

Development and Evaluation of Storm Surge Warning System in Taiwan

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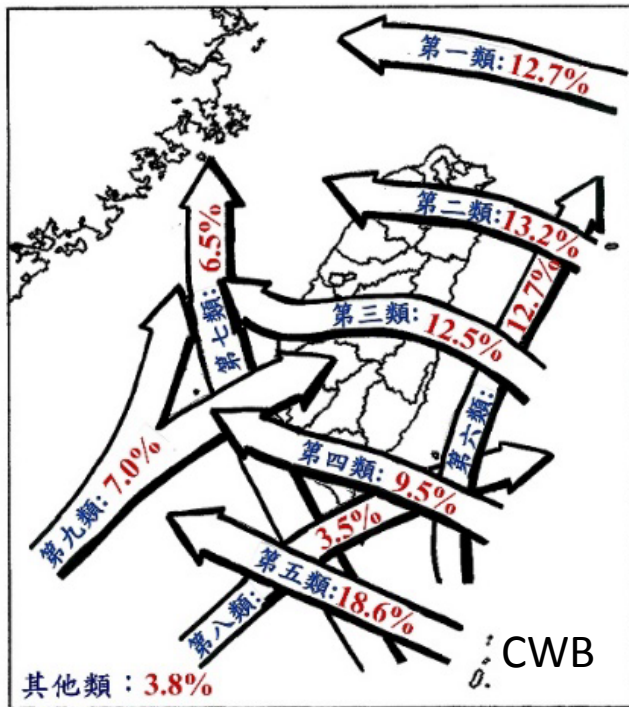
1st International Workshop on Waves, Storm Surges
and Coastal Hazards

Why we established a storm surge warning system

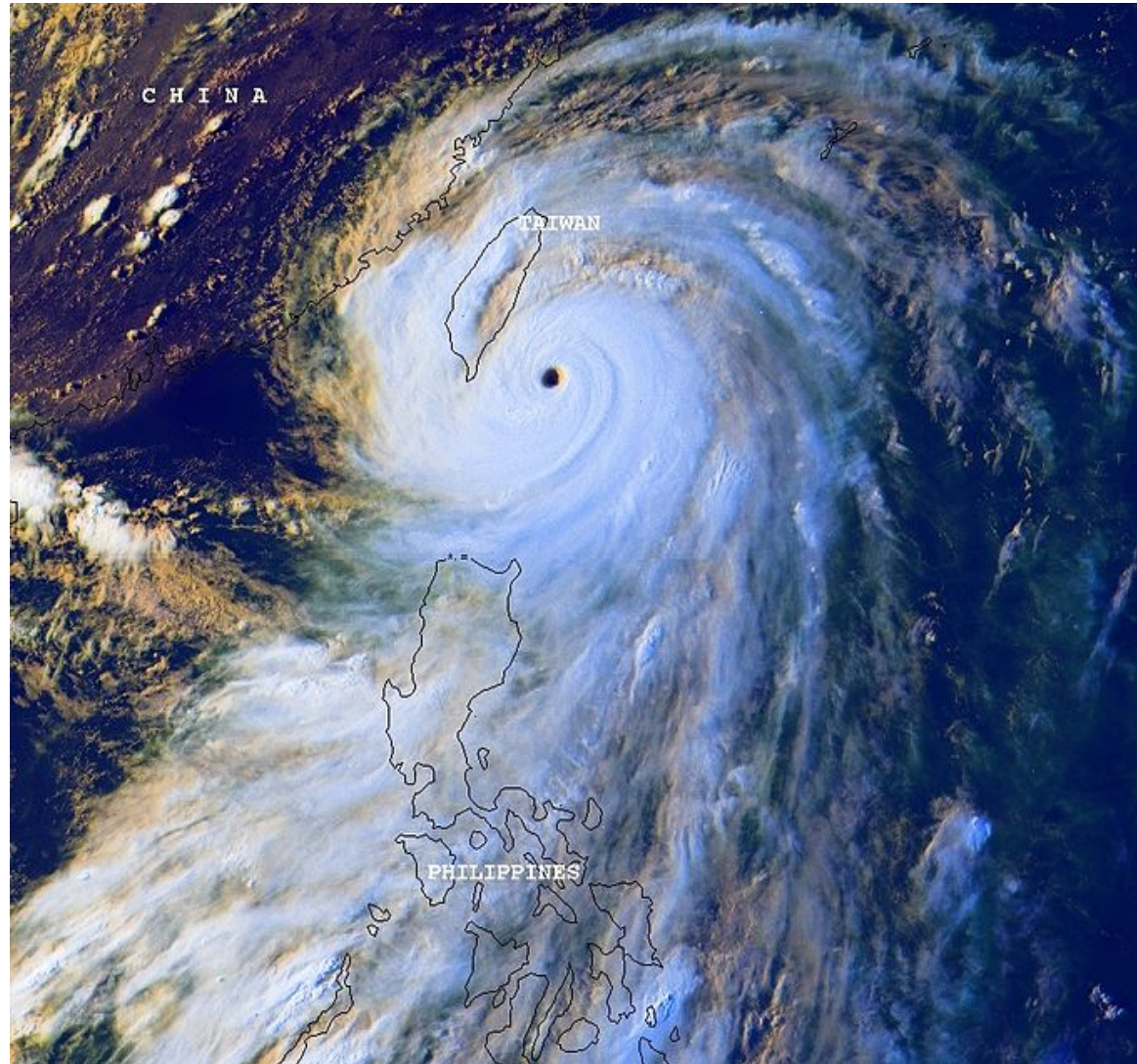


3-4 typhoons in a year

NARLabs



<http://www.cwb.gov.tw>

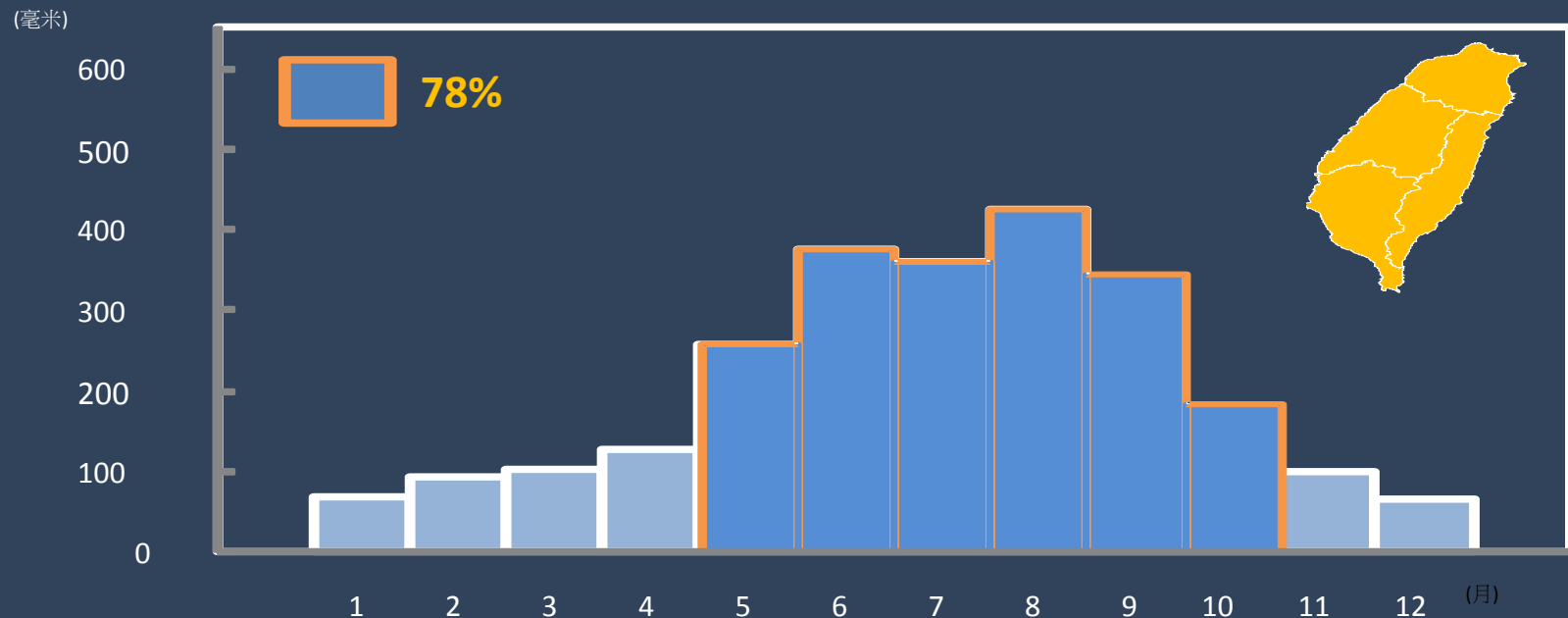


NOAA/Operational Significant Event Imagery

Intense Rainfall

2.5 times of
World Average

Average annual rainfall distribution in Taiwan



2,502mm
(Average value from 1949 till 2011)

Increasing Trend of heavy typhoon Rainfall in Taiwan

JOURNAL OF CLIMATE

Large Increasing Trend of Tropical Cyclone Rainfall in Taiwan and the Roles of Terrain

15 JUNE 2013

CHANG ET AL.

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TABLE 1. The 12 typhoons in 1960–2011 with total rainfall over Taiwan exceeding 3500 mm during the three phases, ranked according to total rainfall amount. The eight since 2004 are highlighted in boldface.

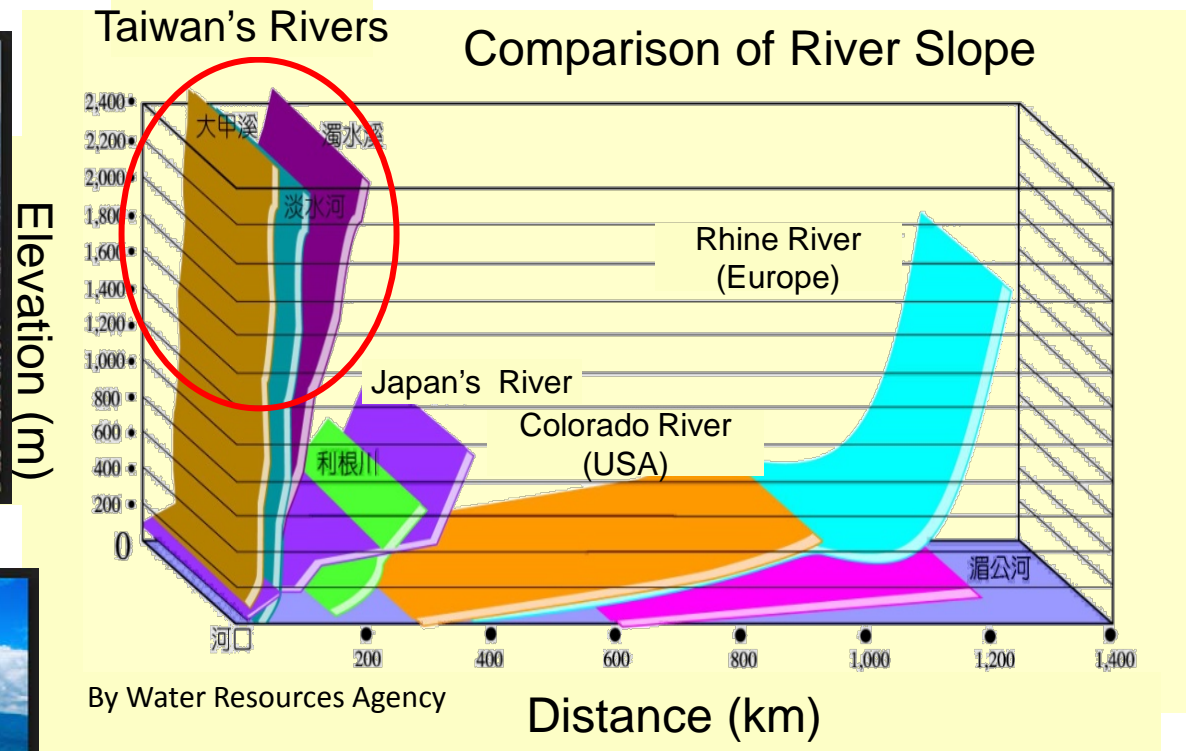
Rank	Year	Typhoon name	PR (h)	OL (h)	EX (h)	Total duration (h)	Rainfall (mm)	Type of track
1	2009	Morakot	12	15	18	45	8996	CWB 3 (C)
2	2001	Nari	10	51	14	75	8108	CWB Special
3	2008	Sinlaku	16	10	22	48	8105	CWB 2 (N)
4	2005	Haitang	11	9	12	32	5589	CWB 3 (C)
5	1996	Herb	5	7	4	16	4836	CWB 2 (N)
6	1989	Sarah	5	20	13	38	4655	CWB 3 (C)
7	1960	Shirley	3	11	10	24	4637	CWB 2 (N)
8	2007	Krosa	12	1	10	23	3936	CWB 2 (N)
9	2004	Mindulle	16	18	7	41	3856	CWB 6
10	2008	Jangmi	4	13	8	25	3800	CWB 2 (N)
11	2008	Kalmaegi	8	10	5	23	3763	CWB 2 (N)
12	2005	Talim	4	9	4	17	3526	CWB 3 (C)

Short response time

Mountainous Taiwan



City is built along the river

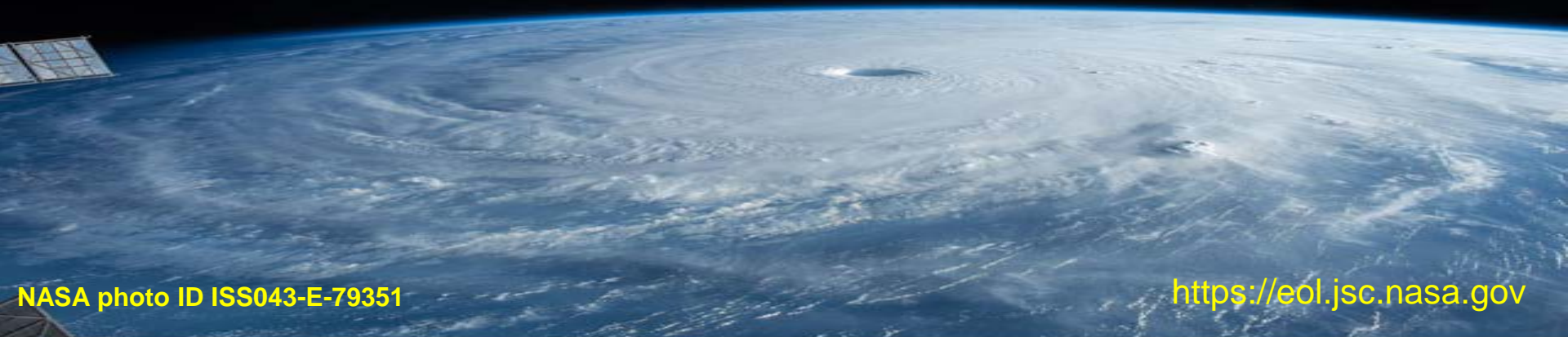


Severe inundation is caused by

intense rainfall +
storm surge +
high tides



How do we provide
joint warning information
for typhoons and storm surges?



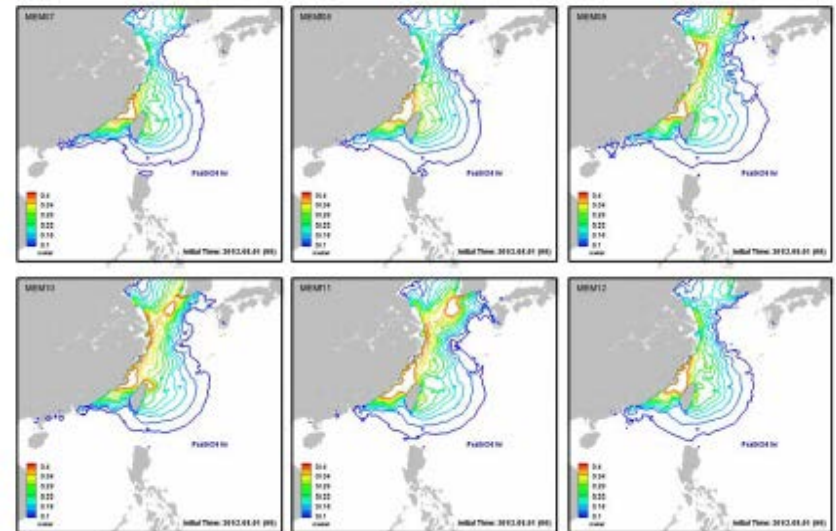
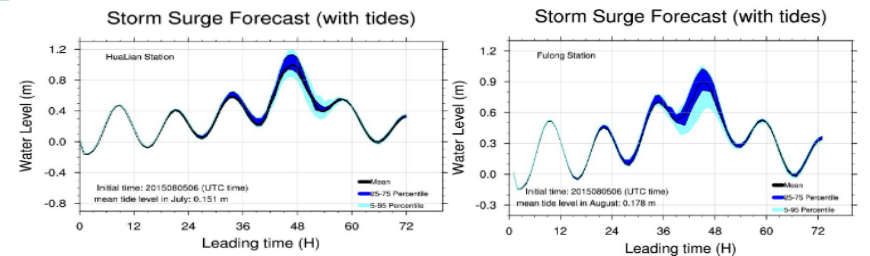
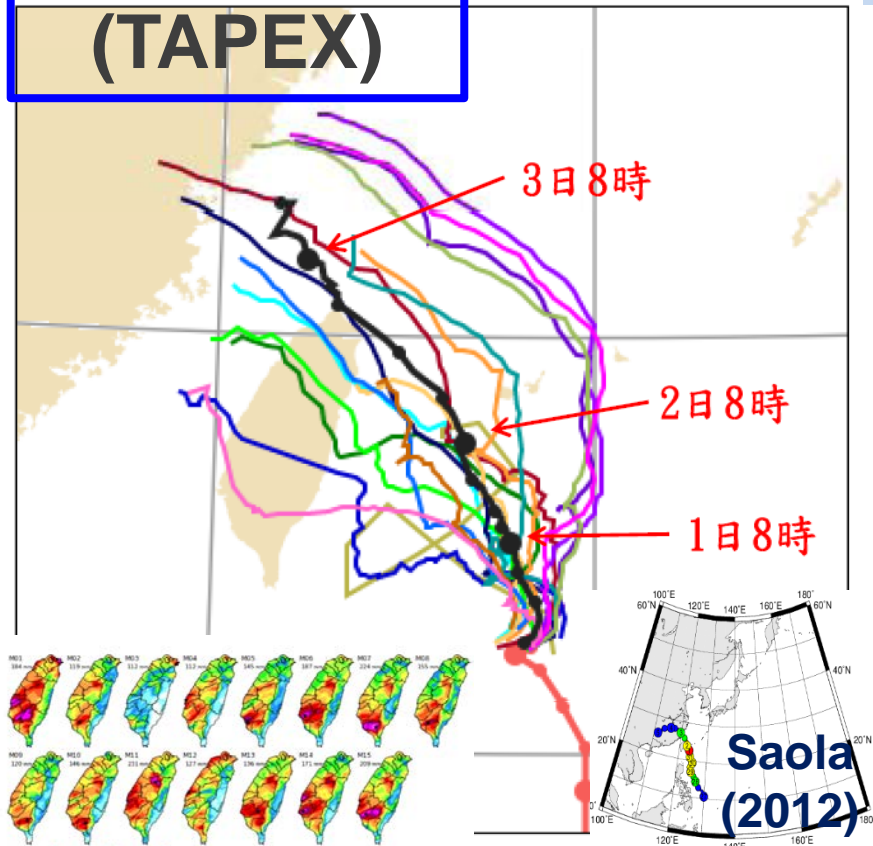
Typhoon & Storm Surge joint warning system

Ensemble
Typhoon
Forecast
(TAPEX)

wind
pressure

Storm surge
warning system

water
level





How well does the storm surge warning system actually work?

Numerical Experiments

Typhoon forcing

Real typhoon:

Ensemble forecast:
WRF members
Grid resolution:
45, 15, 5 km

Real typhoon:

High accuracy forecast:
WRF
Grid resolution:
18, 6, 2 km

Synthetic typhoon:

Holland wind model
Grid resolution:
15 km

Storm Surge Model

Uniform grid
resolution: 15 km

Stretching grid
resolution: 1-15 km

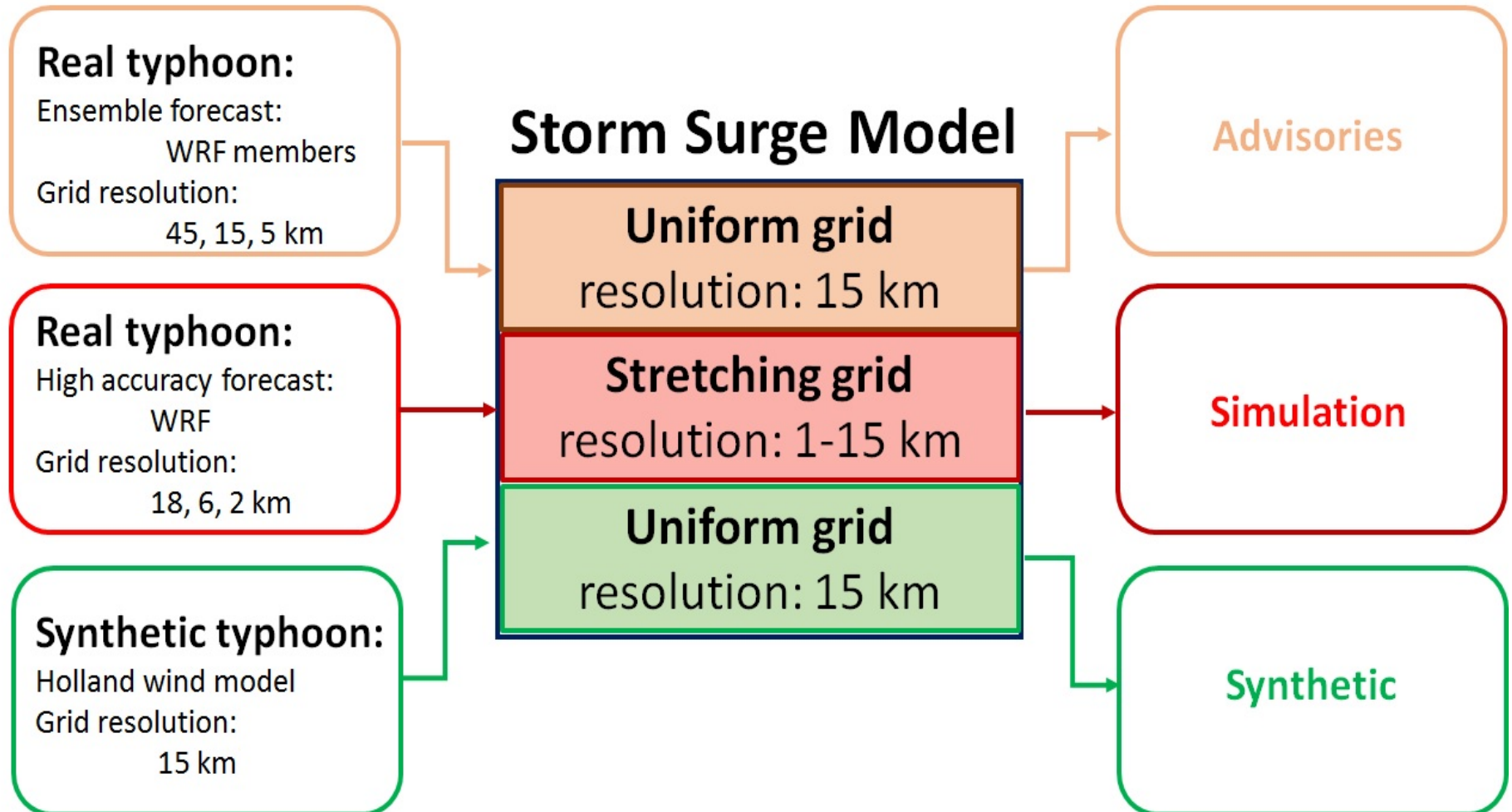
Uniform grid
resolution: 15 km

Surge level

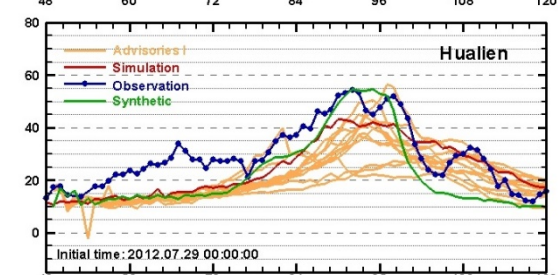
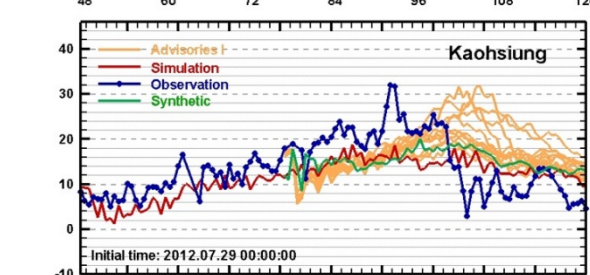
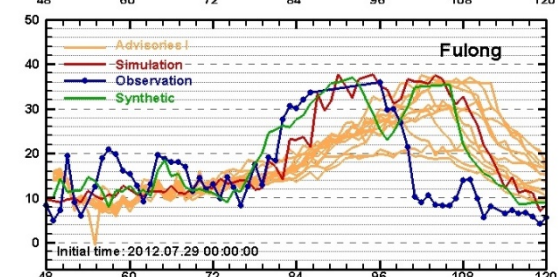
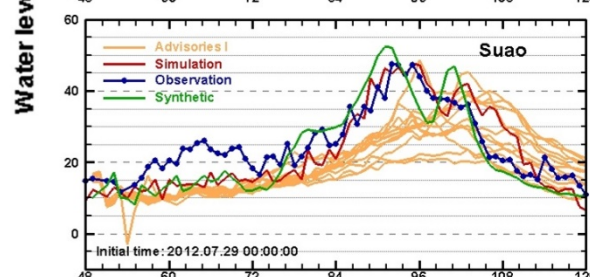
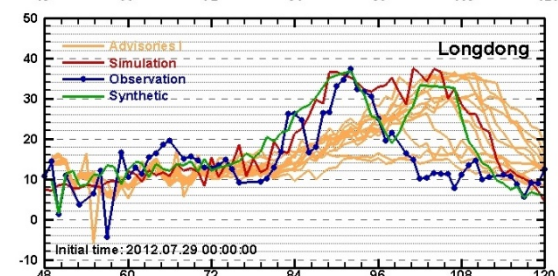
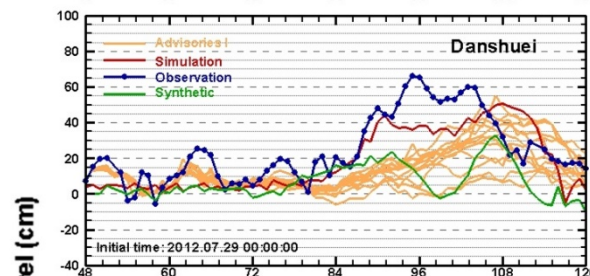
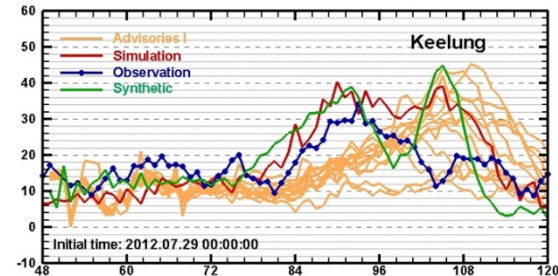
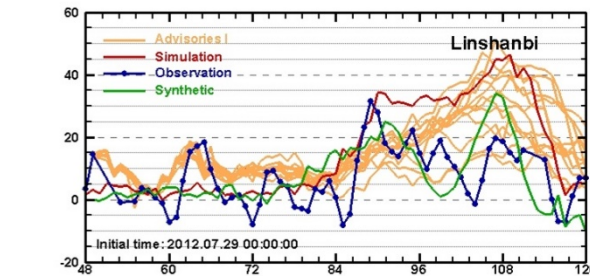
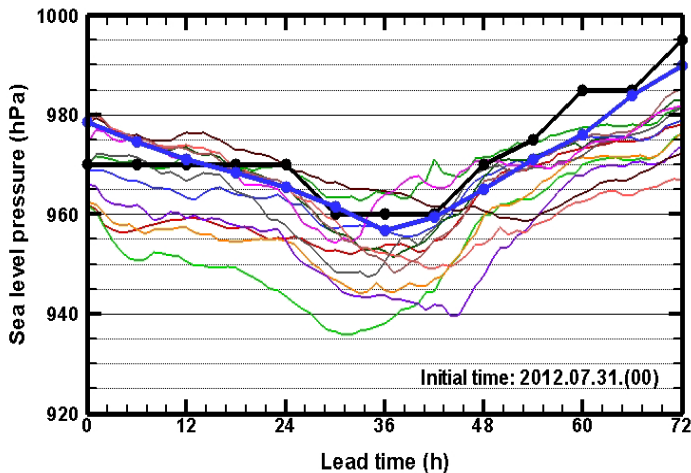
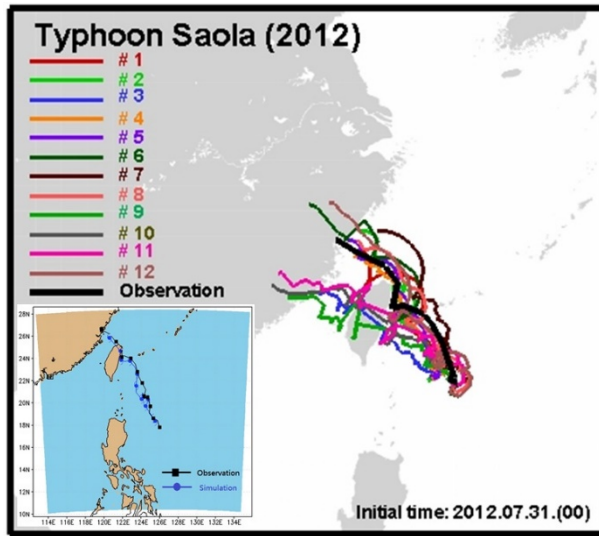
Advisories

Simulation

Synthetic

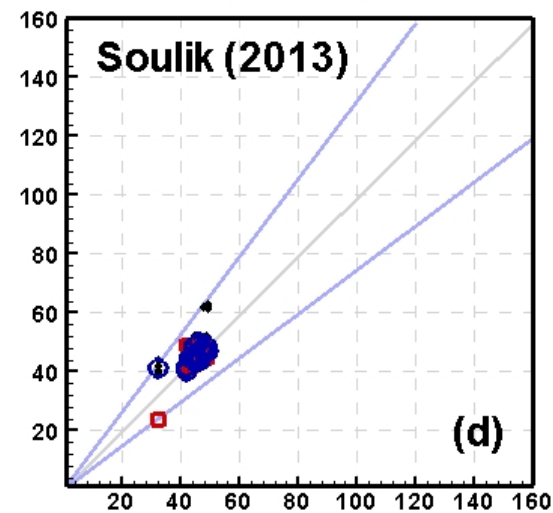
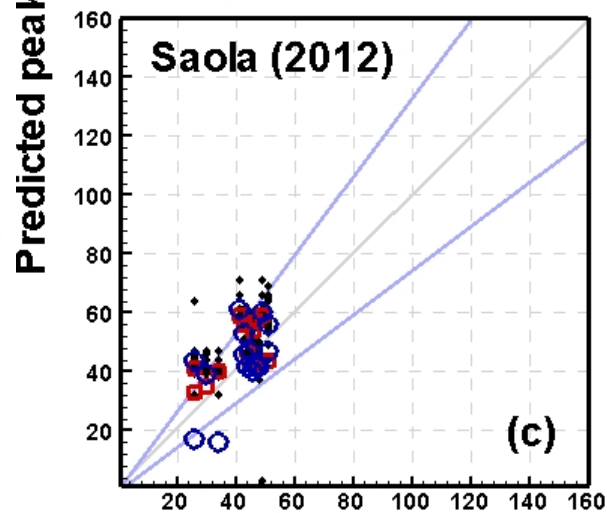
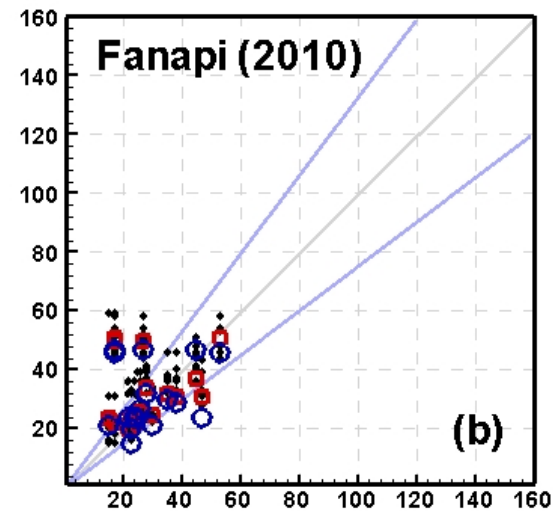
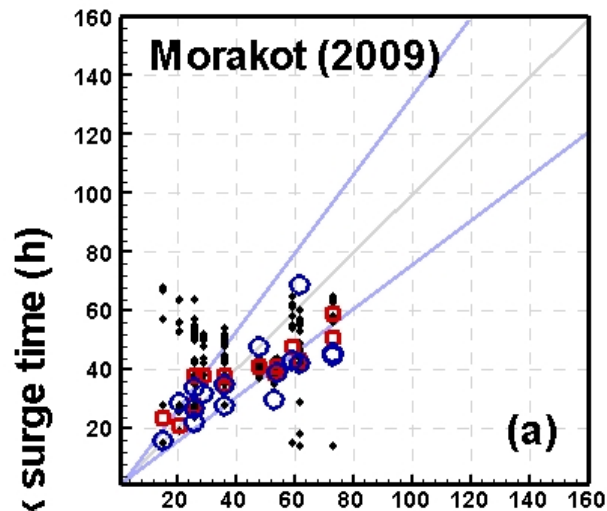
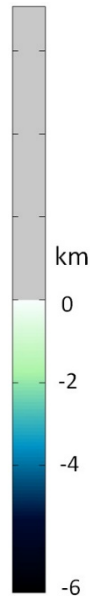
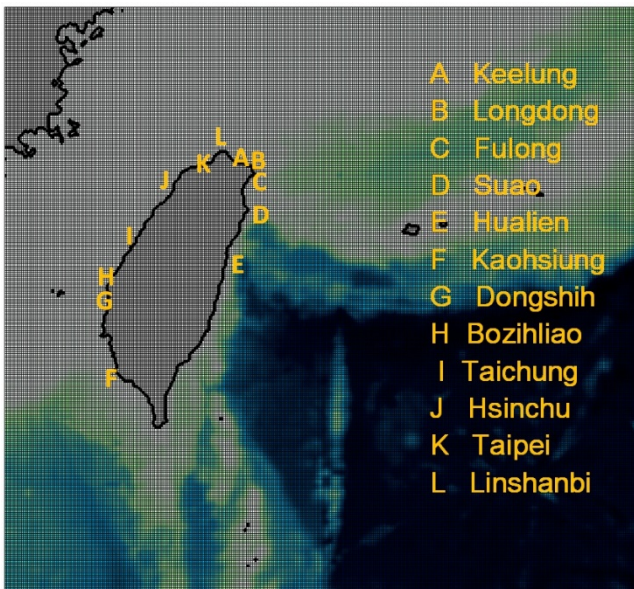
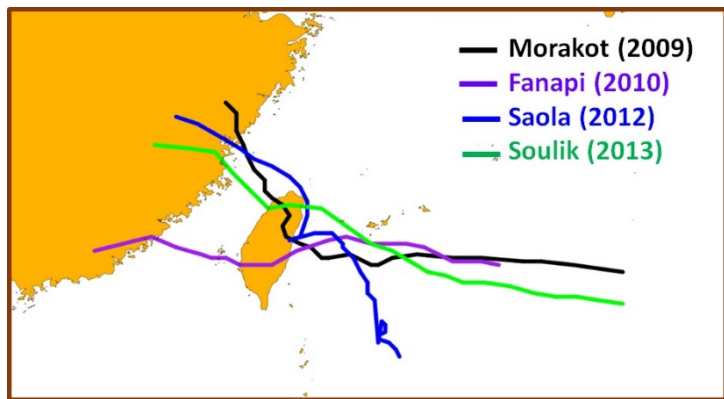


Performance of the warning system



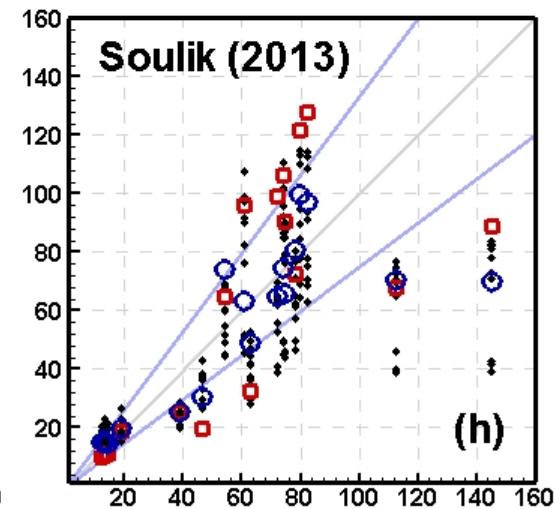
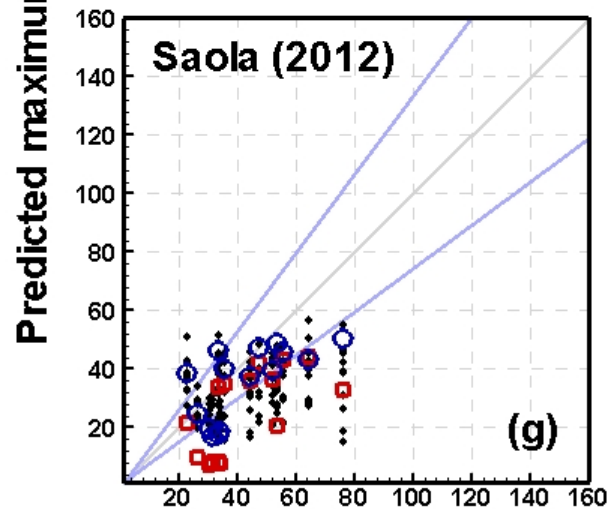
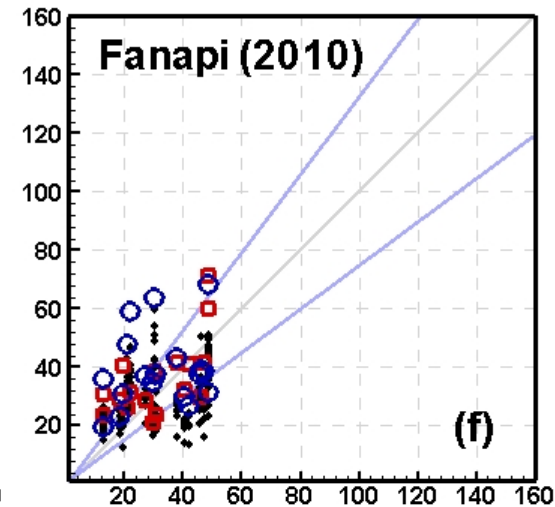
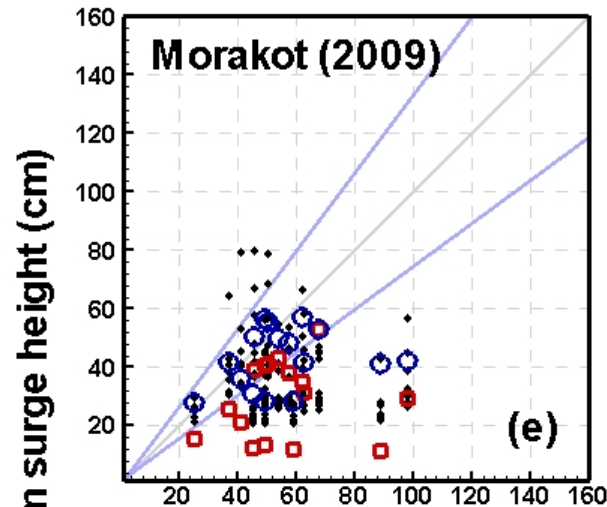
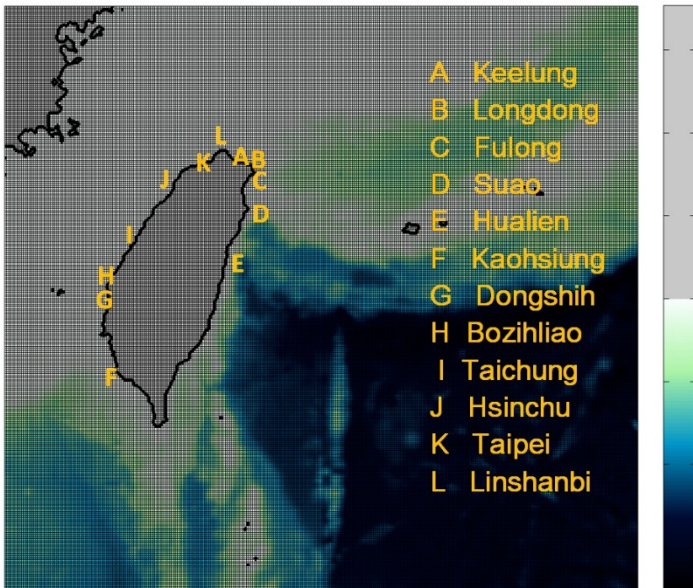
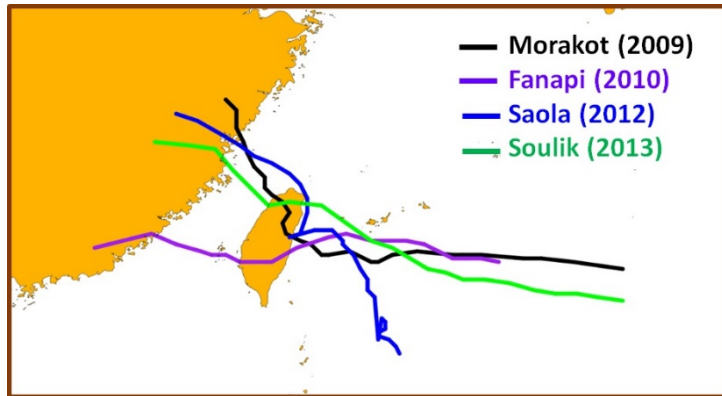
Lead time (h)

Transmission Speed of a typhoon & Timing of a storm surge



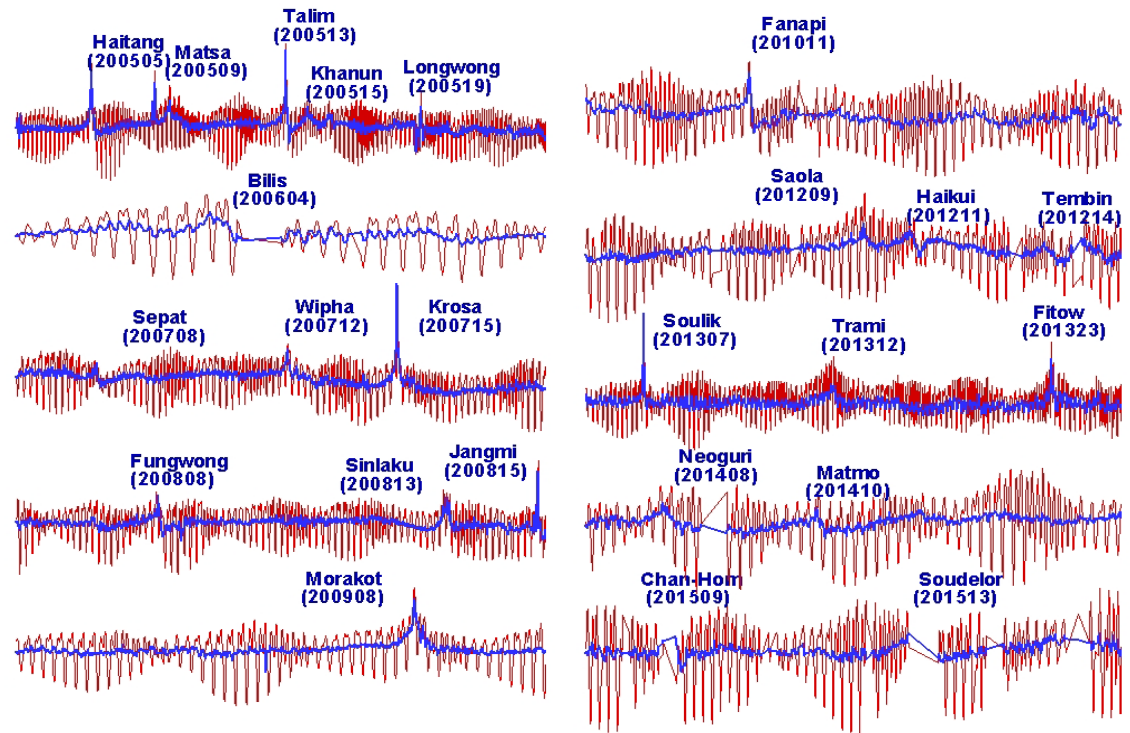
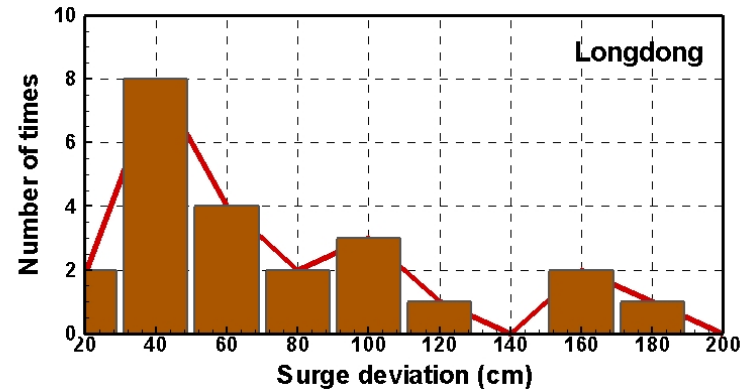
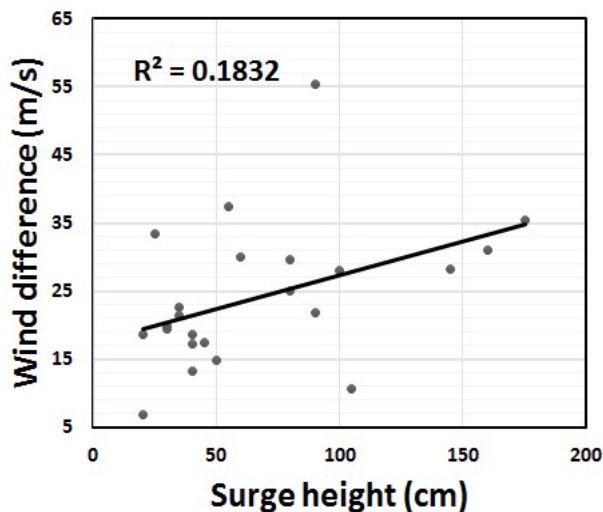
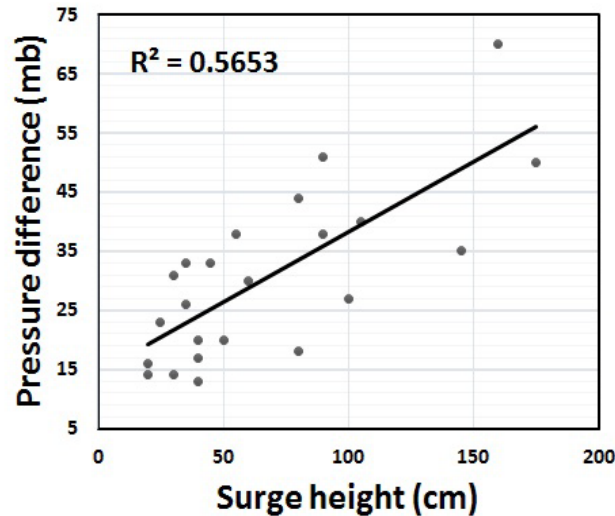
Observed peak surge time (h)

Typhoon Intensity & Surge Deviation



Observed maximum surge height (cm)

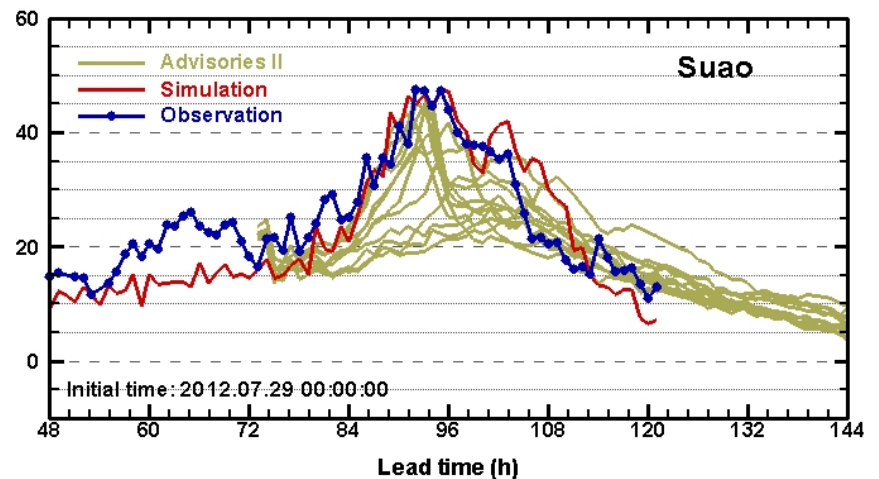
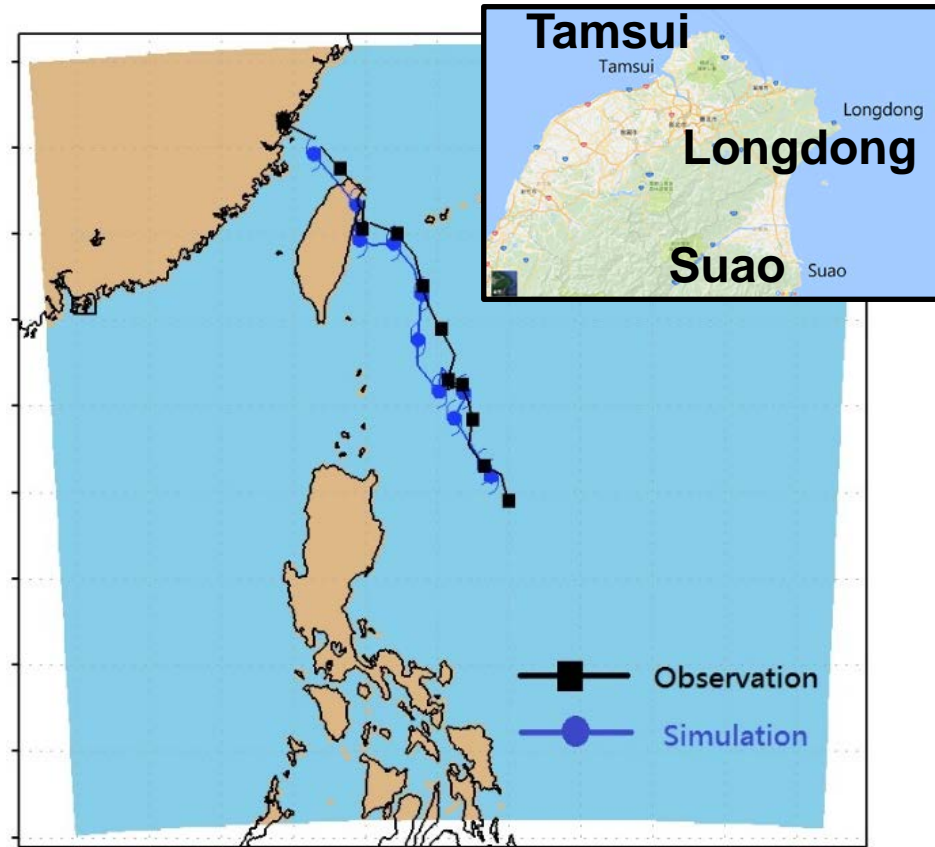
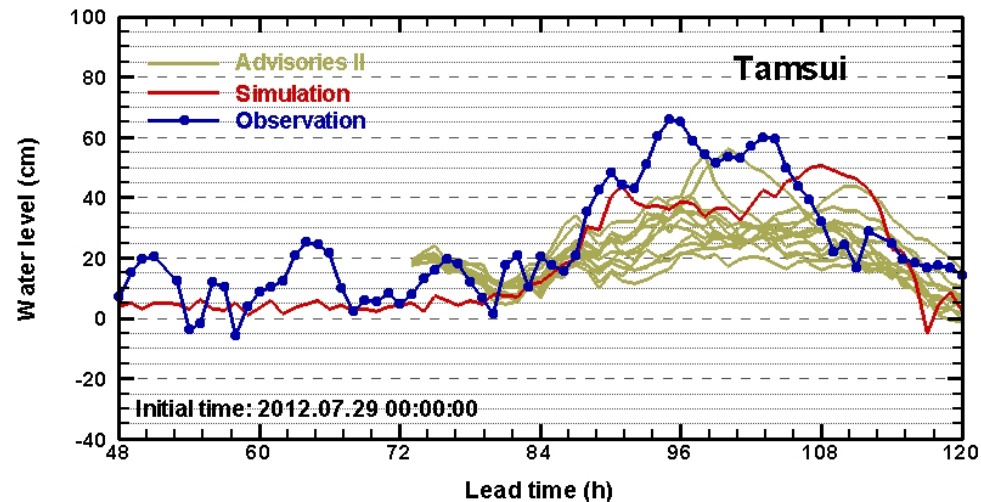
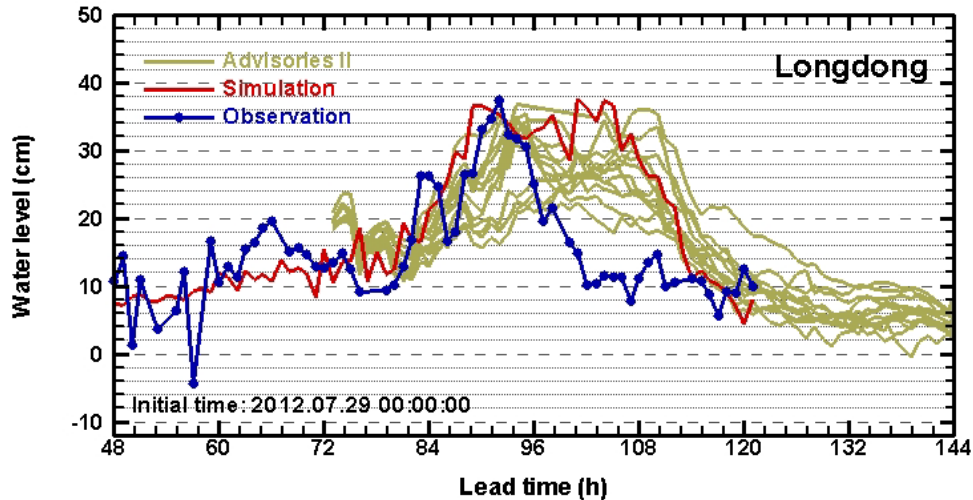
Tide gauge observations



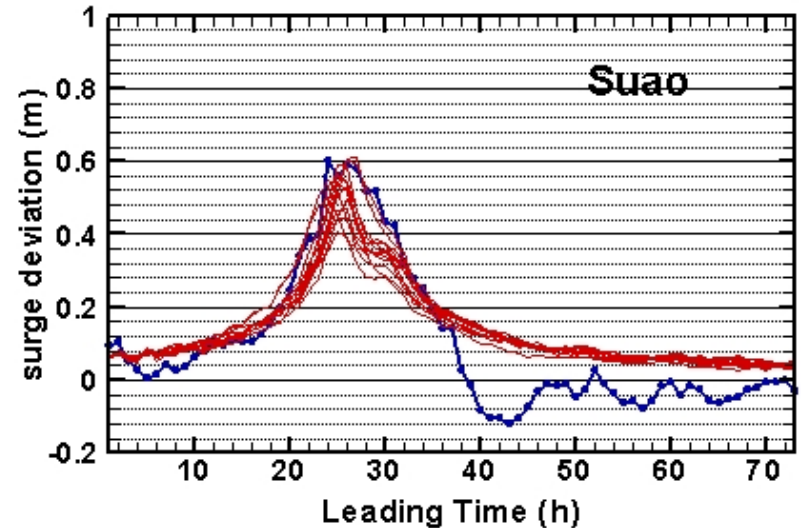
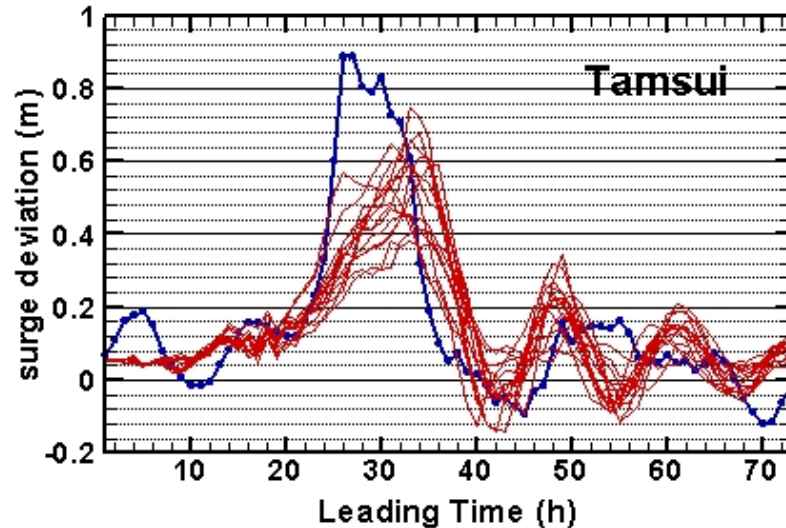
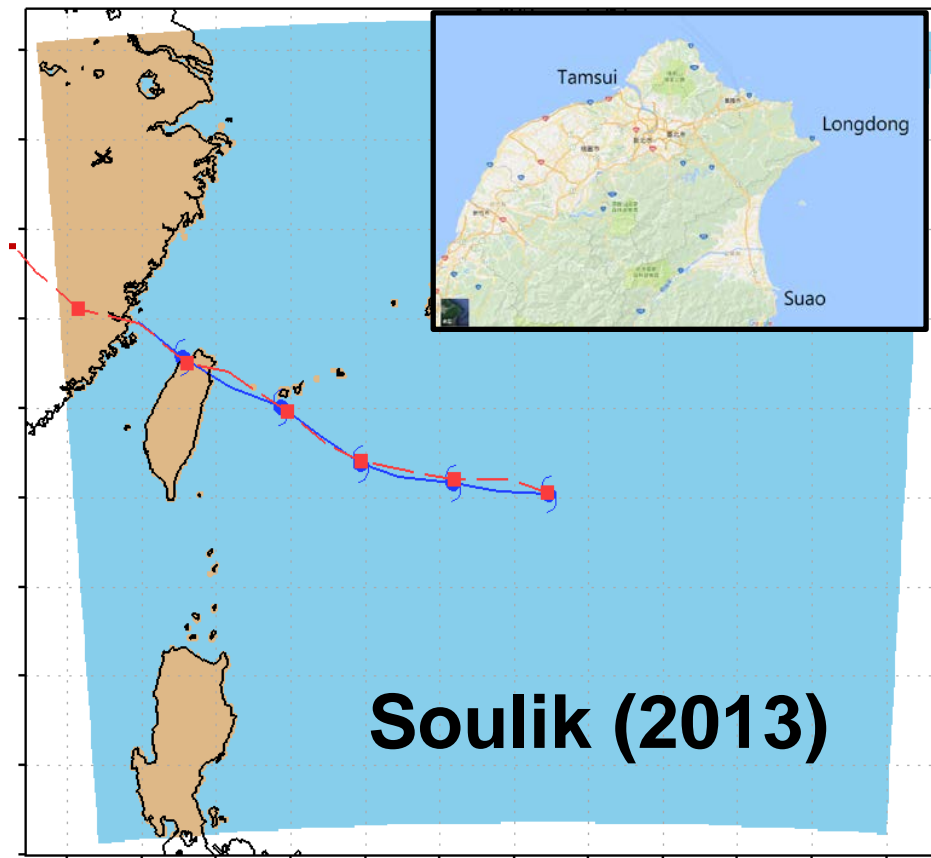
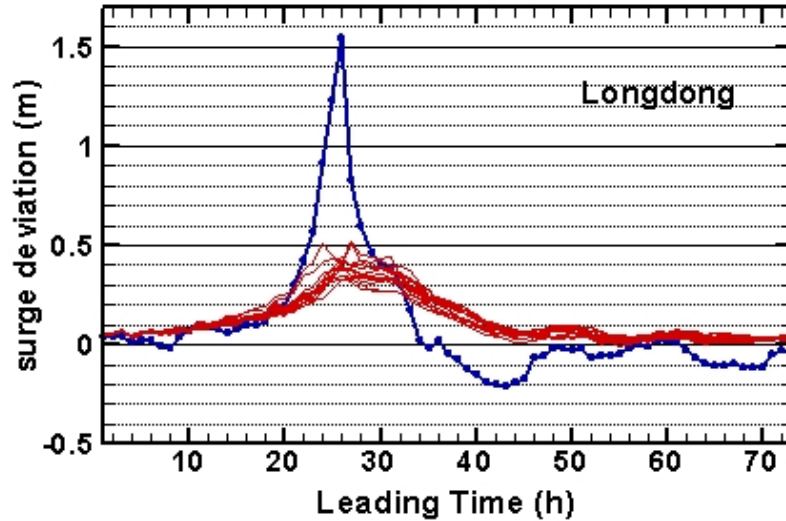


What unresolved physical process is responsible for the discrepancy?

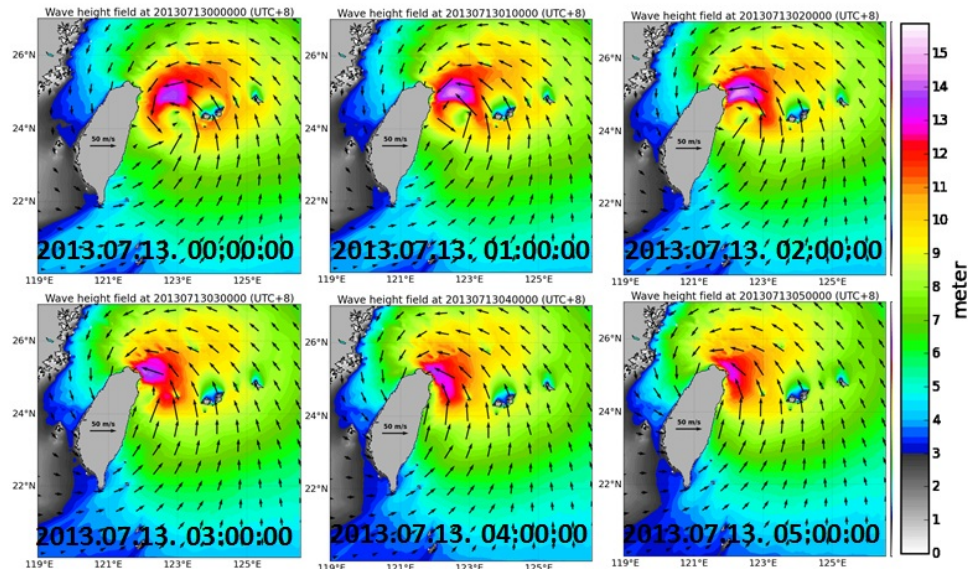
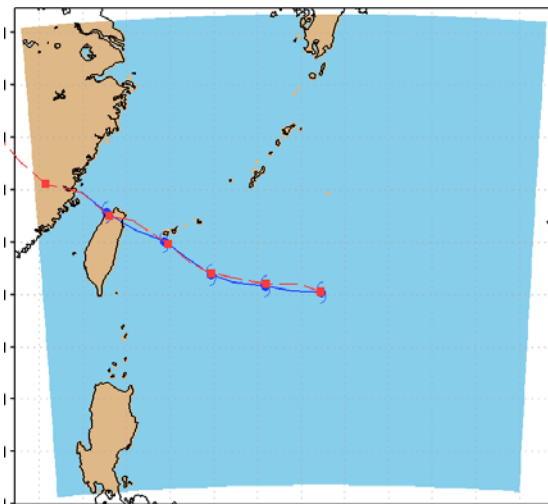
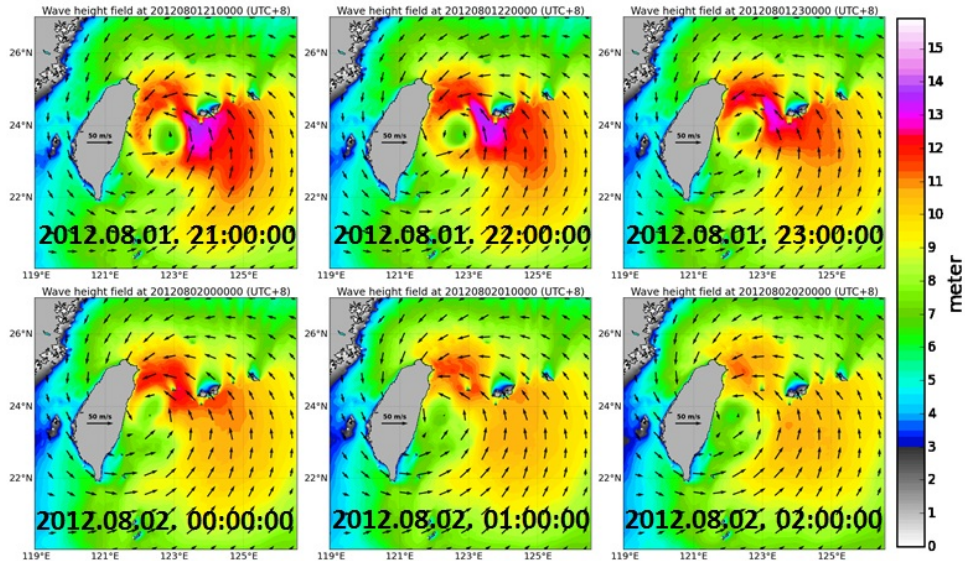
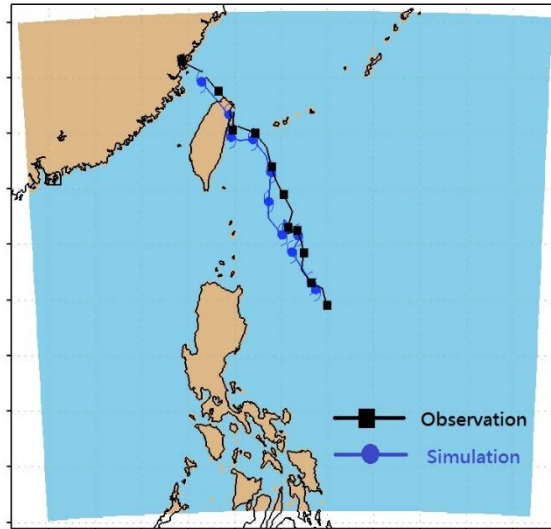
Unresolved physical process_(1/2)



Unresolved physical process_(2/2)



Wave effect on storm surge



Estimate of wave setup

Holman & Sallenger (1985):

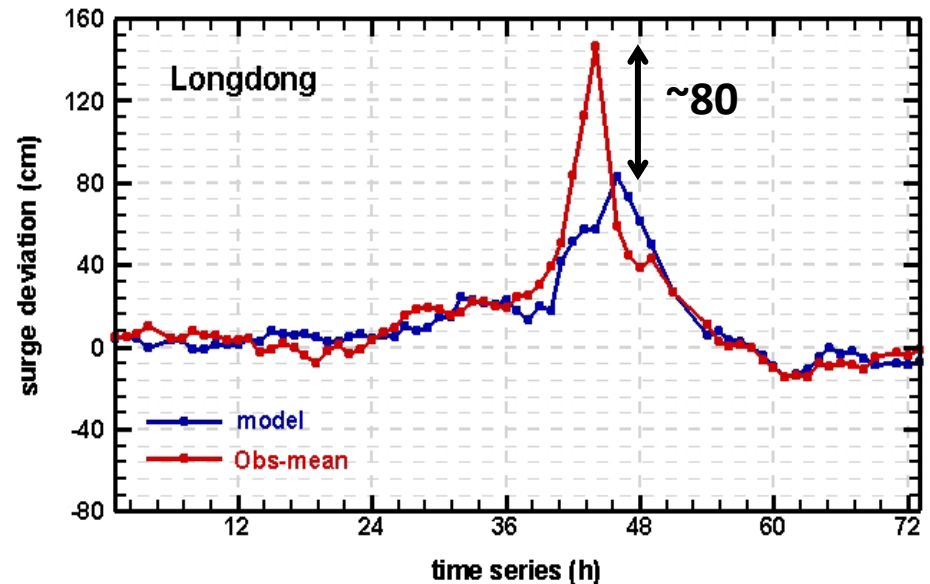
Wave setup at the shoreline η_M is proportional to the wave height H_b at the offshore edge of the surf zone.

$$\eta_M = (0.3\xi_0) \cdot H_b$$

Similarity parameter

$$\xi_0 = \beta / \sqrt{H_0/L_0}$$

β	H_0/L_0	Wave setup
0.04	0.05	0.78 m
0.03	0.05	0.58 m



Summary

- Storm surges are dominated by storm forcing and then influenced by their interactions with wind waves, local geometry, and tides.
- The track, intensity, and transmission speed of a typhoon determines the location, strength, and timing of storm surges.
- When a typhoon passes over northeastern Taiwan, wave effect on the surge is not negligible.



Thank you