Typhoon Observation Based on GNSS-R Technology

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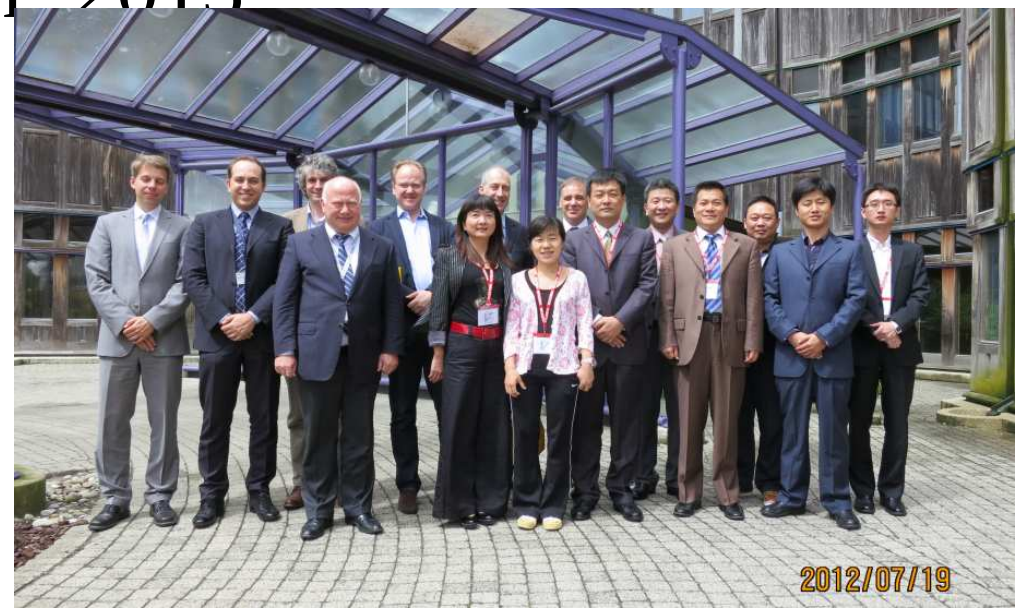
OUTLINE

1. China-Europe joint GNSS-R work group
2. Typhoon and its waveforms
3. Typhoon Detection experiment
4. Summary

1. China-Europe joint GNSS-R work group

- in Nov. 2011, MOST and ESA signed a cooperation agreement on space science and technology area.
- During Munich satellite navigation summit in March 2012, Prof. Hein (ESA) and Jing Zhao(NRSCC) discussed on the cooperation interest in GNSS-R.
- Both sides agreed to set up the joint work group in Jun. 2012 and appointed five members in China side:
  - Convener/Coordinator: Dongkai Yang
  - Member: Yunchang Cao, Yueqiang Sun, Yun Zhang, Songhua Yan

- from 19-22 July, 2012, the work group organize the first workshop in ESTEC, Netherland
- 16 delegates attend the discussion on the GNSS-R and its applications
- It was decided that the 2nd workshop would be held in Shanghai in October, 2013



Workshop in August 2013 in Shenzhen

- in 29/8/2013, Shenzhen
- Presentations
  - Dongkai Yang: GNSS reflectmetry status in China and potential CN_EU cooperation
  - Weiqiang Li: Typhoon observation utilizing GNSS-R technique
  - Yunchang Cao: BeiDou application in Meteorology
  - Cong Yin: Brief introduction on the Typhoon Experiment
  - Antonio Rius: Fundamental on GNSS-R Techonology
  - Zhuang Hongbo: Shenzhen Meterological Observation system and its applications
- Teleconference on the status of TIGRIS in 30/8/2013 and 27/9/2013


GNSS REFLECTMETRY IN CHINA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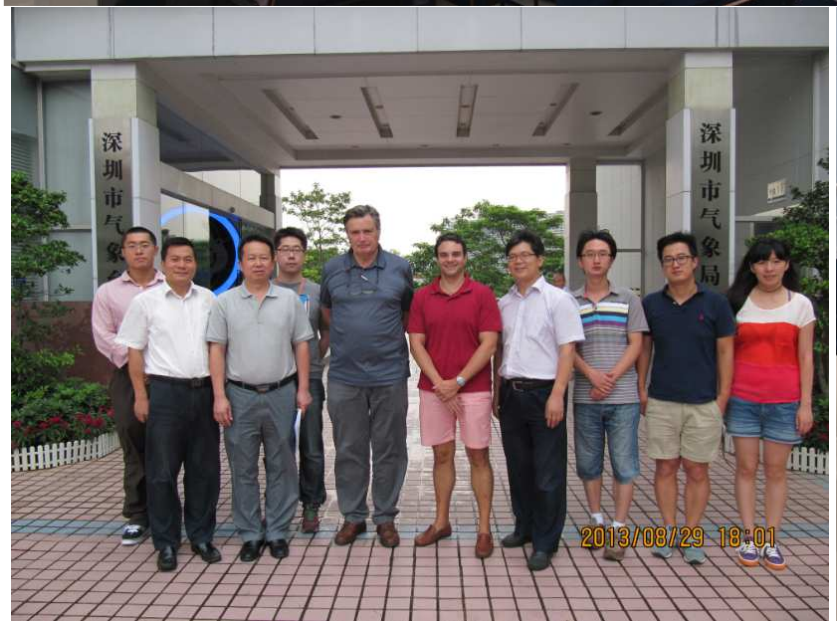
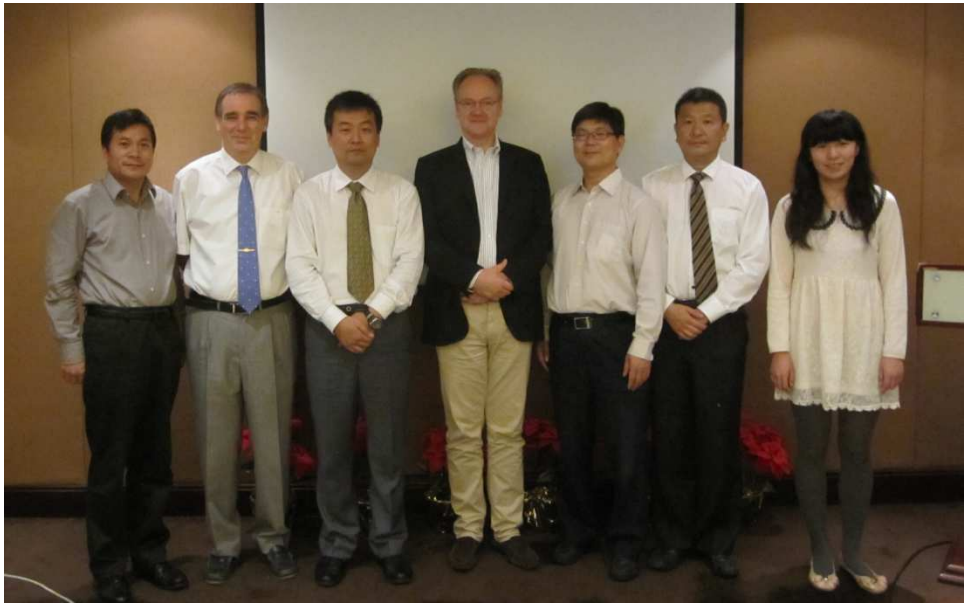

深圳市气象局
深圳市气象局
2013/08/29 18:01

2nd GNSS-R Joint Workshop in October 2013 in Shanghai

- in 14-15, Oct. 2013, Shanghai
- Presentations
  - Dongkai Yang: Review the activities of the working group
  - Martin Neira: ESA activities on GNSS-R area
  - Yunchang Cao: GNSS-R Typhoon Experiment introduction
  - Cong Yin: Typhoon Experiment results analysis
  - Fran Fabra: Preliminary results from IEEC device in Typhoon test
  - LI Weiqiang: Beidou reflections analysis in Typhoon test
  - WU Xiaodan: GNSS-R activities from SHANGHAI aerospace electronic technology institute
  - MENG Wanting: GNSS-R application in Sea Ice detection



2.Typhoon and its waveforms

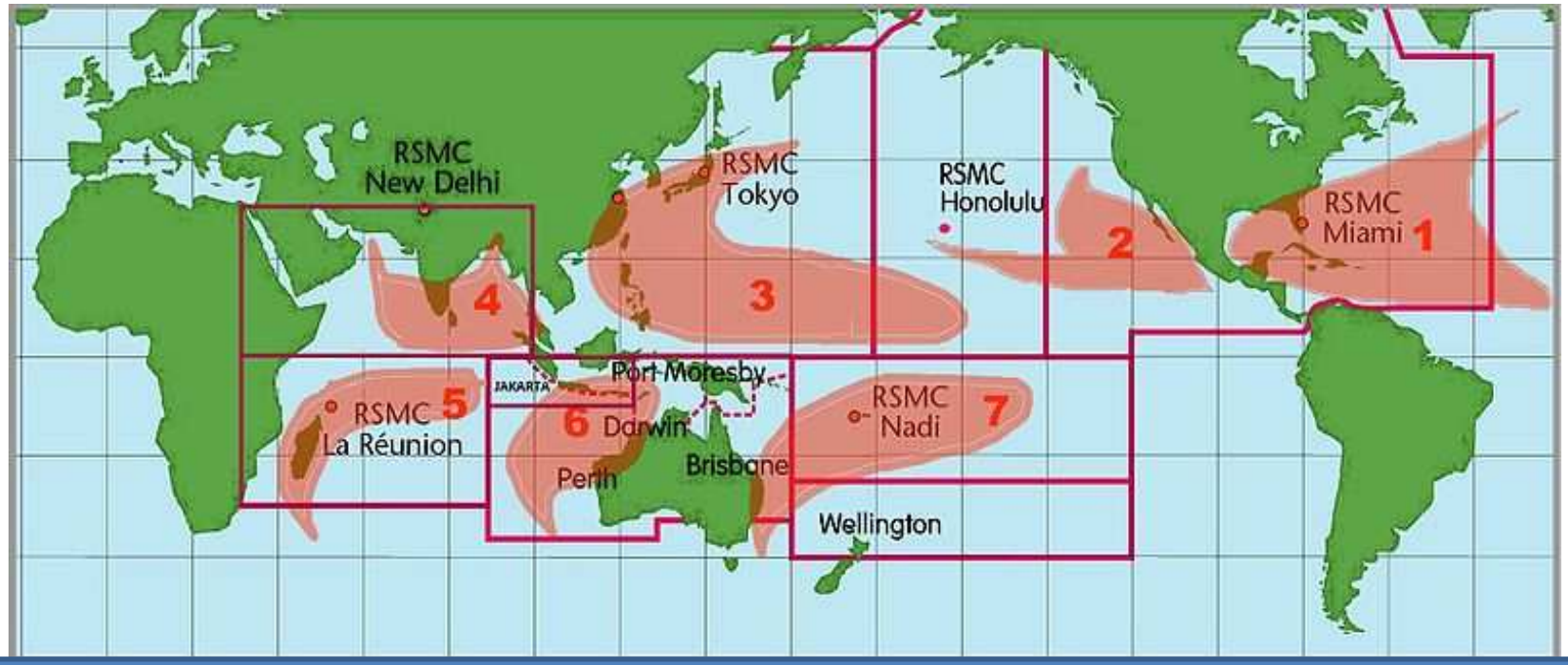
Definition: A **Typhoon** (or **Hurricane)**is a mature **Tropical Cyclone** (wind speed ⩾**32.7m/s** according to the World Meteorological Organization (WMO)).

Category By Wind Intensity（Saffir–Simpson scale）

Category	Wind speeds
Five	⩾70 m/s, ⩾137 kts, ⩾157 mph, ⩾252 km/h
Four	58-70 m/s, 113–136 kts, 130–156 mph, 209–251 km/h
Three	50-58 m/s, 96–112 kts, 111–129 mph, 178–208 km/h
Two	43-49 m/s, 83–95 kts, 96–110 mph, 154–177 km/h
One	33-42 m/s, 64–82 kts, 74–95 mph, 119–153 km/h
Additional classifications	
Tropical storm	18-32 m/s, 35–63 kts, 39–73 mph, 63–118 km/h
Tropical depression	<17 m/s, <34 kts, < 38 mph, <62 km/h

Location

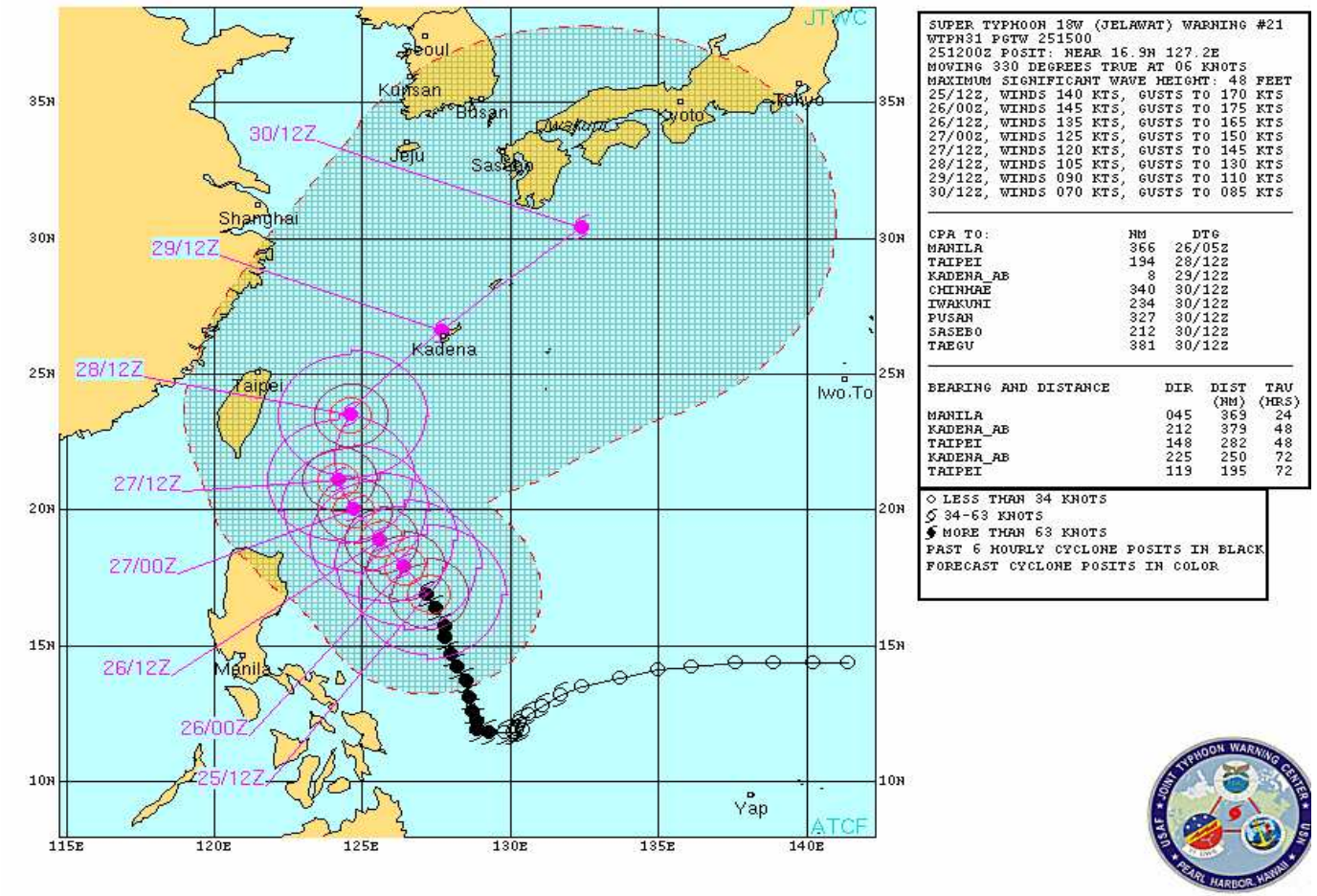
Traditionally, areas of tropical cyclone formation are divided into seven basins. These include the *north Atlantic Ocean*, *the eastern and western parts of the northern Pacific Ocean*, *the southwestern Pacific*, *the southwestern and southeastern Indian Oceans*, and *the northern Indian Ocean (Arabian Sea and Bay of Bengal)*



HAIYAN (Yolanda) affects two-third of Philippines' island chain and the wind gusts 380kph was recorded. 100 people died.

Development and duration

Tropical cyclones have a distinct life cycle of about 4-7 days and the movement of tropical cyclone is not very quick - it only moves at about 20 or 30 km/h.



SUPER TYPHOON 18W (JELAWAT) WARNING #21
WTPN31 PGTW 251500
251200Z POSIT: NEAR 16.9N 127.2E
MOVING 330 DEGREES TRUE AT 06 KNOTS
MAXIMUM SIGNIFICANT WAVE HEIGHT: 48 FEET
25/12Z, WINDS 140 KTS, GUSTS TO 170 KTS
26/00Z, WINDS 145 KTS, GUSTS TO 175 KTS
26/12Z, WINDS 135 KTS, GUSTS TO 165 KTS
27/00Z, WINDS 125 KTS, GUSTS TO 150 KTS
27/12Z, WINDS 120 KTS, GUSTS TO 145 KTS
28/12Z, WINDS 105 KTS, GUSTS TO 130 KTS
29/12Z, WINDS 090 KTS, GUSTS TO 110 KTS
30/12Z, WINDS 070 KTS, GUSTS TO 085 KTS

CPA TO:	NM	DTG
MANILA	366	26/05Z
TAIPEI	194	28/12Z
KADENA_AB	8	29/12Z
CHINHAE	340	30/12Z
IWAKUNI	234	30/12Z
PUSAN	327	30/12Z
SASEBO	212	30/12Z
TAEGU	381	30/12Z

BEARING AND DISTANCE	DIR	DIST (NM)	TAU (HRS)
MANILA	045	369	24
KADENA_AB	212	379	48
TAIPEI	148	282	48
KADENA_AB	225	250	72
TAIPEI	119	195	72

○ LESS THAN 34 KNOTS
◯ 34-63 KNOTS
● MORE THAN 63 KNOTS
PAST 6 HOURLY CYCLONE POSITS IN BLACK
FORECAST CYCLONE POSITS IN COLOR

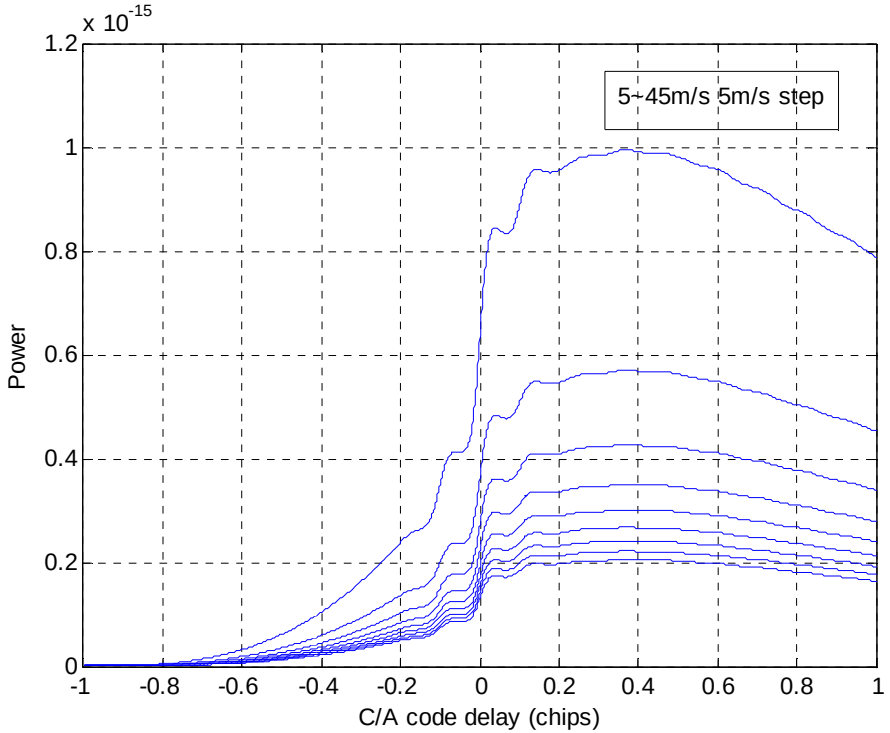
Waveform

The power waveform can be presented as the convolution of the spatial related ocean scattered parameters and the SWH related magnitude-squared Cross Correlation Function (CCF) of the composite signal.

$$Z(\tau) = \int_{\tau-\tau_c}^{\tau+\tau_c} W(\tau_D)U(\tau - \tau_D)d\tau_D$$

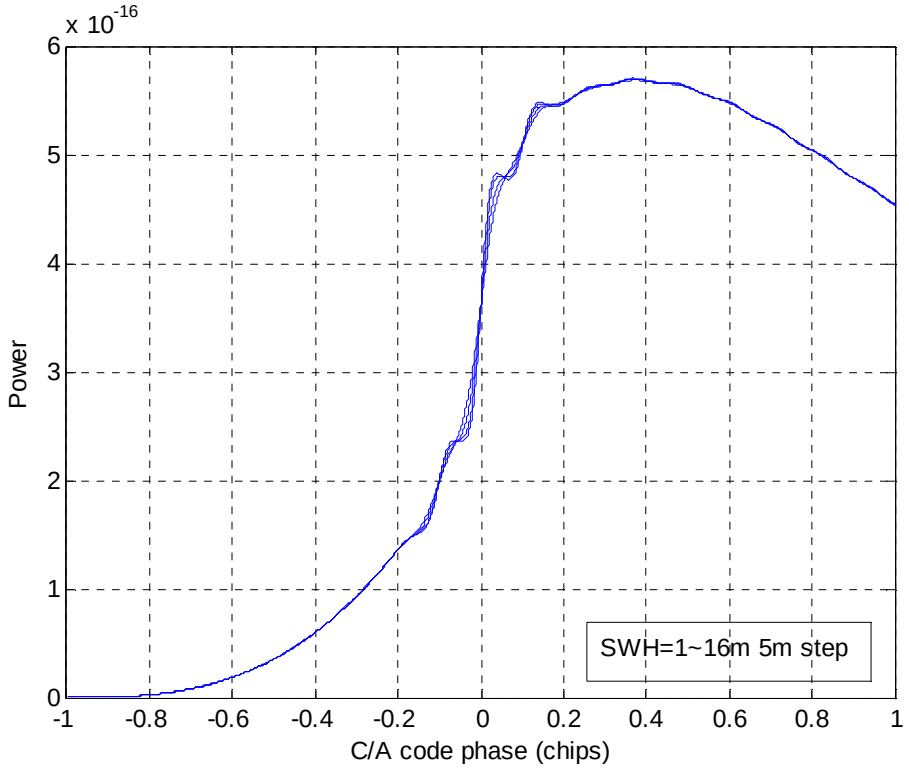
- τ_D is the relative time delay to the specular point ($\tau_D \geq 0$ according to the definition of the specular point)
- τ_c is the period of the chip in C/A code
- $U(\tau)$ is the reflected power waveform related to the SWH
- $W(\tau_D)$ is the weight function at different time delay as a function of the spatial distribution of the bistatic radar cross section and carrier Doppler

The amplitude of the waveform is sensitive to the wind speed.



Waveforms at different wind speeds

The leading edge slope of the waveform is sensitive to SWH.

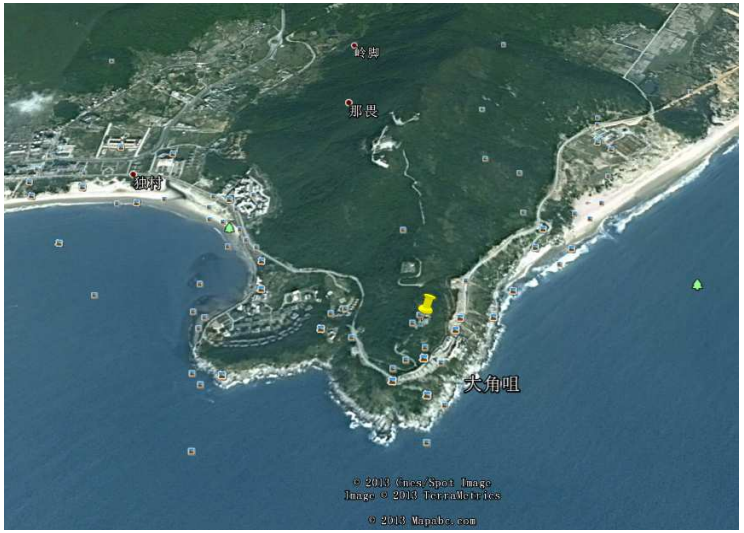


Waveforms at different SWH

3.Typhoon Detection experiment

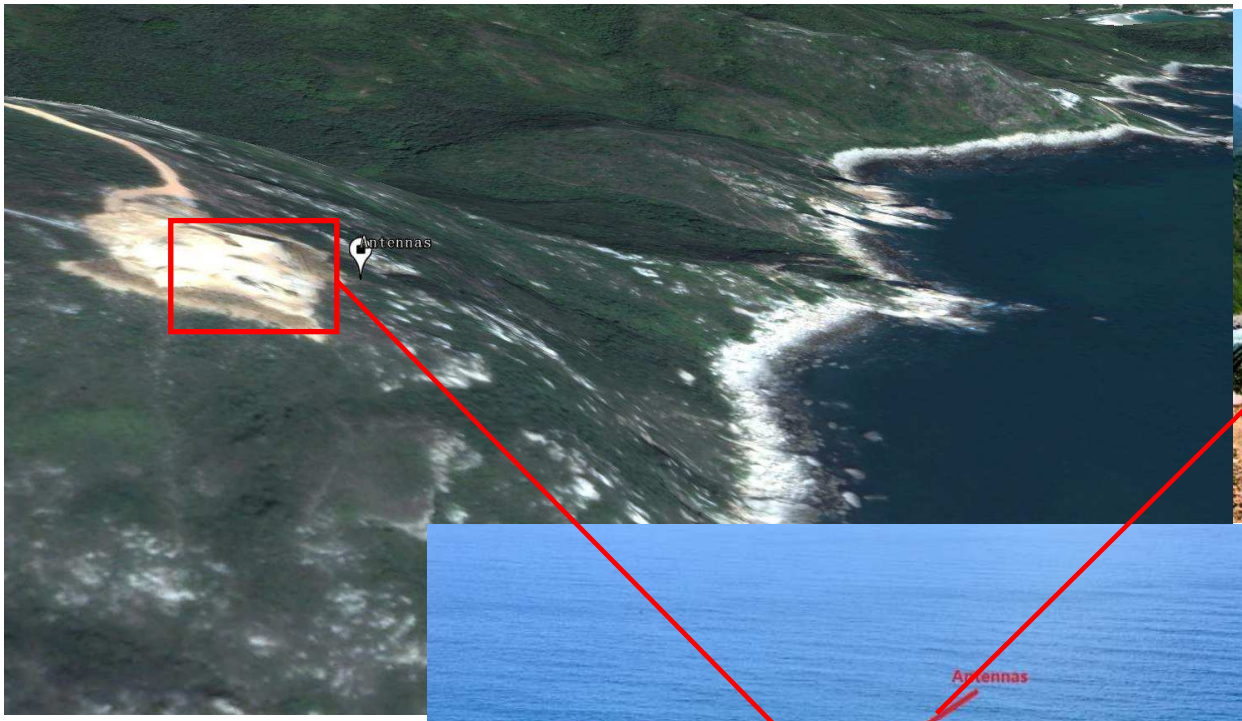
- From July to September 2013, China-Europe jointly performed typhoon detection test in Shenzhen and Yangjiang. It lasts 3 months and got a large number of data (almost 24T). Preliminary data analyze shows good results.

Shenzhen Site (Google earth)



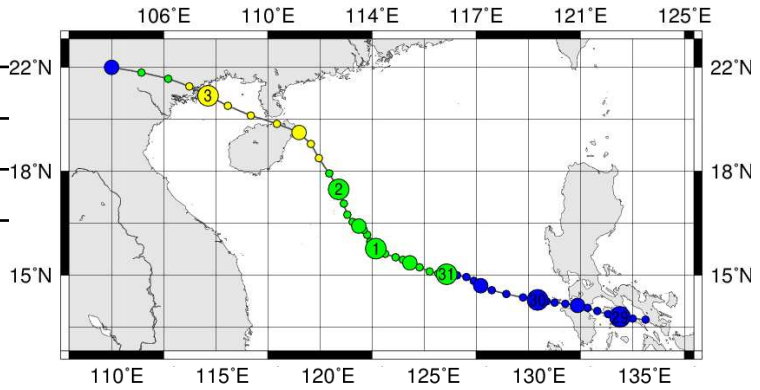
Yangjiang Site (Google earth)

Antennas installation in Shenzhen site



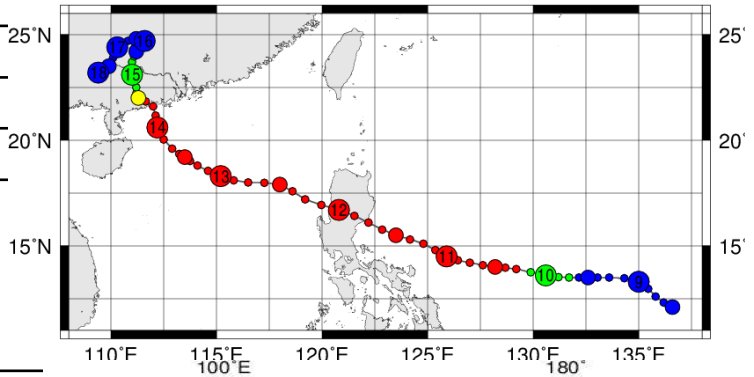
Strong Tropical Storm JEBI (201309)

Site	Start (UTC)	End (UTC)	Data type
Shenzhen	08-01 05:22	08-04 13:33	RAW I.F. samples
Yangjiang	08-02 18:04	08-05 18:00	RAW I.F. samples



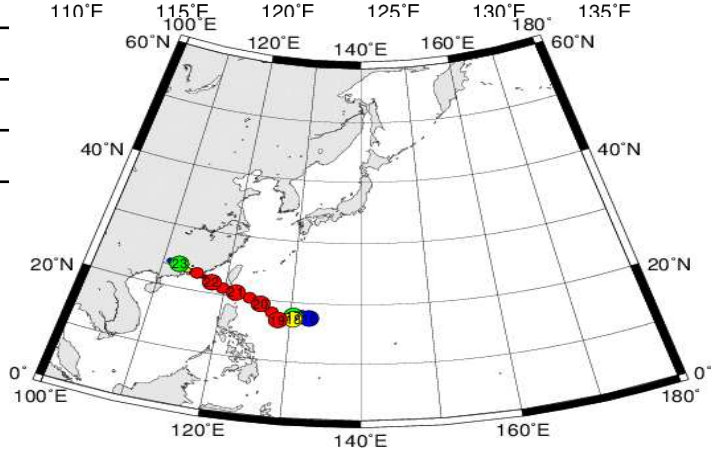
Super Typhoon UTOR (201311)

Site	Start (UTC)	End (UTC)	Data type
Shenzhen	08-13 02:38	08-16 03:00	RAW I.F. samples
Yangjiang	08-12 11:45	08-14 03:00	RAW I.F. samples



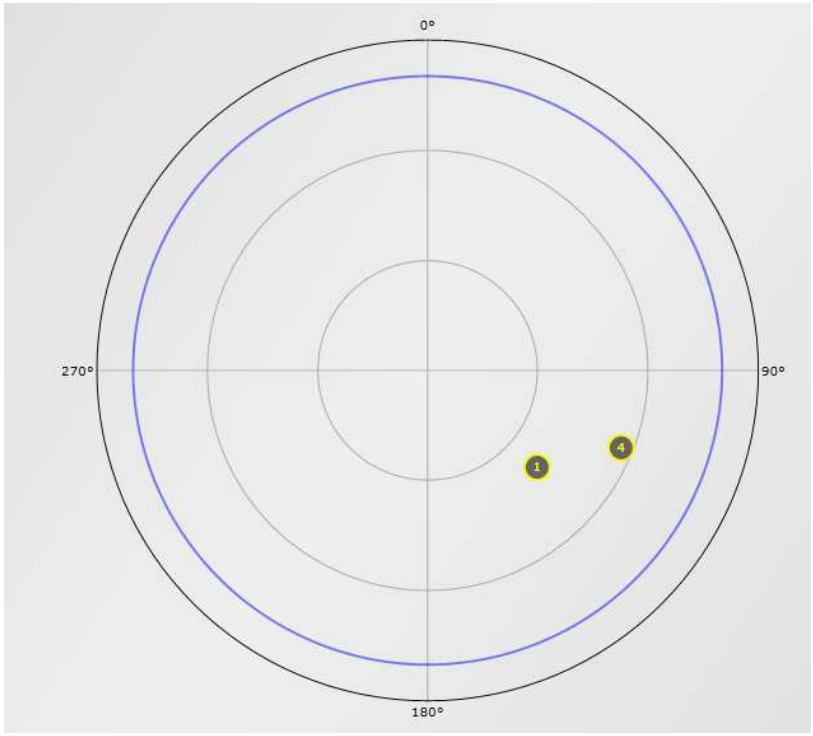
Super Typhoon USAGI (201319, Cat. 5)

Site	Start (UTC)	End (UTC)	Data type
Shenzhen	09-18 00:00	09-24 00:00	RAW I.F. samples

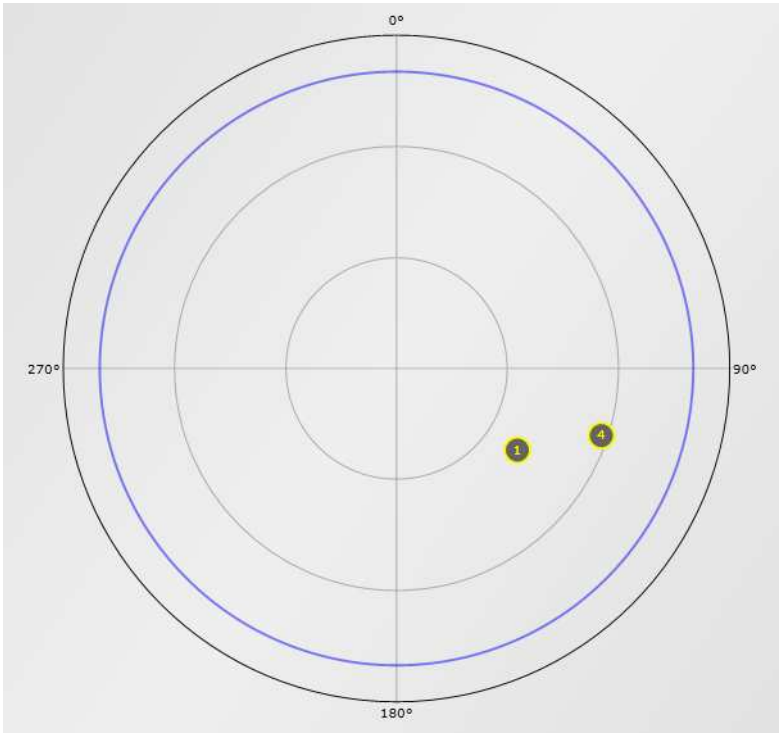


BeiDou GEO #1 and #4, with

- Stable geometry
- Sharper auto-correlation function (2.046 M chips rate)



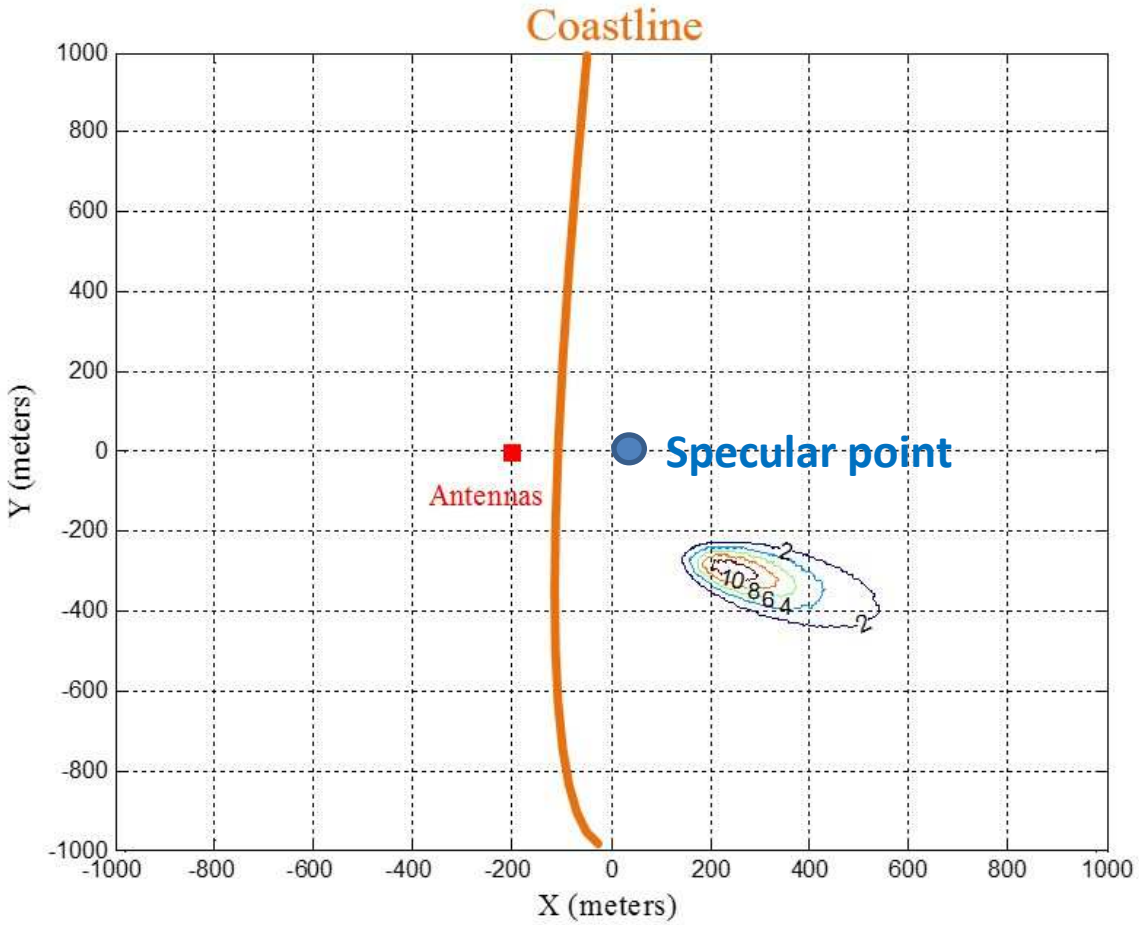
Shenzhen site



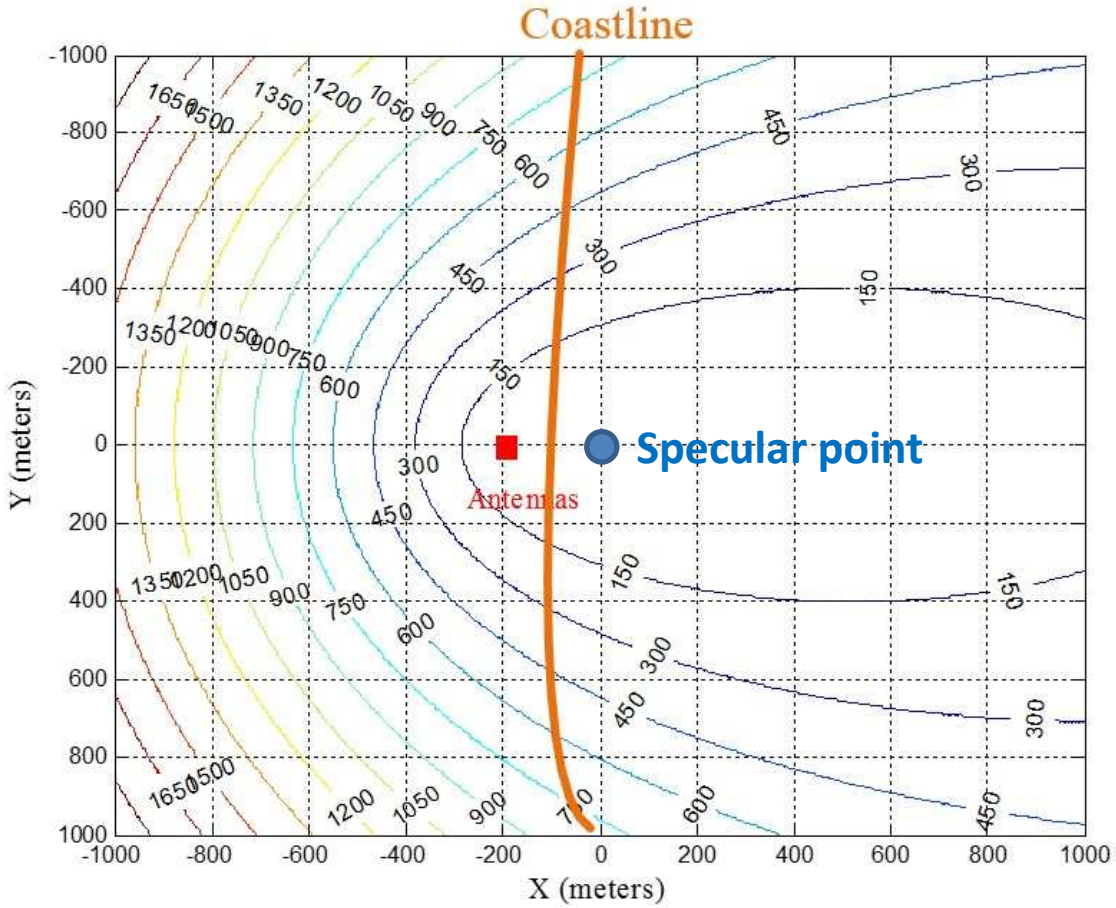
Yangjiang site

Preliminary Data Processing Results

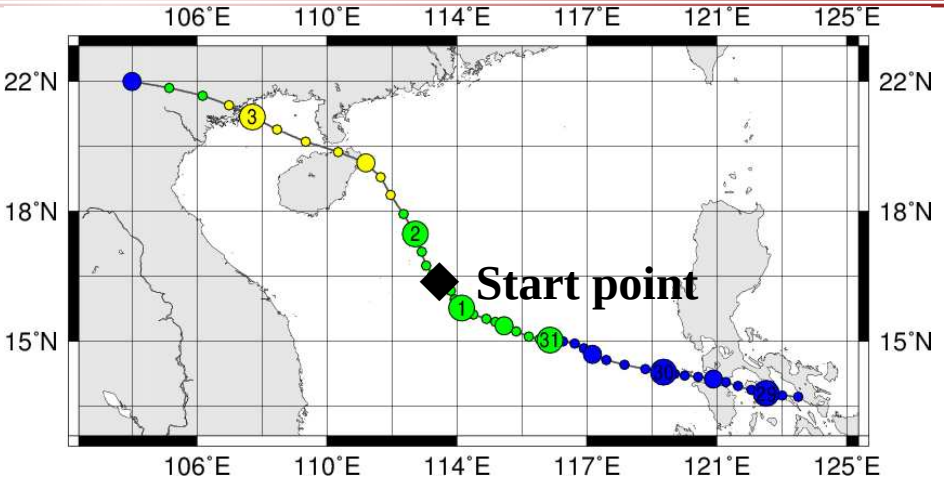
Down-looking high-gain antenna footprint



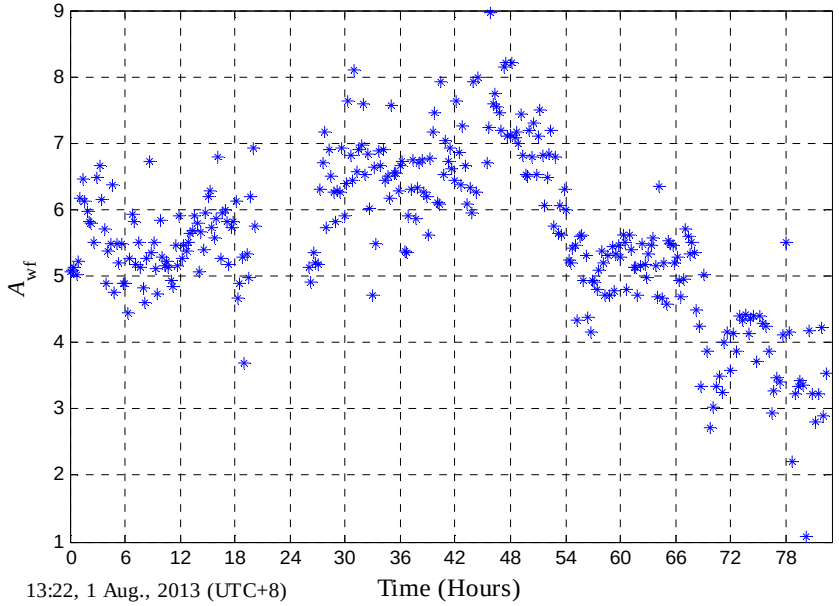
Relationship Between Delay and Spatial Coordinates



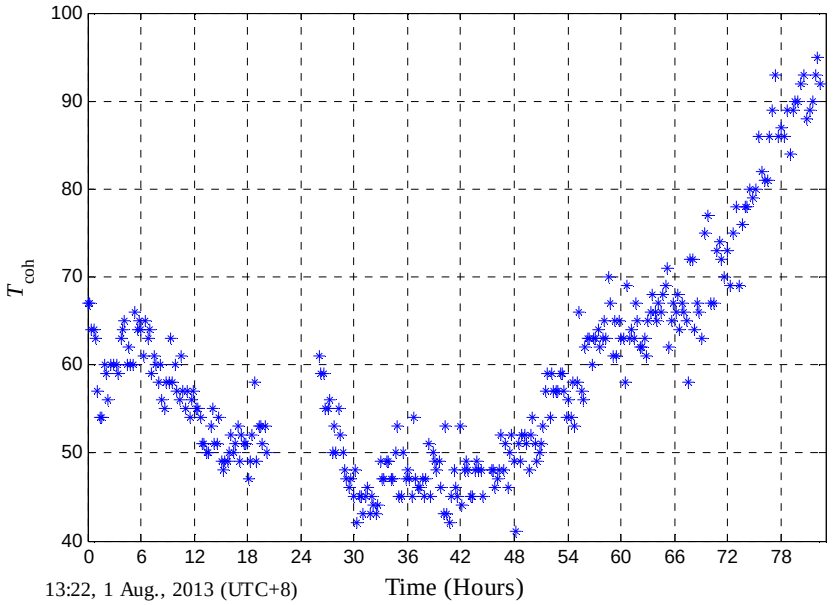
JEBI @ Shenzhen site



- **Waveform parameter**

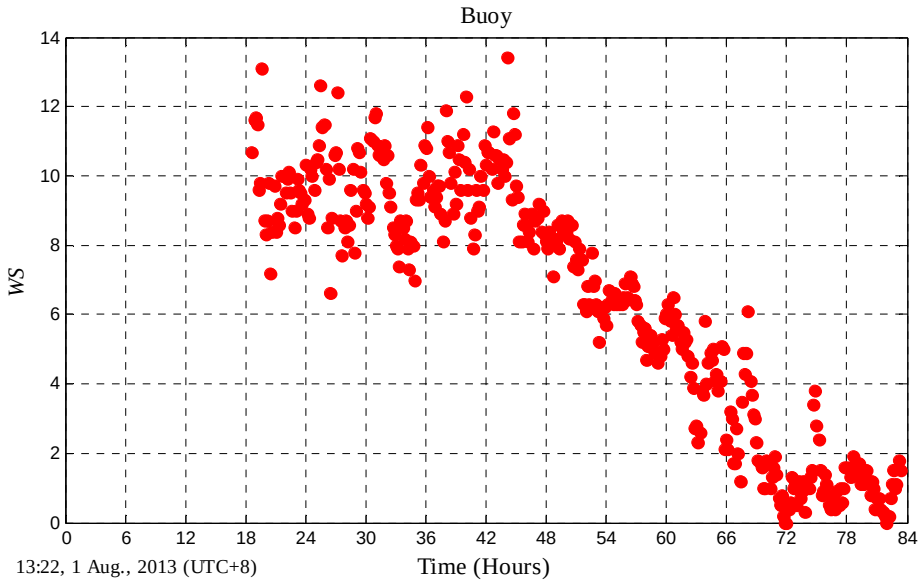


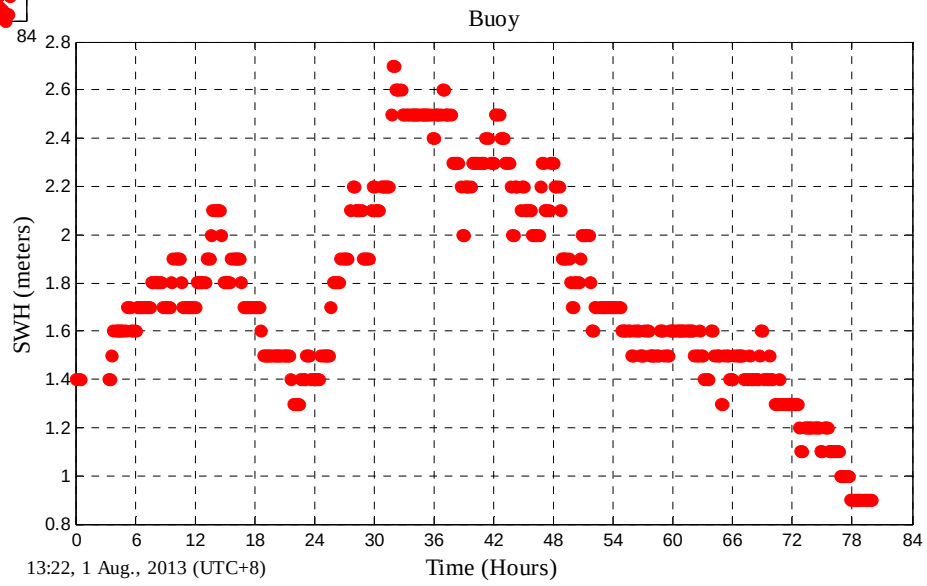
correlation power



correlation time

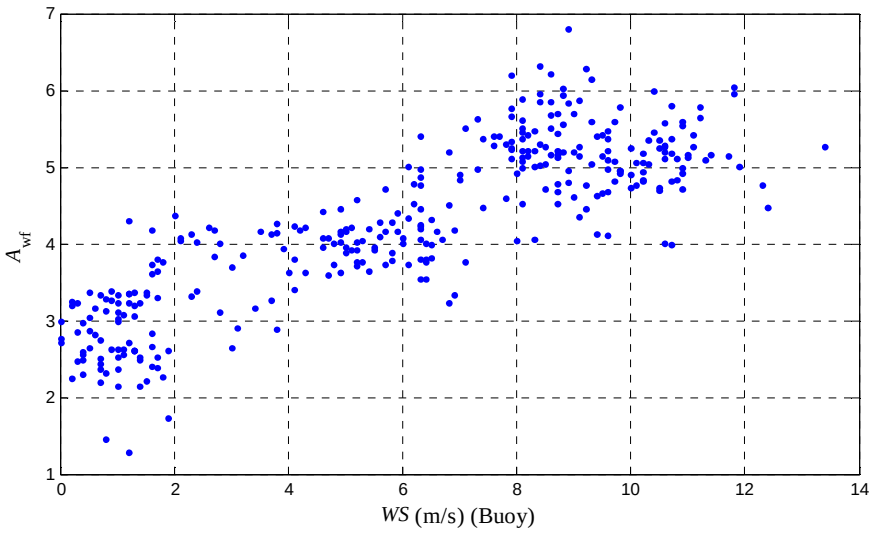
JEBI @ Shenzhen site: *in-situ* WS and SWH measurements

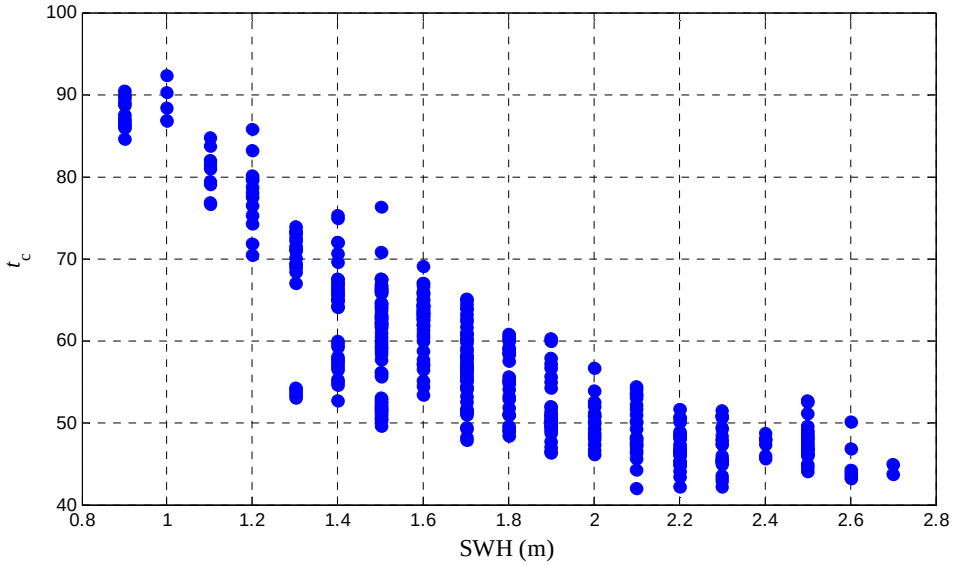




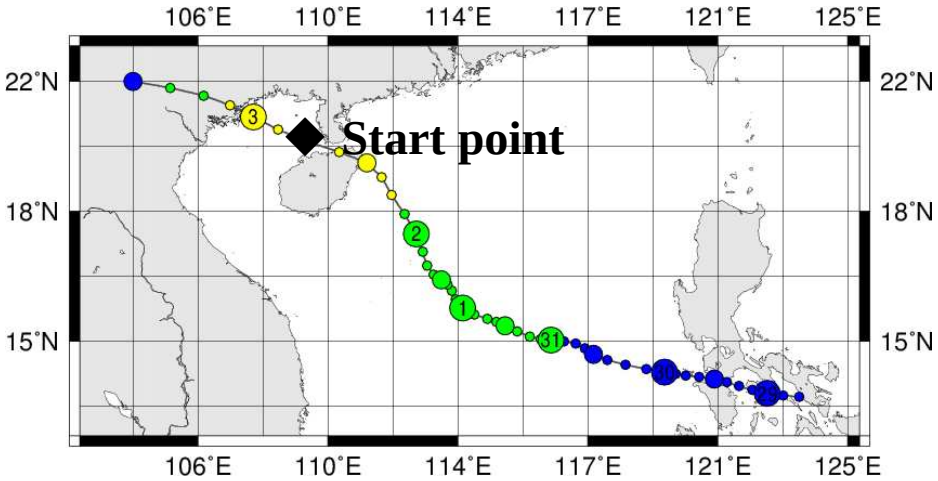
JEBI @ Shenzhen site: comparison between *in-situ* measurement and waveform parameters

Time （Hours）	18	24	30	36	42	48	54	60	66
Corr. Pow.	5.83	5.61	5.98	5.53	6.14	5.41	5.07	4.21	3.22
WS (m/s)	11.2	10.7	11.6	10.4	11.8	8.3	6.5	4.7	3.4
Coh. Time (ms)	62	64	49	45	47	50	61	62	66
SWH (m)	1.6	1.5	2.1	2.5	2.4	2.1	1.7	1.6	1.4

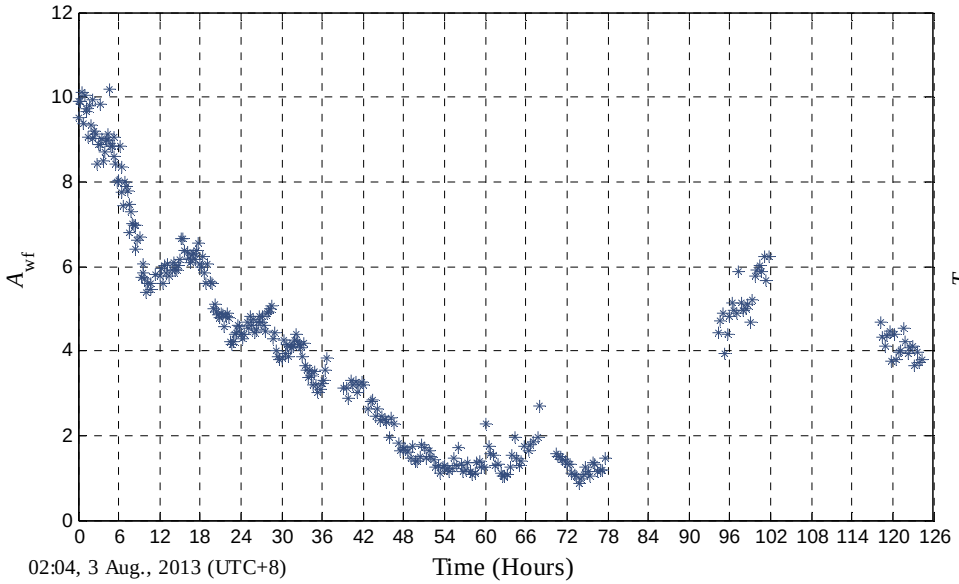




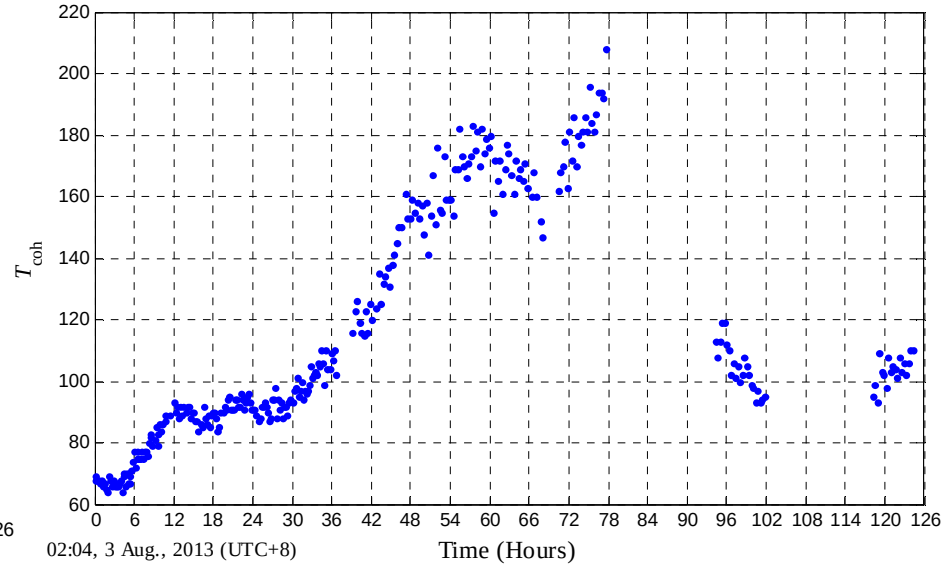
JEBI @ Yangjiang site



- **Waveform parameter**

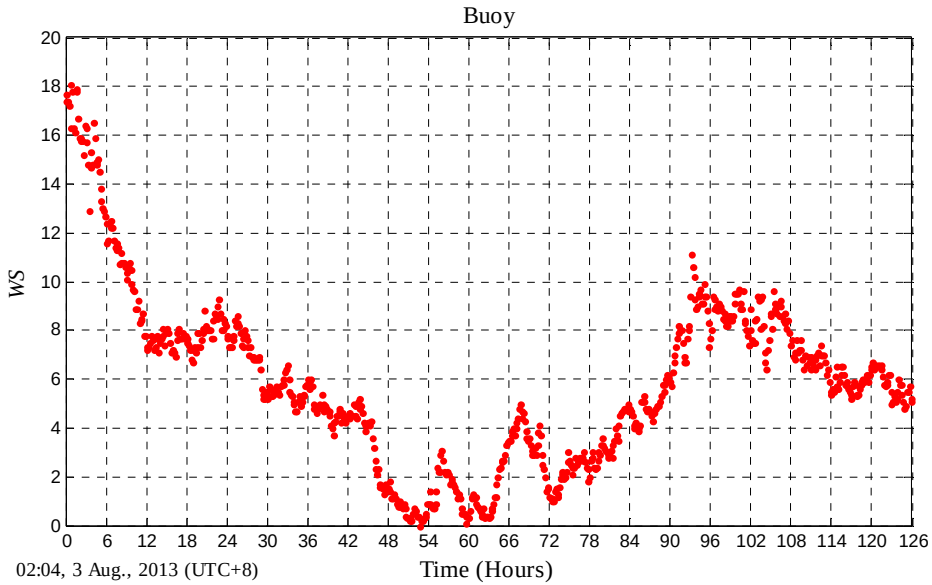


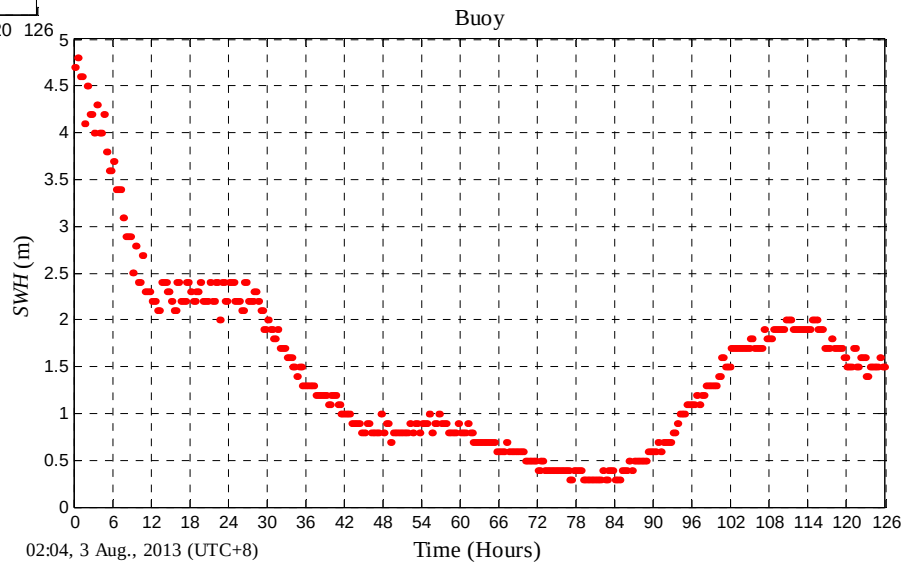
correlation power



correlation time

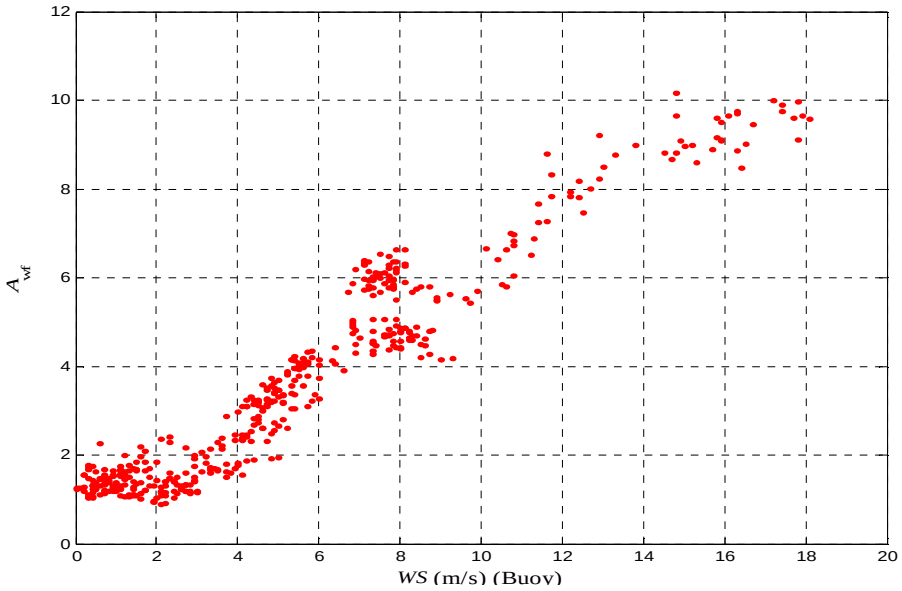
JEBI @ Yangjiang site: *in-situ* WS and SWH measurements

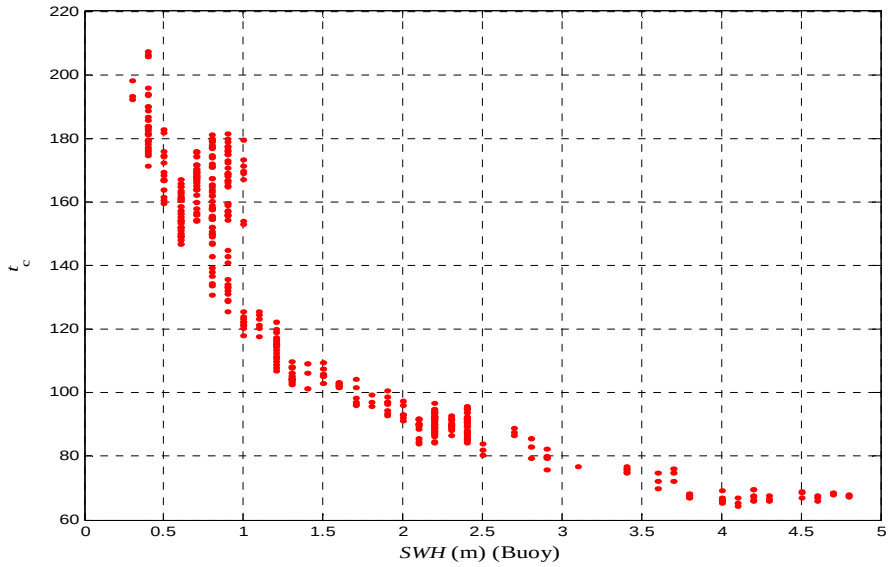




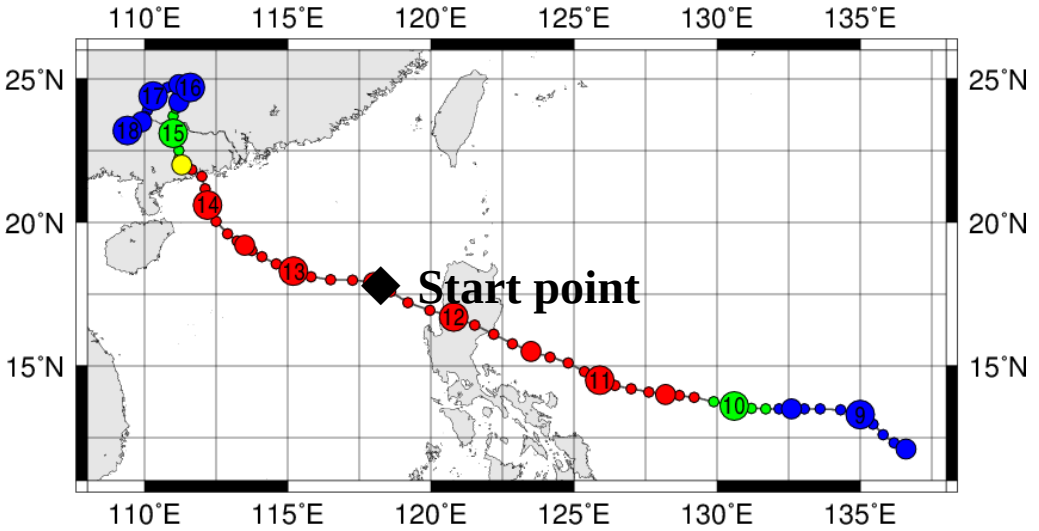
JEBI @ Yangjiang site: comparison between *in-situ* measurement and waveform parameters

Time （Hours）	0	6	12	18	24	30	36	42	48
Corr. Pow.	9.82	8.44	4.53	4.62	4.87	5.41	3.52	2.72	1.73
WS (m/s)	17.3	12.5	7.2	7.4	8.5	5.4	4.8	4.2	1.8
Coh. Time (ms)	67	73	91	94	92	101	111	122	148
SWH (m)	4.8	3.7	2.3	2.4	2.3	1.8	1.3	1.1	0.8

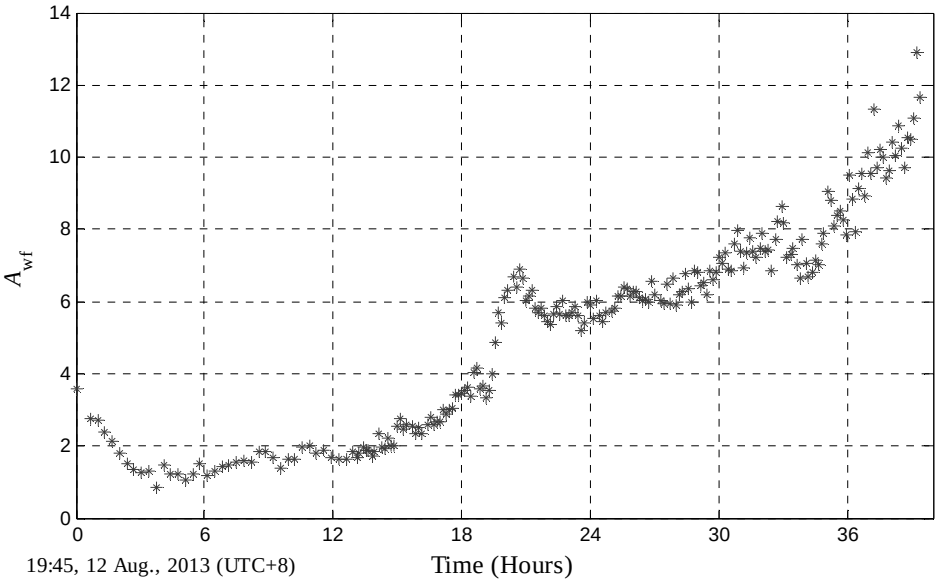




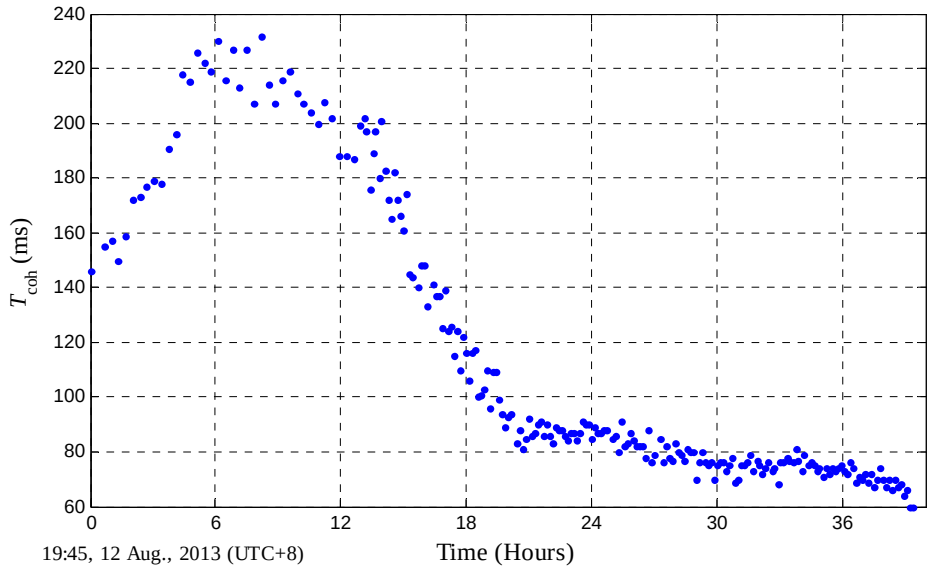
UTOR@ Yangjiang site



- **Waveform parameter**

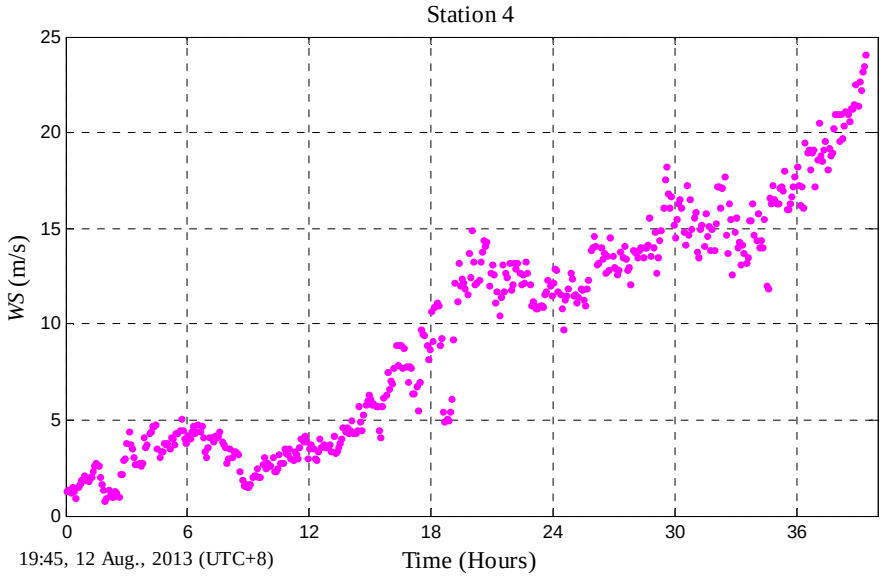


correlation power

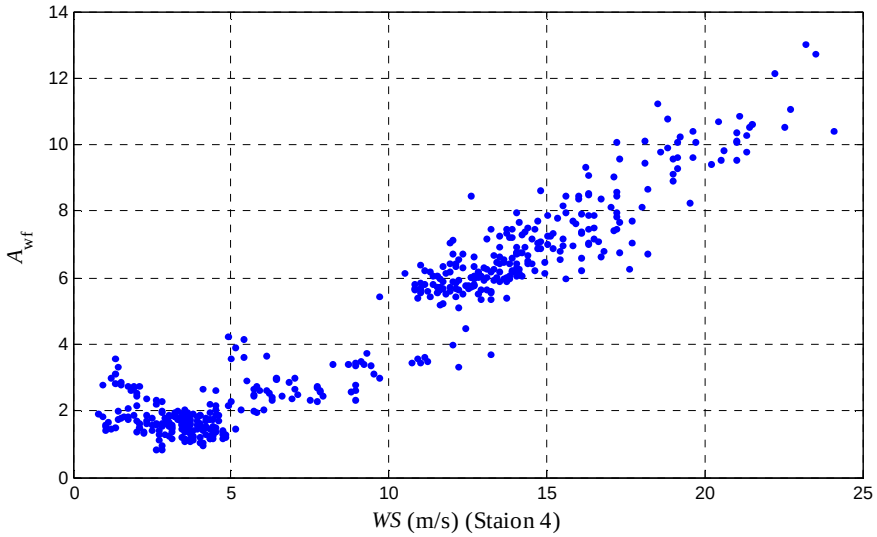


correlation time

UTOR@ Yangjiang site: *in-situ* WS measurements and comparision



Wind speed measurement from the meteorological station



Comparison between in-situ wind speed measurement and waveform parameters

Time （Hours）	0	6	12	18	24	30	36	40
Corr. Pow.	1.73	2.11	2.02	3.45	3.82	6.82	8.64	11.89
WS (m/s)	1.9	4.7	3.8	8.6	11.8	15.2	17.3	24.1

4.Summary

- **Land based GNSS-R receiver configuration is a new way to provide meterological observation data**
- **BeiDou GEO satellites could be used to detect the Typhoon on the observation field**
- **BeiDou reflections has correlation with the existing observation stations result on wind speed measurement**