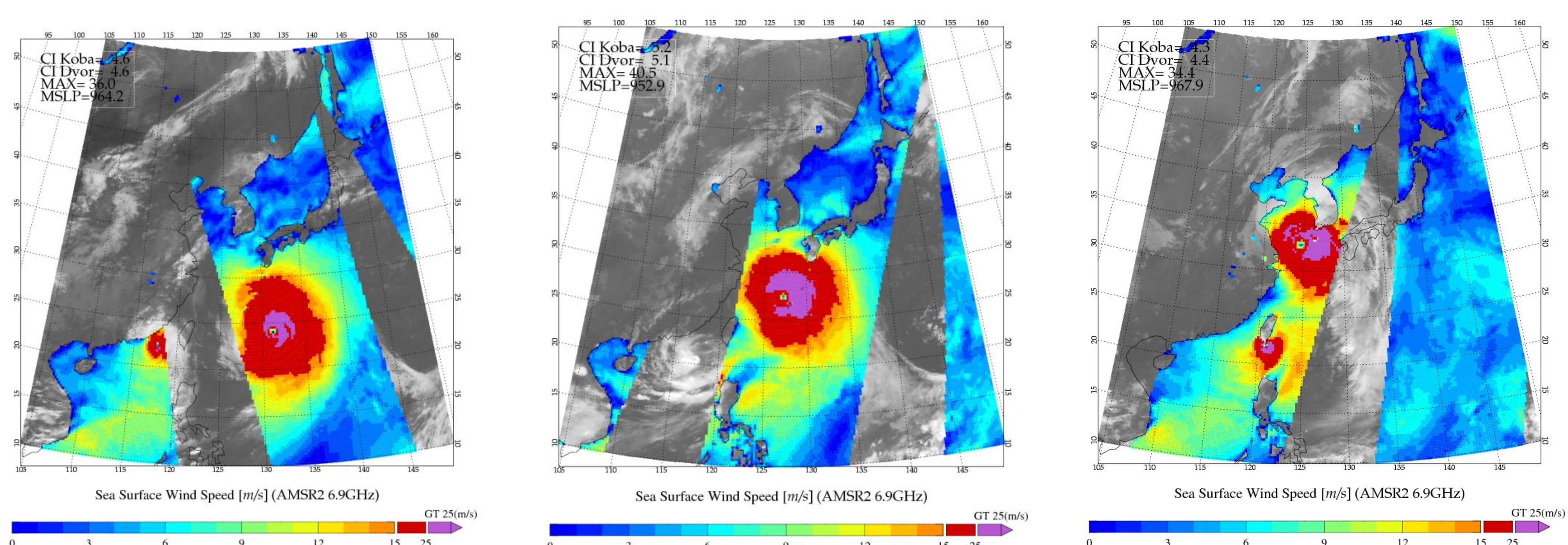


Fig 4: CI index (intensity) of Typhoon Bolaven on (a) 25 August, (b) 26 August, and (b) 27 August, 2013 using the presented algorithm. In this case, the conversion table provided by Koba et al. (1990) was applied.

(2) Typhoon intensity analysis (Typhoon Bolaven in 2013)

	Time (UTC)	ADT	CI index	P_{MIN} (hPa)	CI (SAREP)	P_{MIN} (JMA)
Typhoon Bolaven	8. 25. 06	5.2/6.0	4.6(36.0)	964.2	5.5/6.0	920
	8. 26. 18	4.8/4.8	5.2(40.5)	952.9	5.5/5.0	940
	8. 27. 18	4.1/4.1	4.3(34.4)	967.9	4.0/3.5	960

Summary

- We developed a sea surface wind speed retrieval algorithm for use in both rainy and rain-free conditions.
- This algorithm consists of satellite observation and RTM simulations as follows:
  - V-polarized reflectivity is estimated using satellite observation and simulation.
  - H-polarized reflectivity is estimated from a radiative transfer calculation with ECMWF as input data.
- The retrieved W_S shows the improved results (low bias and RMSE) compared AMSR L3 W_S.
  - W_S was directly validated with the TAO buoy data and indirectly validated with the TCs intensity.
- This W_S algorithm is applied for operational purpose to analyze TCs properties including center position, size, and intensity of typhoons.

Reference

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