Wave-effect considering two-step wind speed retrieving algorithm for new GNSS-R satellite, TRITON

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1. Introduction and motivation

Global navigation satellite system reflectometry (GNSS-R) is designed to get the quasi-specular reflection of the GNSS signal over the Earth's surface. The reflected signal of GNSS-R recorded on a Delay-Doppler Map (DDM) may then be used to retrieve wind speed, ocean surface roughness, and latent heat flux over the open ocean and to retrieve soil moisture over the land.
The L-band signal from GNSS is transmitted via forward (quasi-specular) scattering geometry, obeying the geometric optics (GO) limit of the Kirchhoff approximation (KA). One of the factors on DDM is bistatic radar cross section (BRCS) which represents sea surface roughness. The ocean surface slope and roughness spectrum sensed by GNSS-R response to the energy transferred to the ocean makes it possible for the wind speed to retrieve from the GNSS-R DDM. L-band (~1.5 GHz) microwave is less sensitive to the rain than higher frequency band signals such as Ku- band and C- band. There is a potential to use the L-band signal to retrieve wind speed over not only the fully-developed sea but over limited-fetch sea under more extreme weather systems, such as under tropical cyclones.
In this study, we will present the ocean measurements and a wave-considering retrieving wind speed algorithm for the new GNSS-R satellite, TRITON. TRITON (Wind-Hunter Satellite) is designed and manufactured by Taiwan Space Agency (TASA) and will be launched in the third season of 2023.

2. Level 1b calibration- Generation of DDM observable, DDMA

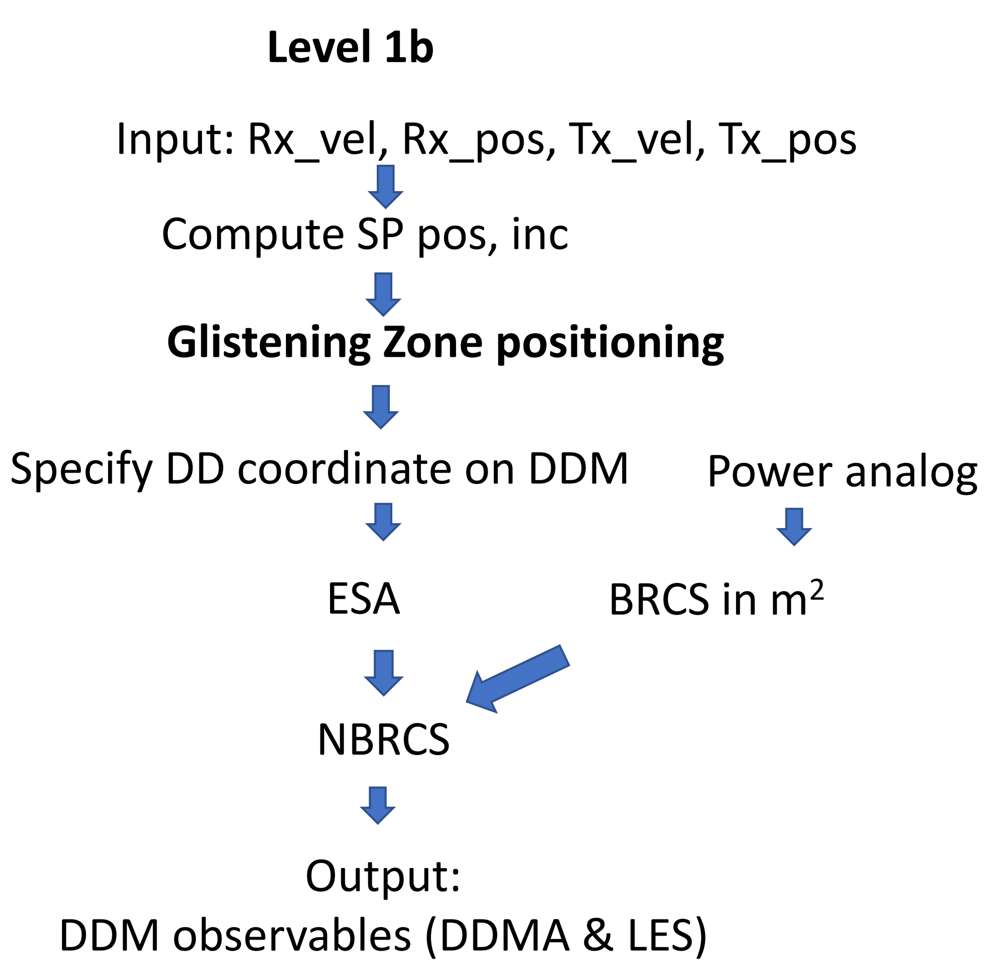

Figure 1. Flowchart to do Level 1b calibration

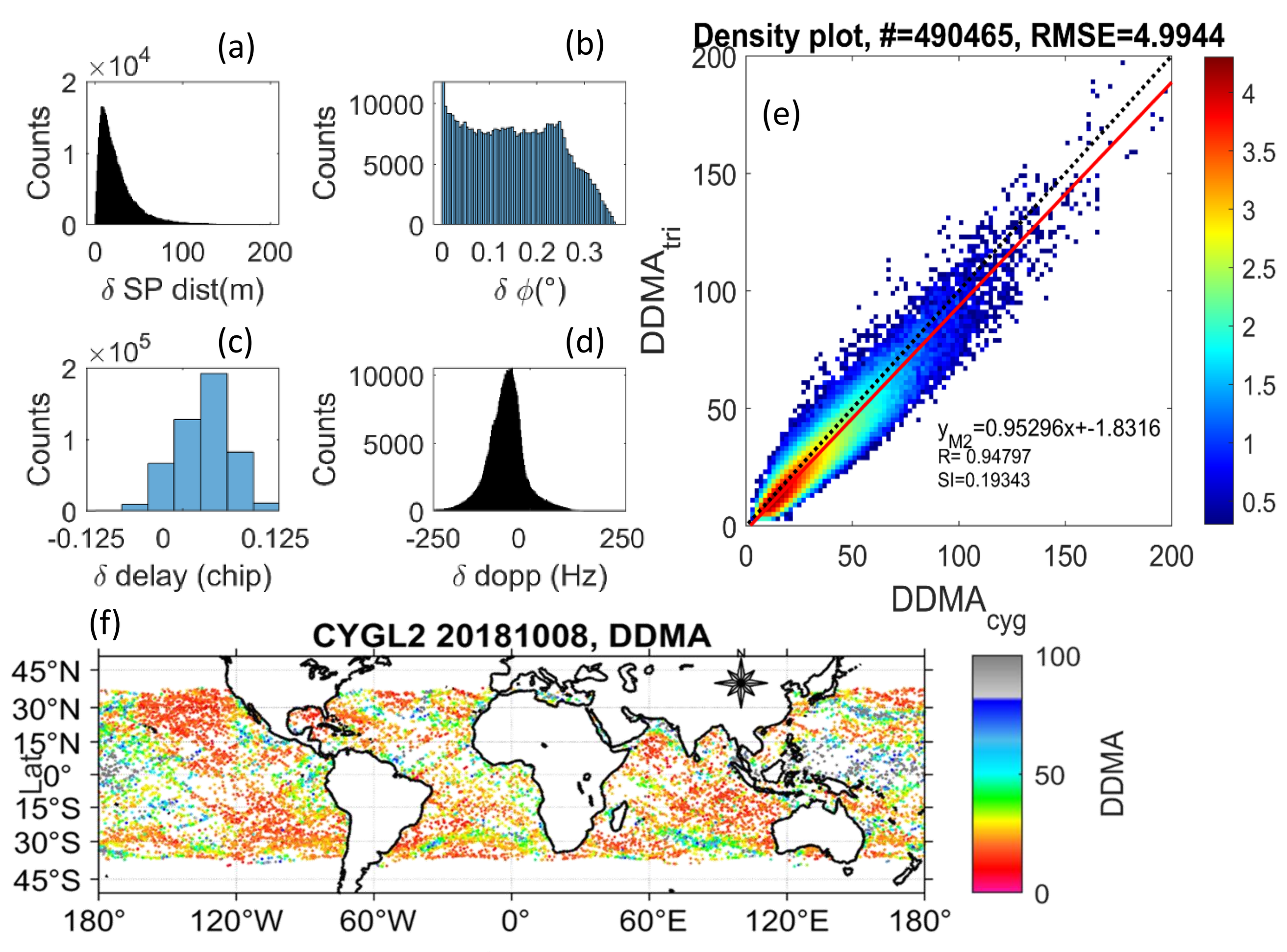

Figure 2. Performance assessment of Level1 b calibration

Good agreements have been found compared to the CYGNSS results. The coefficient among ~0.5 million DDMA_cygnss and DDMA_Triton points regression is 0.95. The root-mean-squared error is 4.99, with data ranging from 0 to 200, and the scattering index is 0.19.

3. DDMA-U_{10} GMF generation and performance assessment

$u_{10} = a_0+a_1*ddma^{-1}+a_2*ddma^{-1/2}$

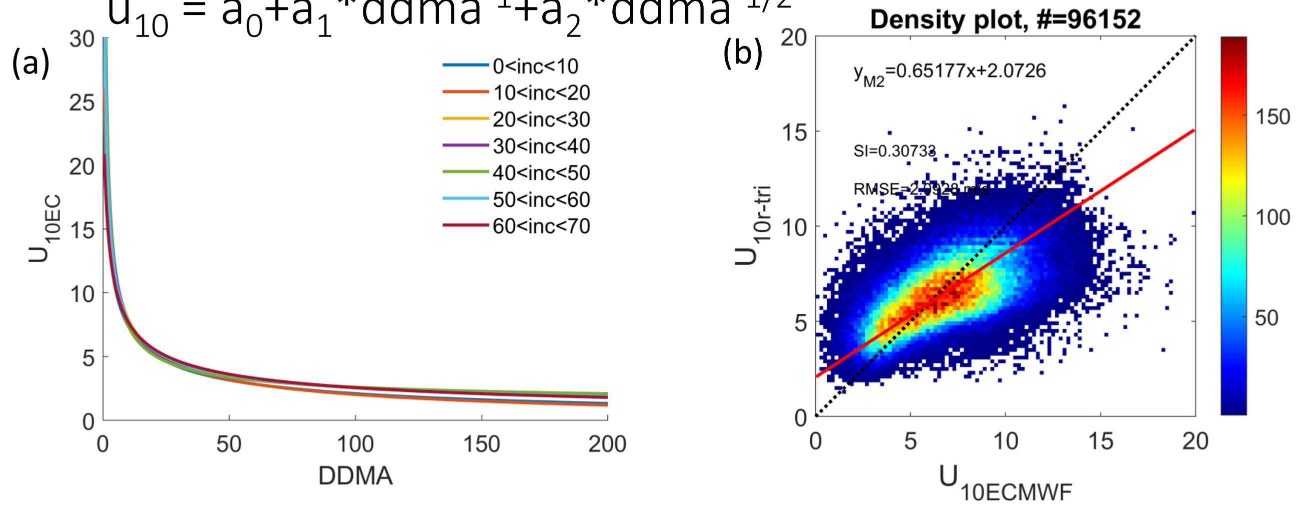

Figure 3. Performance assessment of Level1 b calibration

4. Using two-step GMF to retrieve wind speed U_{10}

In the L2 algorithm, wind speed will be retrieved in two steps. In the first step, NBRCS will be used to compute the mean square slope (mss) with the help of the Fresnel reflection coefficient. In the second step, the relationship between wave age, mss, and wind speed developed based on the state-of-art microwave remote sensing study will be applied to retrieve wind speed.

4.1 From DDMA to MSS

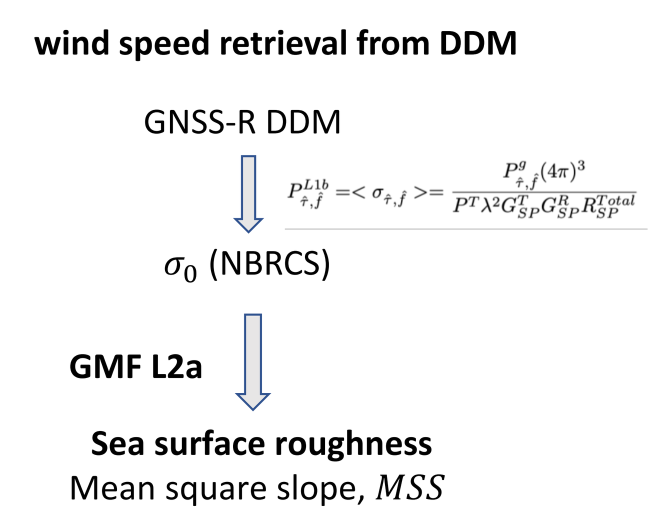

Figure 4. Flowchart of computing MSS from GNSS-R DDM

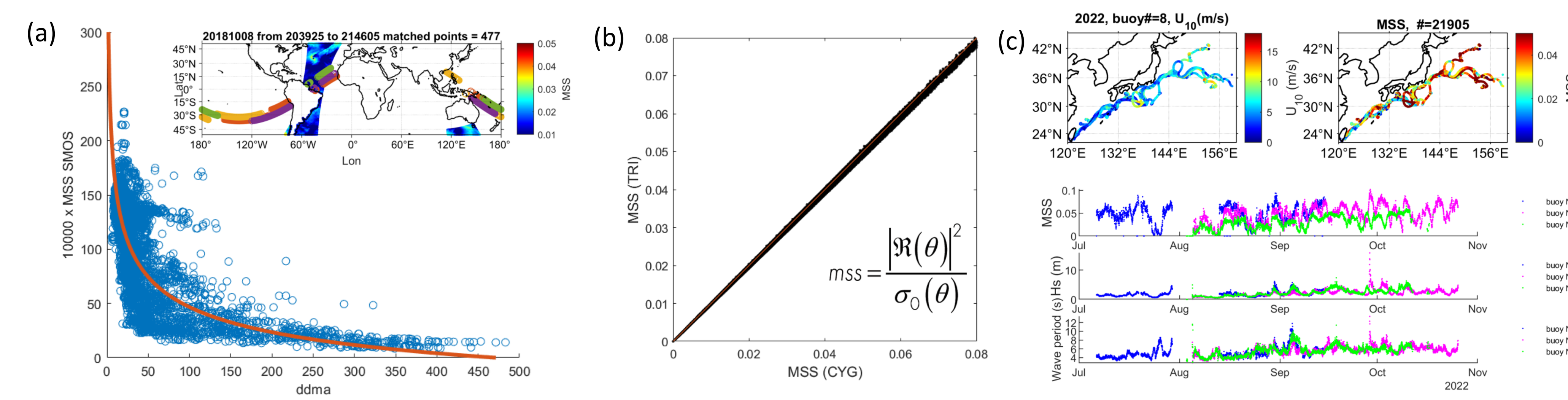

Figure 5. Three ways to get MSS. (a) Building SMOS MSS-DDMA GMF to retrieve MSS. (b) Computing from Fresnel coefficient (SST and SSS are variable) and DDMA and compare the result with CYGNSS results calculated in the same way (c) MSS computed from direct measured wave slope using miniature wave buoy.

	Product name
1	L2 Triton computed MSS on L1 CYG points (from Fresnel coefficient)
2	L2 Triton MSS on L1 CYG points Retrieve from SMOS MSS- DDMA GMF
3	Miniature wave buoy (NCU)

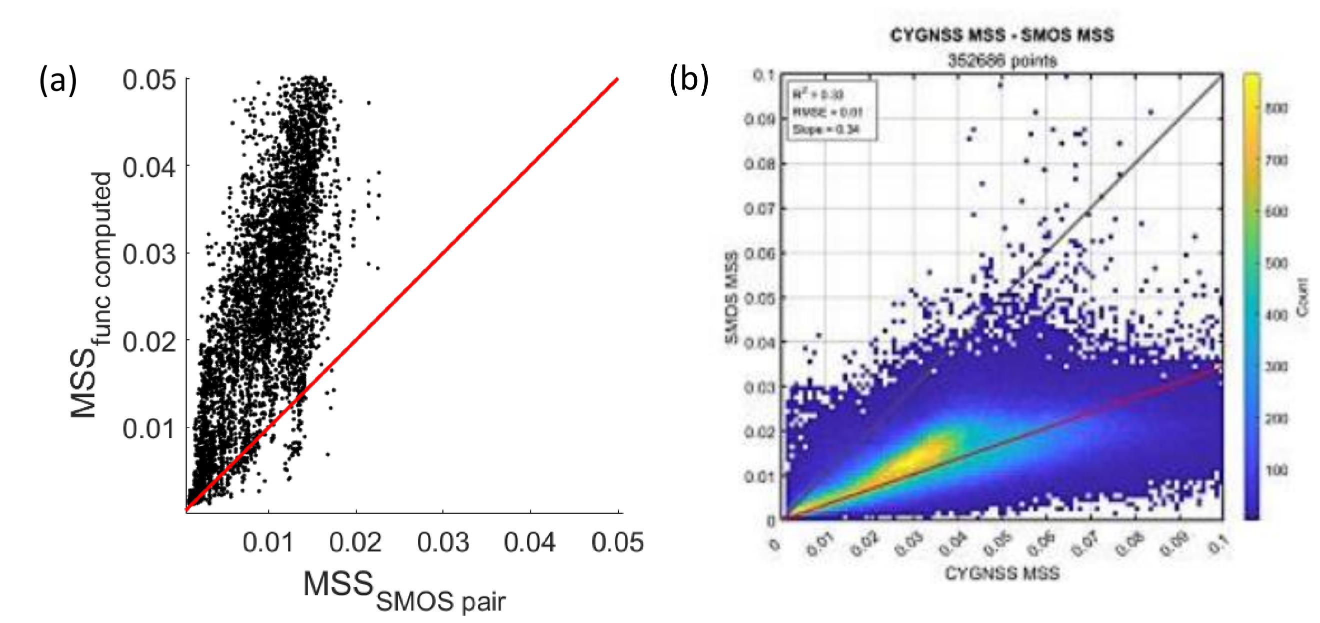

Figure 6. Cross comparison of
(a) Comparison between MSS computed from SMOS MSS-Triton DDMA GMF and MSS directly computed from Fresnel coefficient
(b) Comparison between MSS from CYGNSS Level 2 dataset and SMOS MSS at matchup points

4.2 From MSS to U_{10}

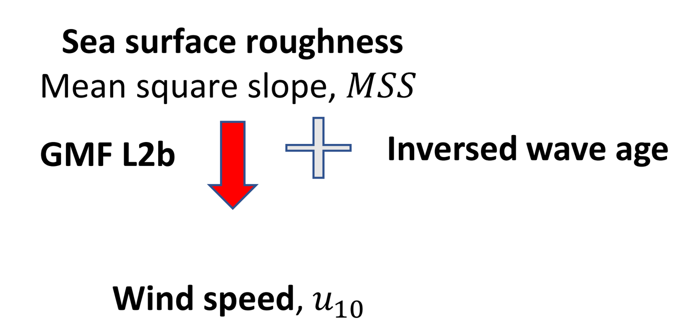

Figure 7. Flowchart of computing U0 from MSS and inversed wave age

One may get wind speed by substituting the mean square slope from the MSS computed and integrated from 1st step, and the computed inversed wave age into GMF

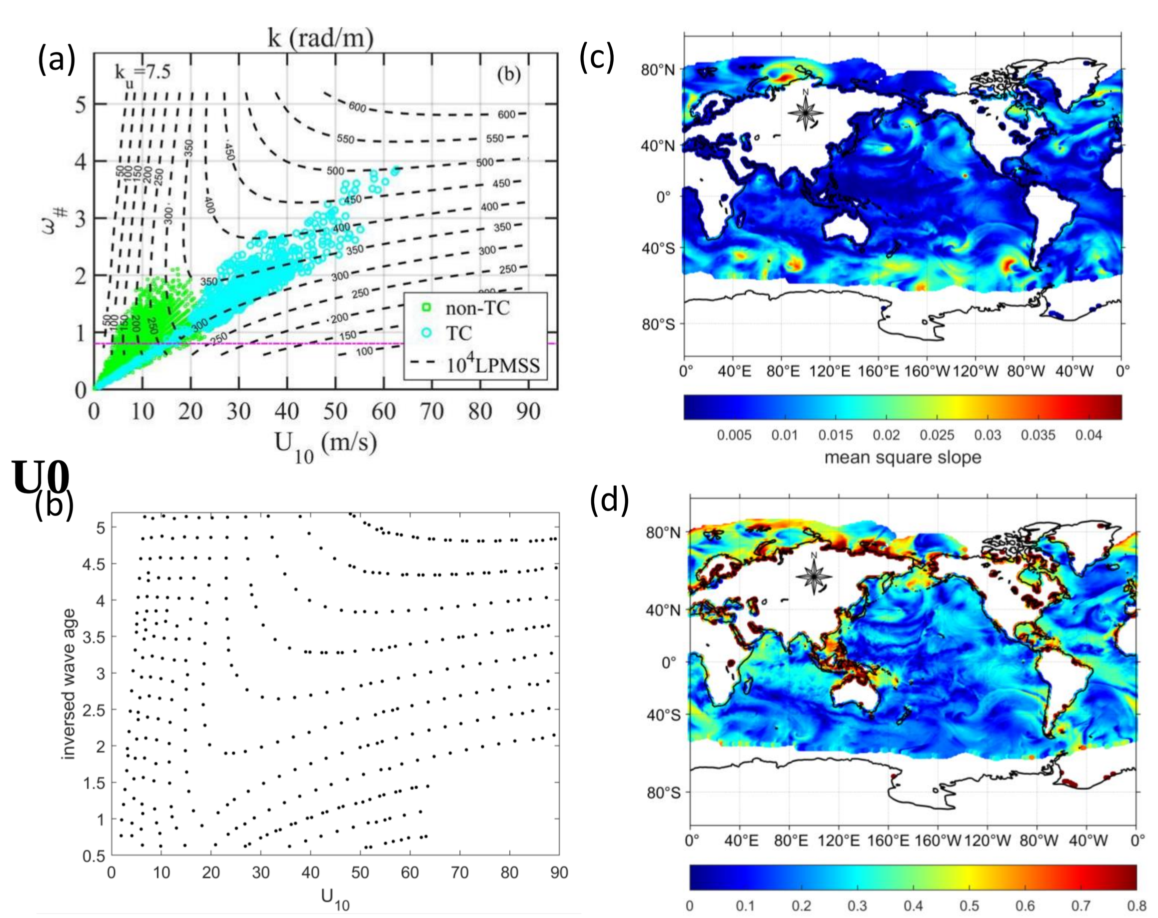

Figure 8. MSS-inversed age-U10 GMF to retrieve wind speed. (a) MSS-inversed age-U10 GMF from Hwang (2020) (b) GMF digitailized from (a), (c) example MSS data from ECMWF ERA5 to submit into GMF (d) inversed wave age computed from Hs and U10 using Zhang and Oey (2018) method.

5. References

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5. CYGNSS. 2020. CYGNSS Level 2 Science Data Record Version 3.0. Ver. 3.0. PO.DAAC, CA, USA. Dataset accessed [YYYY-MM-DD] at https://doi.org/10.5067/CYGNS-L2X30