Applying GNSS-Reflectometry for ocean wind retrieval under typhoon condition using simulated Delay-Doppler Maps

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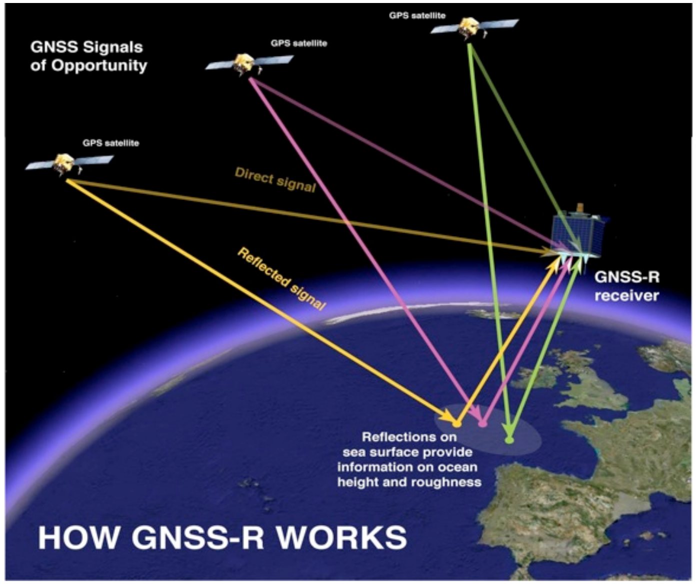
Introduction

- Global Navigation Satellite System – Reflectometry (GNSS-R) exploits the signals of GPS constellations after reflection on the Earth surface providing geophysical information of surface properties: ocean roughness, soil moisture, snow depth, sea ice…

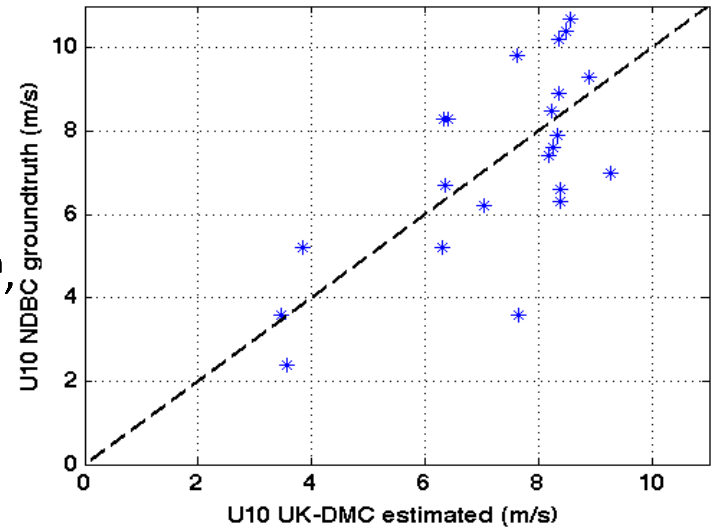
- UK-DMC
  Launched on 27th September 2003. First spaceborne demonstration of wind signal from GPS reflections. The near surface wind speed was estimated with an uncertainty of 1.65 m/s RMS relative to NDBC ground truth winds

- TechdemoSat-1 with onboard GNSS-R receiver
  Launched 8 July 2014, flown since UK-DMC over 10 years ago. First public data set released on March 5th, 2015

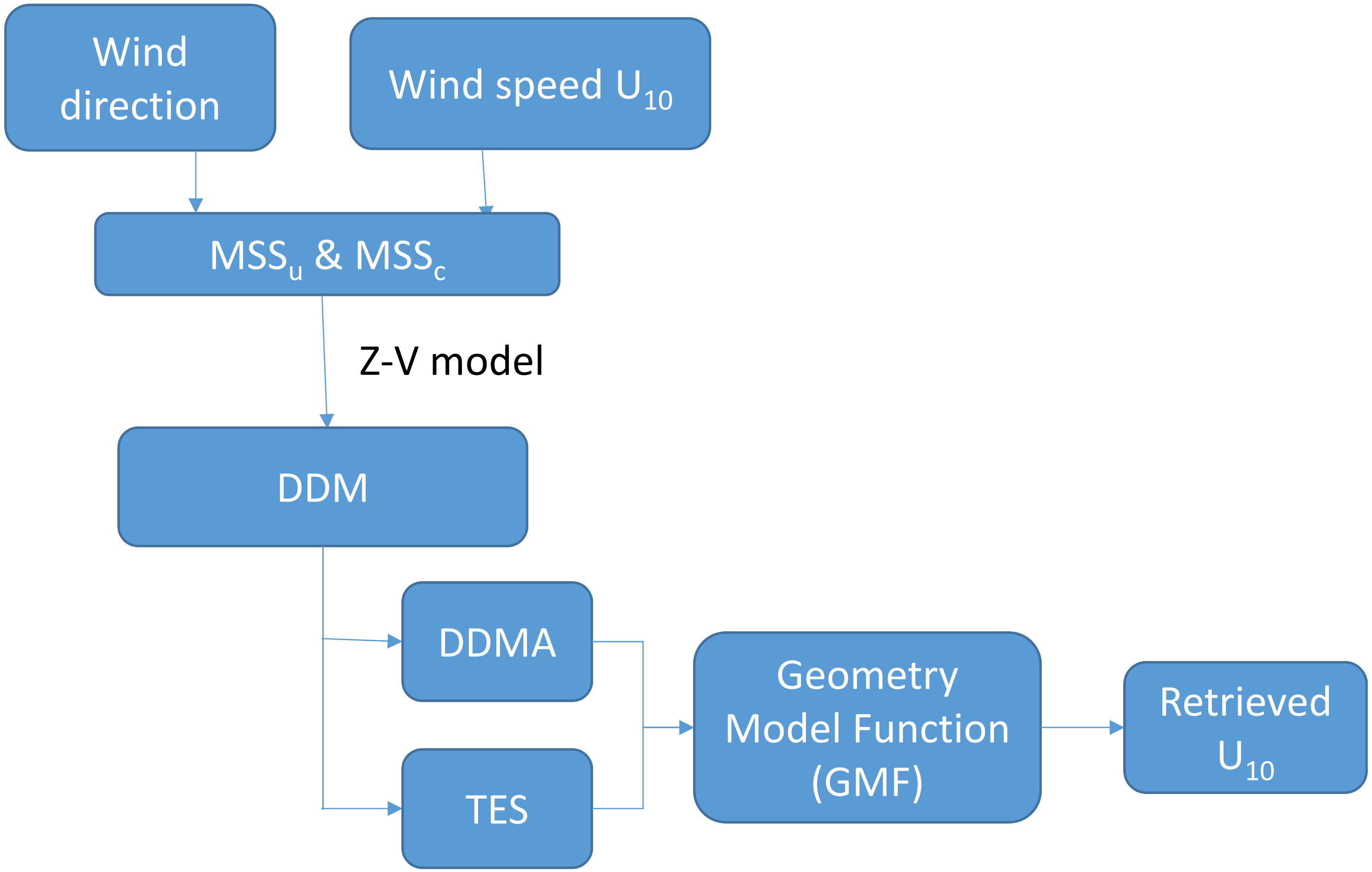
- NSPO is planning to launch the FORMOSA-7R before 2020.



Source: noc.ac.uk

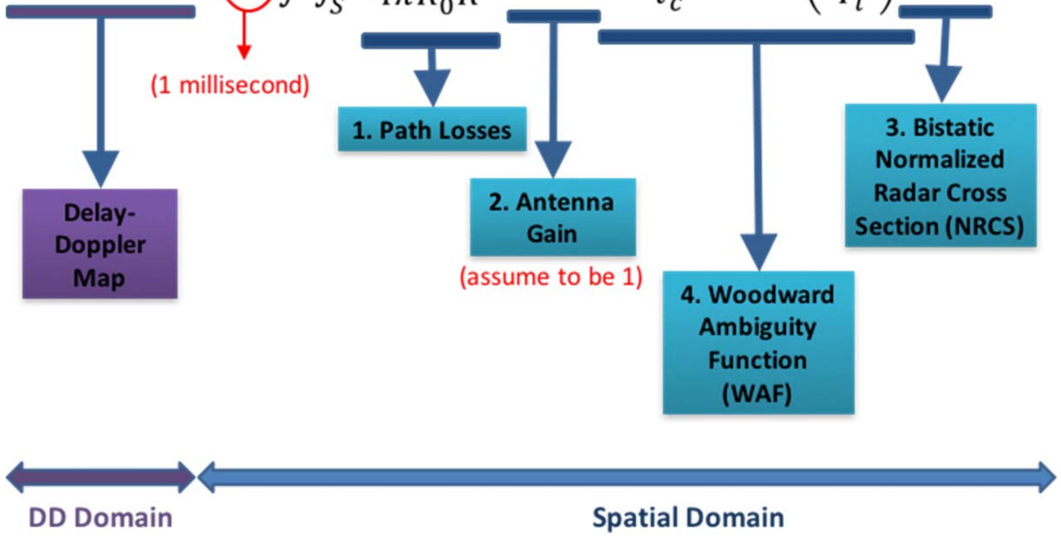


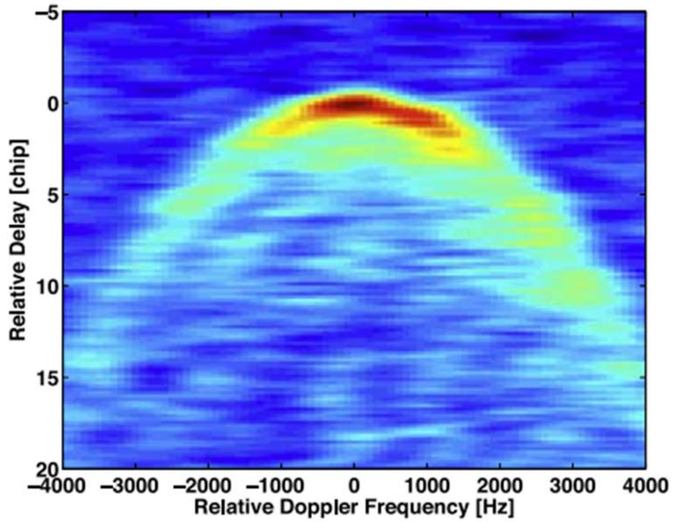
Wind speed Retrieval Algorithm using Observables: DDMA and TES



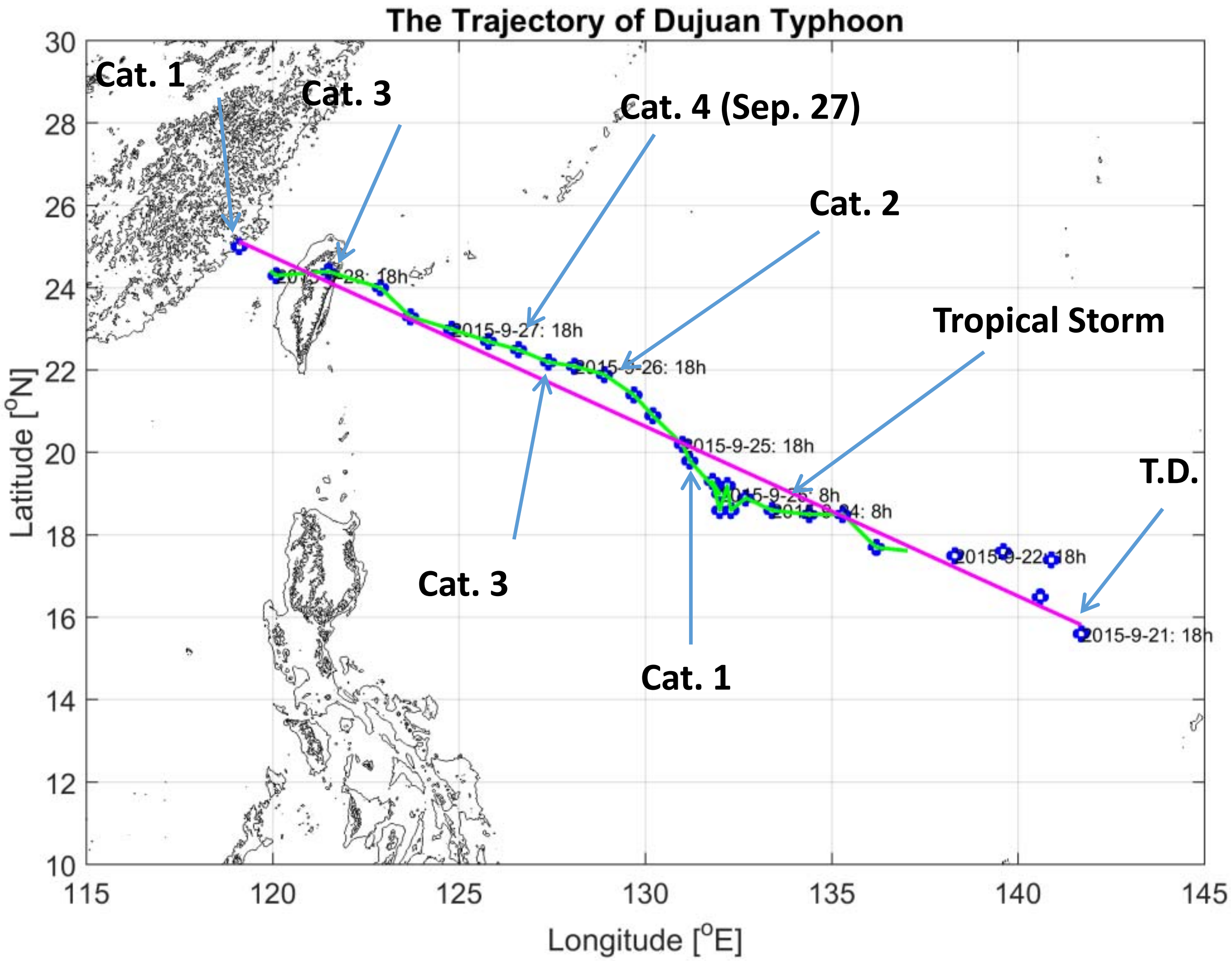
Z-V model

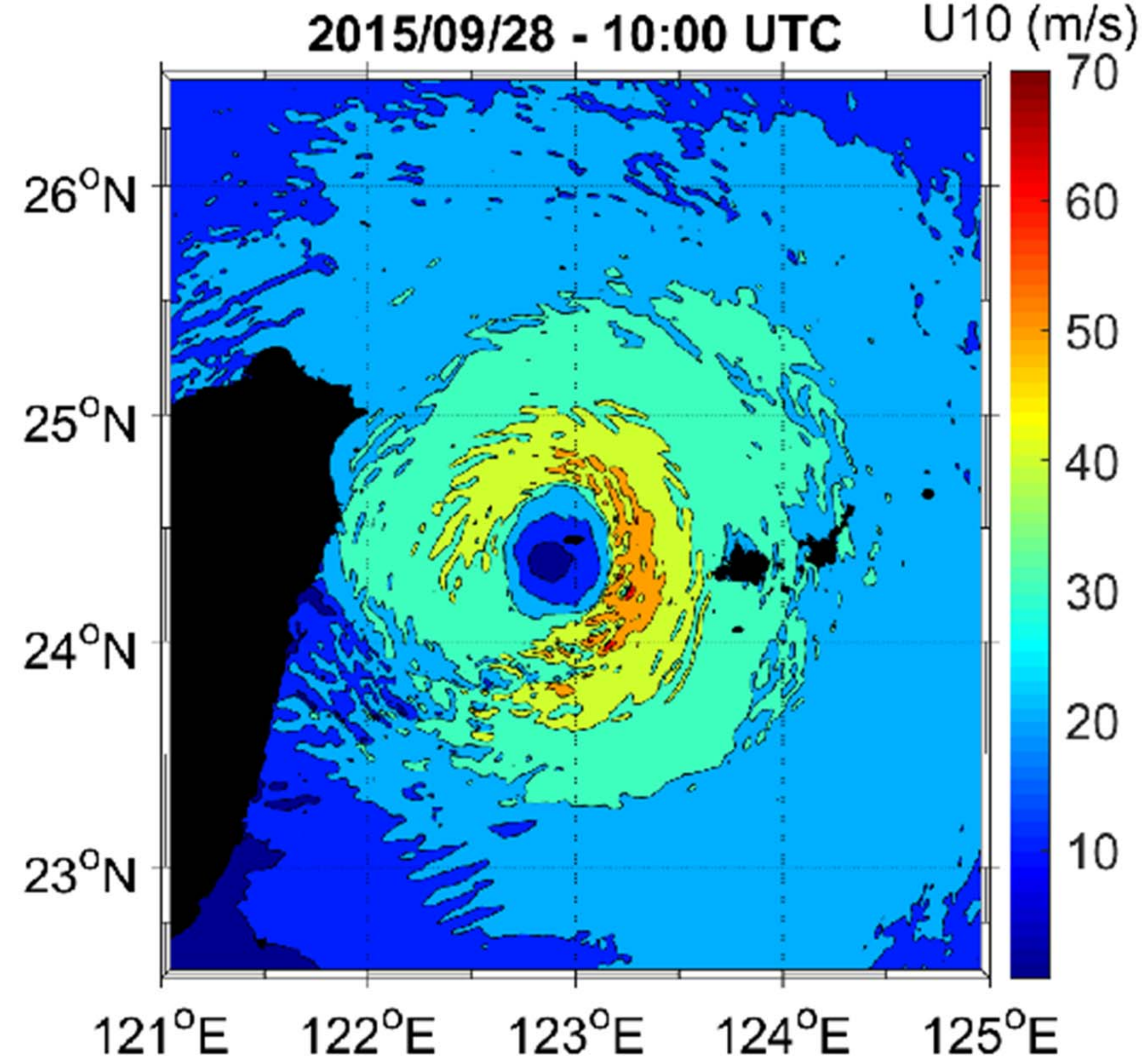
$$\langle \mathrm{P}(\tau, f_D) \rangle = T_i^2 \int\int_S \frac{1}{4\pi R_0^2 R^2} D^2(\boldsymbol{r}) \Lambda^2\left(\frac{\delta\tau}{\tau_c}\right) sinc^2\left(\frac{\delta f_D}{T_i}\right) \sigma_o(\boldsymbol{r}) d^2 r$$





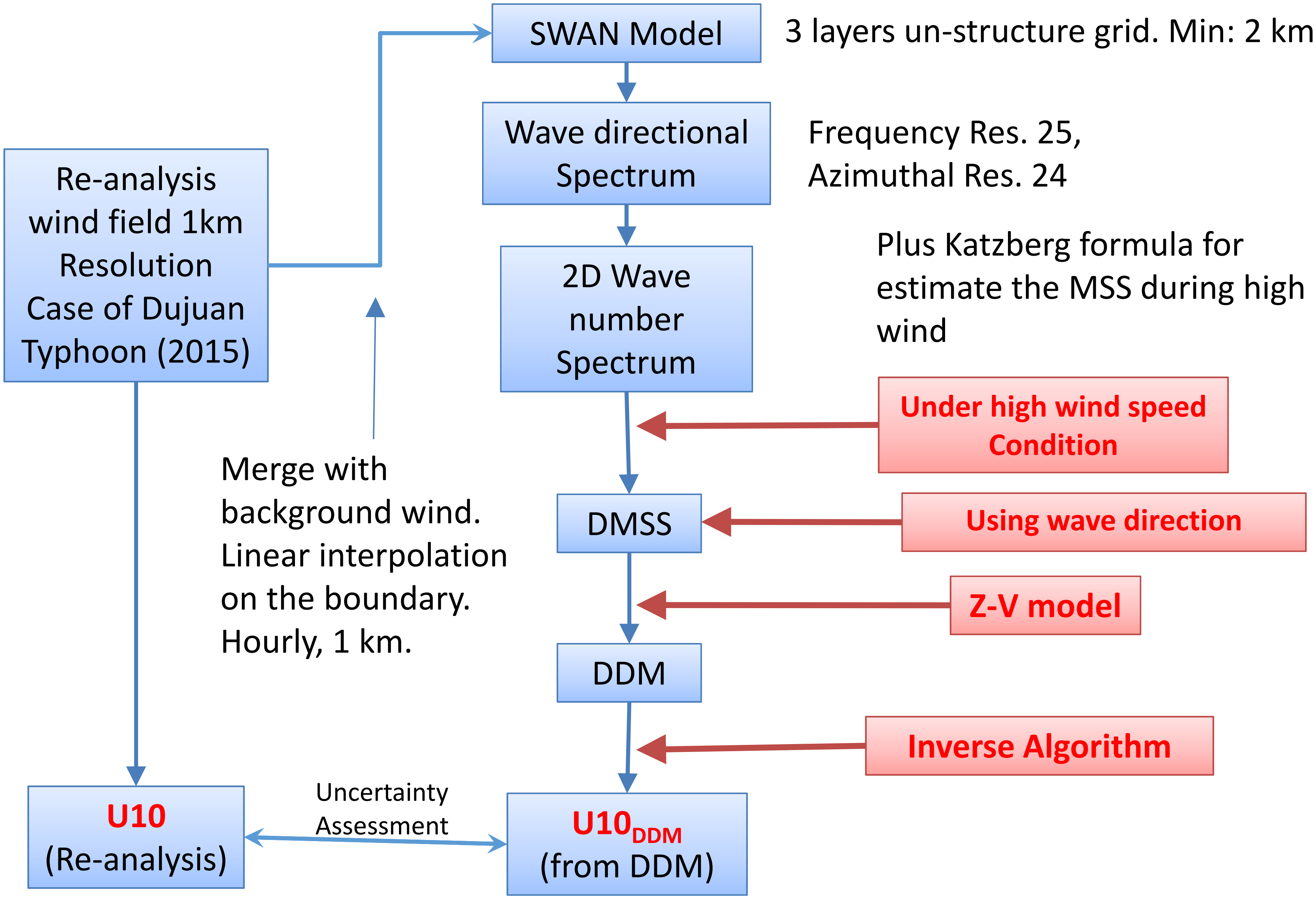
Typhoon Dujuan (2015 Sep.)





Dujuan typhoon at 10 am, 2015/09/28, with maximum wind speed up to 70 m/s

How to Consider the Swell Contribution to DMSS ?



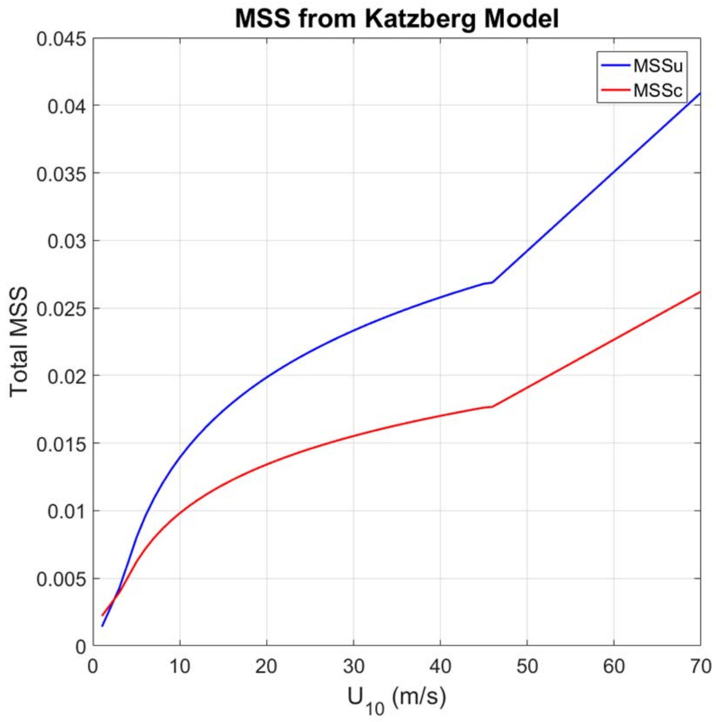
Katzberg Model
Semi-Empirical Model for High-Wind Speed Surface Roughness

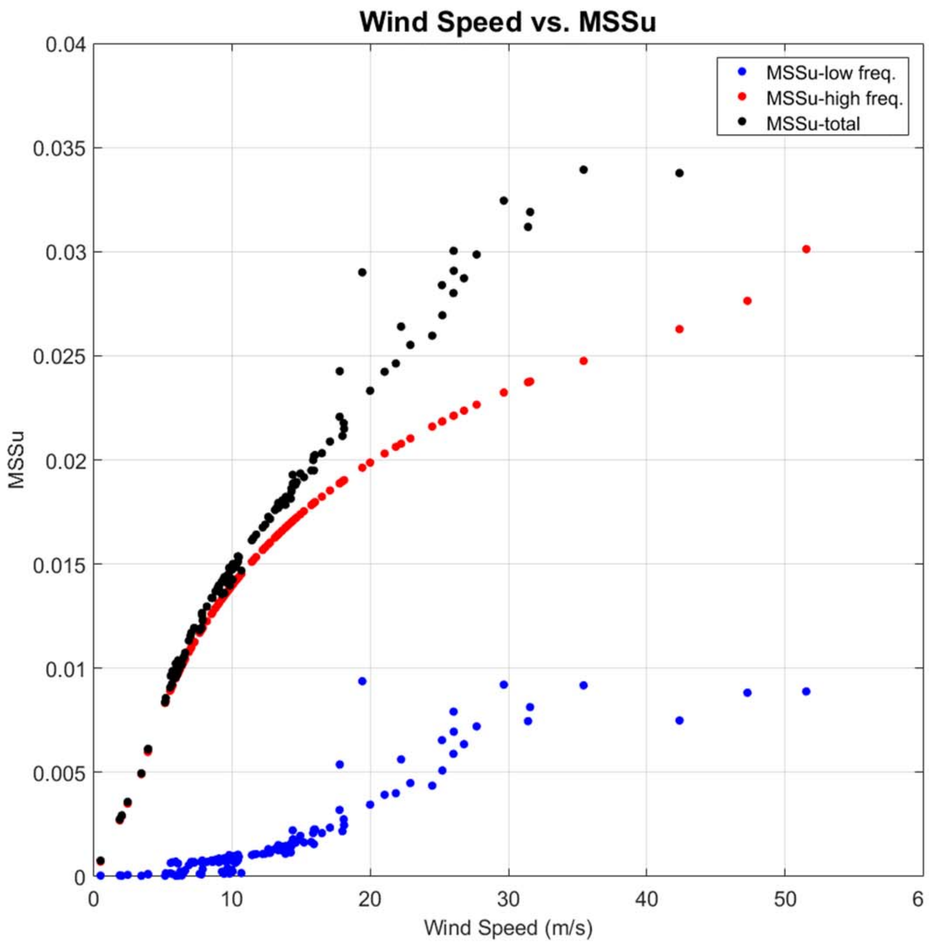
- The modified mean-square-slope relationships :

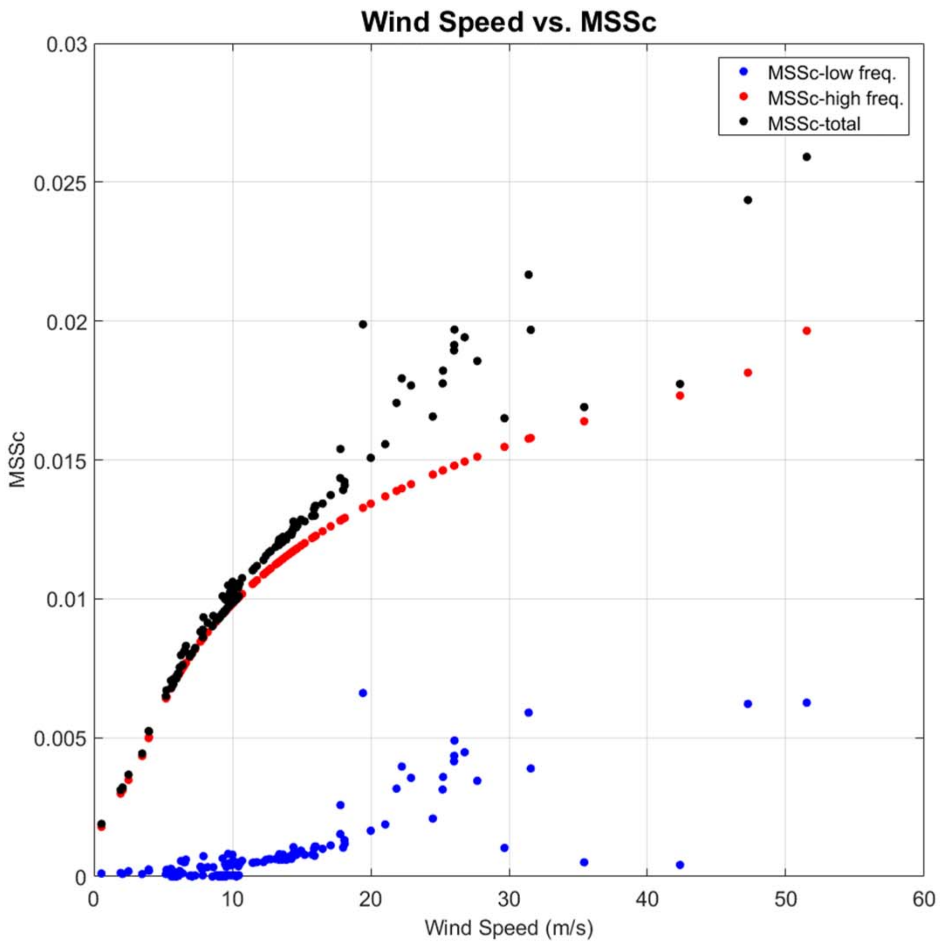
$$mss_{\parallel} \equiv \sigma_u^2 = 0.45 \cdot (0.00 + 0.00316 f(U))$$
$$mss_{\perp} \equiv \sigma_c^2 = 0.45 \cdot (0.03 + 0.00192 f(U))$$

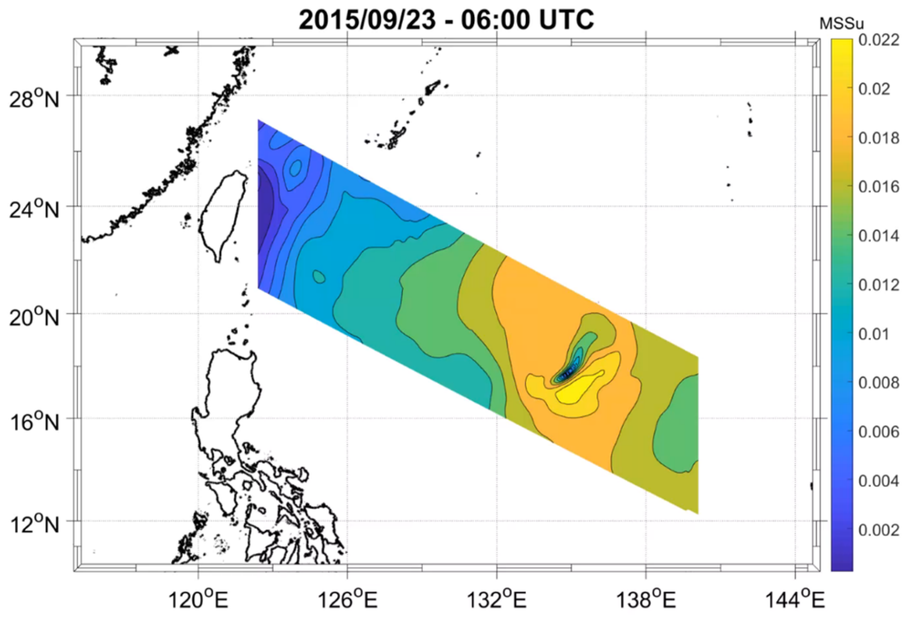
where the U is related to the actual wind speed through:

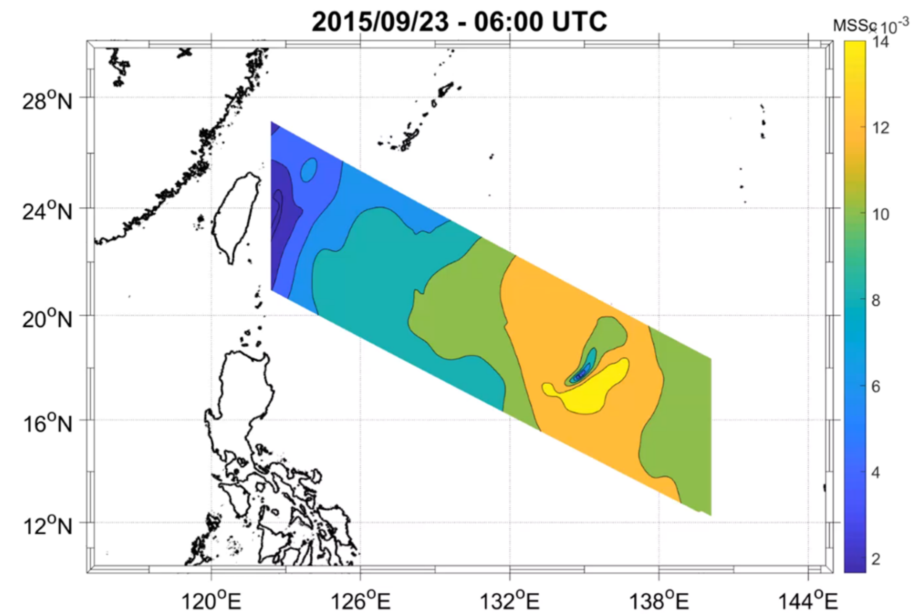
$$f(U) = \begin{cases} U & 0.00 < U < 3.49 \\ 6 \cdot \ln(U) - 4.0 & 3.49 < U < 46 \\ 0.411 \cdot U & 46.0 > U \end{cases}$$



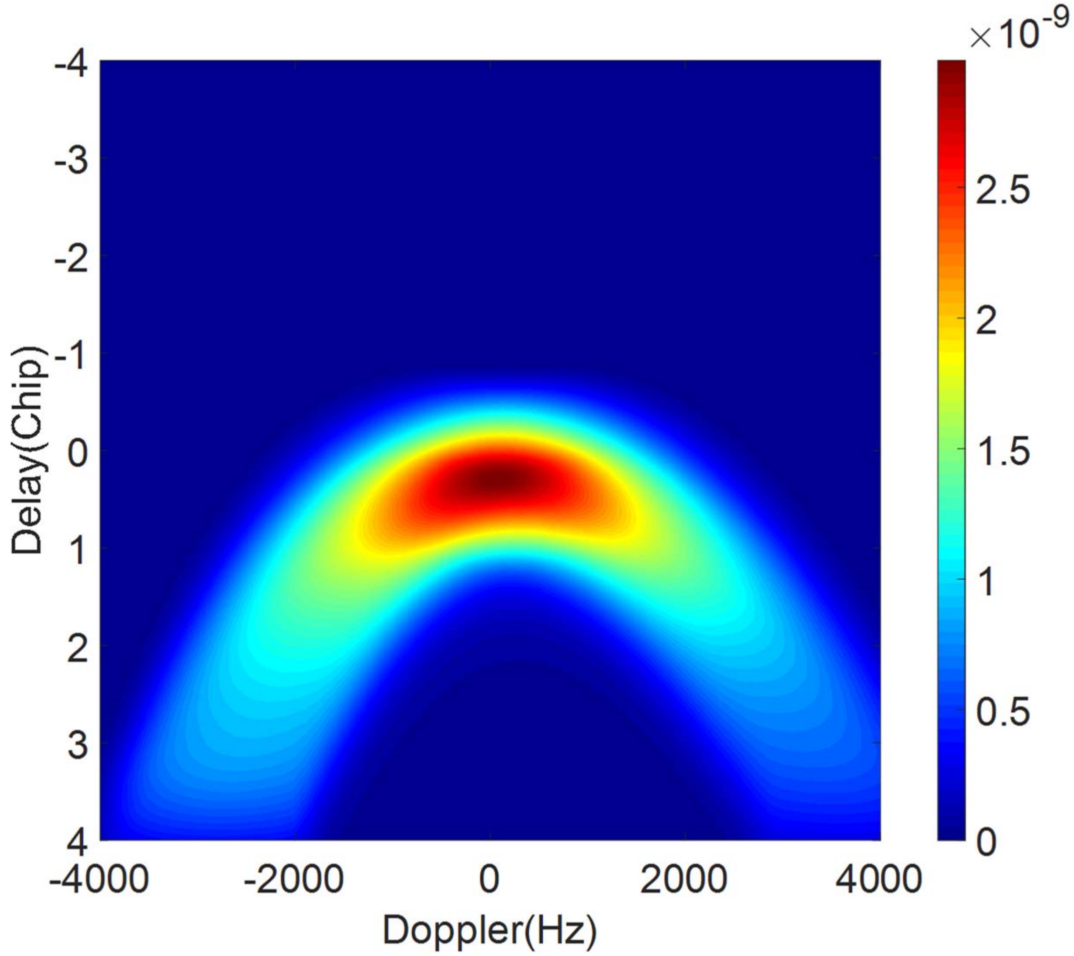

Wind Speed vs. MSSu
MSSu-low freq.
MSSu-high freq.
MSSu-total
MSSu
Wind Speed (m/s)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
10
20
30
40
50
6


Wind Speed vs. MSSc
MSSc-low freq.
MSSc-high freq.
MSSc-total
MSSc
Wind Speed (m/s)
0.03
0.025
0.02
0.015
0.01
0.005
0
0
10
20
30
40
50
60


2015/09/23 - 06:00 UTC
MSSu
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
28°N
24°N
20°N
16°N
12°N
120°E
126°E
132°E
138°E
144°E


2015/09/23 - 06:00 UTC
MSSc 10^-3
14
12
10
8
6
4
2
28°N
24°N
20°N
16°N
12°N
120°E
126°E
132°E
138°E
144°E

DDM from Spectrum Data



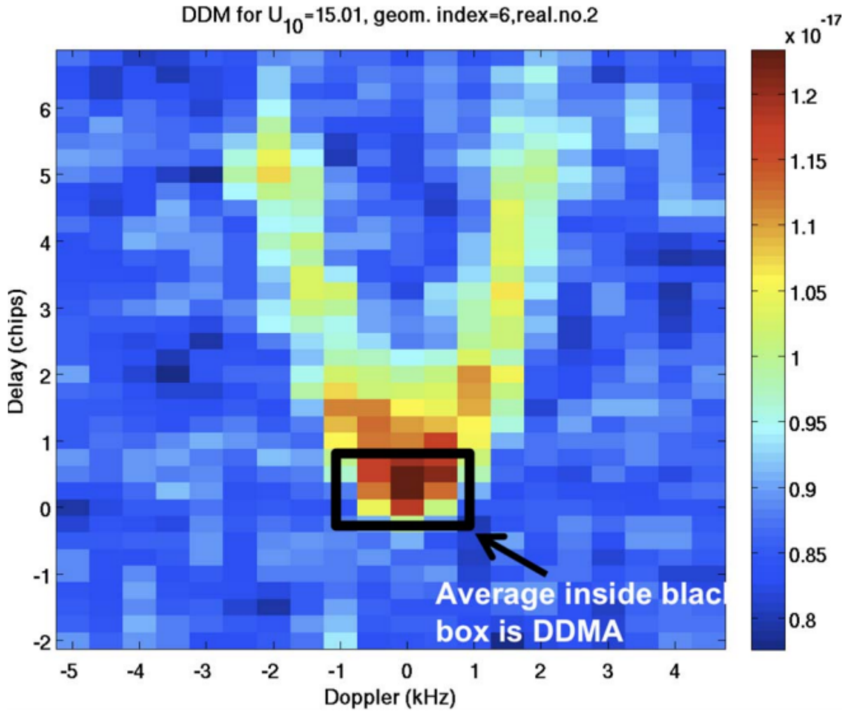
Observable:
Delay Doppler Map Average (DDMA)

DDMA is the average scattered power computed over the DDM around the SP:

The DDMA exploits the region in the DDM that is most sensitive to varying wind speed

Two important parameters that characterizes the DDMA:

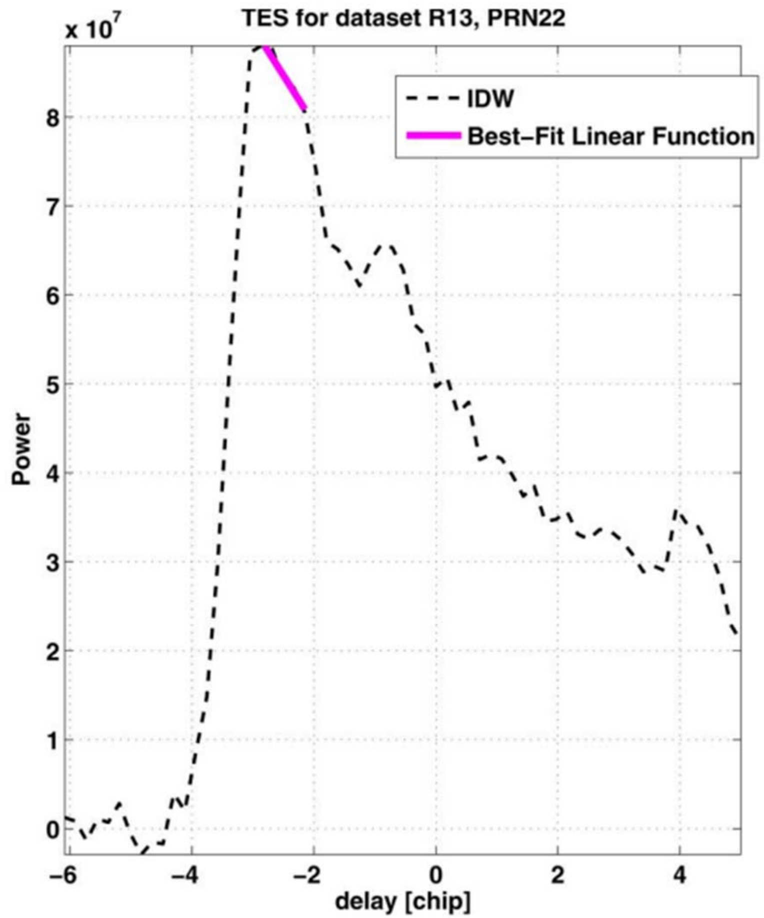
- The location of the SP in the DDM
- The delay and Doppler ranges over which to average DDMA

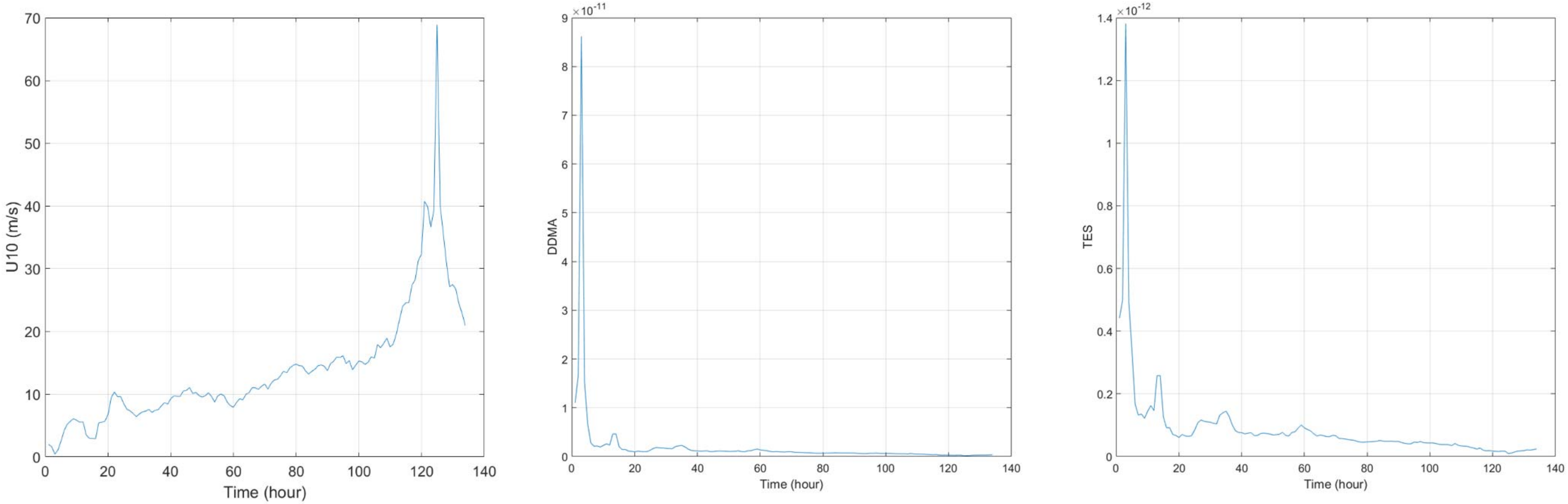


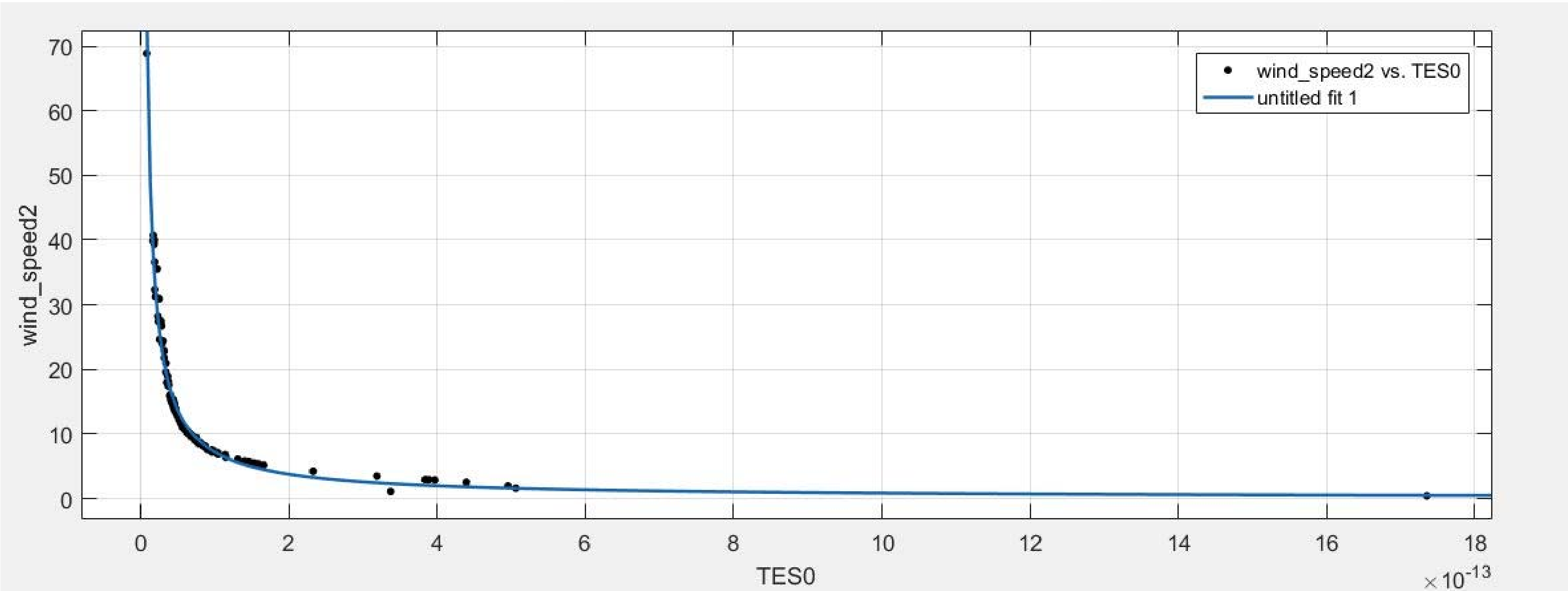
Trailing Edge Slope (TES)

The IDW also has a trailing edge whose slope responds to changes in the wind speed

The TES is calculated as the slope of the waveform region extending from the waveform peak to 0.75 chips from the peak



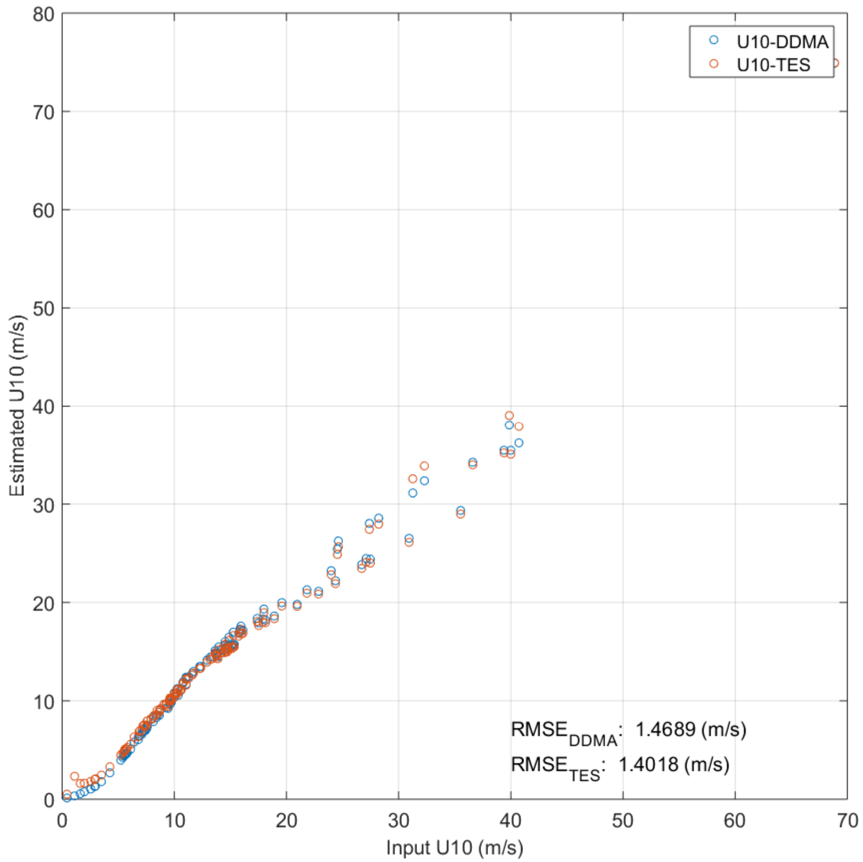




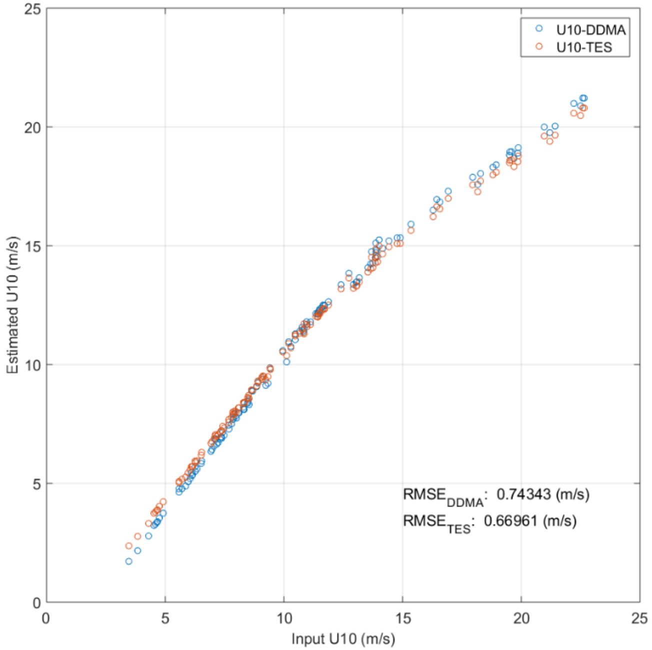
$$wind\_DDMA = 2.964*(10^{-11})*(DDMA^{-0.9619})$$

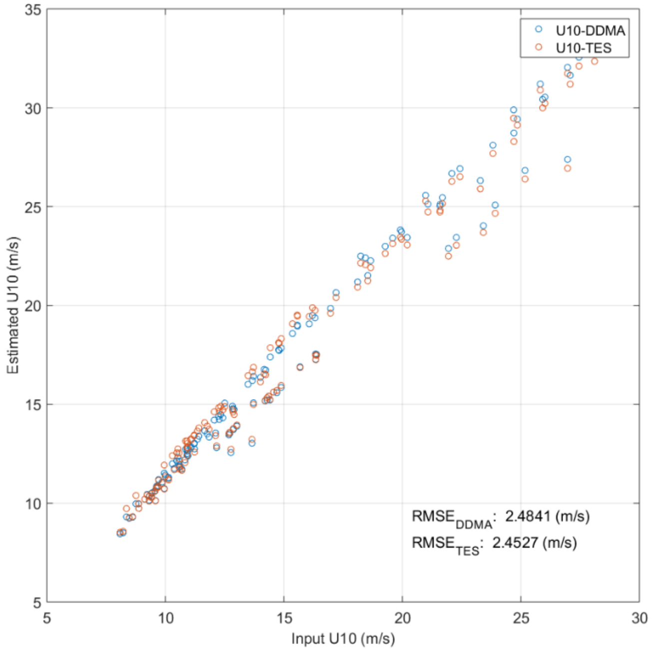
$$wind\_TES = 6.441*(10^{-12})*(TES^{-0.9268})$$

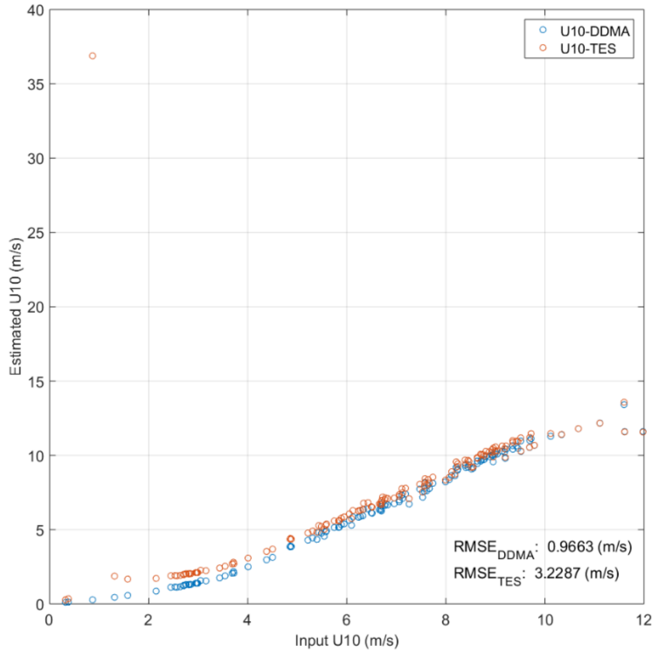
Estimated U10 – compared to U10 from model

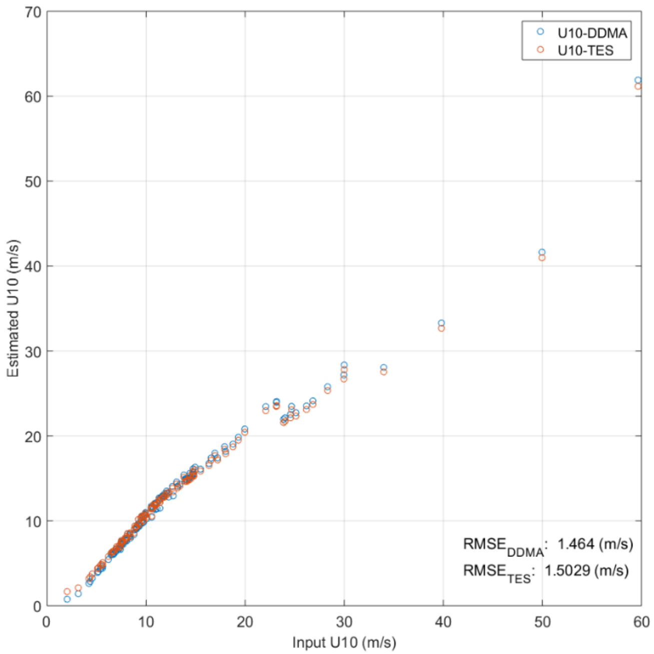


Apply GMF to other data points

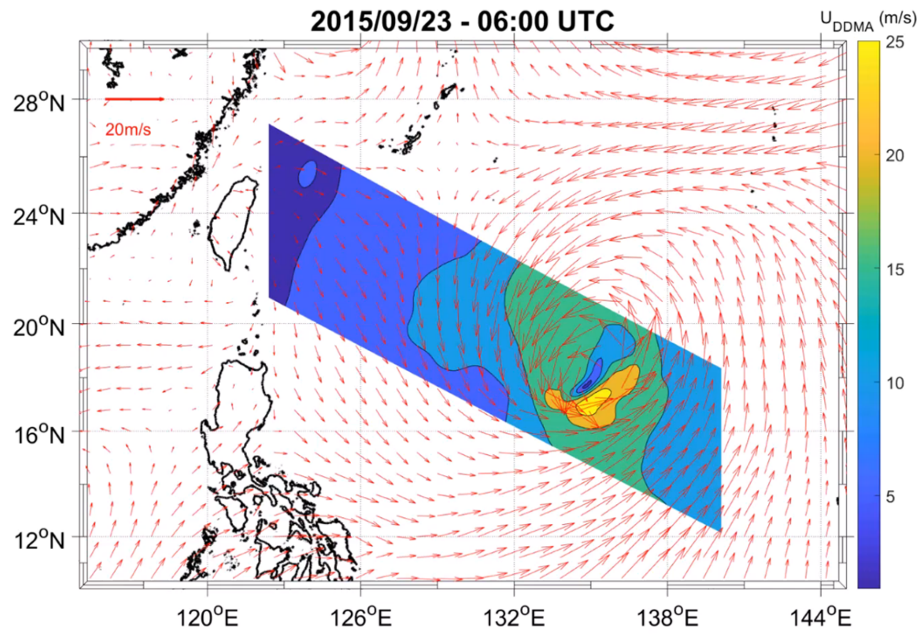




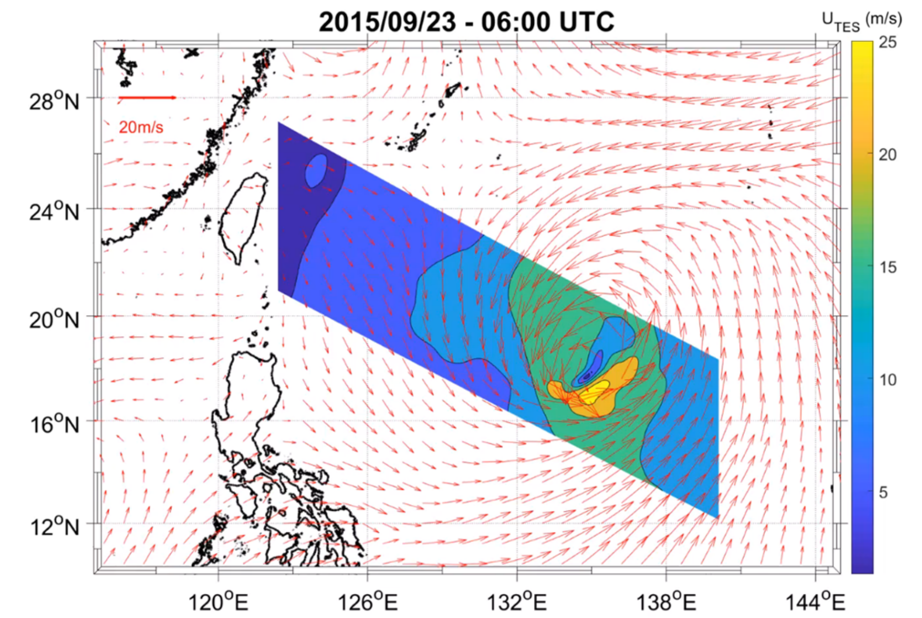


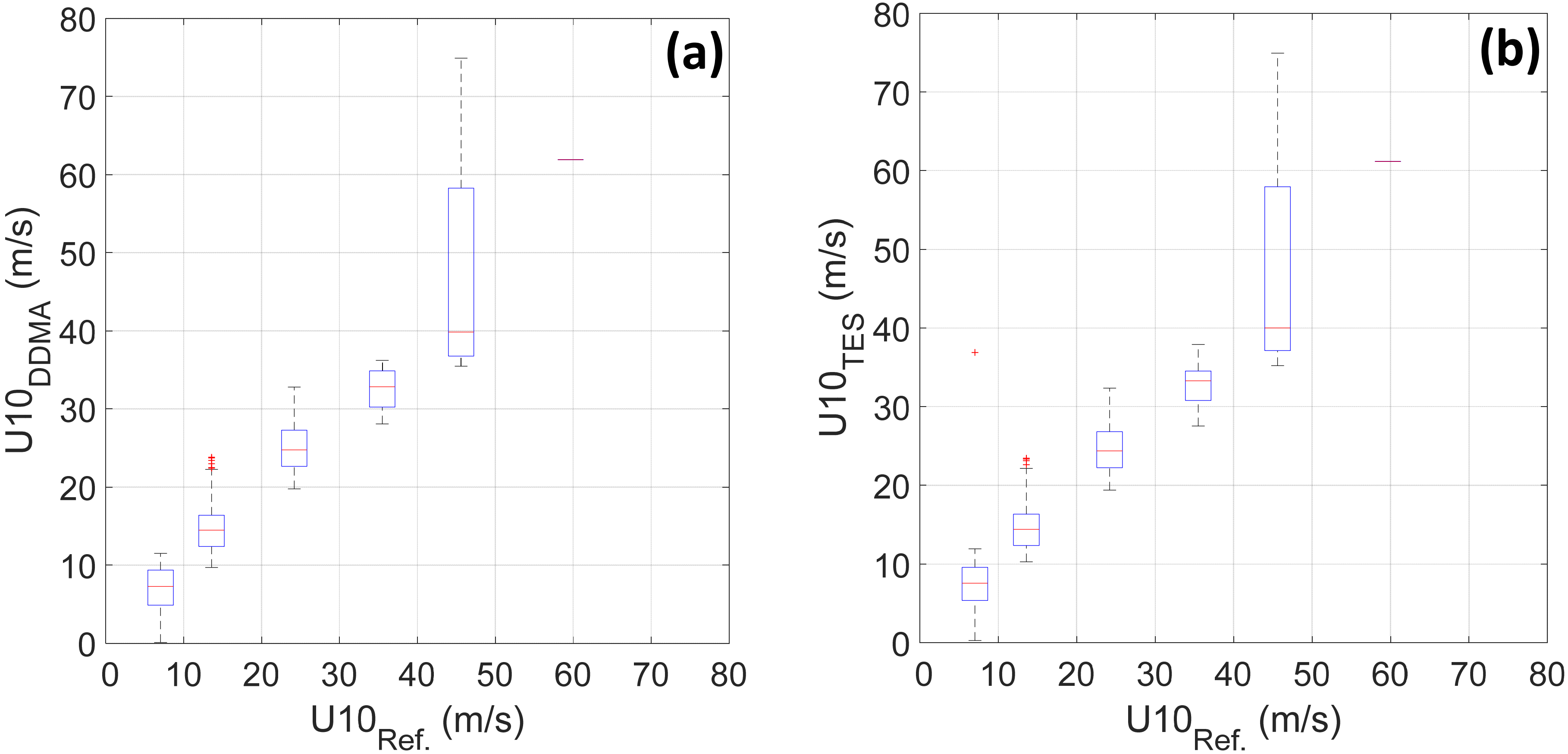


Re-Constructed U_{10} field using DDMA



Re-Constructed U_{10} field using TES





The uncertainties of retrieved wind speed using 2 observables DDMA (a) and TES (b) compared to reference wind speed (horizontal axis).

Summary

- In low wavenumber part, the contribution from wave and swell to total MSS increase rapidly with wind speed for $U_{10} > 40$m/s.
- The principle wave slope direction exhibit significant difference to wind direction in typhoon. In high wind speed regime of typhoon, the DMSS (upwind, cross-wind) are scattered leading to the uncertainty of U_{10} estimation.
- The DMSS are scatter due to the huge spatial variability of wave directional spreading and the deviation of wind and wave direction.
- Better parameterization model of DMSS in typhoon is needed based on observation.