台灣海域波候現況與海岸溢淹風險分析

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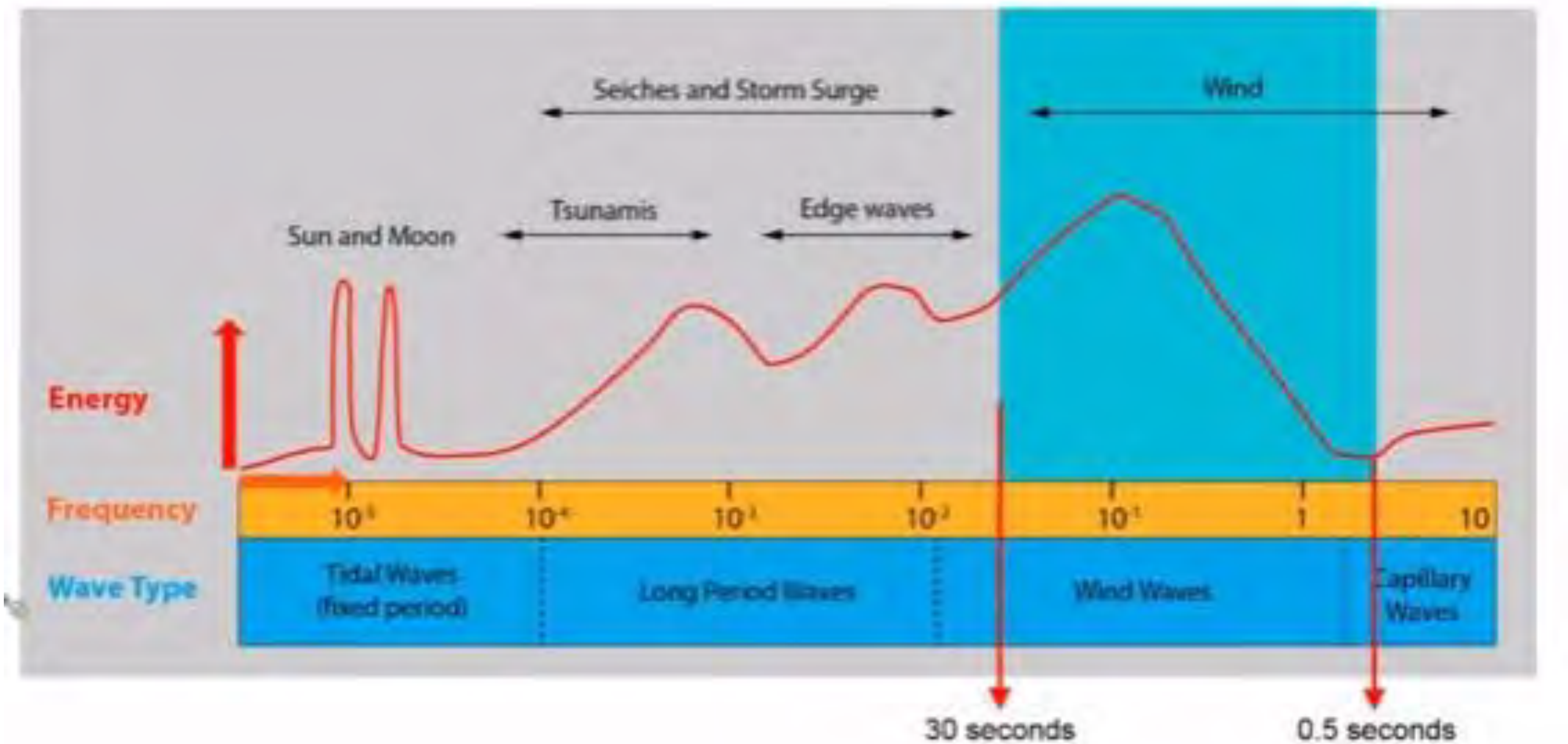
Tainan Hydraulics Laboratory
National Cheng Kung University

September 05, 2017 台灣大學

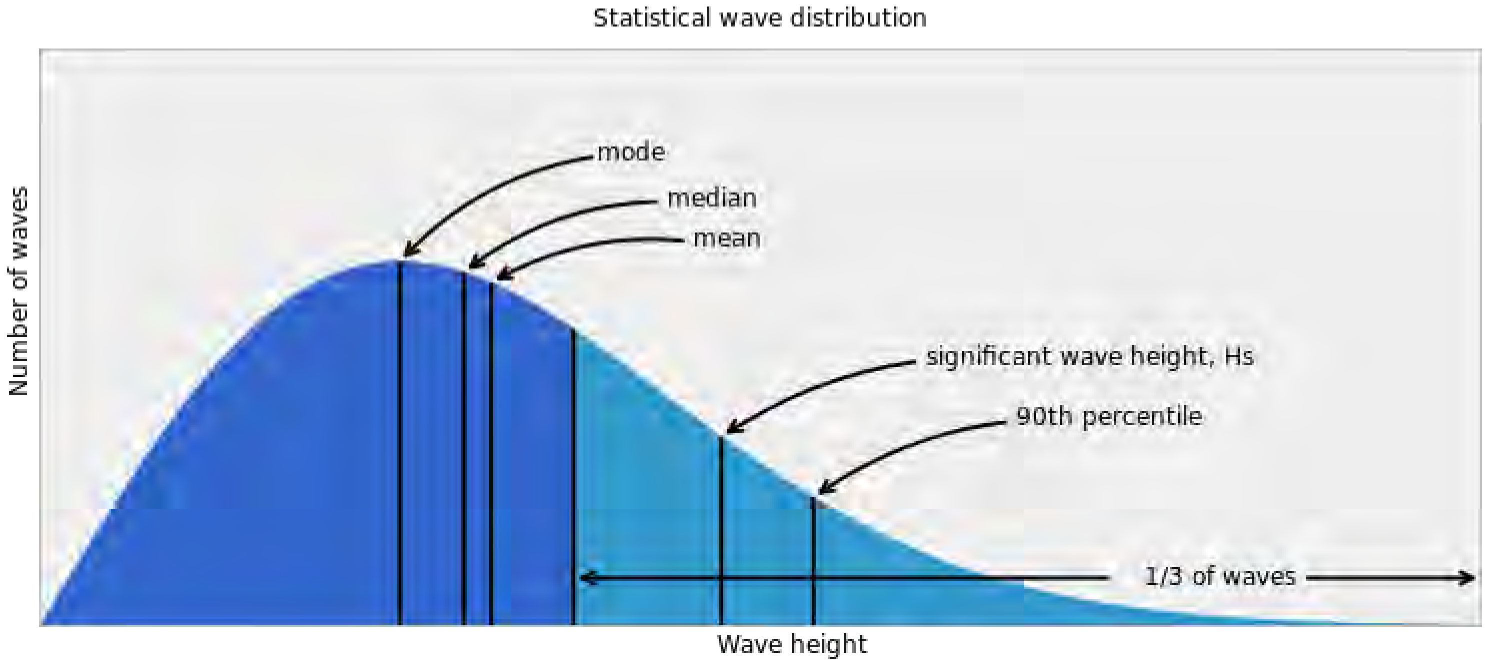
海洋波動頻譜



Seiches and Storm Surge
Wind
Tsunamis
Edge waves
Sun and Moon
Energy
Frequency
1
10
Wave Type
Tidal Waves
(fixed period)
Long Period Waves
Wind Waves
Capillary
Waves
30 seconds
0.5 seconds

Significant wave height

- H_s 、H_{mo} or H_{sig}
- Rayleigh distribution.
- H_s is 10 metres (33 feet), statistically:
- 1 in 10 will be larger than 10.7 metres (35 ft)
- 1 in 100 will be larger than 15.1 metres (50 ft)



國內波浪觀測

成大水工所

中央氣象局

港研中心

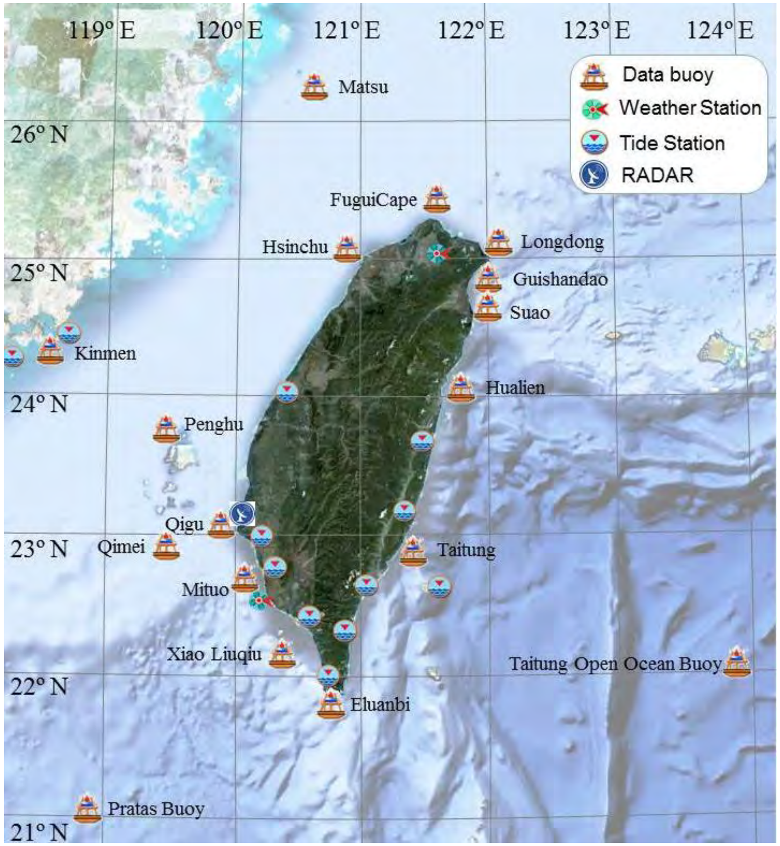
近海水文中心

其它

台灣海洋中心

近海水文中心操作的觀測網

2015年7月協助政府操作之長期作業化觀測站共32站：



Networks put into operation by COMC

Since 1998, the government has sponsored the establishment of over 50 stations, mainly includes:

經濟部水利署　**應用於海岸災害預警**

WRA, for coastal hazards mitigation

交通部中央氣象局　**應用於海氣象預報**

CWB, for marine weather forecasting

交通部觀光局　**應用於海域遊憩活動安全**

Tourism Bureau, for oceanic recreation safekeeping

資料浮標

1. 於淺水及深水區蒐集海氣象資料。
2. 作為近海水文觀測之基礎。

Data Buoys

1. To collect marine & meteorological data in any water depth .
2. To be the basis of ocean monitoring.

1997年取得第一型資料浮標專利

Data Buoy Type I (patented in 1997)
Diameter : 2.5 m

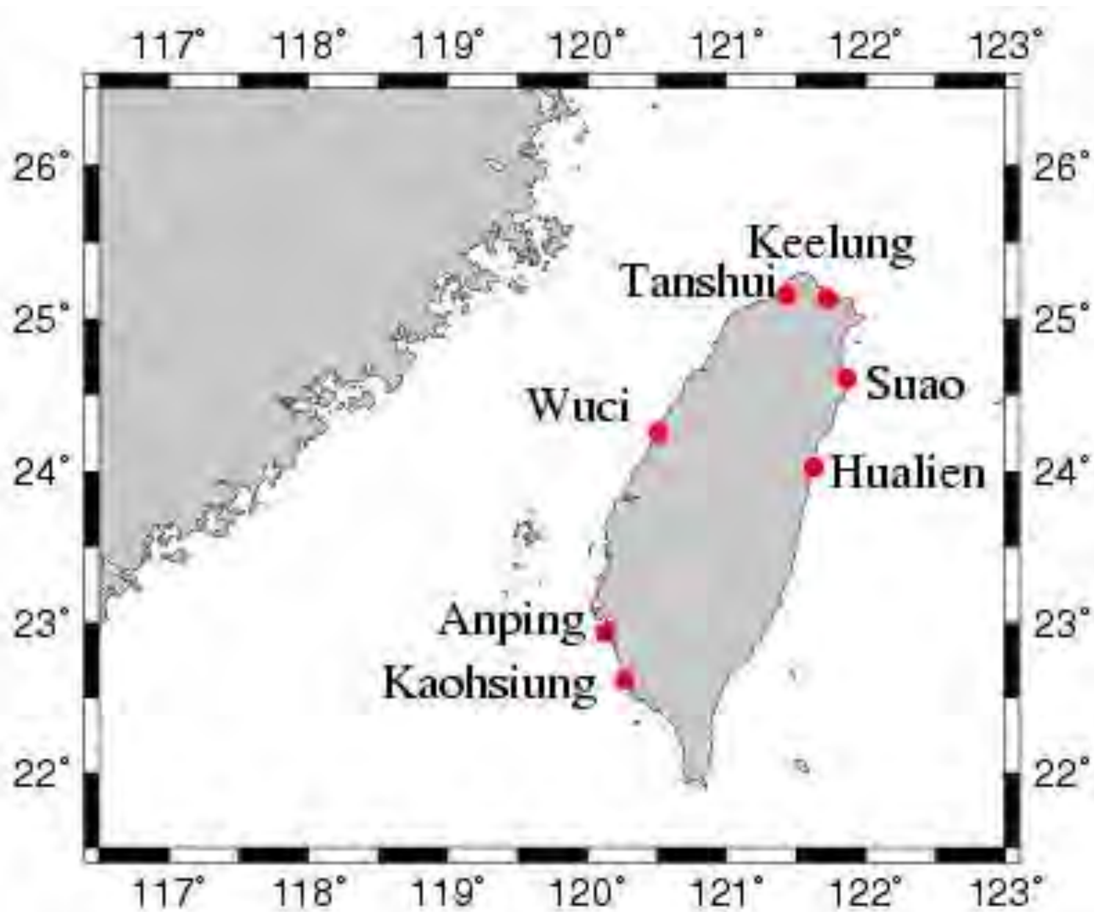
觀測項目

波浪‧海流‧水溫‧氣壓
‧風‧氣溫‧其他(水質…)

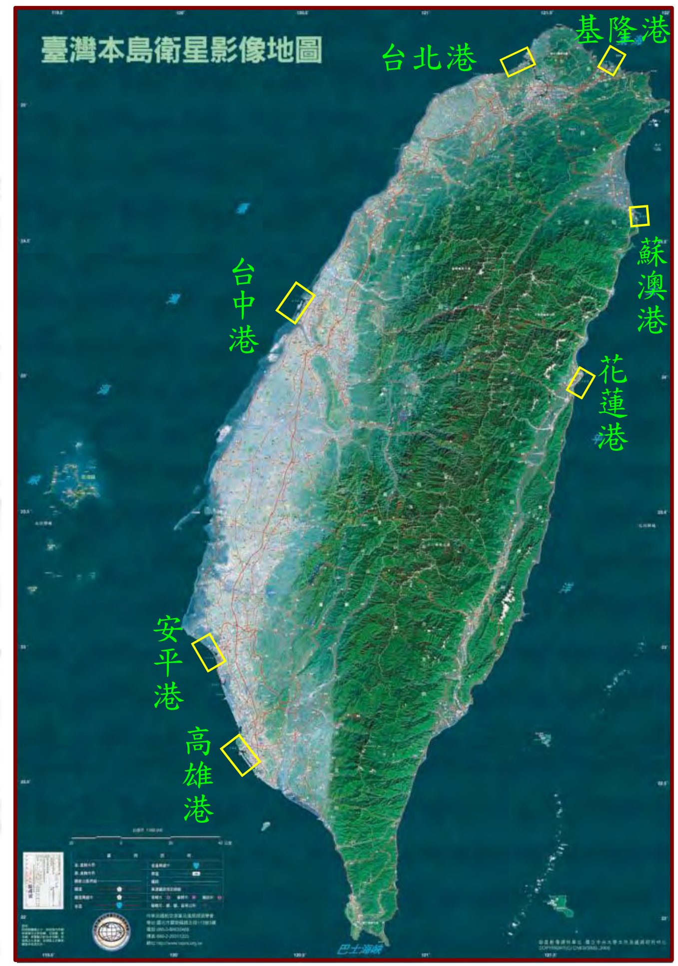
Measurable items:

-Wave
-Current
-Water temperature
-Barometric pressure
-Wind
-Air temperature
-Others, such as water quality

港研中心所屬觀測站



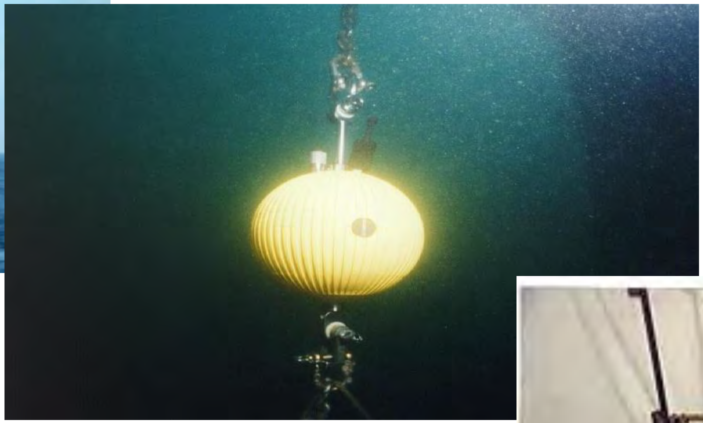
117°
118°
119°
120°
121°
122°
123°
26°
25°
24°
23°
22°
Keelung
Tanshui
Suao
Wuci
Hualien
Anping
Kaohsiung



臺灣本島衛星影像地圖
基隆港
台北港
蘇澳港
台中港
花蓮港
安平港
高雄港

InterOcean公司-S4儀器
(臺北港與安平港觀測樁)

InterOcean公司-S4
海氣象儀器觀測系統



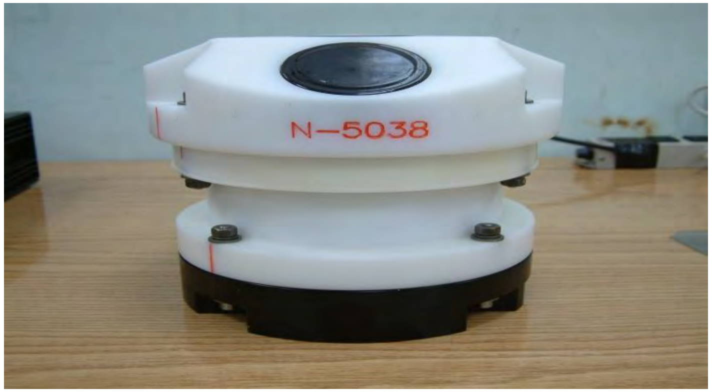
台北港及安平港觀測樁觀測

重力加速度式浮球波浪儀
(荷蘭-DATAWELL)

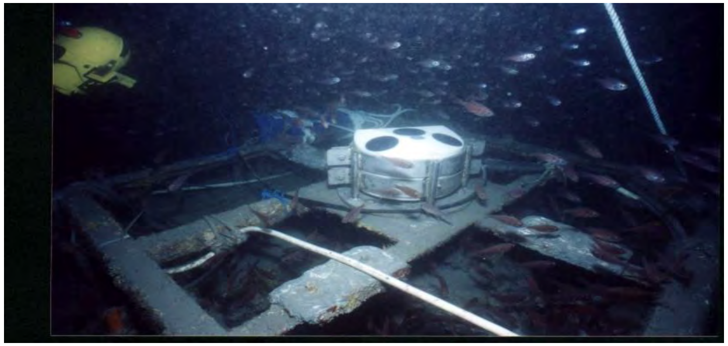
量測波浪早期儀器是荷蘭-DATAWELL-重力加速度式浮球波浪儀(70公分直徑無波向觀測)(90公分直徑有波向觀測)

挪威 NORTEK 公司AWCP

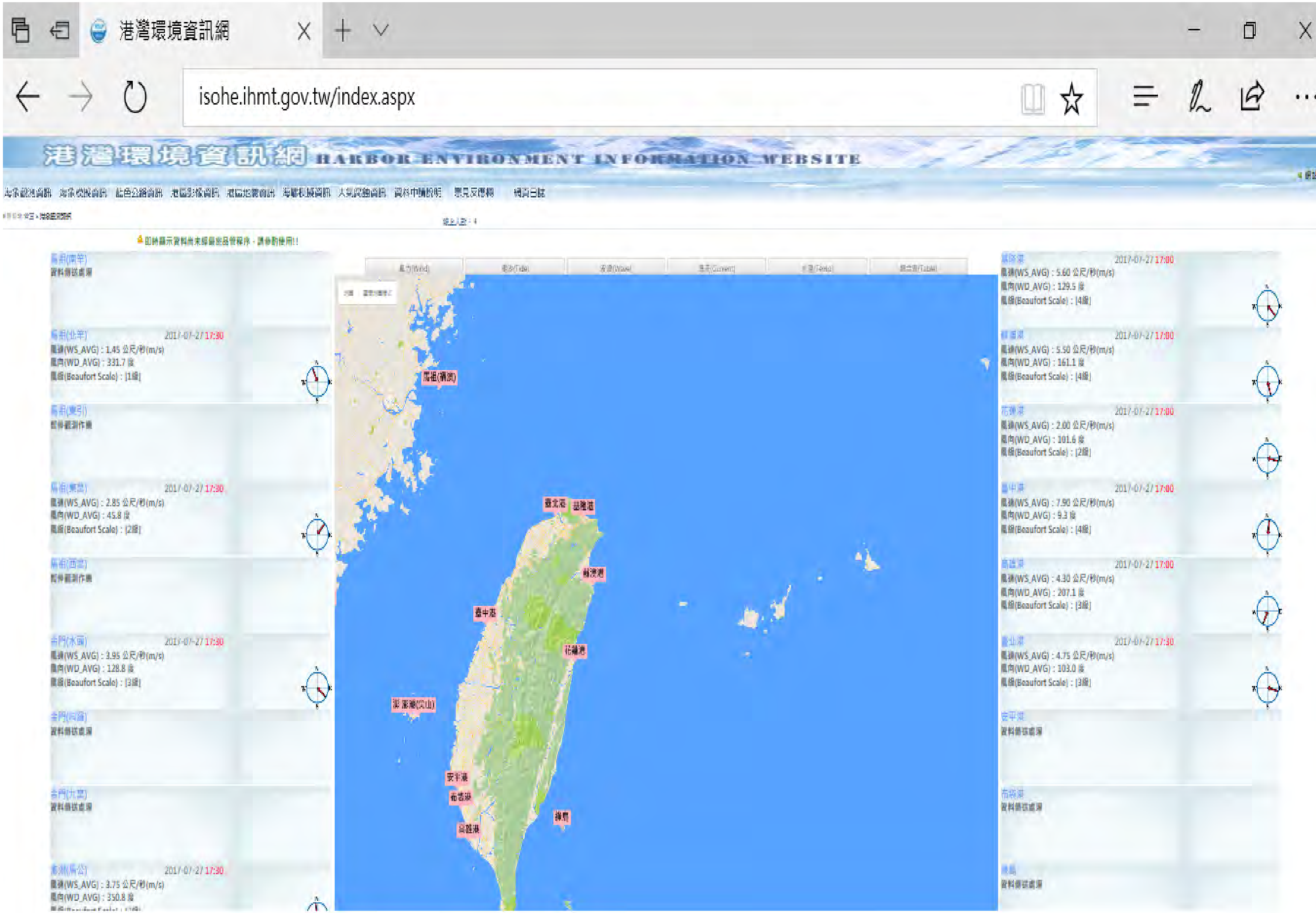
(超音波式波向波高與剖面海流儀)(潮位及海溫)







五個國際港海氣象(波流潮)觀測站(即時傳送監測系統)



港灣環境資訊網
isohe.ihmt.gov.tw/index.aspx
港灣環境資訊網 HARBOR ENVIRONMENT INFORMATION WEBSITE

港灣環境資訊網

http://isohe.ihmt.gov.tw/Station/SimChart/Taichung.aspx

圖形動畫： 臺灣近

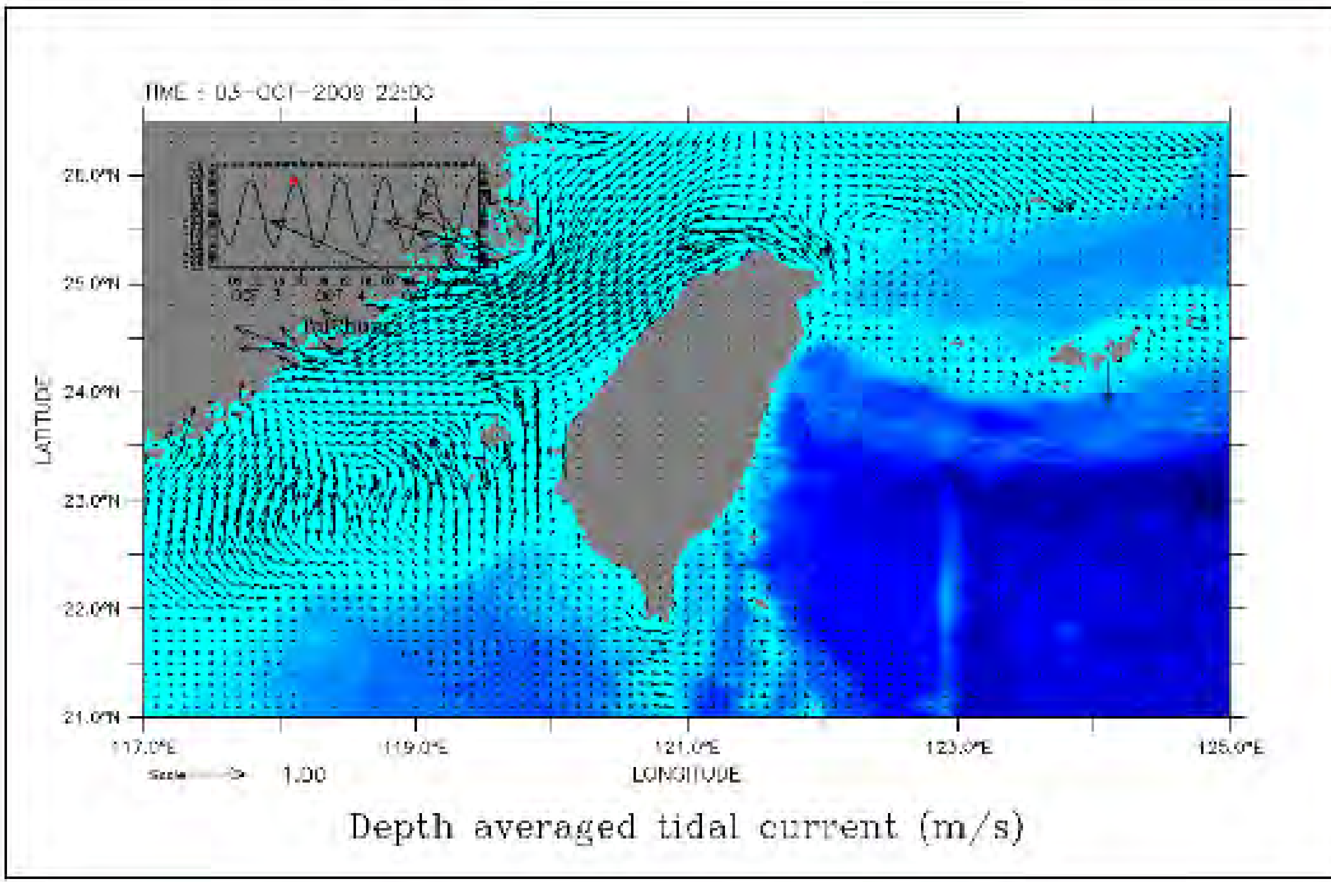
颱風年度： 2009

颱風名稱： 芭瑪

潮汐 | 海流 | 波浪-波高 | 波浪-波向 | 波浪-週期 | 風力 | 歷線圖

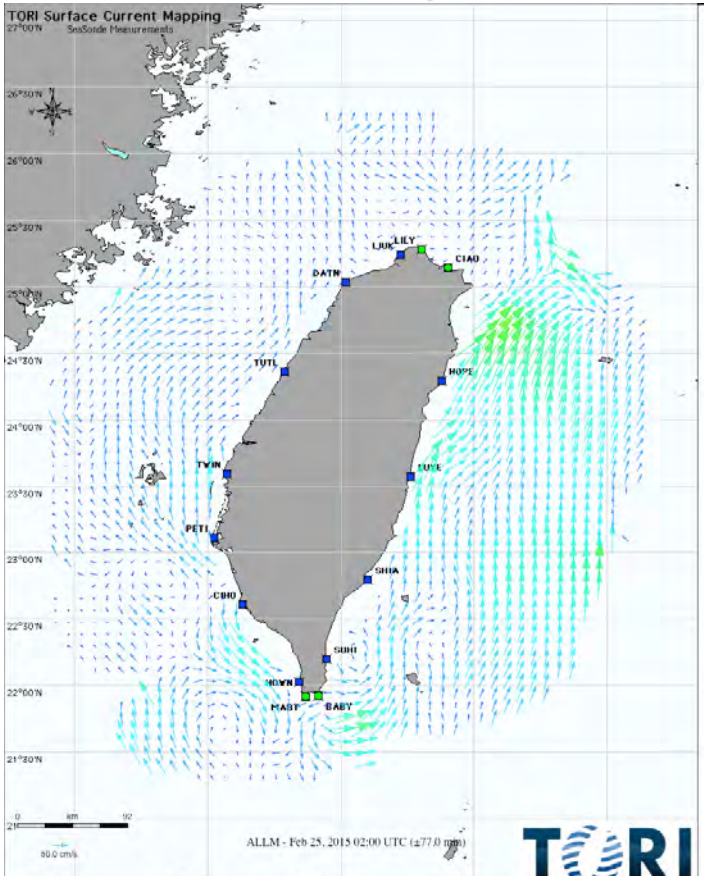
上一格 | 暫停 | 下一格

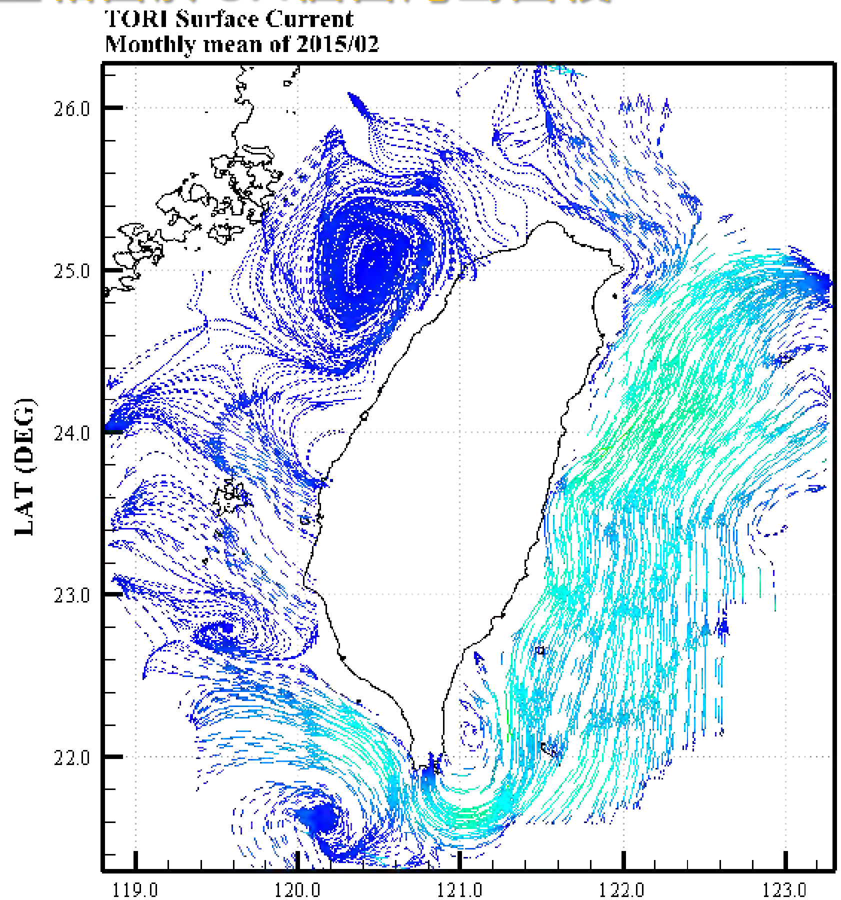
颱風名稱:芭瑪 發佈警報期間：2009.10.03~2009.10.05

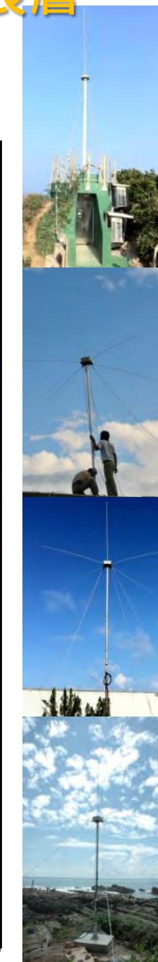


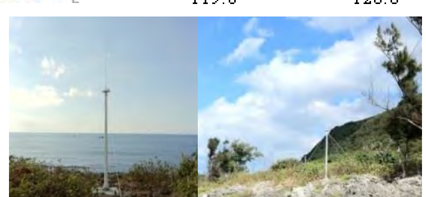
環台岸基海洋雷達系統

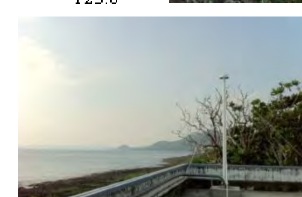
2015/01完成環繞台灣海域的海洋雷達觀測網17座，測站觀測之表層海流面積超過194,608平方公里相當於 5.4個台灣島面積





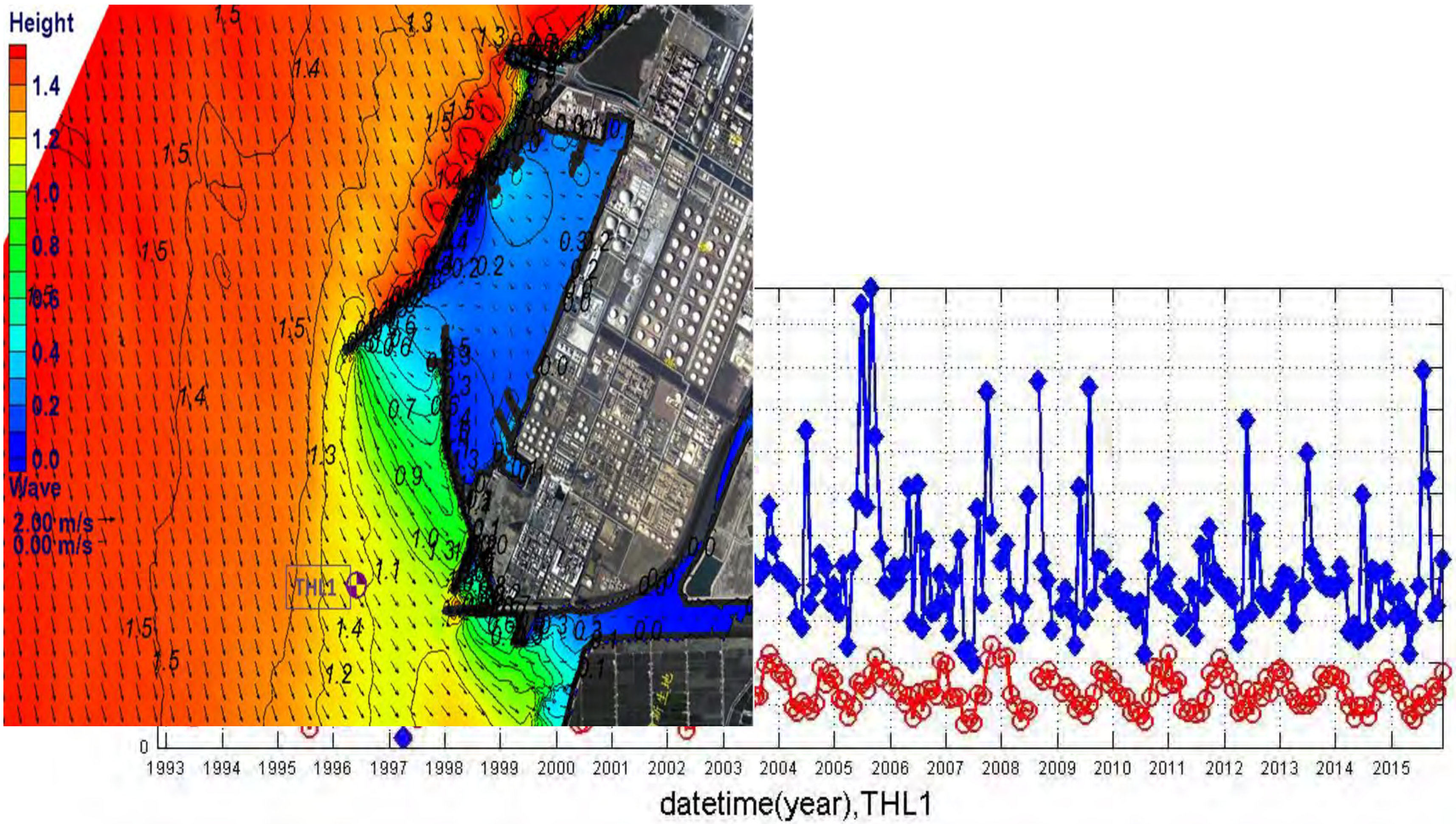




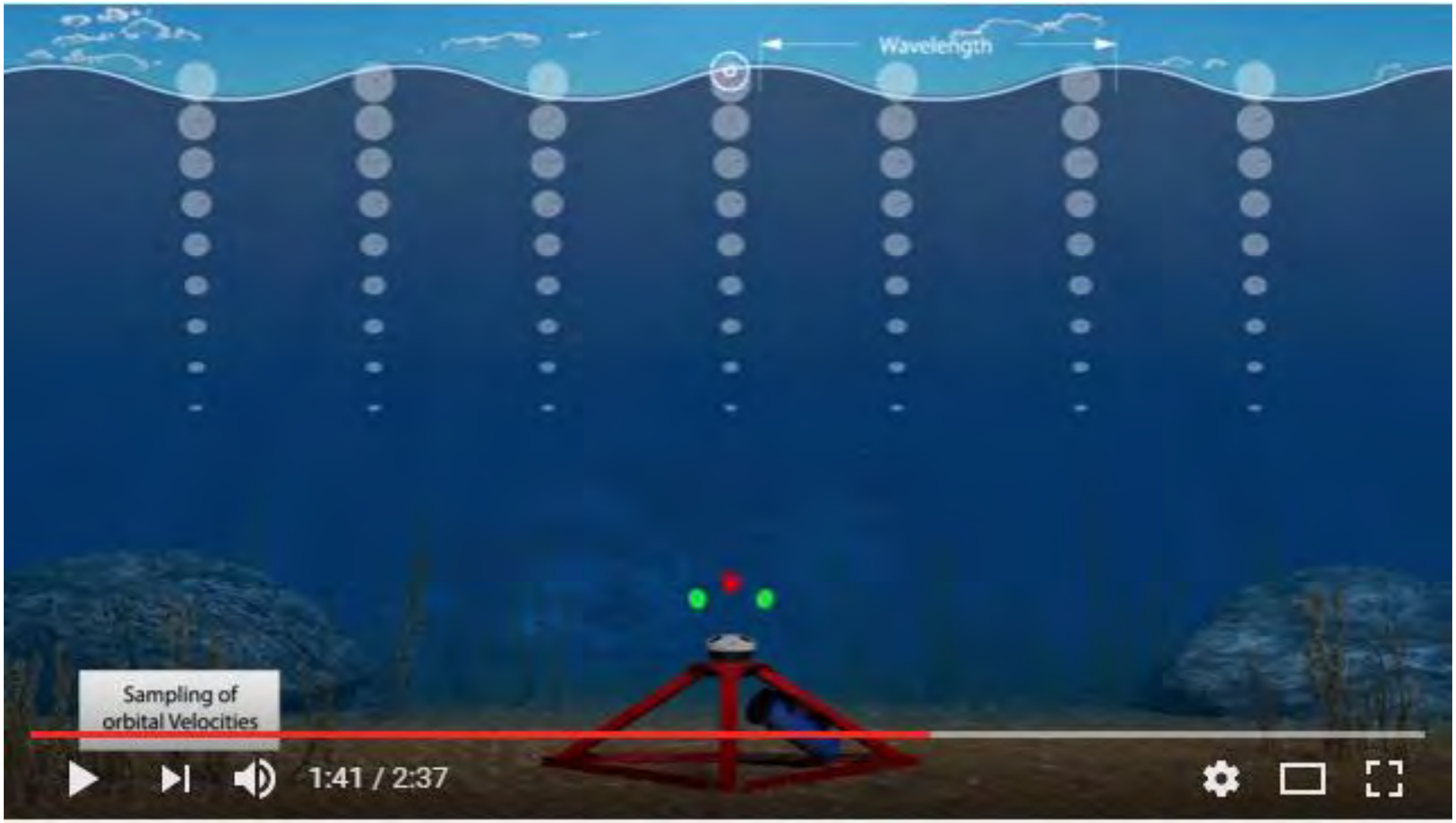


歷年環境監測調查成果(自然環境)：波浪

- 麥寮港完成後，其南側台西與新興區海域受麥寮港遮蔽，東北季風期波高相較建港前變小。

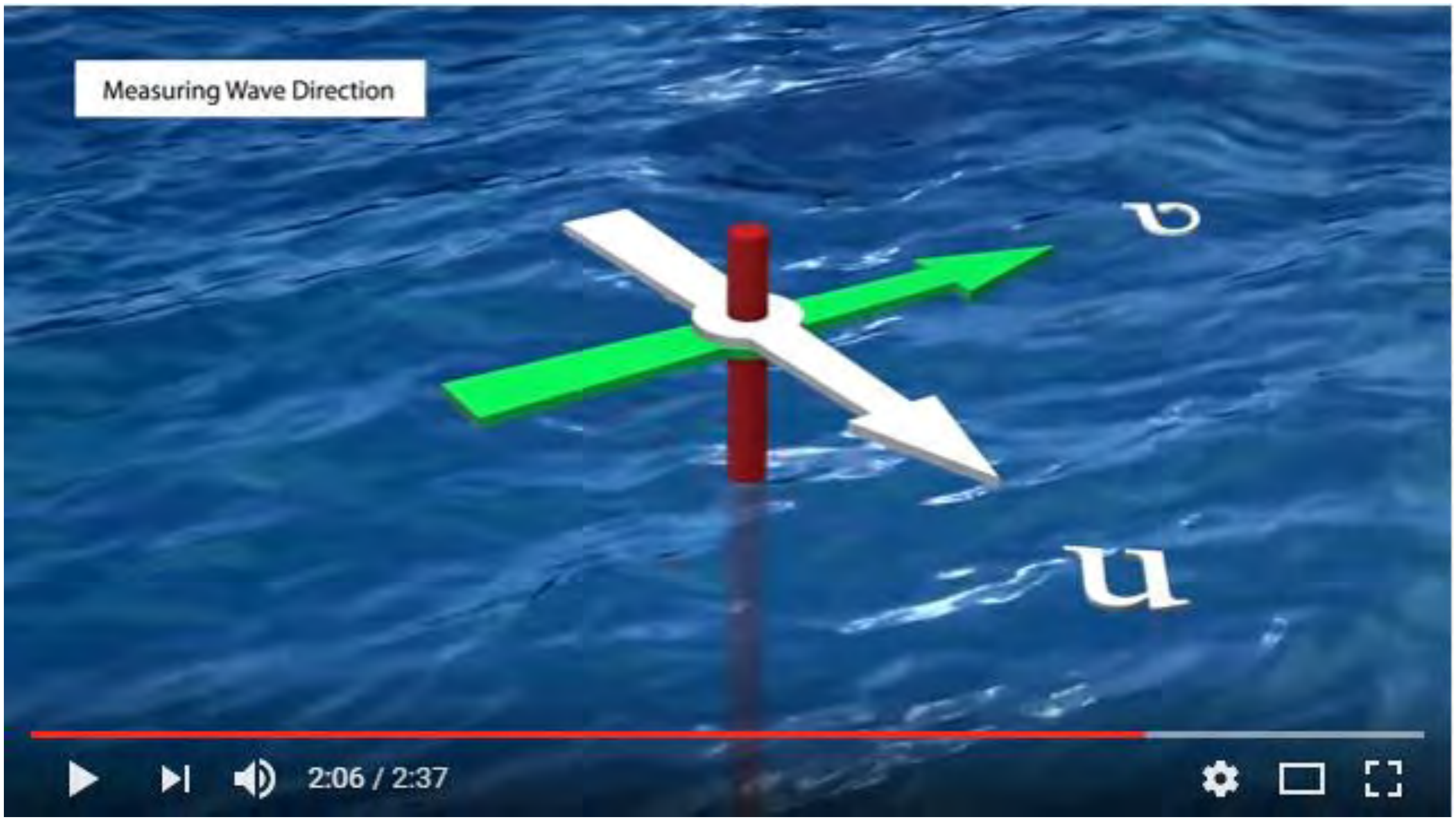


PUV法觀測波浪



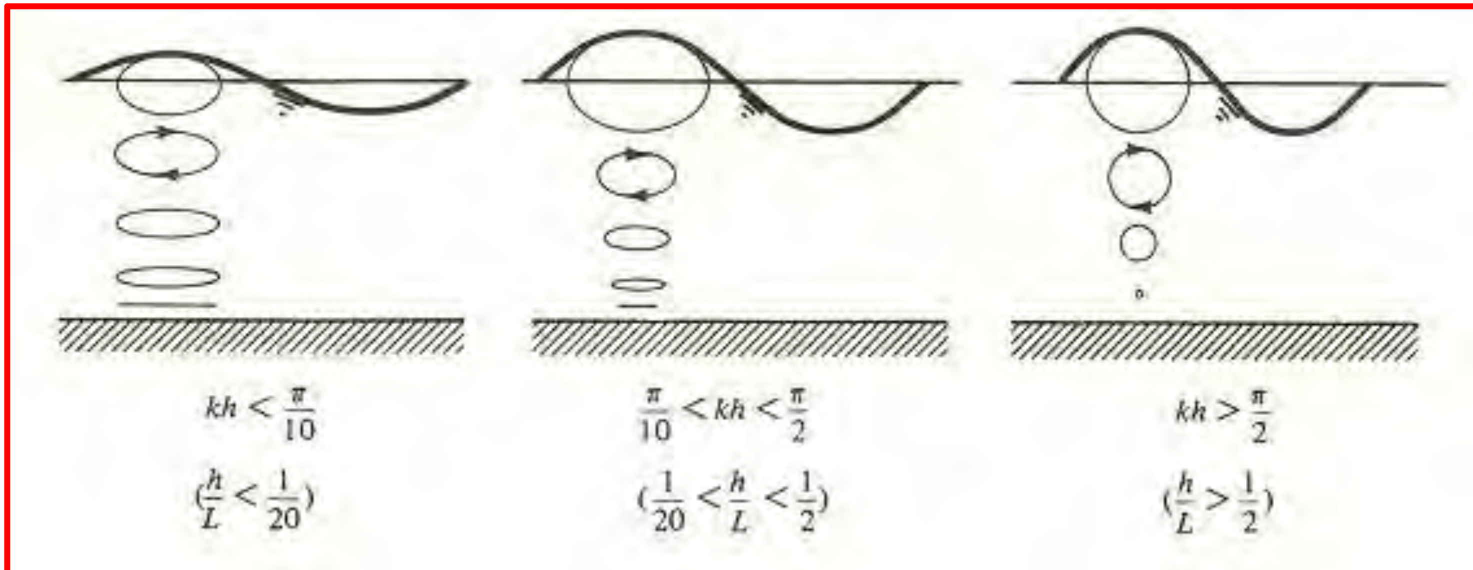
http://www.nortek-as.com/en/knowledge-center/wave-measurements-with-the-nortek-awac

PUV法觀測波浪

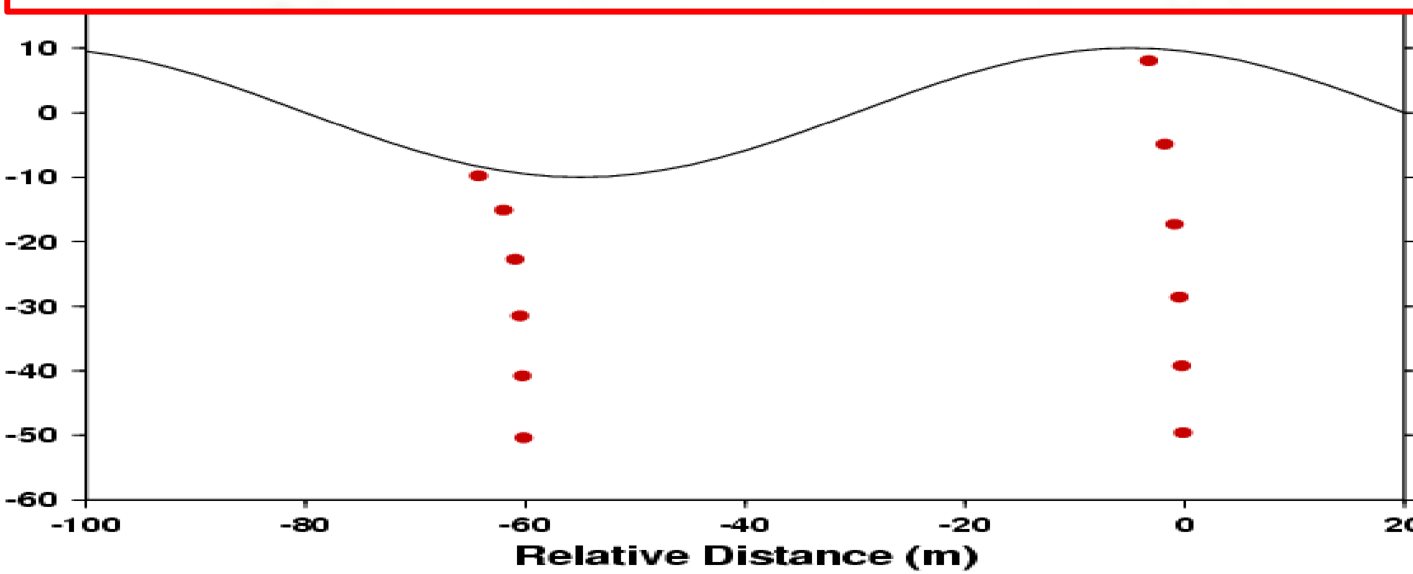


http://www.nortek-as.com/en/knowledge-center/wave-measurements-with-the-nortek-awac

波動隨水深減衰

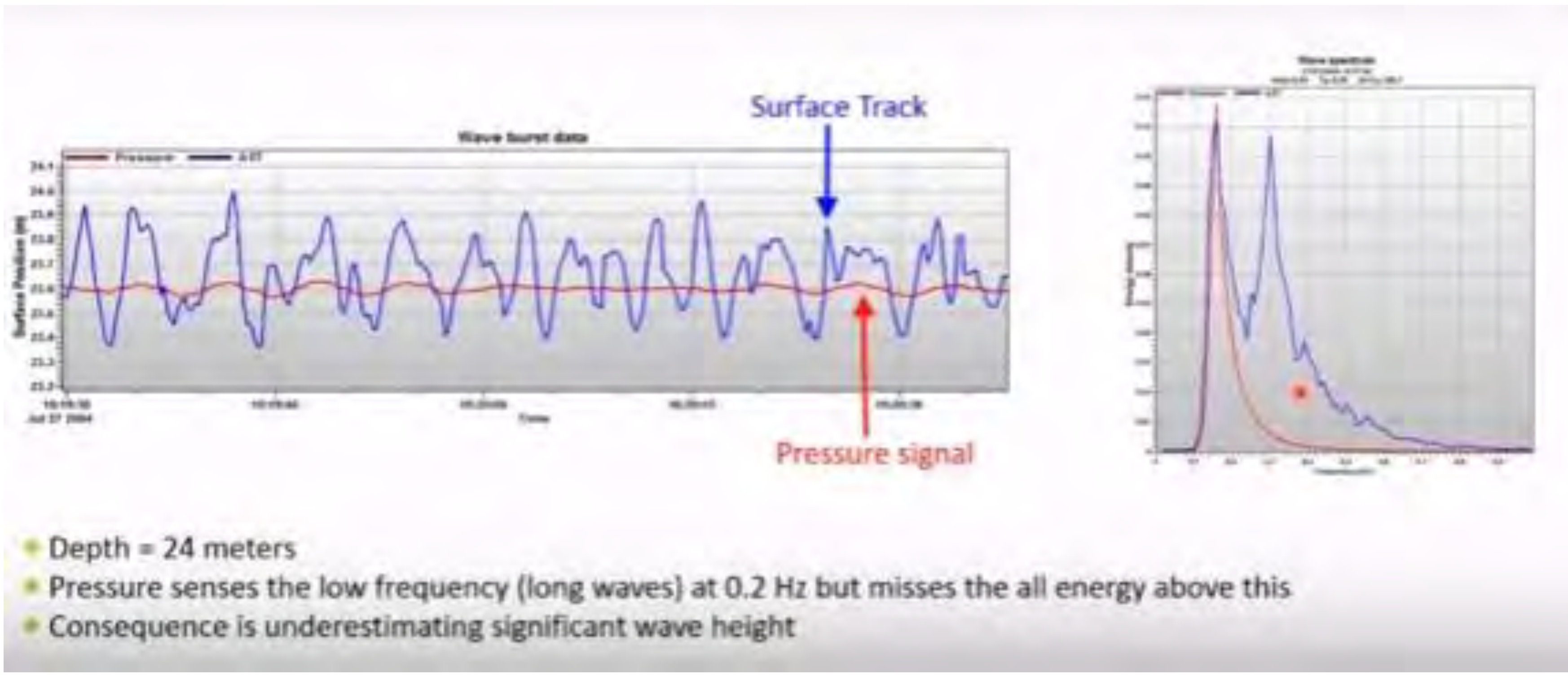


kh < π/10
(h/L < 1/20)
π/10 < kh < π/2
(1/20 < h/L < 1/2)
kh > π/2
(h/L > 1/2)



10
0
-10
-20
-30
-40
-50
-60
-100
-80
-60
-40
-20
0
20
Relative Distance (m)

波動隨水深減衰



http://www.nortek-as.com/en/knowledge-center/wave-measurements-with-the-nortek-awac

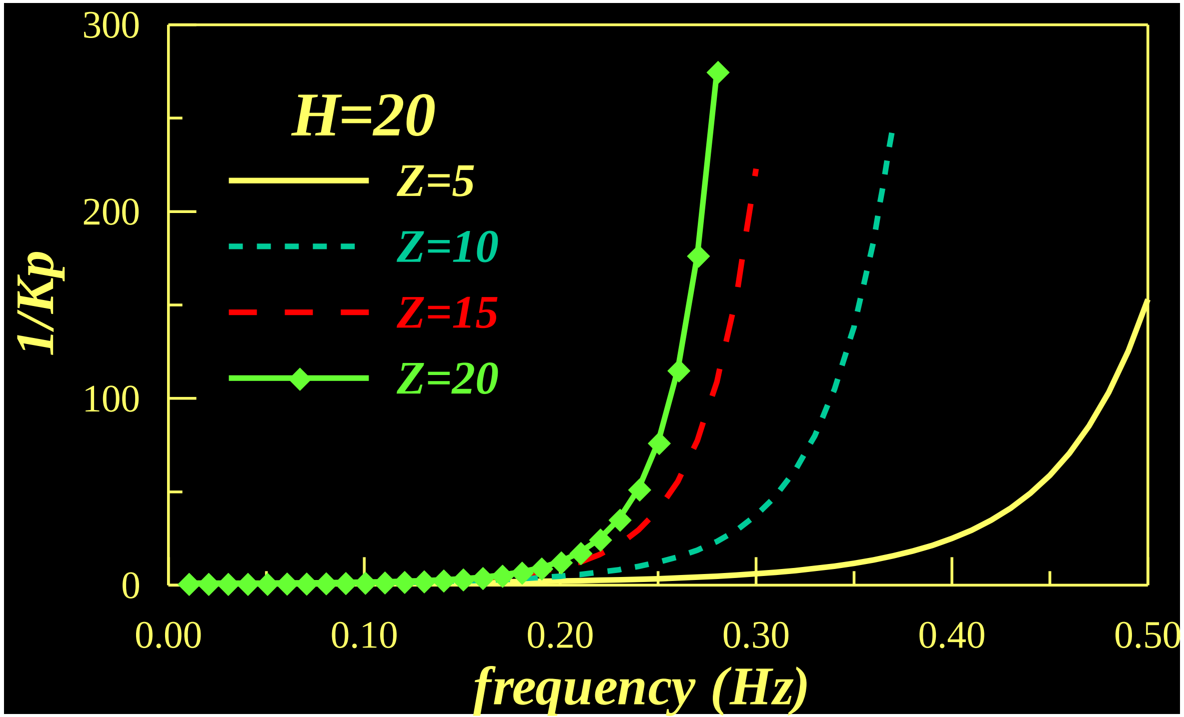
線性轉換函數 (linear pressure response function)

$$p = \eta\, k_p$$

$$S_{\eta\eta}(f) = \frac{1}{k_p{}^2(f)} S_{pp}(f)$$

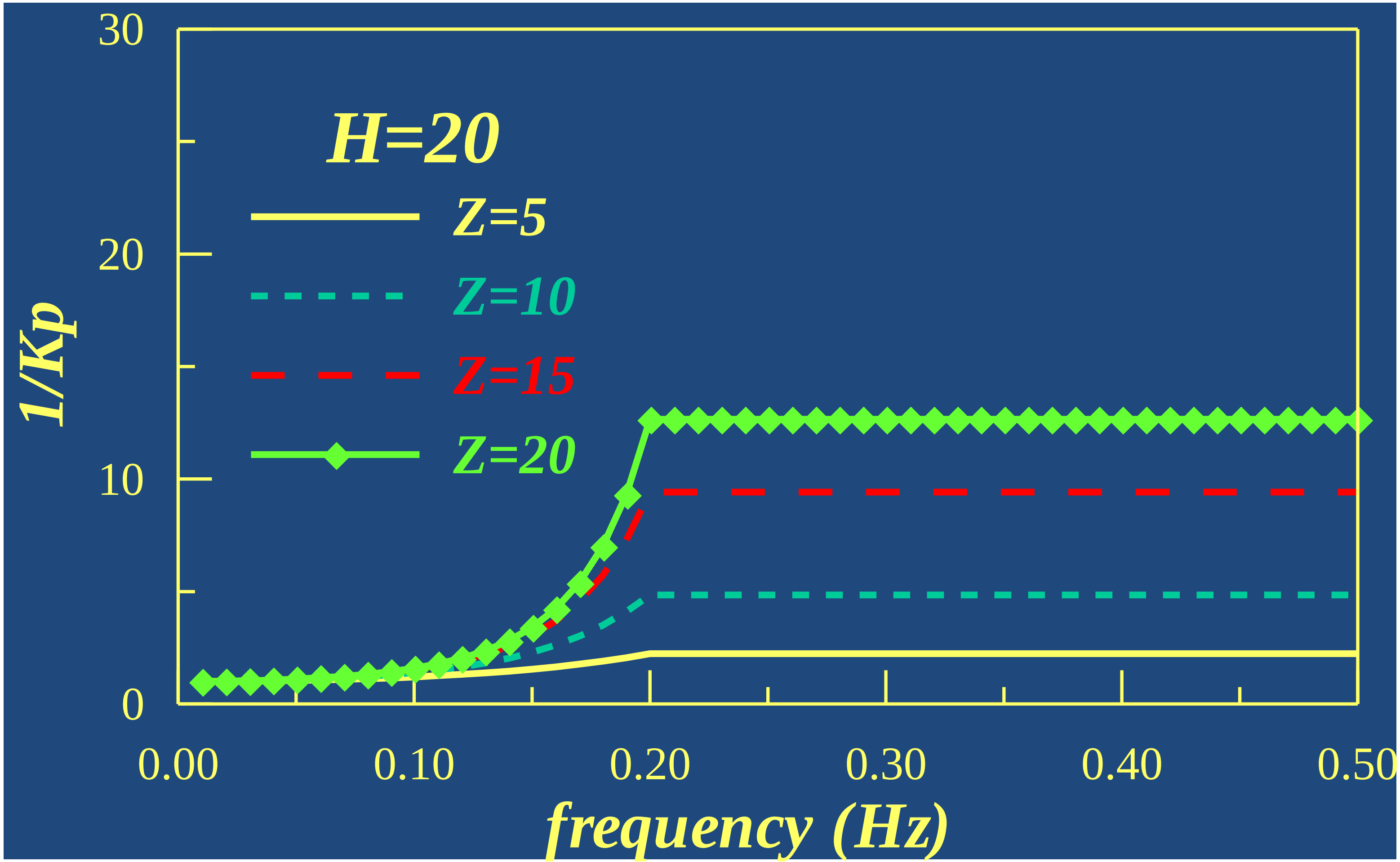
Linear wave theory：

$$k_p = \frac{\cosh k(h+z)}{\cosh kh}$$



線性轉換函數 (linear pressure response function)

- 修正之壓力轉換函數 D / L =0.5



複合式波浪觀測


GENERAL ACOUSTICS

Test Winner RIZA 2005 Rijkswaterstaat

LOG_aLevel®

Calibration Free Remote Sensing of Water Level and Waves

LOG_aLevel® is a cost-effective, complete, remote sensing and stand-alone water level gauge on the basis of ultrasonic sensors. The system works automatically and is (optional) independent of any external connections. It is free of calibration and needs no maintenance.

High performance ultrasonic sensors guarantee reliable, fast and precise measurements of all kinds of water level and its dynamics.

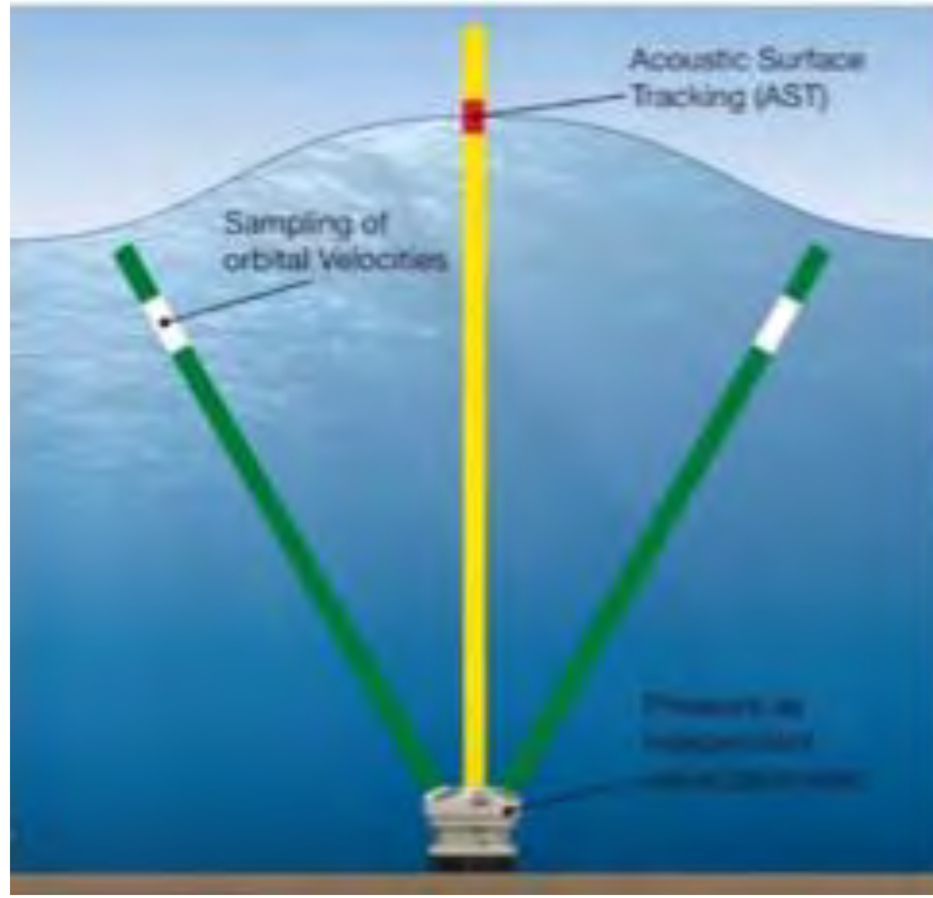
Advantages:

- Maintenance-Free
- Quick assembly and initiation
- Precise, robust and economical
- Always reliable under extreme conditions: flood, ice, storms, debris, etc.
- Calibration Free due to Outstanding Sound Velocity Compensation
- High Resolution Wave Measurement possible
- Remote data transmission, control and alerting
- Network integrity and multi event triggering
- World-wide proved and tested
- Easy to use Windows-Software

Applications:

- Storm Tide, Flood and Tsunami Measuring Networks
- Wave Monitoring and Analysis
- Hydrography
- Operating Level Gauge for Dredging and Surveying
- Event Alerting System
- Water Reservoir Management
- Monitoring Discharger of e.g. Power Stations
- Environmental monitoring

LOG_aLevel®

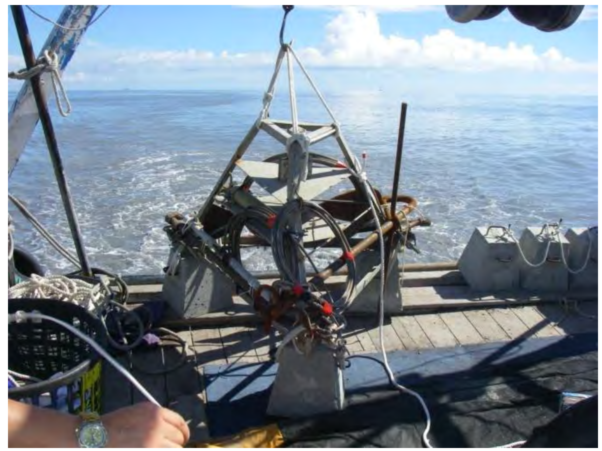


波浪觀測現場作業

- http://www.nortek-as.com/en/products/current-profilers

波浪觀測現場作業

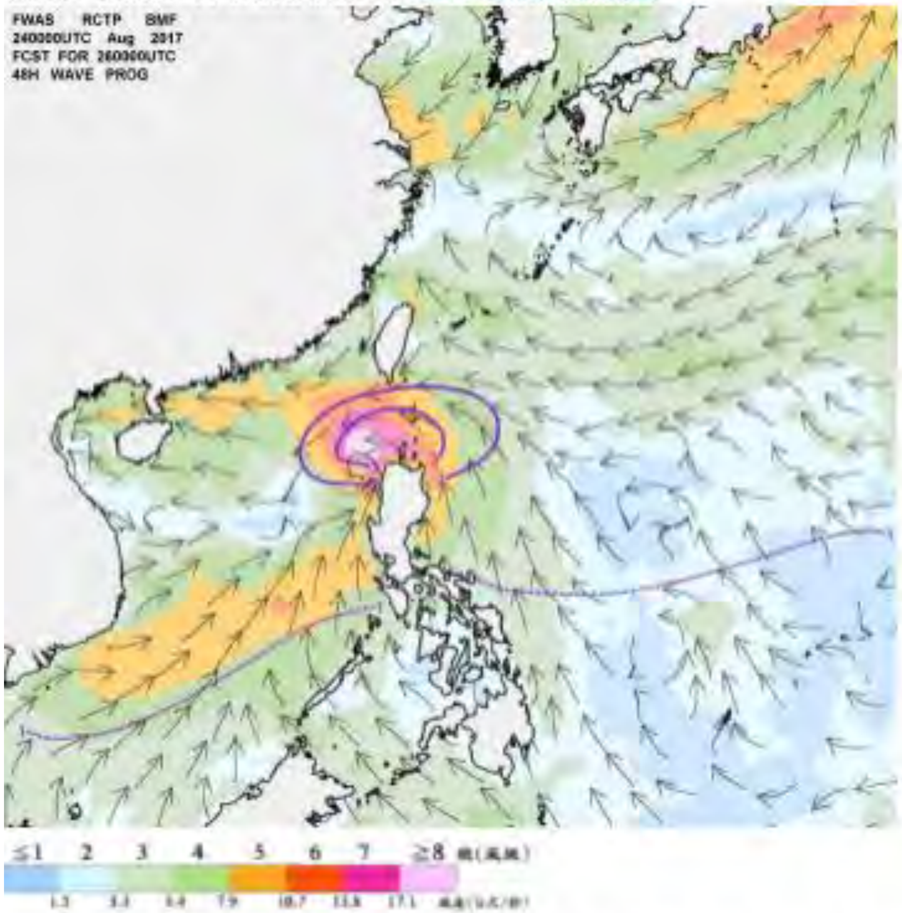
現場施放方式的演進
- 施放海域不同
- 當地漁撈作業
- 底質運移情形
- 作業船隻需求不同

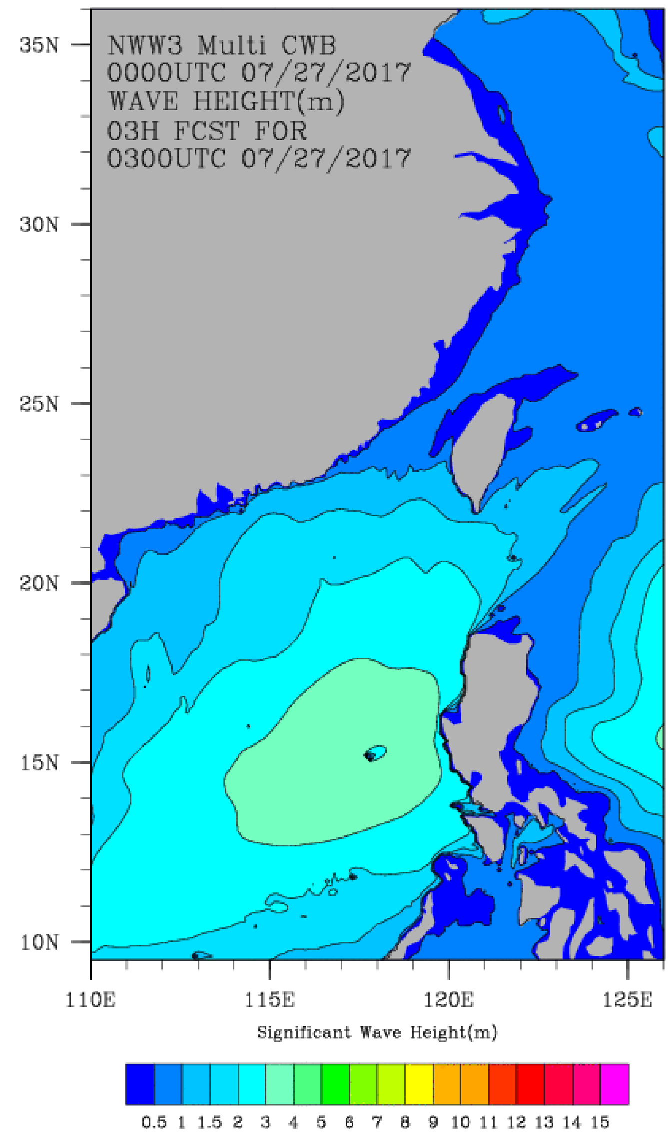


中央氣象局波浪預報

首頁 > 預報 > 分析及預測圖 > 48小時波浪預報圖



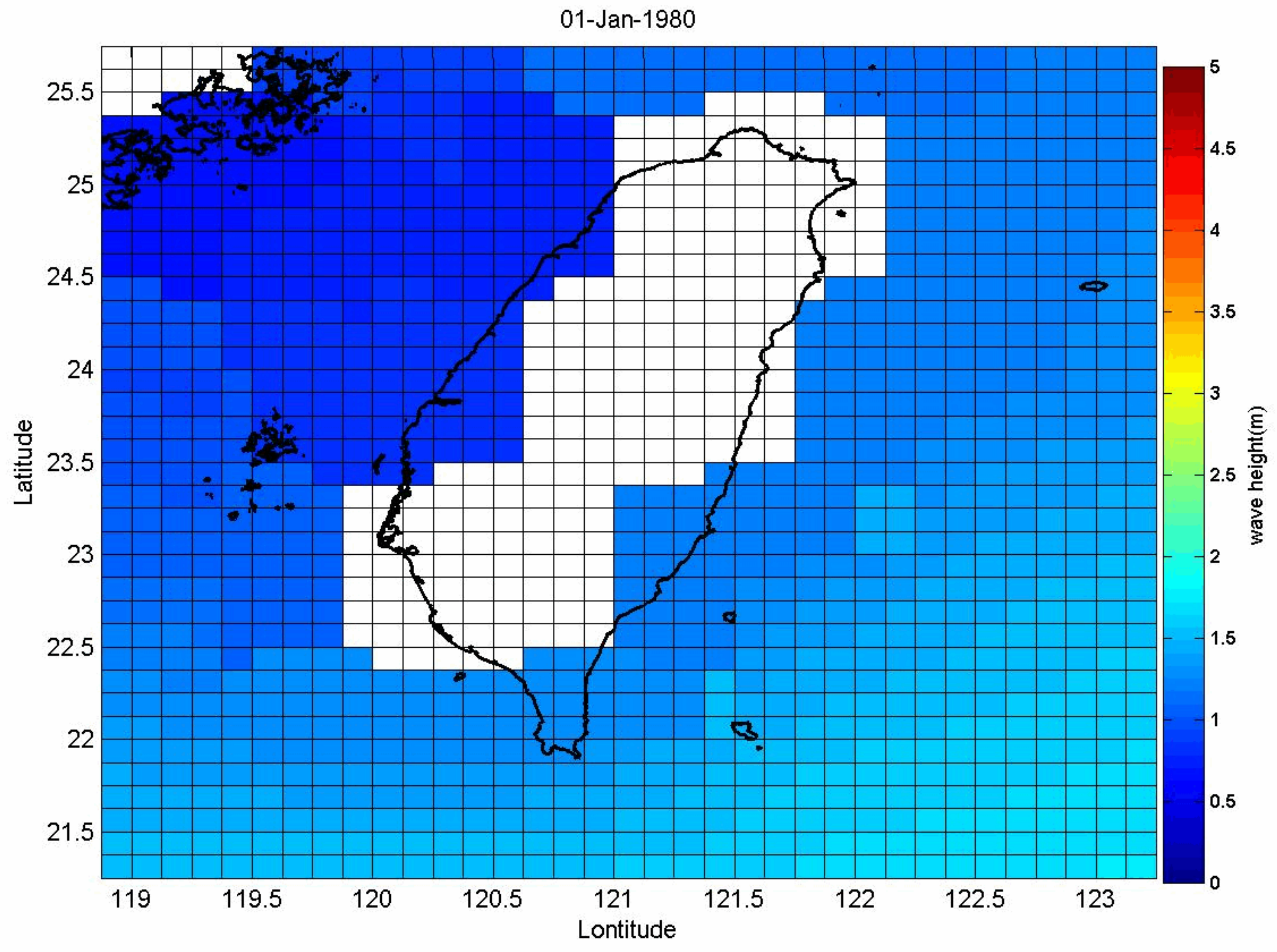
- 波浪圖之等值線代表海上所有波的前三分之一較大波之平均波高。
- 最大波有可能到達上述波高的兩倍，使用此圖需加以注意。



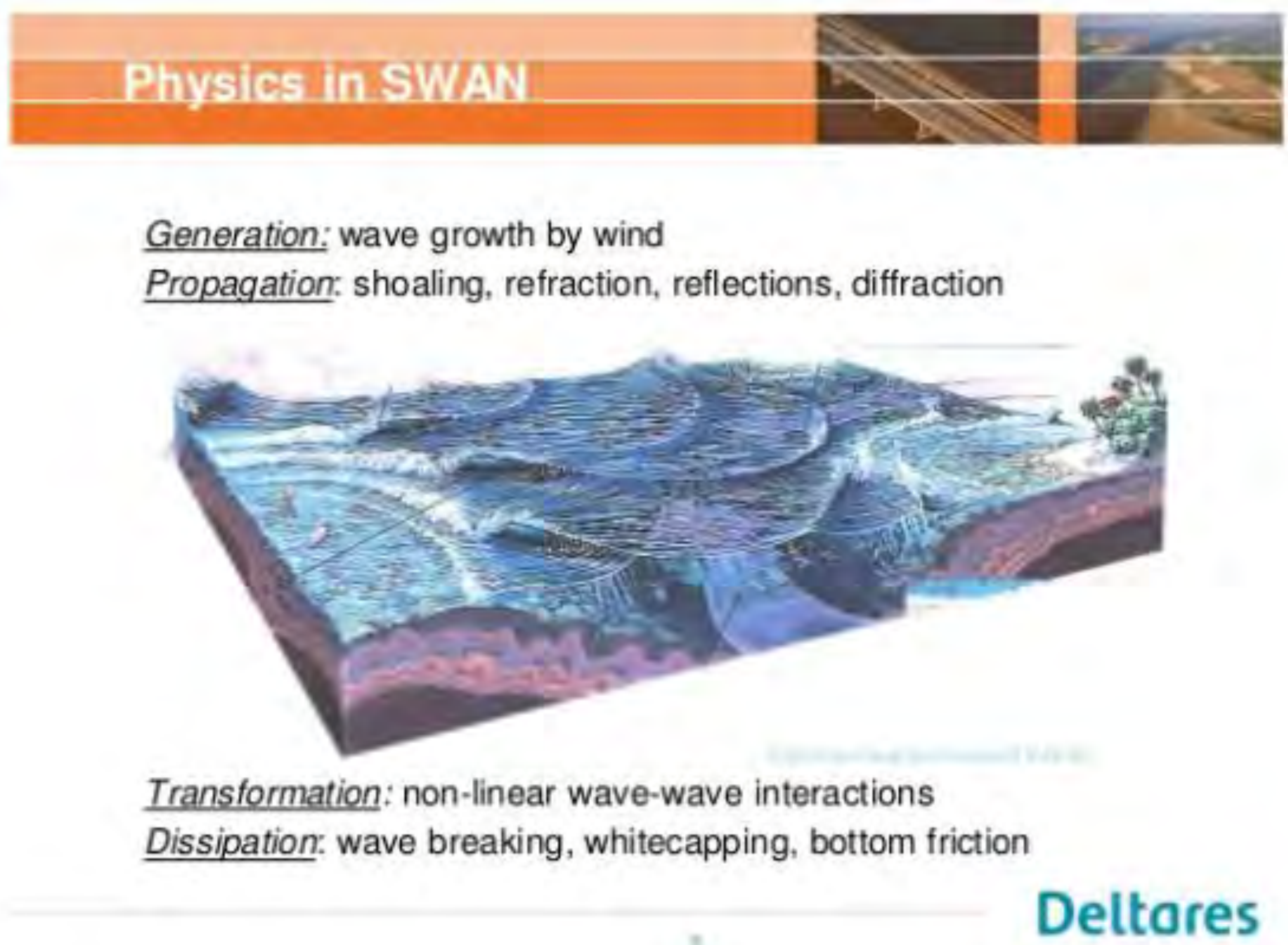
ECMWF

- http://www.ecmwf.int/research/ifsdocs/.
- In third-generation models of this type, the major properties of the forecasts are determined by the action balance equation.
- Since January 26, 2010, the resolution has been increased to 0.25° at the equator, with an average resolution of 28 km. The wave spectrum now has 36 frequency bins and 36 directions. This has resulted in more accurate forecasts in coastal areas and enclosed seas.

European Centre for Medium-Range Weather Forecasts

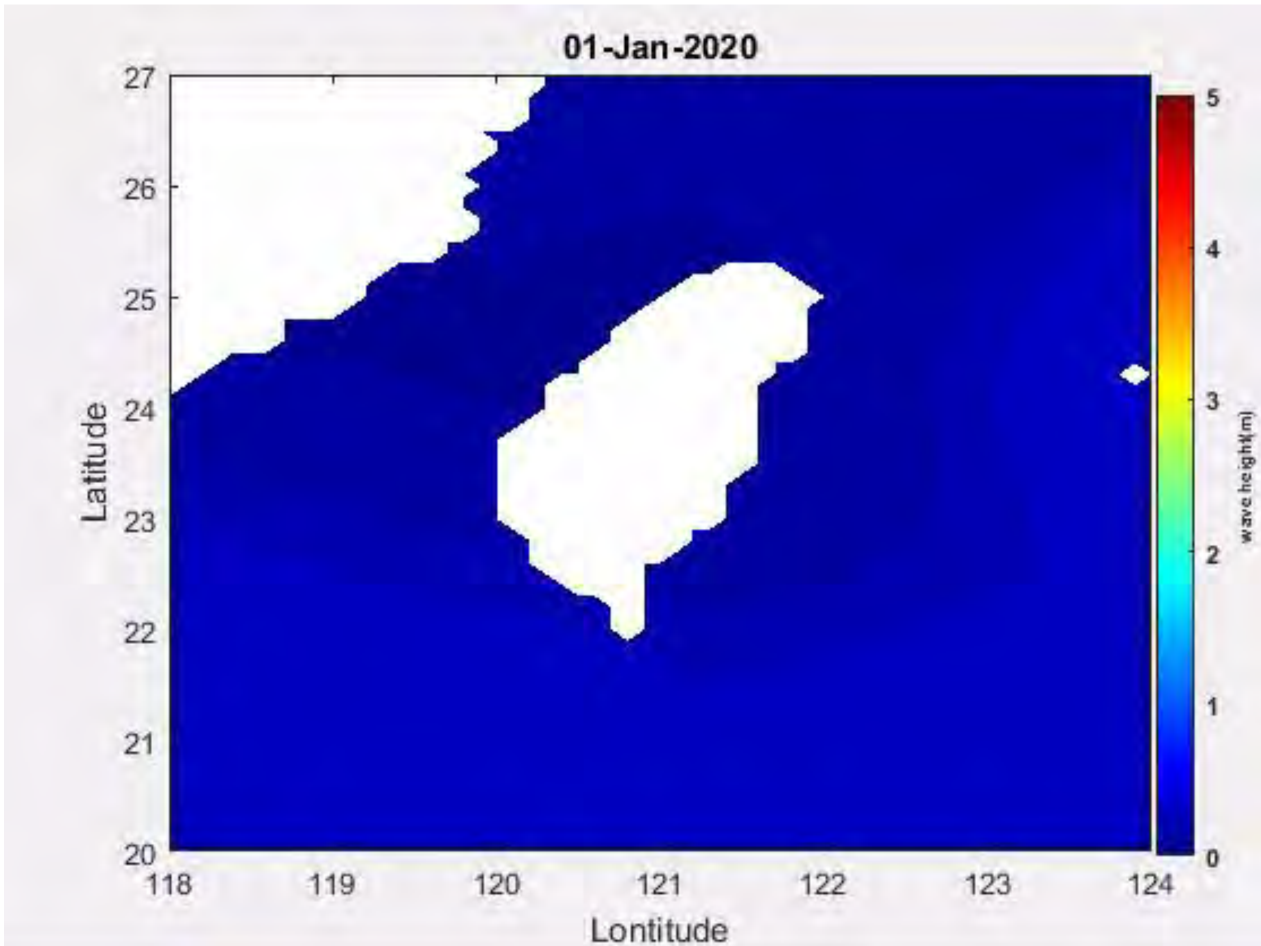


Simulating WAves Nearshore



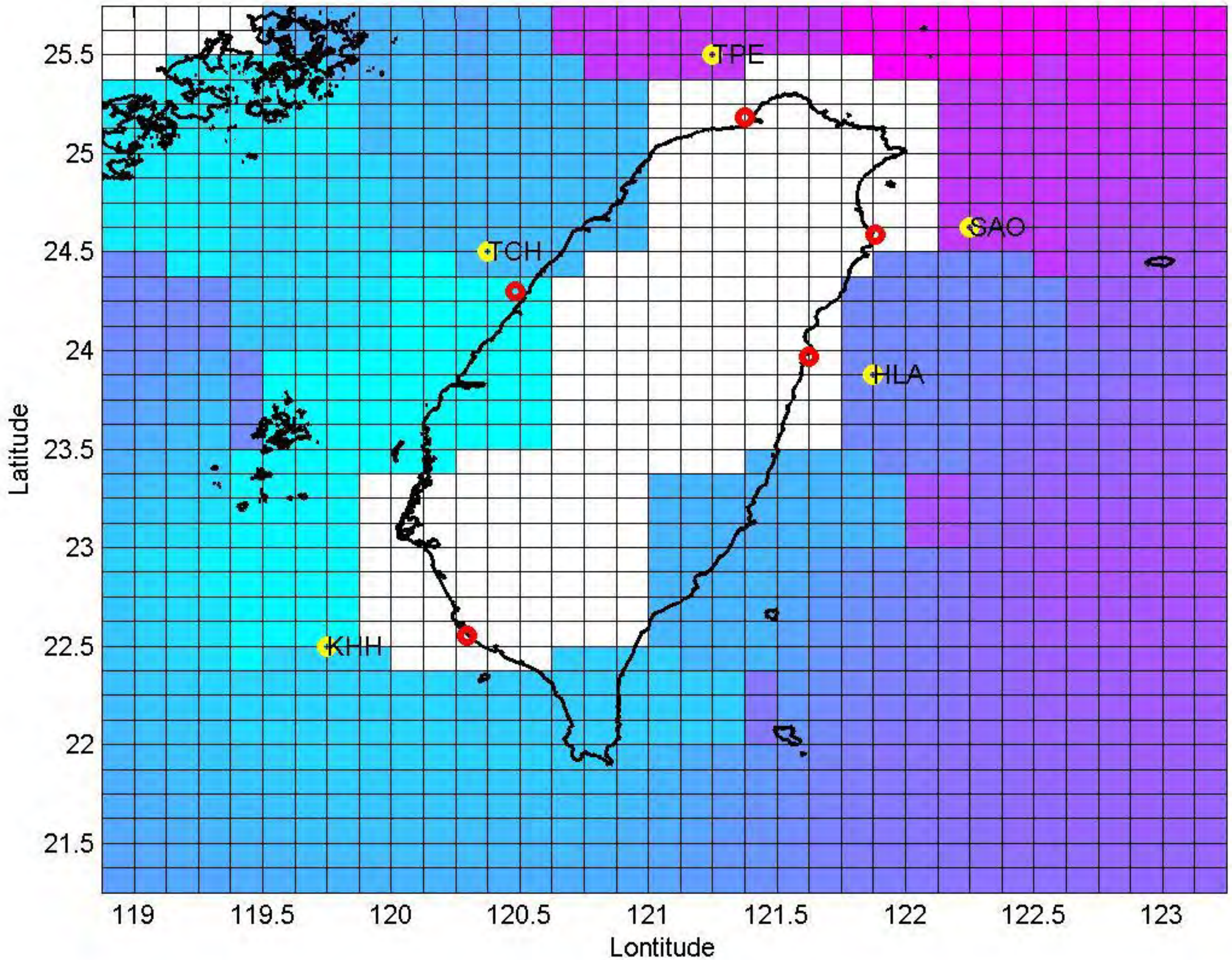
https://www.slideshare.net/Delft_Software_Days/dsdint-swan-advanced-course-03-model-physics-in-swan

SWAN simulation

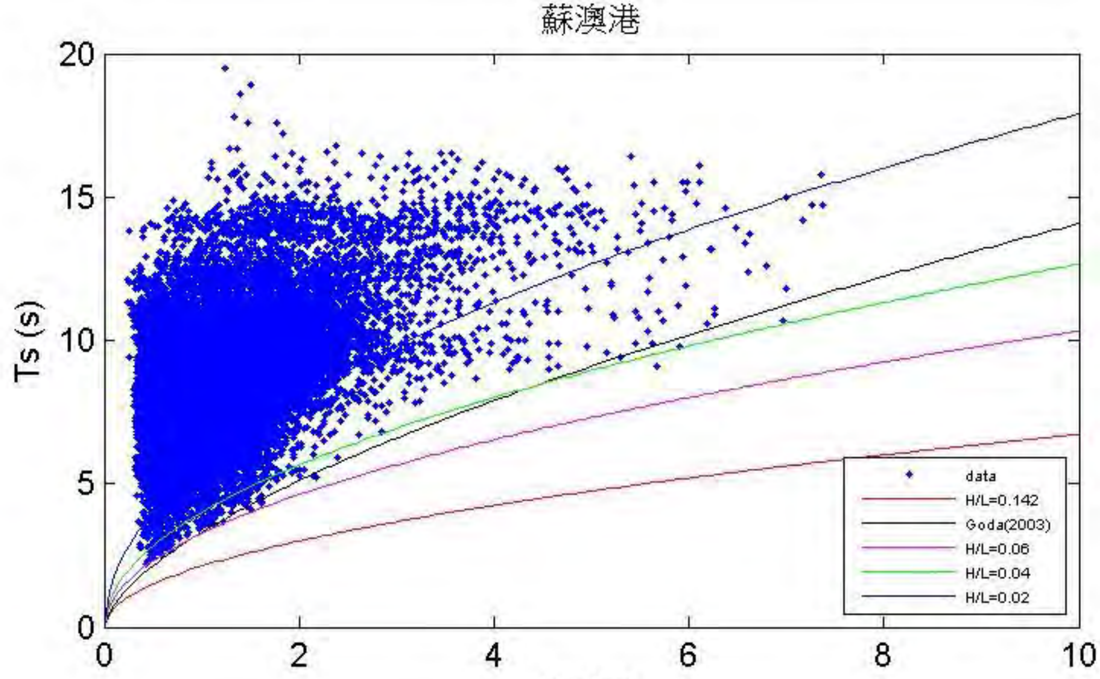


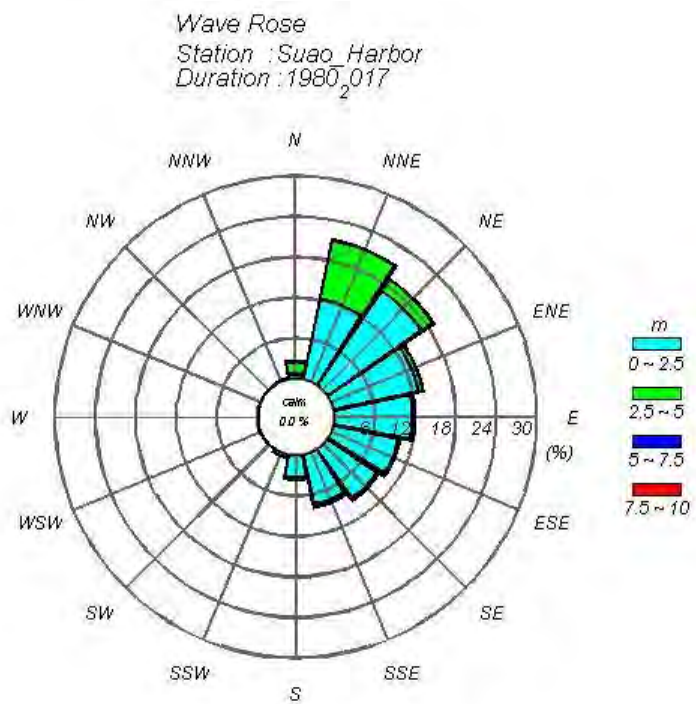
近岸與外海波浪特性

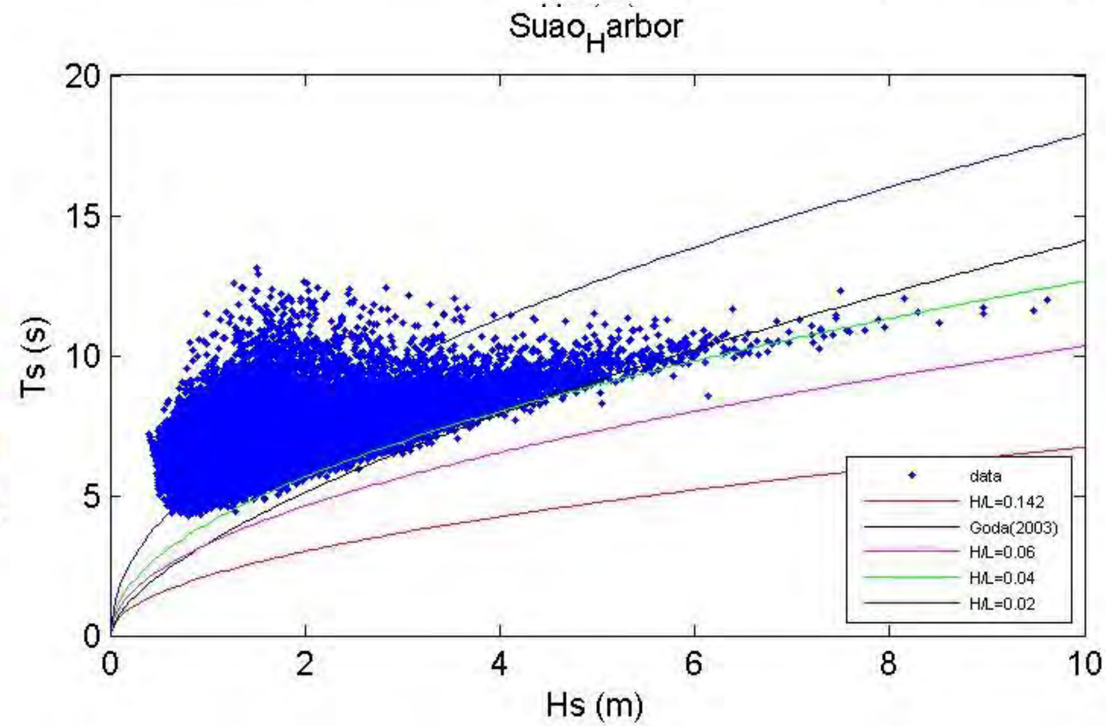
討論測站

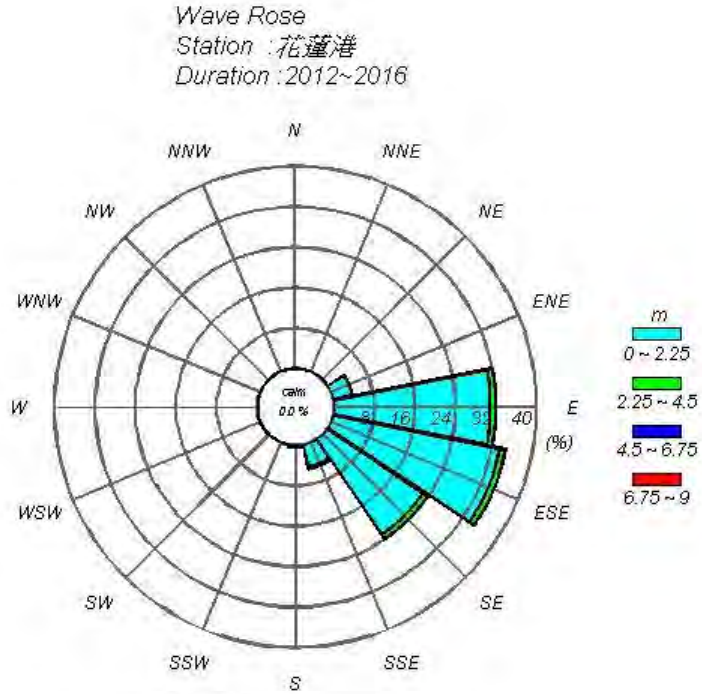


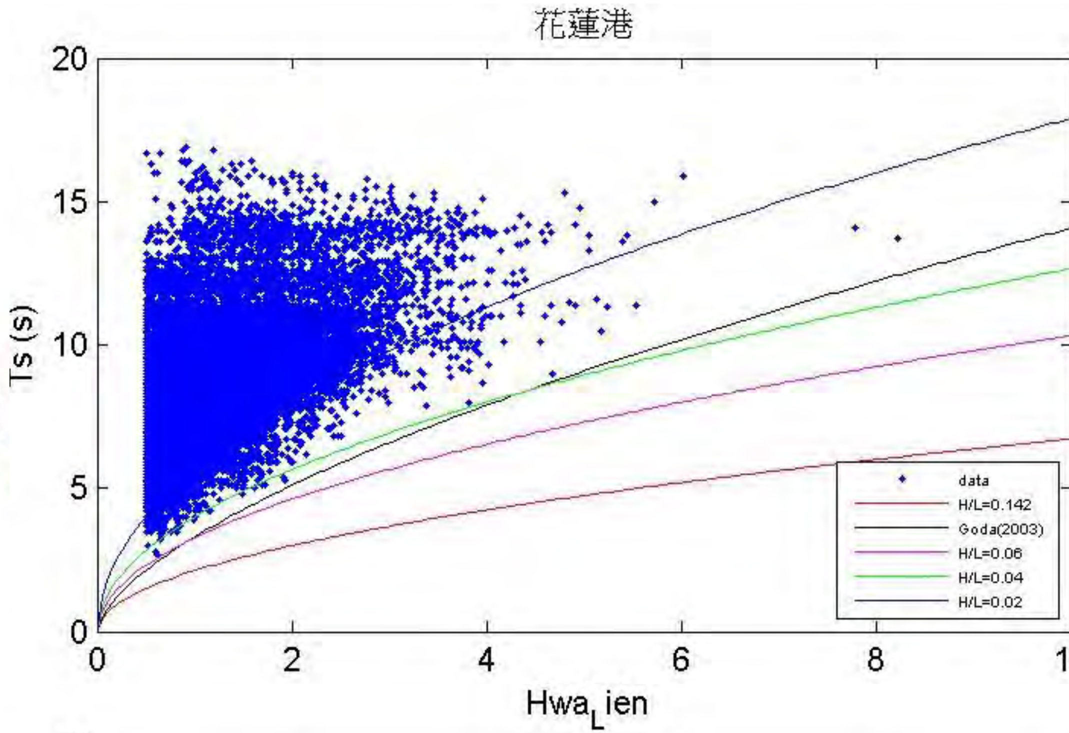

Wave Rose
Station :蘇澳港
Duration :2012~2016
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
calm
0.0 %
6
12
18
24
30
(%)
m
0 ~ 2
2 ~ 4
4 ~ 6
6 ~ 8

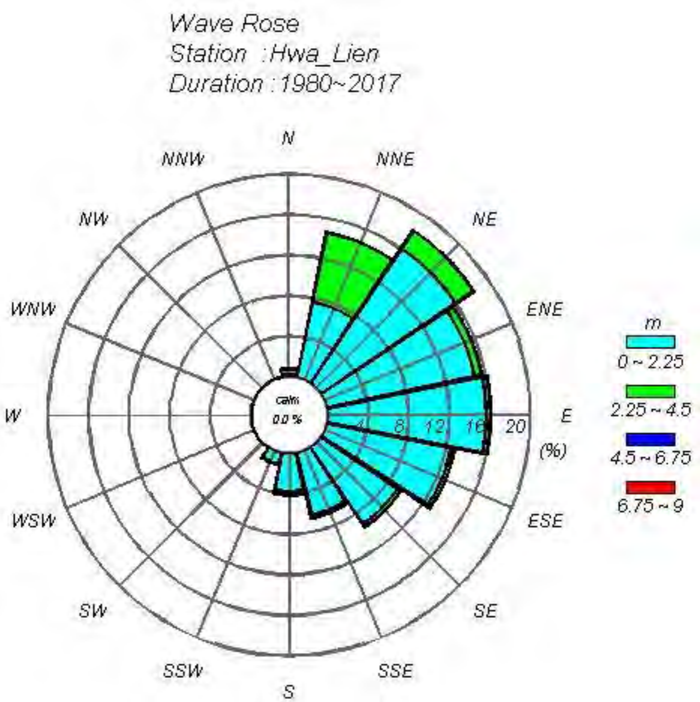

蘇澳港
Ts (s)
20
15
10
5
0
0
2
4
6
8
10
data
H/L=0.142
Goda(2003)
H/L=0.06
H/L=0.04
H/L=0.02

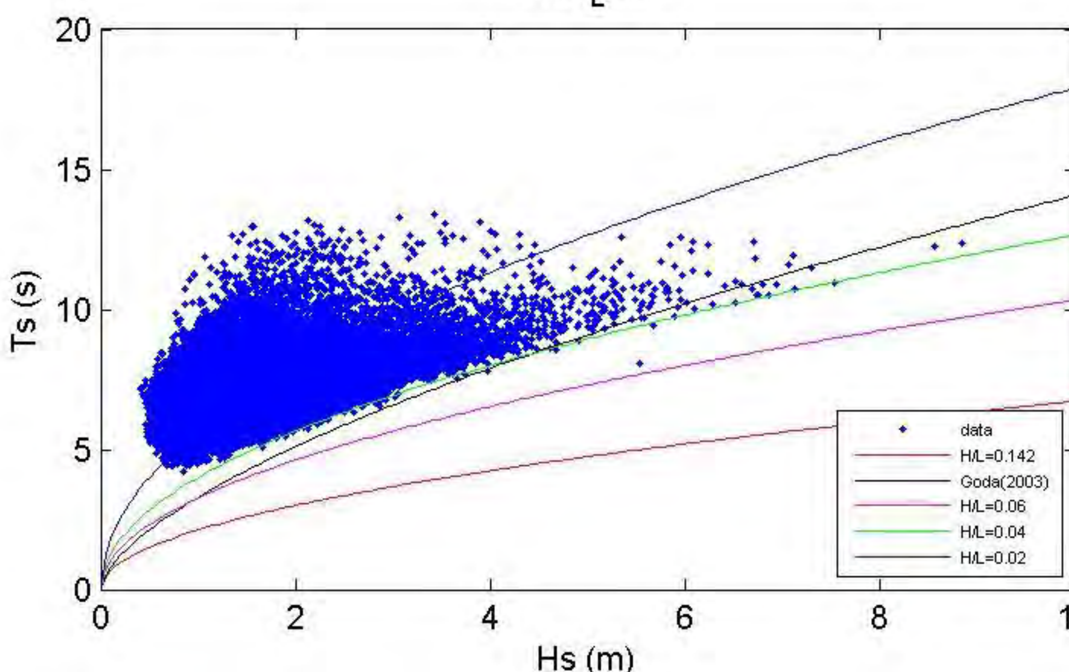

Wave Rose
Station :Suao_Harbor
Duration :1980_2017
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
calm
0.0 %
6
12
18
24
30
(%)
m
0 ~ 2.5
2.5 ~ 5
5 ~ 7.5
7.5 ~ 10

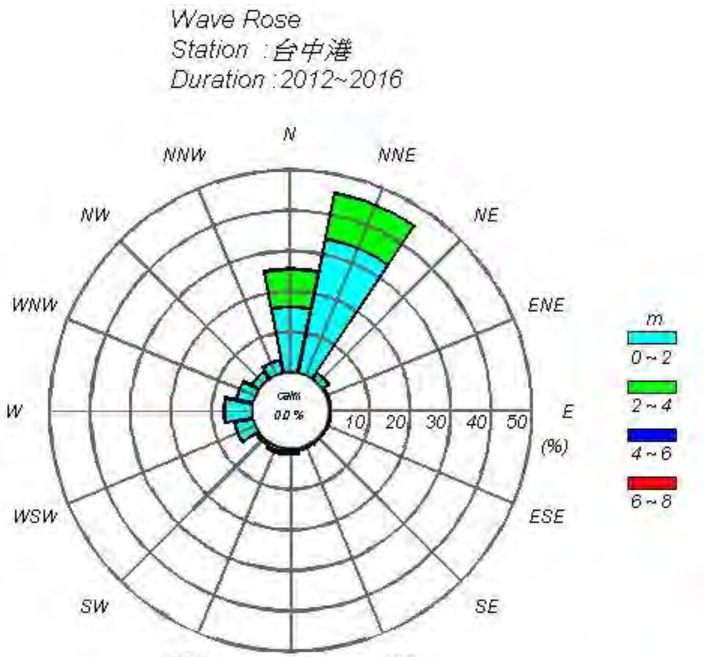

Suao_Harbor
Ts (s)
Hs (m)
20
15
10
5
0
0
2
4
6
8
10
data
H/L=0.142
Goda(2003)
H/L=0.06
H/L=0.04
H/L=0.02

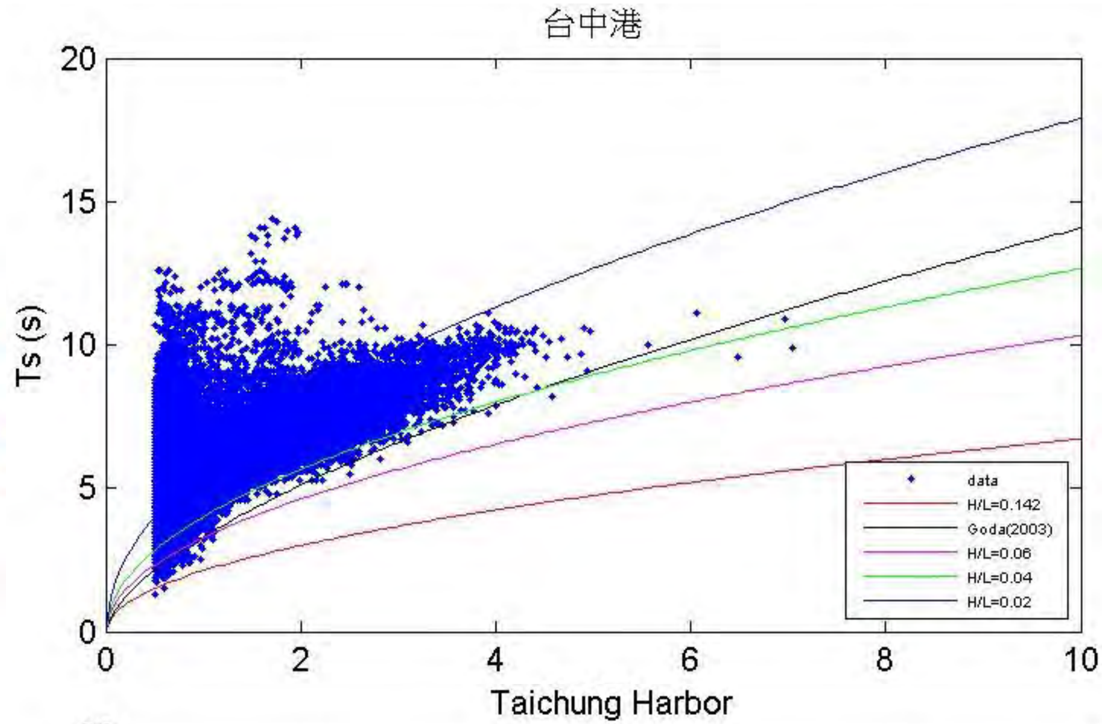

Wave Rose
Station :花蓮港
Duration :2012~2016
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
calm
0.0 %
8
16
24
32
40
(%)
m
0 ~ 2.25
2.25 ~ 4.5
4.5 ~ 6.75
6.75 ~ 9

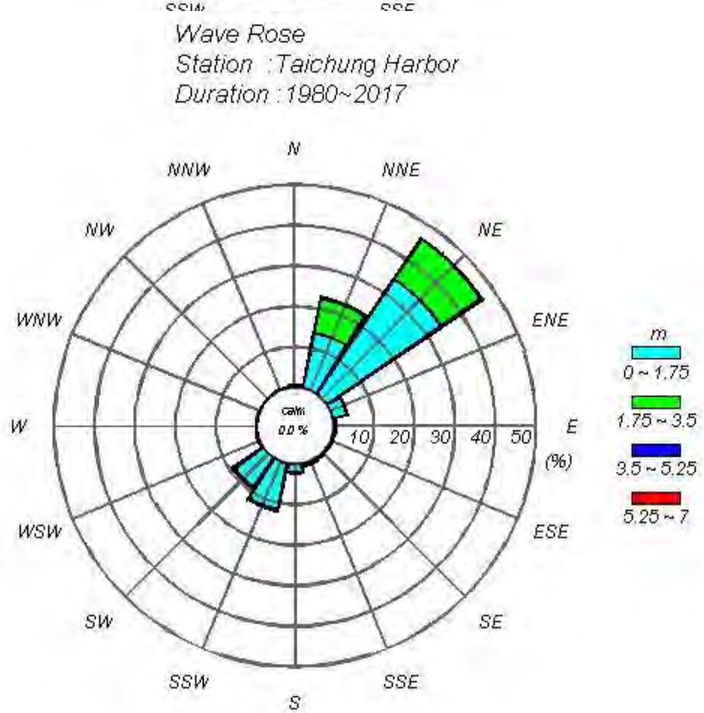

花蓮港
Ts (s)
Hwa_Lien
data
H/L=0.142
Goda(2003)
H/L=0.06
H/L=0.04
H/L=0.02

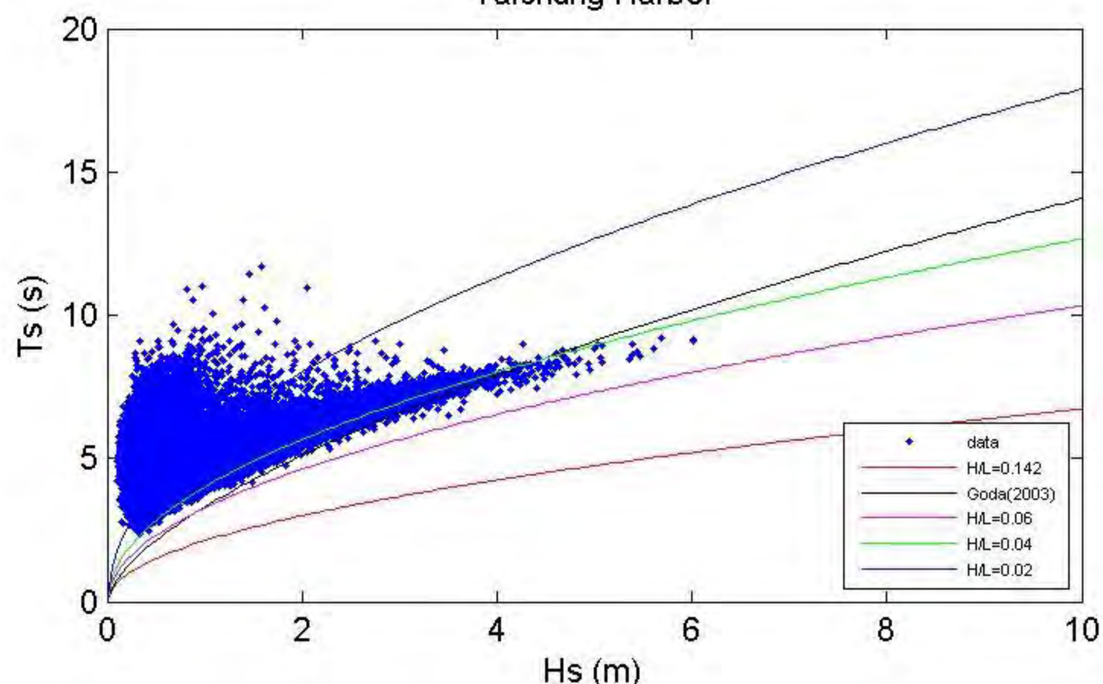

Wave Rose
Station :Hwa_Lien
Duration :1980~2017
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
calm
0.0 %
4
8
12
16
20
(%)
m
0 ~ 2.25
2.25 ~ 4.5
4.5 ~ 6.75
6.75 ~ 9

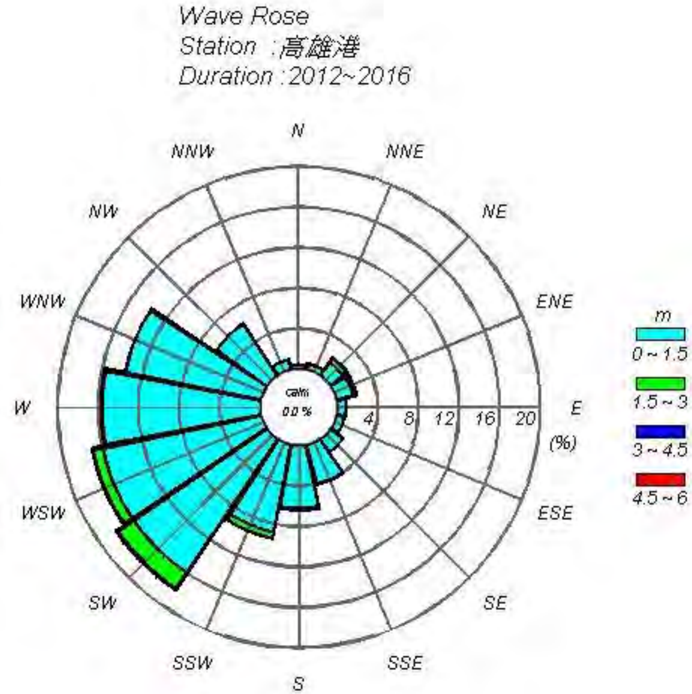

Ts (s)
Hs (m)
data
H/L=0.142
Goda(2003)
H/L=0.06
H/L=0.04
H/L=0.02

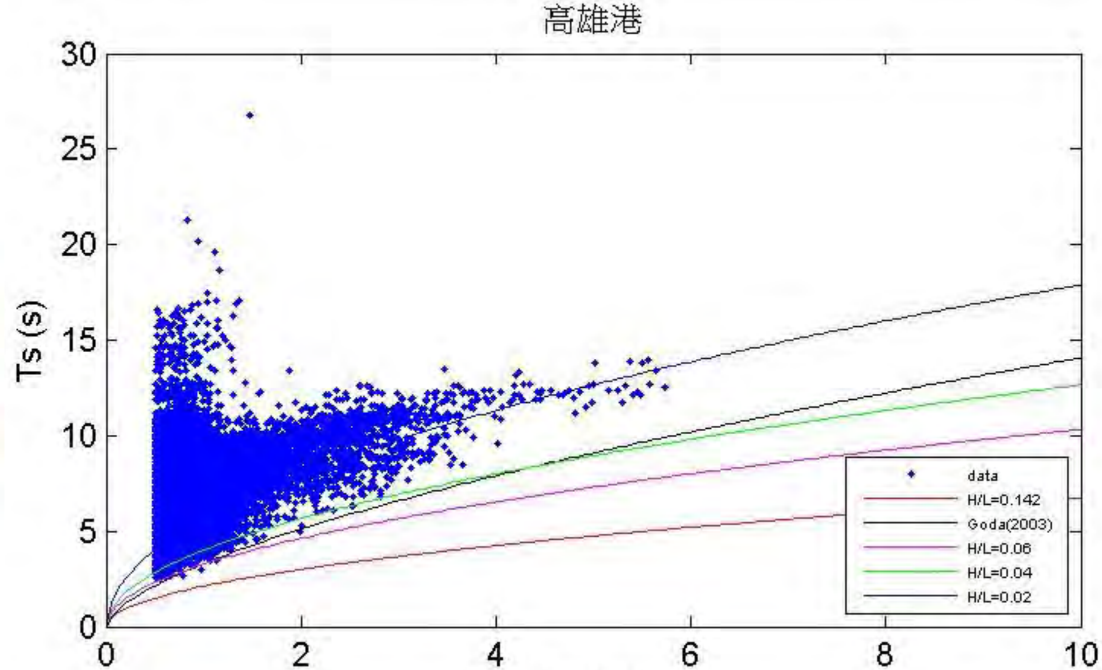

Wave Rose
Station :台中港
Duration :2012~2016
N
NNE
NE
ENE
E
ESE
SE
SSE
SSW
SW
WSW
W
WNW
NW
NNW
calm
0.0 %
10
20
30
40
50
(%)
m
0 ~ 2
2 ~ 4
4 ~ 6
6 ~ 8

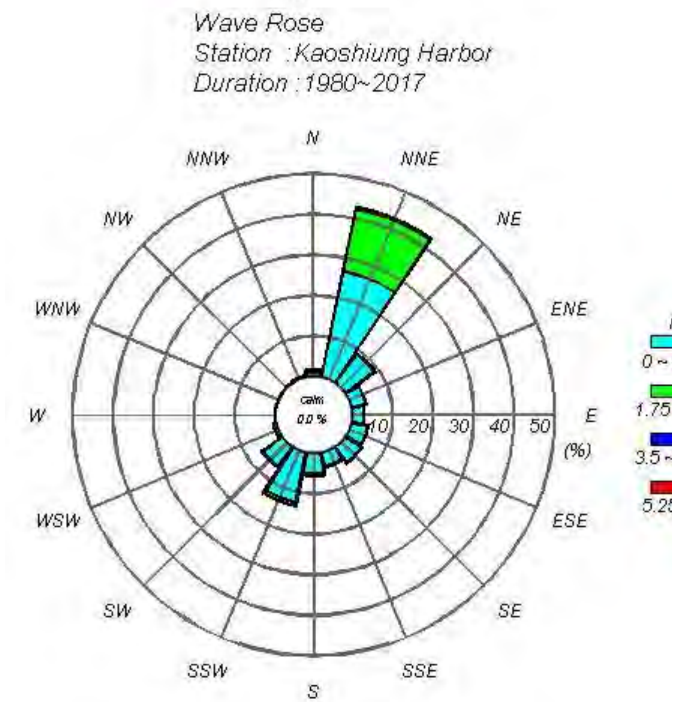

台中港
Ts (s)
20
15
10
5
0
0
2
4
6
8
10
data
H/L=0.142
Goda(2003)
H/L=0.06
H/L=0.04
H/L=0.02

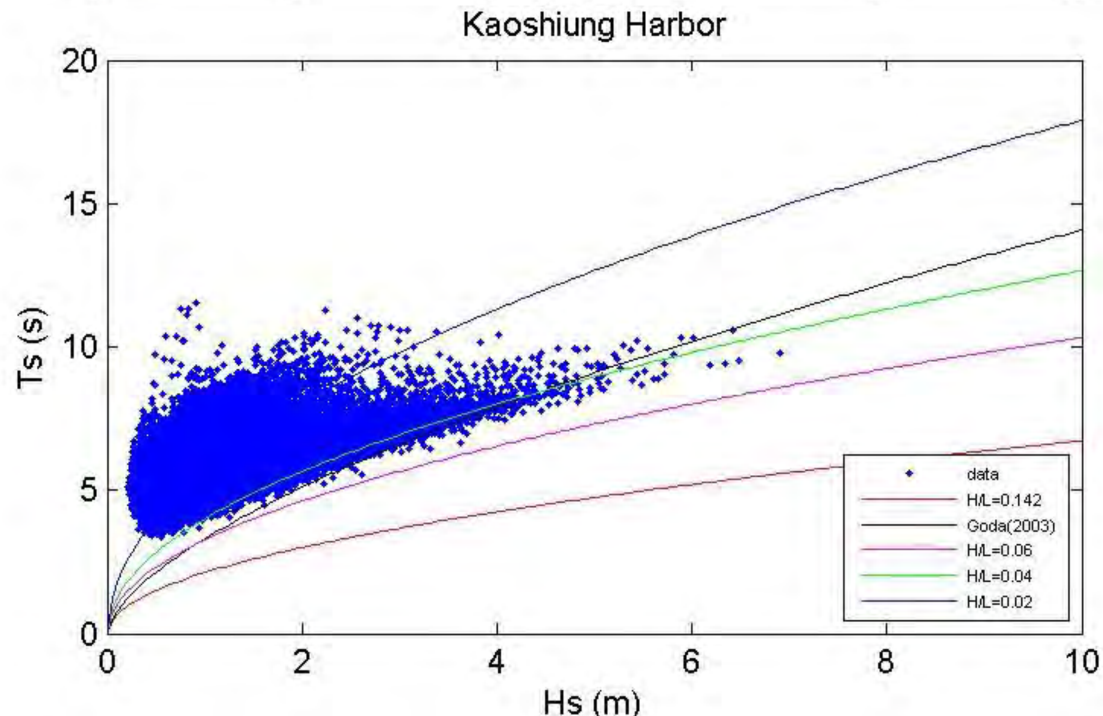

Wave Rose
Station :Taichung Harbor
Duration :1980~2017
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
calm
0.0 %
10
20
30
40
50
(%)
m
0 ~ 1.75
1.75 ~ 3.5
3.5 ~ 5.25
5.25 ~ 7


Taichung Harbor
Ts (s)
20
15
10
5
0
0
2
4
6
8
10
Hs (m)
data
H/L=0.142
Goda(2003)
H/L=0.06
H/L=0.04
H/L=0.02

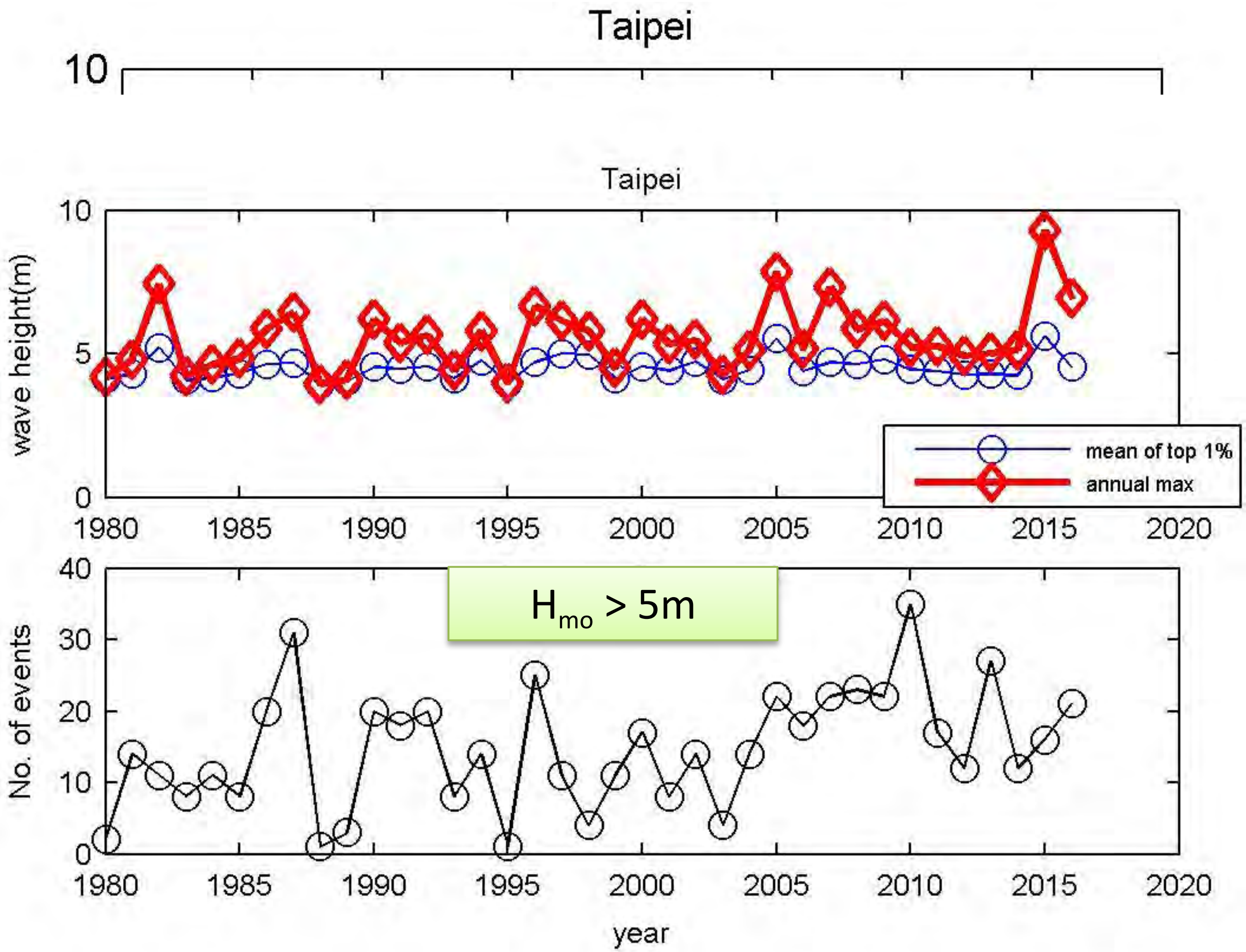

Wave Rose
Station :高雄港
Duration :2012~2016
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
calm
0.0 %
4
8
12
16
20
(%)
m
0 ~ 1.5
1.5 ~ 3
3 ~ 4.5
4.5 ~ 6


高雄港
Ts (s)
data
H/L=0.142
Goda(2003)
H/L=0.06
H/L=0.04
H/L=0.02


Wave Rose
Station :Kaoshiung Harbor
Duration :1980~2017
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
calm
0.0 %
10
20
30
40
50
(%)

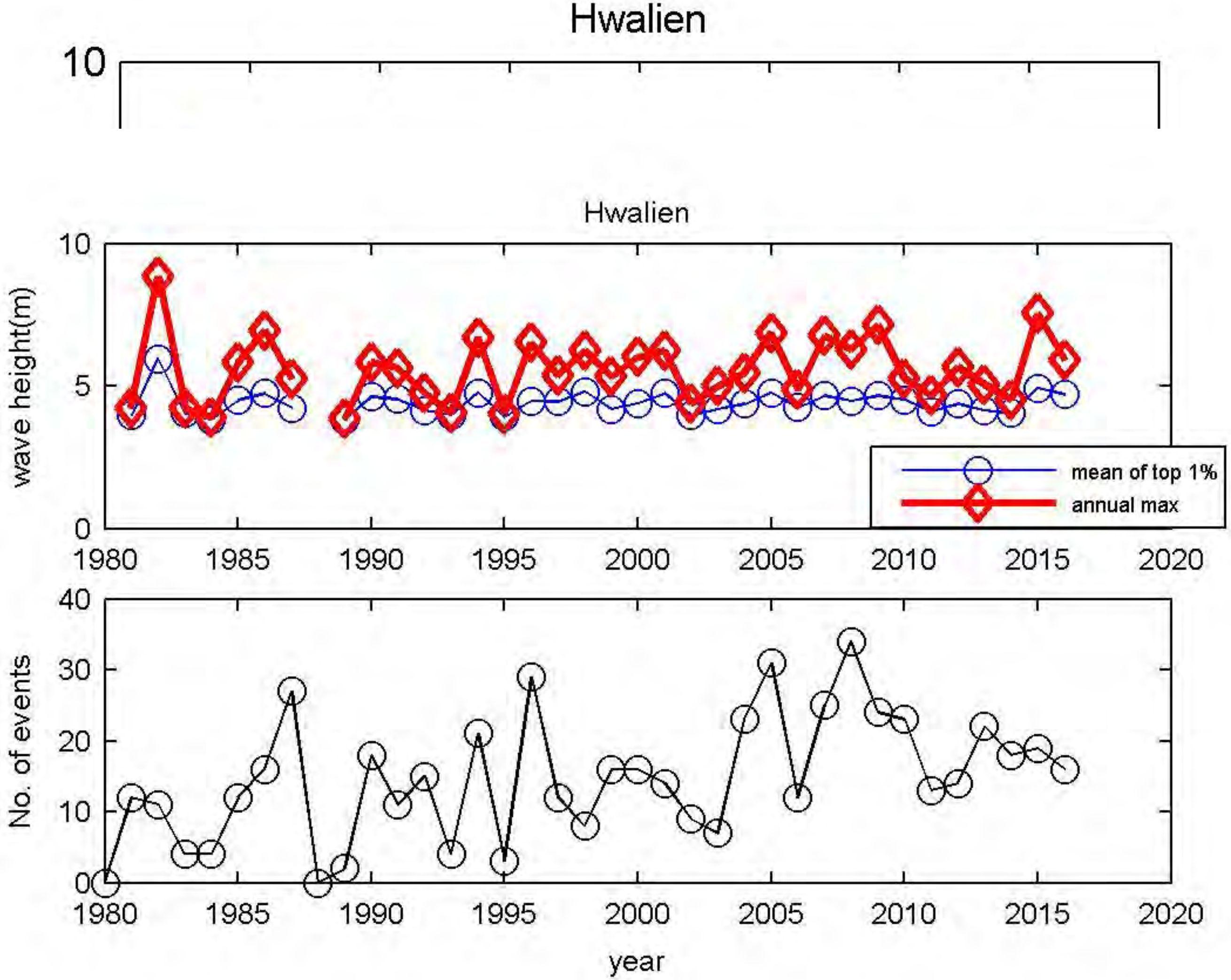

Kaoshiung Harbor
Ts (s)
Hs (m)
data
H/L=0.142
Goda(2003)
H/L=0.06
H/L=0.04
H/L=0.02

台北波高長期演變



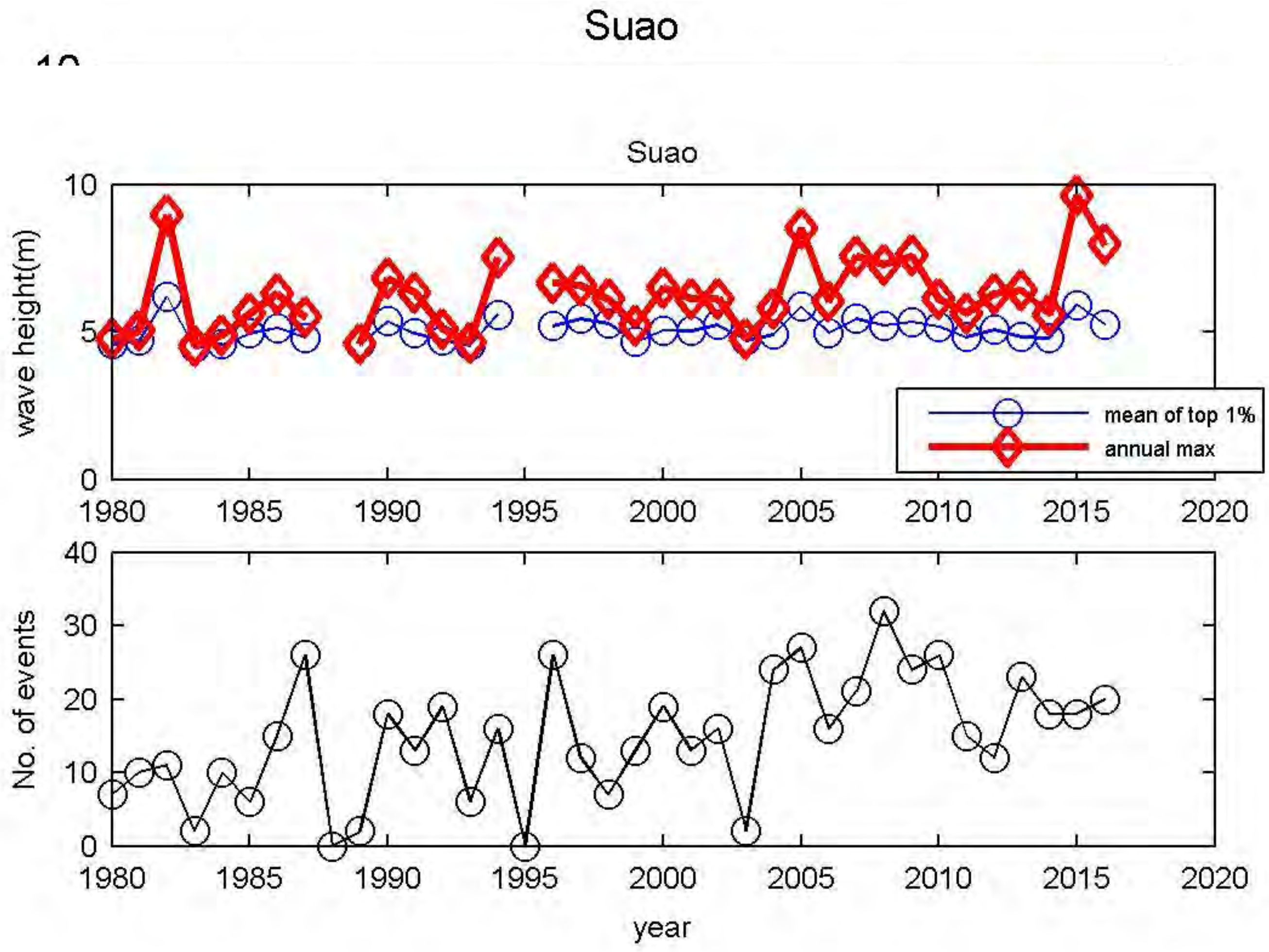
H_{mo} > 5m

花蓮波高長期演變



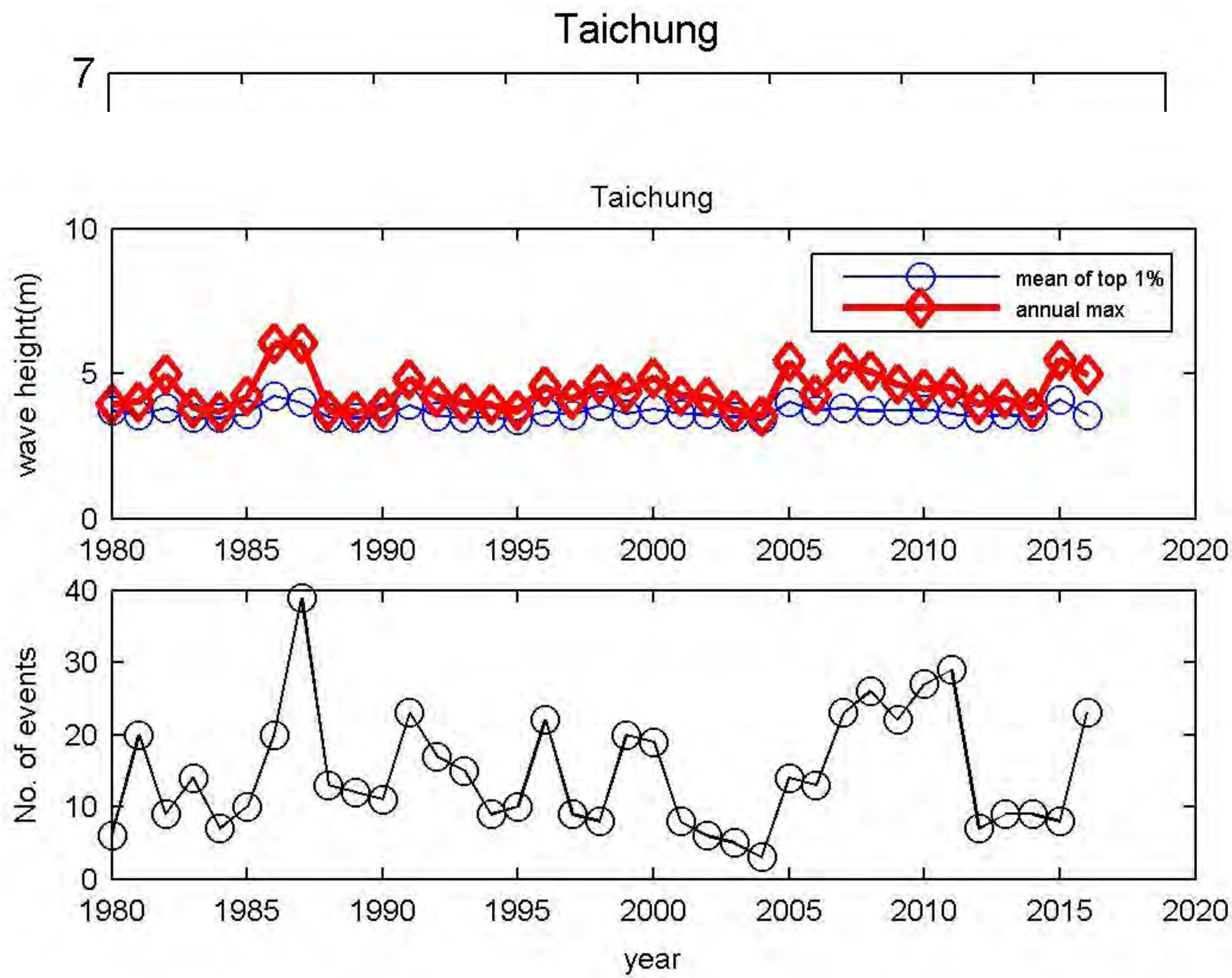
Hwalien
10
Hwalien
wave height(m)
mean of top 1%
annual max
10
5
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
No. of events
40
30
20
10
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
year

蘇澳波高長期演變

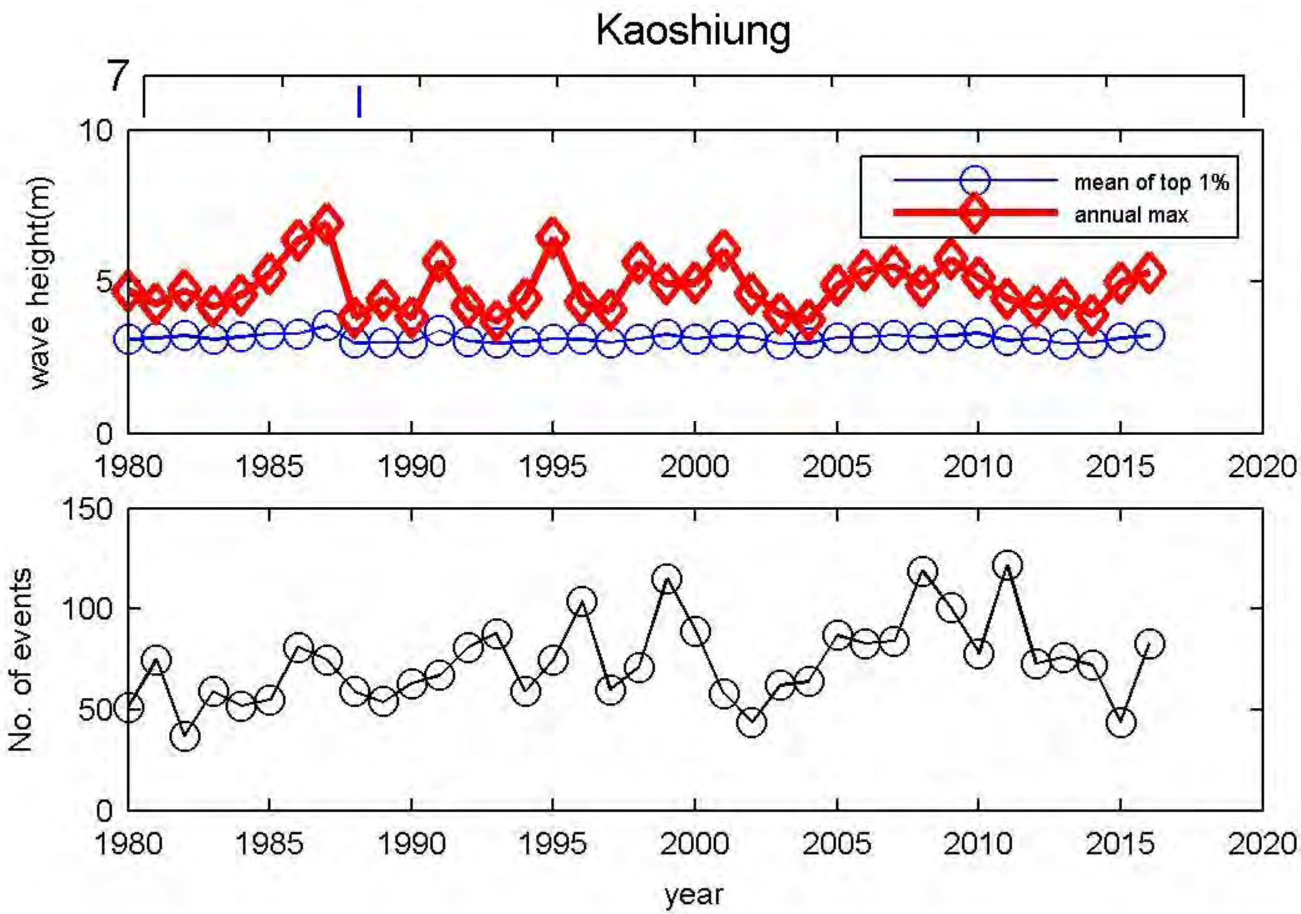


Suao
Suao
wave height(m)
mean of top 1%
annual max
No. of events
year

台中波高長期演變


Taichung
7
Taichung
10
5
0
wave height(m)
mean of top 1%
annual max
1980
1985
1990
1995
2000
2005
2010
2015
2020
40
30
20
10
0
No. of events
1980
1985
1990
1995
2000
2005
2010
2015
2020
year

高雄波高長期演變


Kaoshiung
7
10
5
0
wave height(m)
mean of top 1%
annual max
1980
1985
1990
1995
2000
2005
2010
2015
2020
150
100
50
0
No. of events
1980
1985
1990
1995
2000
2005
2010
2015
2020
year

H_{50} (50年迴歸期波高) based on ECMWF dataset

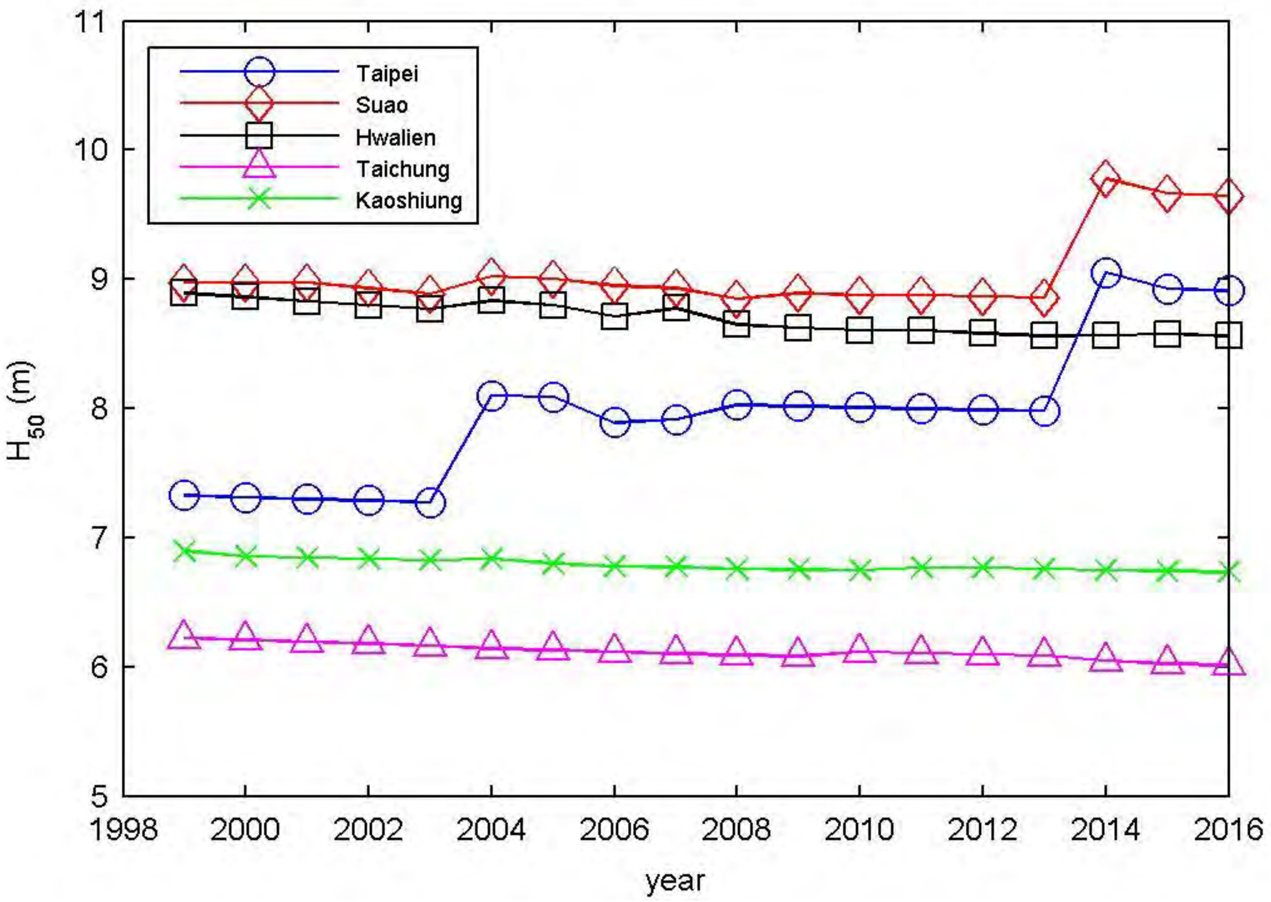
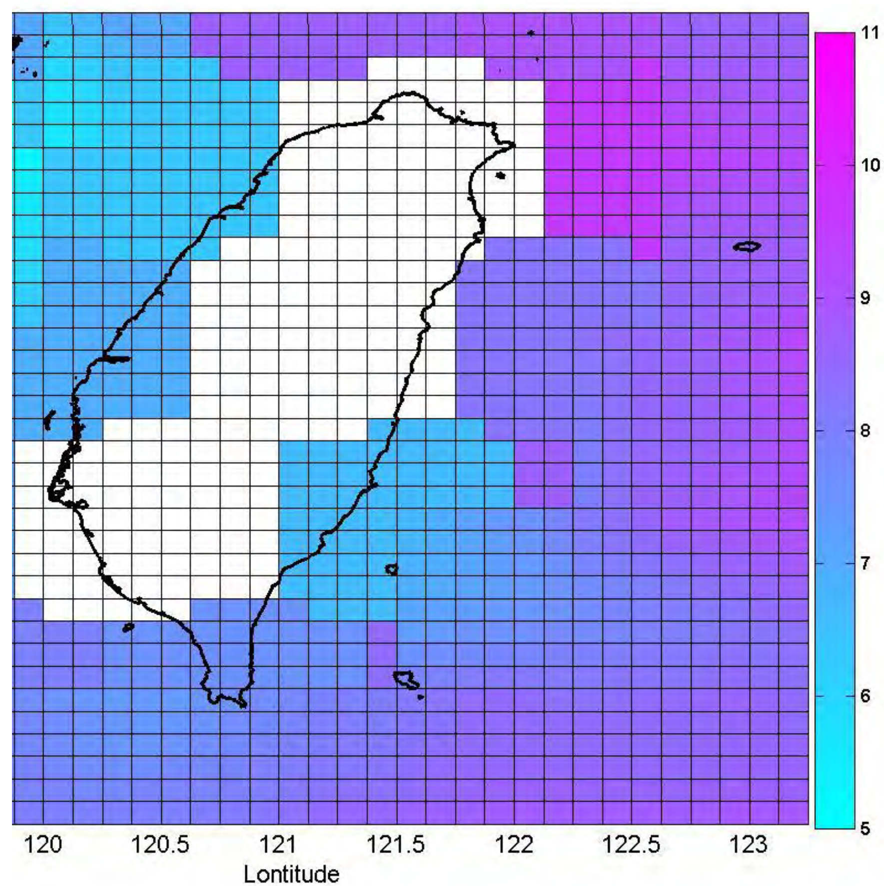


表 1　南台灣與東台灣地區不同重現期距之波高

地點	波高重現期				
	5 年	10 年	20 年	50 年	100 年
北門	5.37 m	5.94 m	6.40 m	6.90 m	7.22m
將軍	5.09 m	5.52m	5.85m	6.22 m	6.45m
網仔寮	5.08 m	5.49 m	5.82 m	6.16 m	6.39 m
七股	5.93 m	6.37 m	6.72 m	7.09 m	7.32 m
安平	5.39 m	5.77 m	6.06 m	6.37 m	6.56 m
灣裡	5.28 m	5.64 m	5.91 m	6.21 m	6.40 m
茄萣	5.70 m	6.10 m	6.40 m	6.73 m	6.94 m
永安	5.19 m	5.54 m	5.82 m	6.11 m	6.30 m
高雄	5.54 m	5.89 m	6.16 m	6.45 m	6.64 m
林園	4.55 m	4.86 m	5.09 m	5.35 m	5.51 m
東港	5.25 m	5.59 m	5.85 m	6.14 m	6.32 m
塭豐	5.12 m	5.47 m	5.73 m	6.02 m	6.20 m
枋寮	5.26 m	5.62 m	5.90 m	6.21 m	6.40 m
嘉和	5.65 m	6.08 m	6.42 m	6.78 m	7.01 m
枋山	5.65 m	6.07 m	6.41 m	6.77 m	7.00 m
楓港	5.45 m	5.86 m	6.17 m	6.51 m	6.73 m
車城	5.33 m	5.71 m	6.00 m	6.32 m	6.51 m
後灣	5.75 m	6.23 m	6.60 m	7.01 m	7.27 m
鵝鑾嘴	5.87 m	6.32 m	6.67 m	7.05 m	7.30 m
後壁湖	6.12 m	6.61 m	7.00 m	7.41 m	7.68 m
成功	7.80 m	8.65 m	9.33 m	10.1 m	10.6 m
花蓮	8.53 m	9.72 m	10.7 m	11.8 m	12.5 m
蘇澳	8.44 m	9.62 m	10.6 m	11.7 m	12.4 m

CMWF dataset 2016



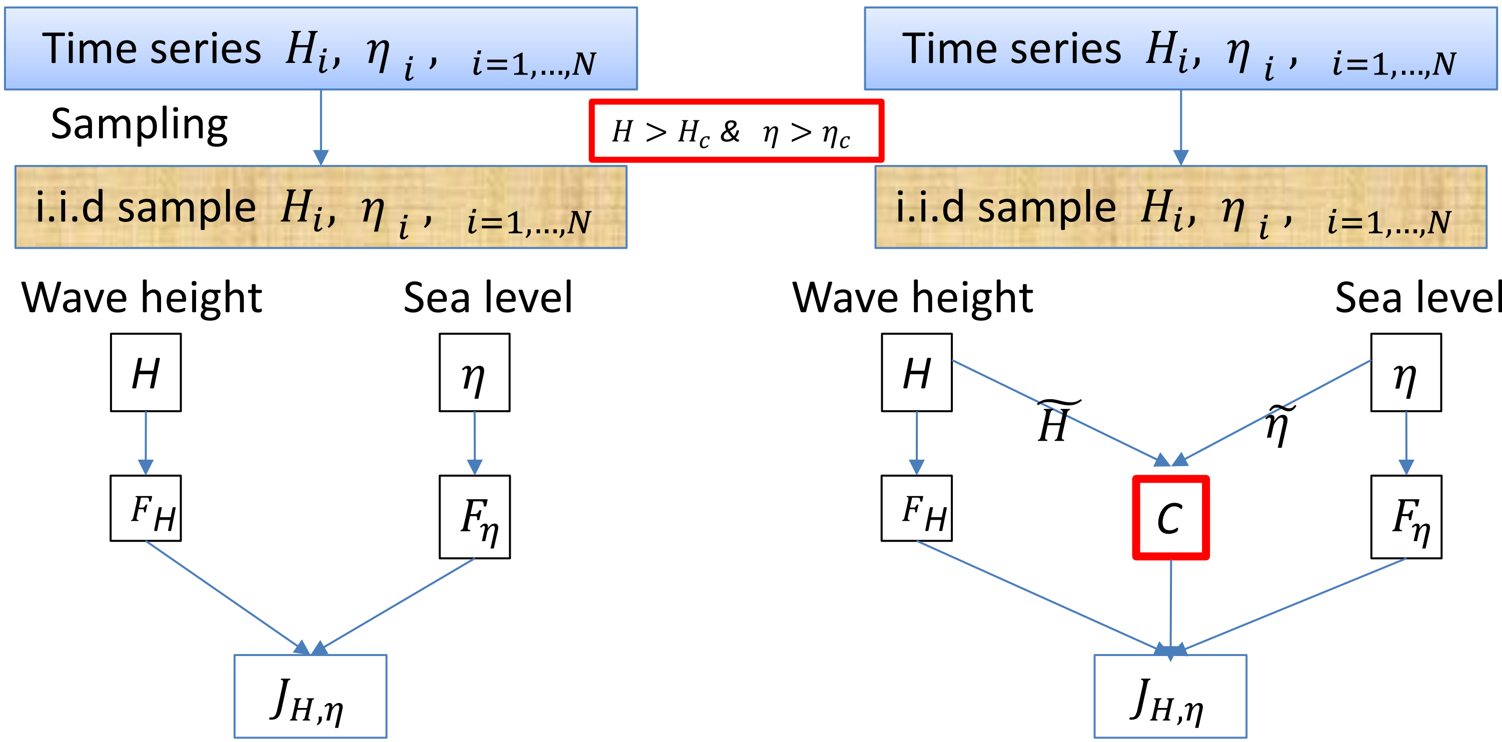
海岸溢淹風險分析

- 平均海平面高度
- 天文潮位高
- 氣象潮高 *(S_{50})*
- 波浪溯升 *(H_{50}, T_{50})*
- 海床地形

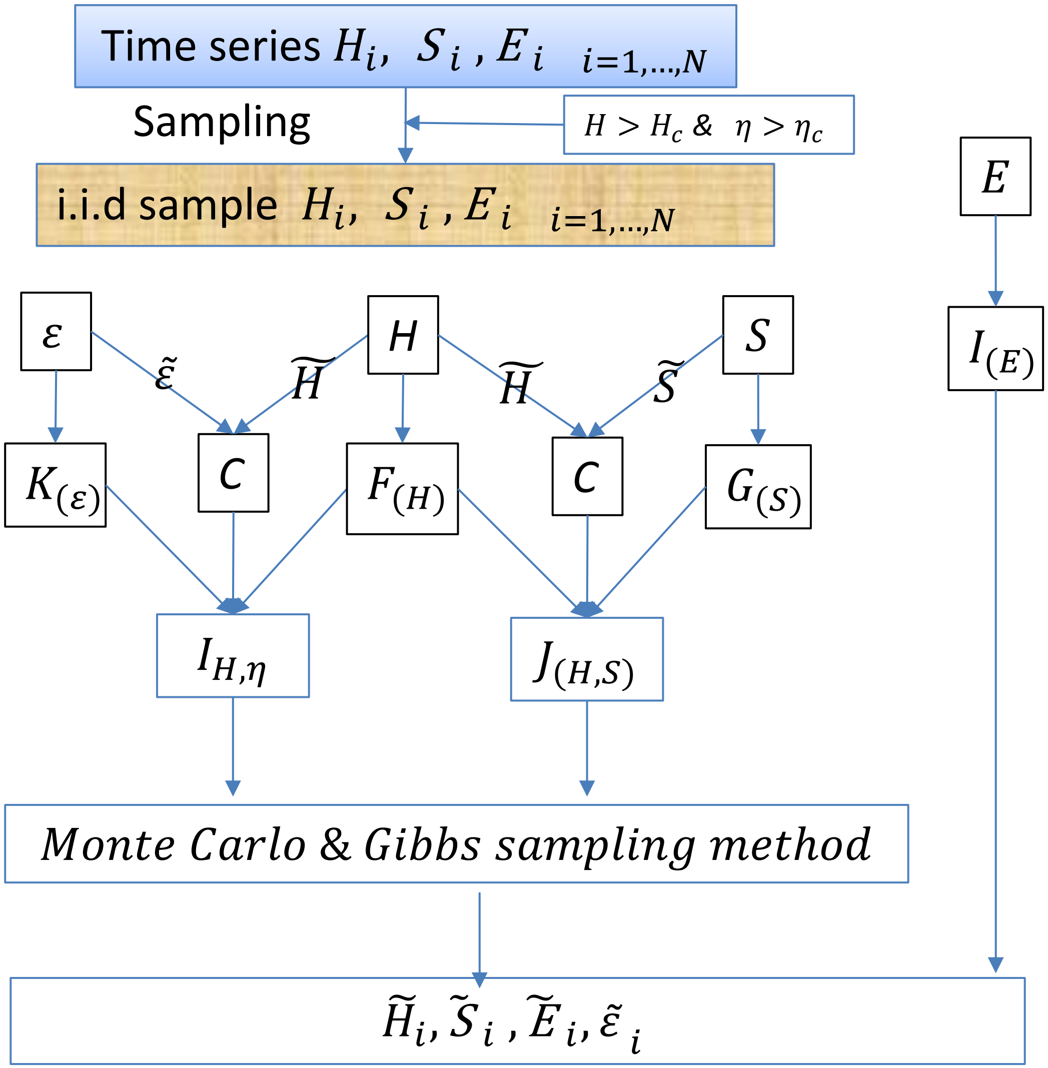
$$R_{2\%} = H_{50}\left[2.99 - 2.73\ exp\left(-0.57 \cdot \tan\beta/\sqrt{H_{50}/L5_0}\right)\right]$$

$$+ MSL + E + S50$$

雙變數聯合機率分布函數方法



多變數聯合機率分布函數建立



Data sampling strategy

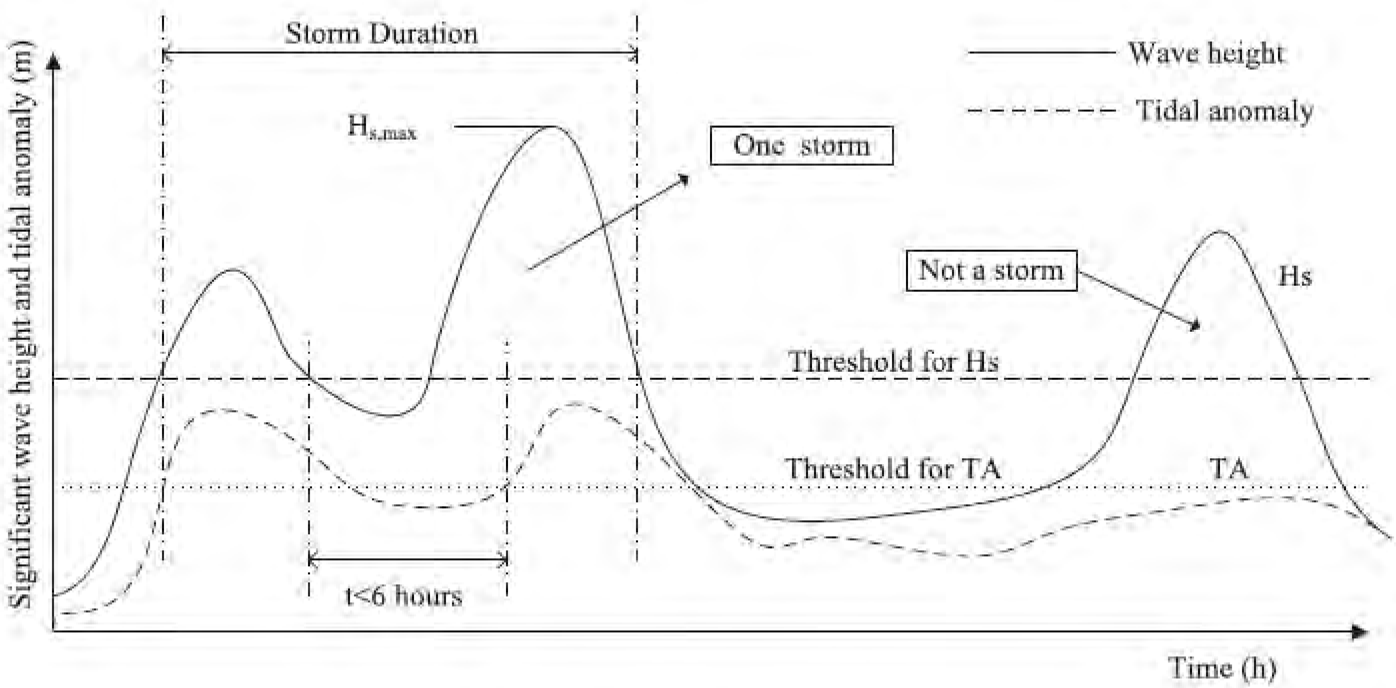
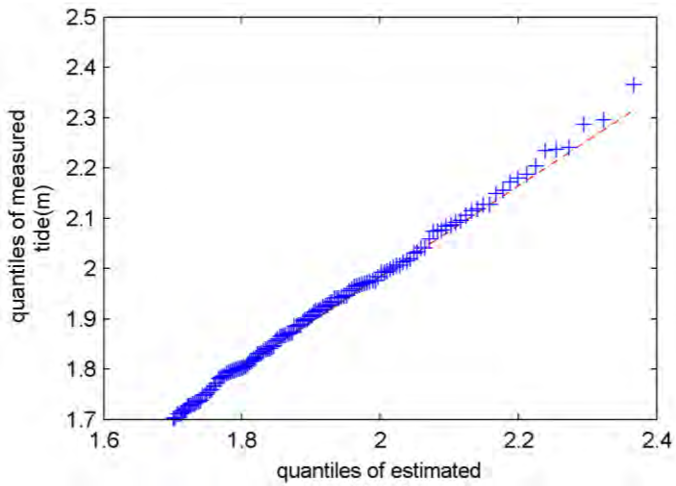
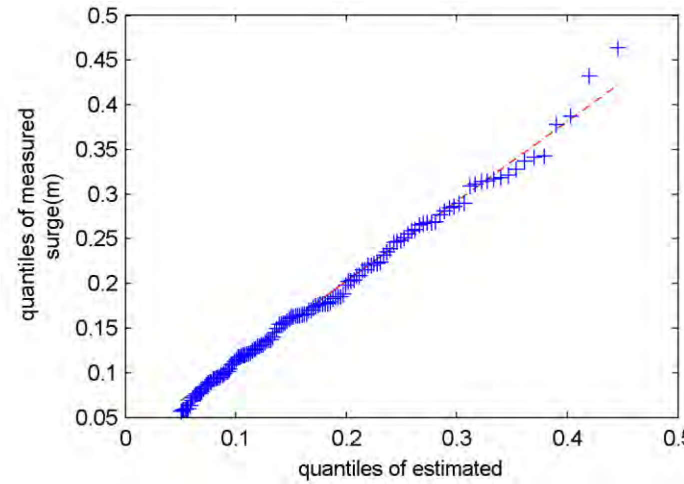


Fig. 2. Definition of independent storm events.

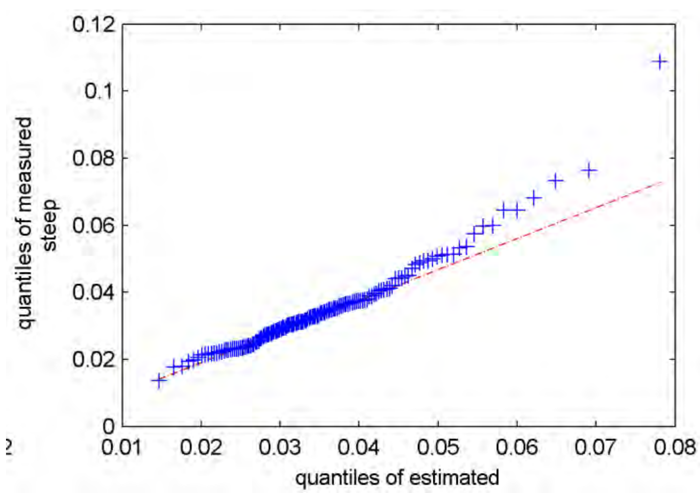
各變數統計機率分布



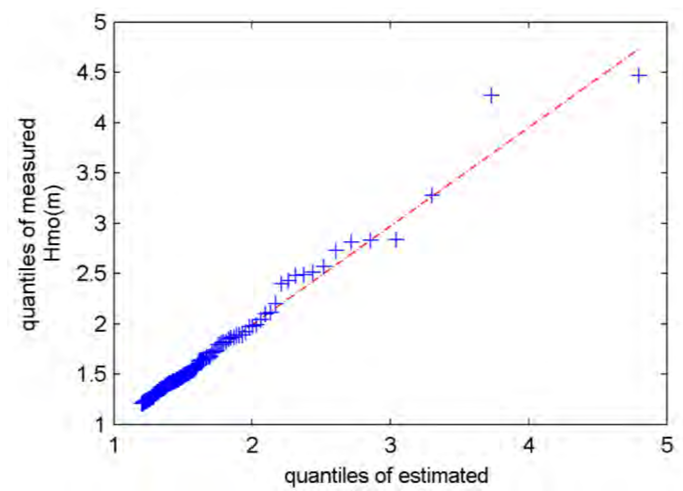
quantiles of measured tide(m)
quantiles of estimated



quantiles of measured surge(m)
quantiles of estimated



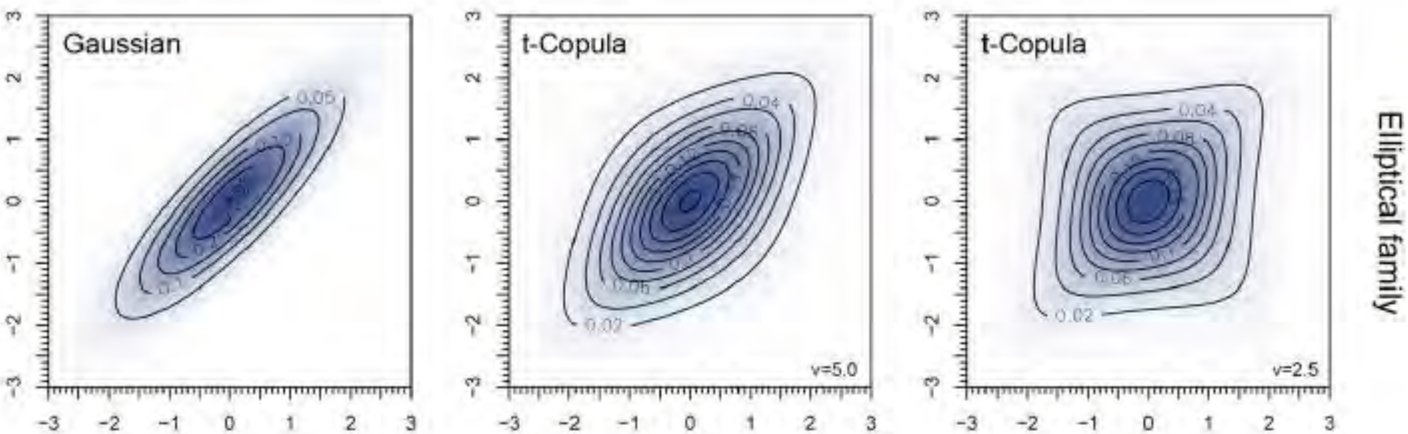
quantiles of measured steep
quantiles of estimated



quantiles of measured Hmo(m)
quantiles of estimated

Copula Joint Distribution

Student t-copula



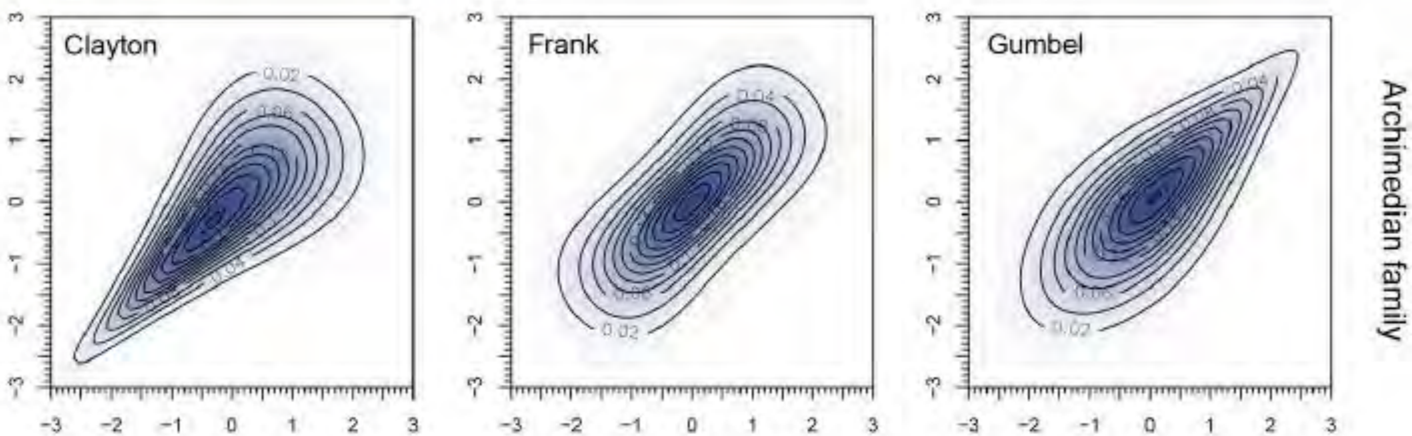
Student t-Copula

- Based on an extension of the multivariate t-distribution

$$C_{\vec{X}}(u_1, \ldots, u_m) = F_{t(\nu,\Sigma)}(F^{-1}_{t(\nu)}(u_1), \ldots, F^{-1}_{t(\nu)}(u_m))$$

Copula Joint Distribution

Archimedean copulas



Archimedean copulas

- Based on so called generator functions

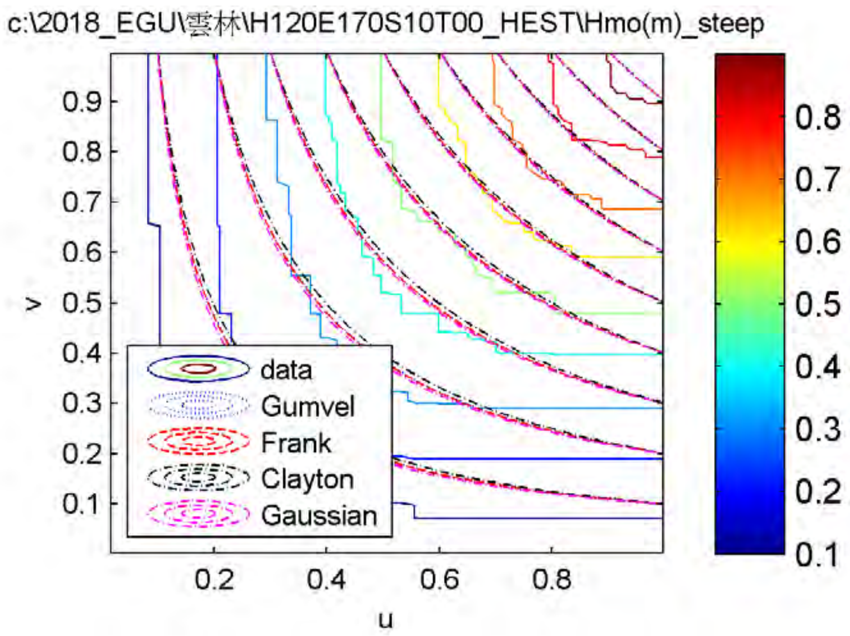
$$C_{\vec{X}}(u_1, \ldots, u_m) = \phi^{-1}\left(\phi(u_1) + \cdots + \phi(u_m)\right)$$

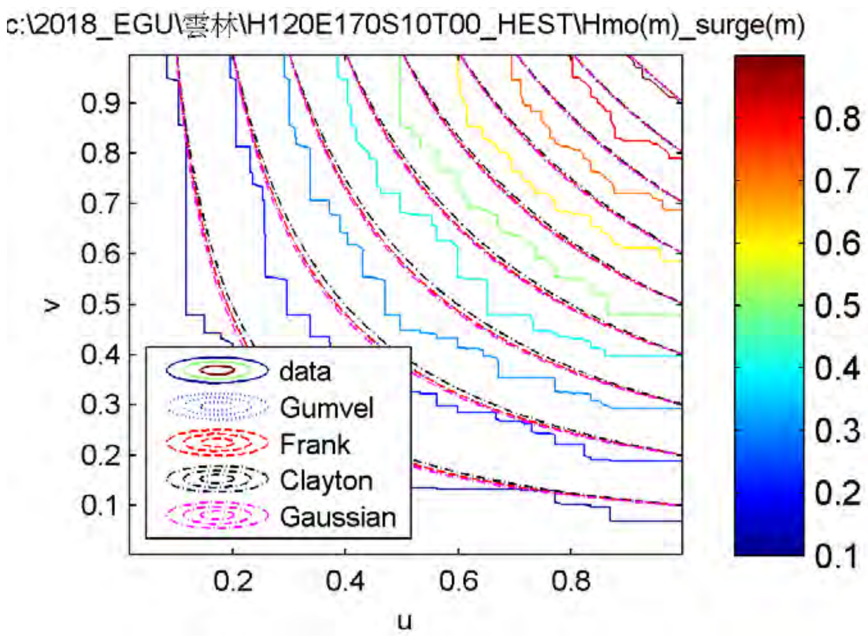
Clayton copula: $\phi_C(u) = u^{-\theta_C} - 1$

Frank copula: $\phi_F(u) = \log\left(\frac{e^{\theta_F u} - 1}{e^{\theta_F} - 1}\right)$

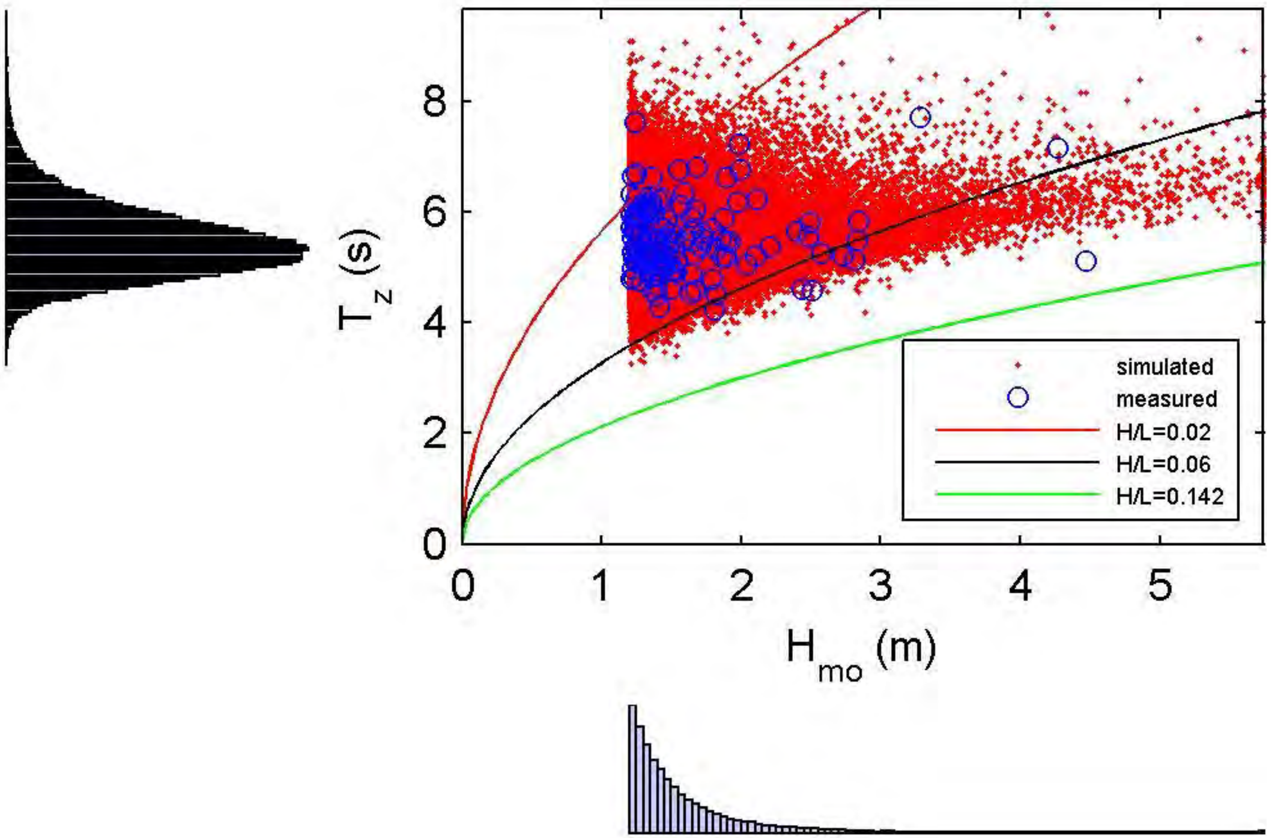
Gumbel copula: $\phi_G(u) = (-\log u)^{\theta_G}$

Copula function fitting

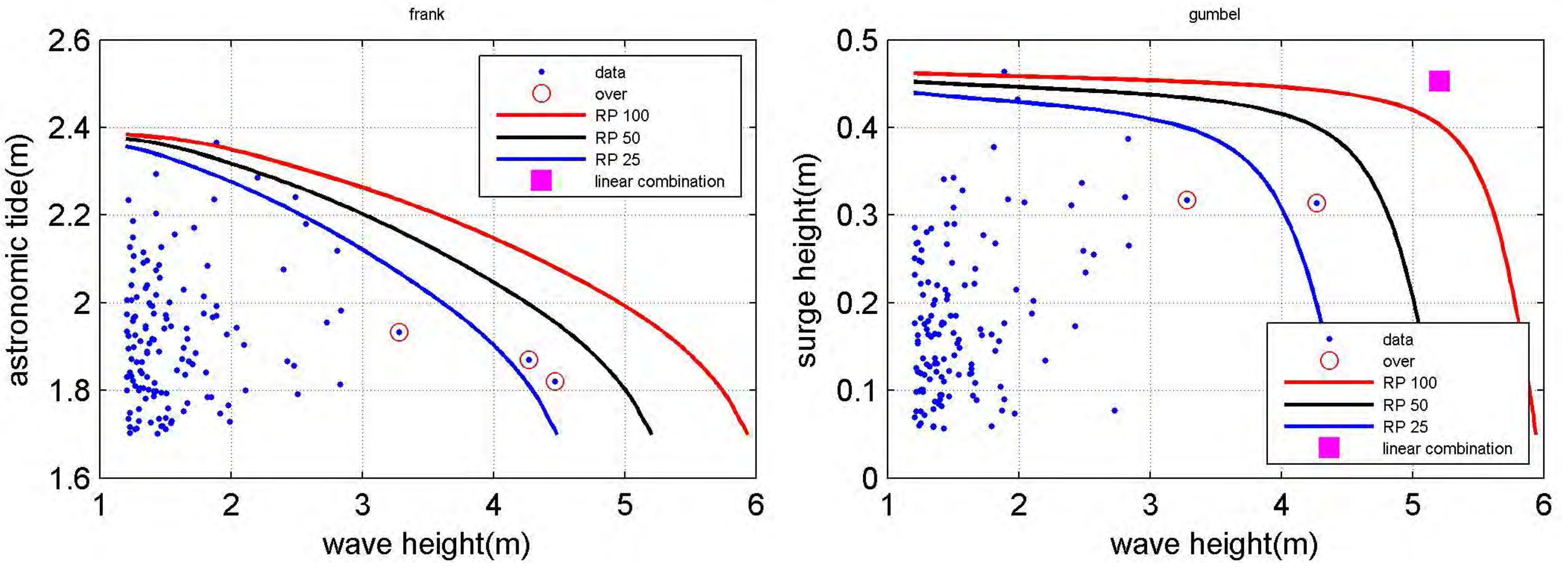




Simulated sample

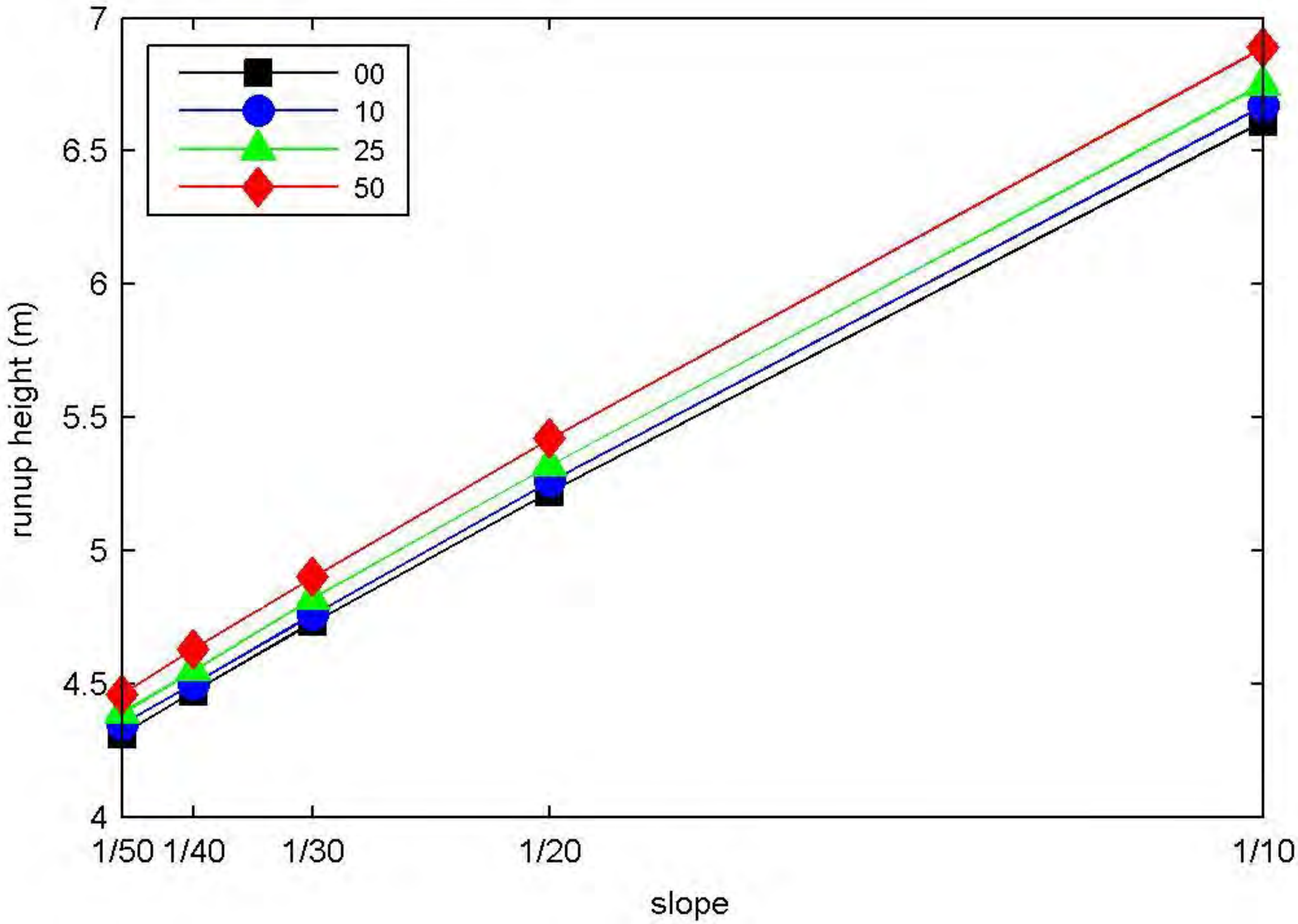


Joint Occurrence Probability

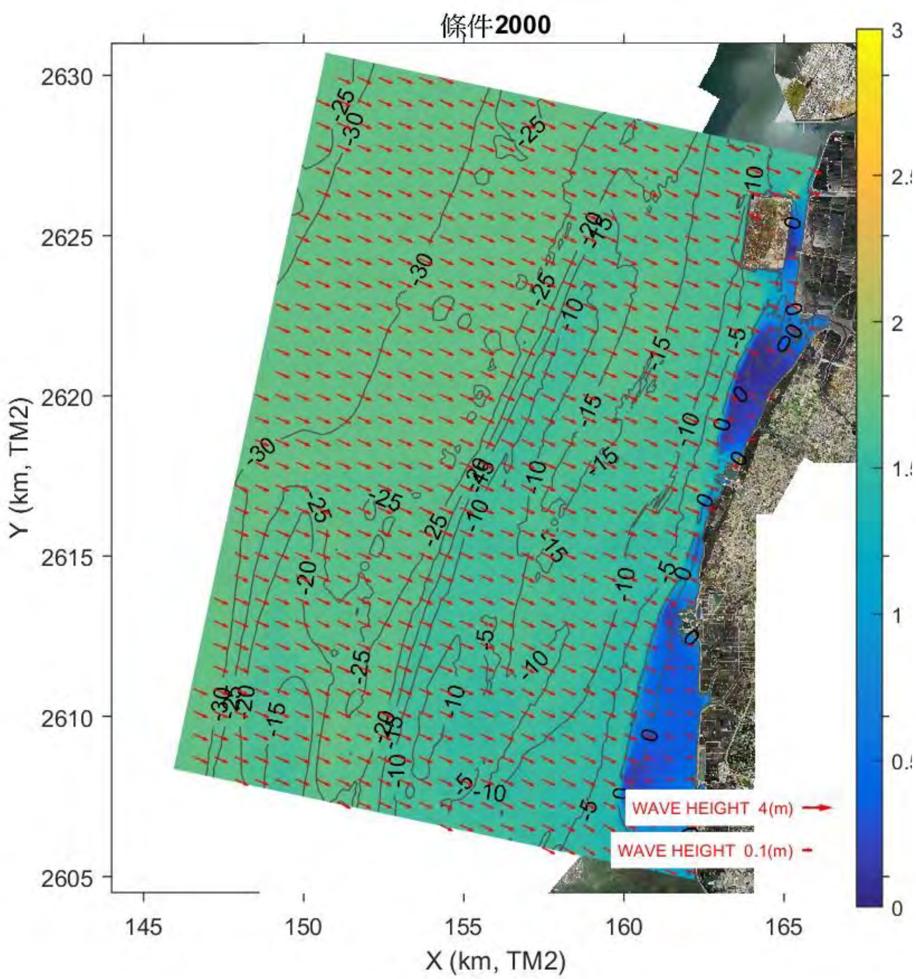


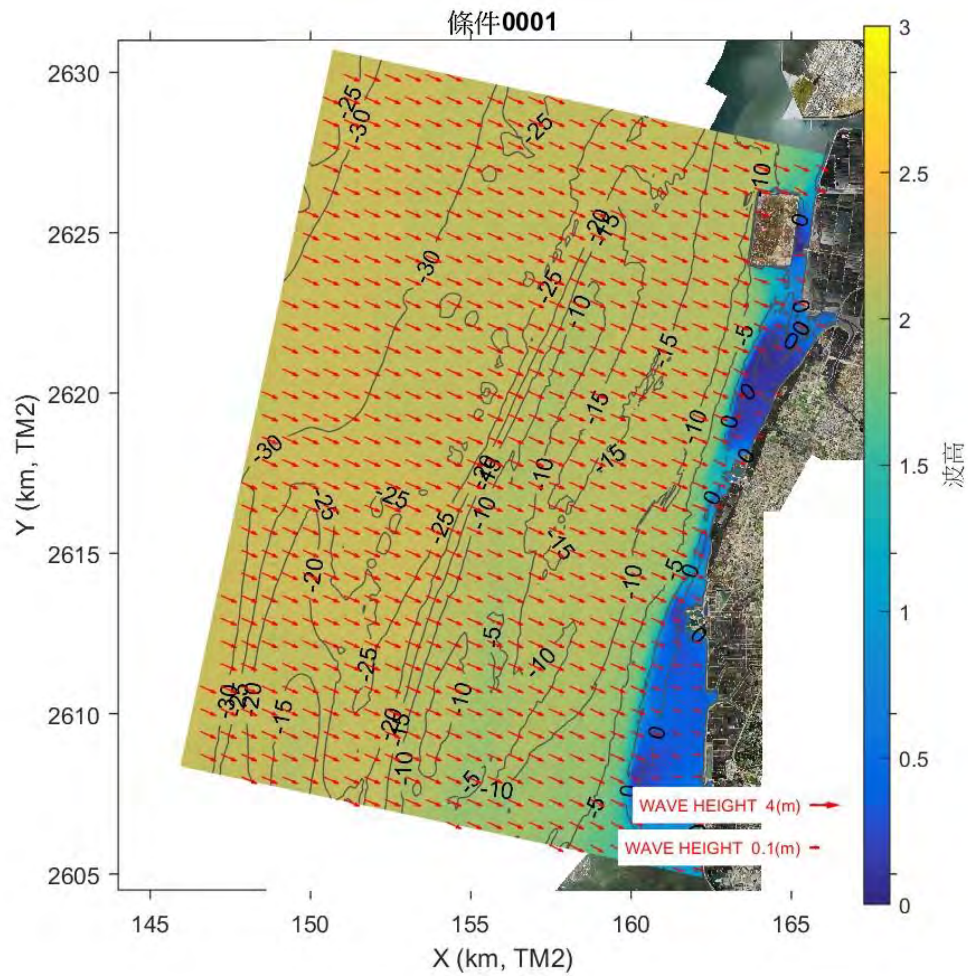
統計50年迴歸期溯升高

Ideal seabed profile case

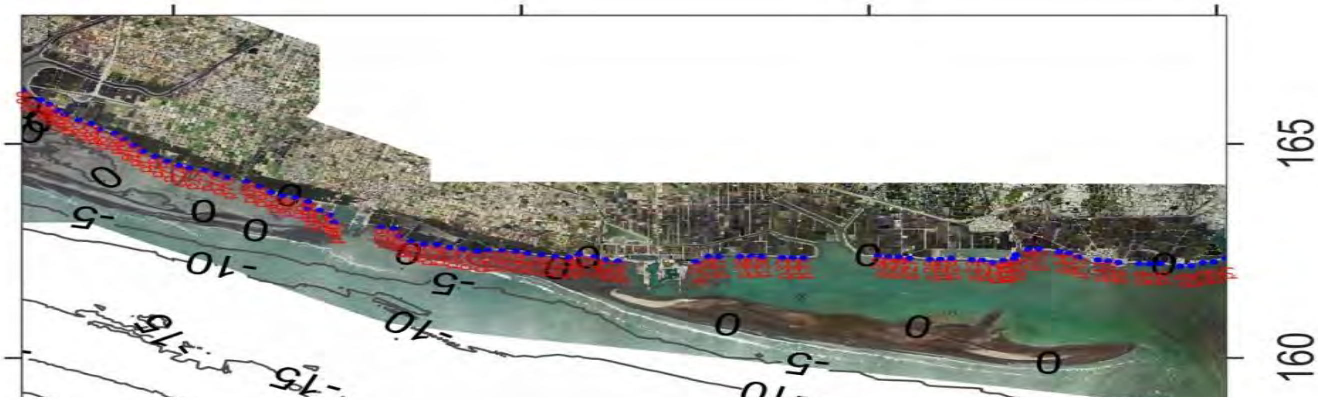


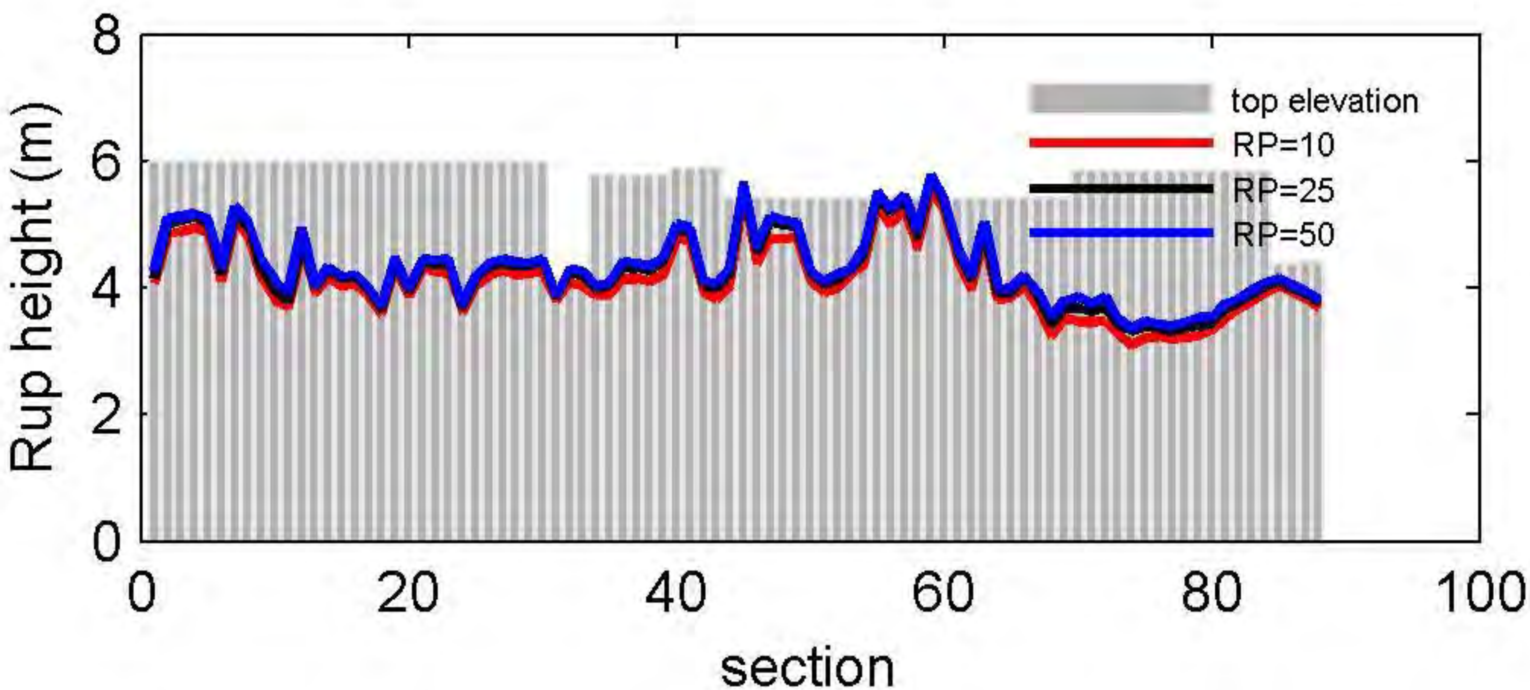
Nearshore Wave Model
Coastal Engineering Manual



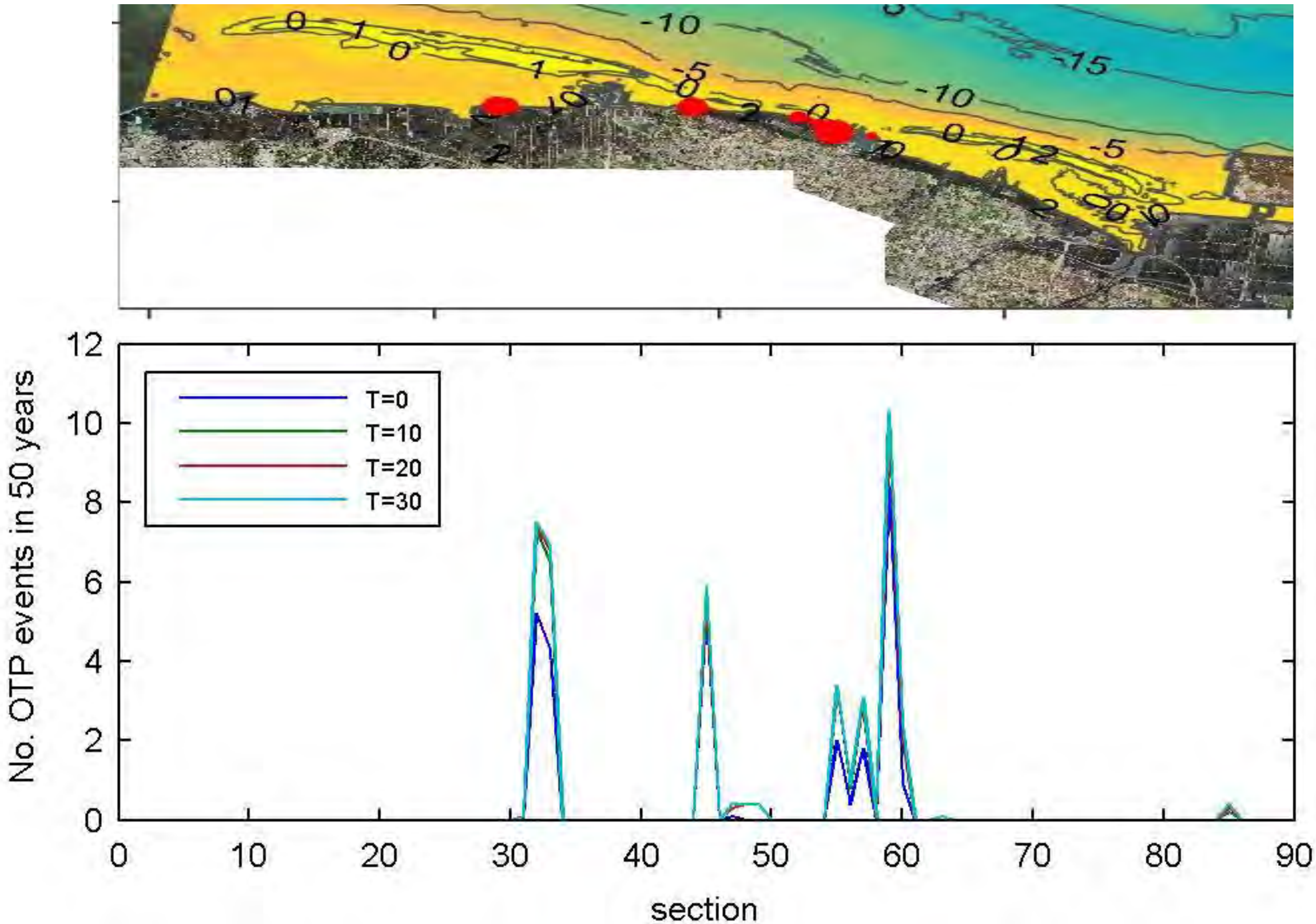


雲林海域波浪溯升高


165
160
0
-5
-10


top elevation
RP=10
RP=25
RP=50
Rup height (m)
section
0
2
4
6
8
0
20
40
60
80
100

雲林海岸溢淹風險



Conclusions

- 介紹台灣海域波候特性
- 應用多變數聯合機率方法在海岸溢淹風險評估介紹
- 減降海岸侵蝕是海岸防護最優先考量