A comprehensive monitoring and forecasting system applied for cross-sea immersed tube tunnel constructions

Lunyu Wu

2023.5.3

Outline

- Background
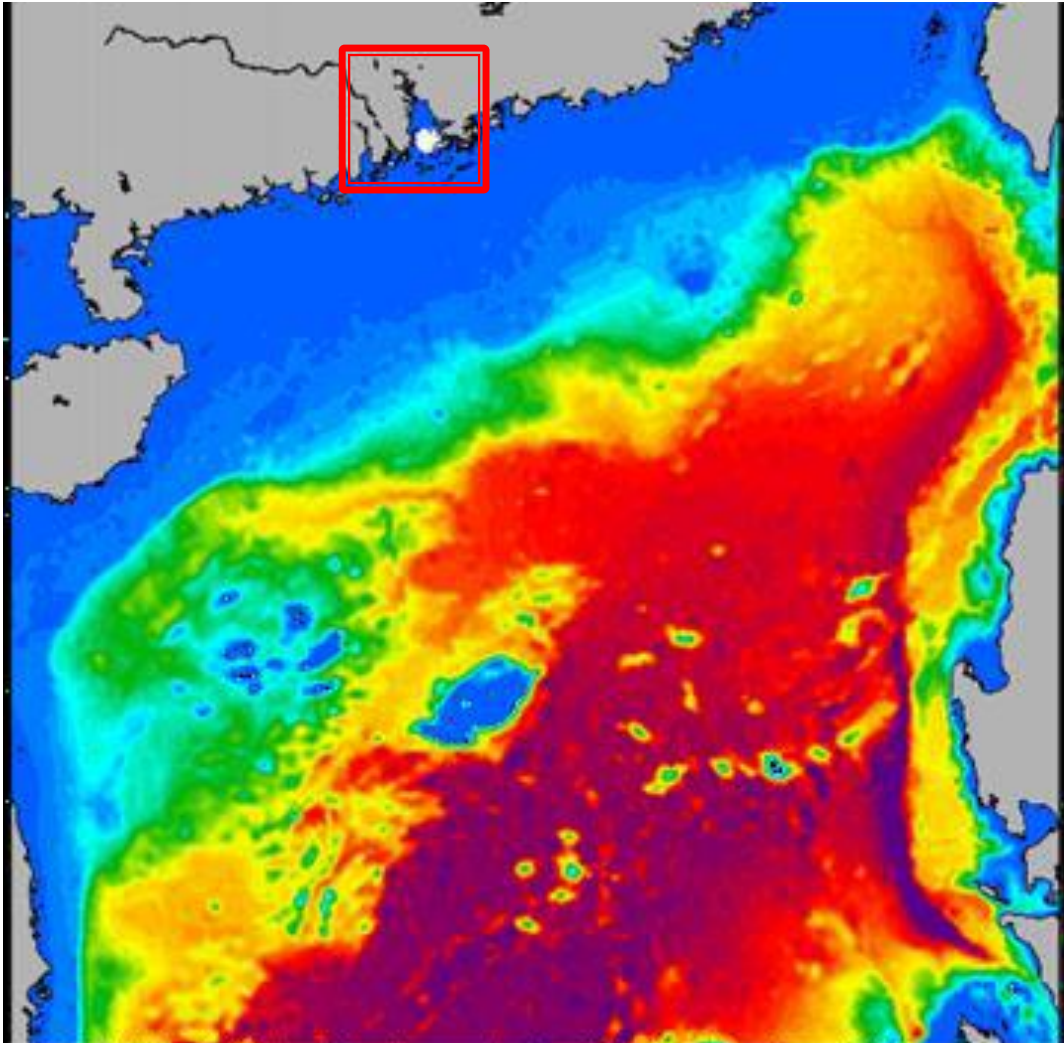
- The system

- Currents
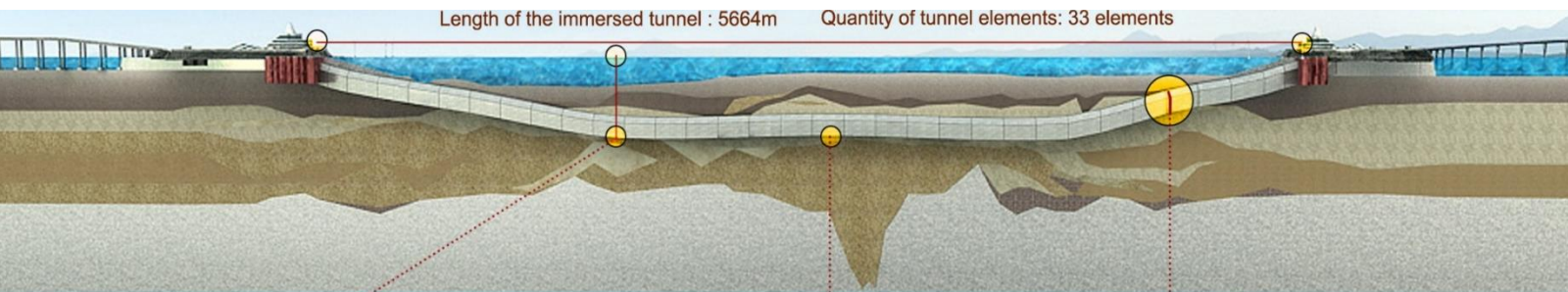
- Disastrous waves

- Summary

Background-The location

Pearl River Estuary(PRE)

Shenzhong Link
2019 –presnet

Hong Kong-Zhuhai-Macau Bridge
2012~2017

Background-Tube tunnel constructions

Hong Kong-Zhuhai-Macau Bridge-Tunnel System

Length of the immersed tunnel : 5664m   Quantity of tunnel elements: 33 elements

沉放水深：最深处44.5m
Maximum water depth of tunnel element immersion :44.5m

标准管节长度：180m
Length of a typical tunnel element : 180m

最终接头：E29与E30管节之间
Closure joint: between tunnel element E29 and element E30

主体结构：C45自防水混凝土，56d强度C50，抗渗等级P12
Main structure : C45 water proof concrete, concrete strength of 56 day reaching the strength of concrete C50, anti-permeability level P12
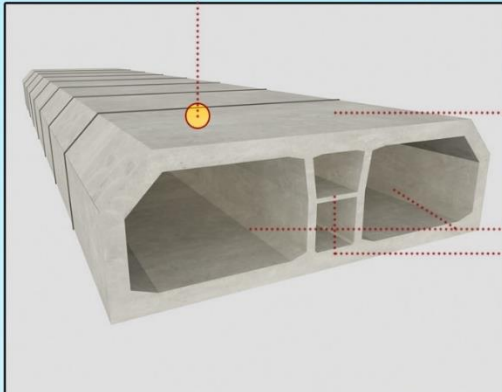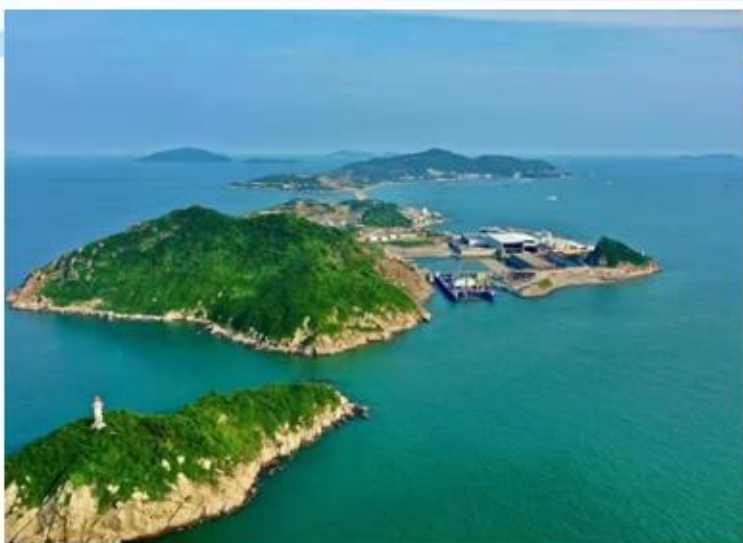
标准管节构造：节段式管节 8 x 22.5m
Structure of typical tunnel element: segmental tunnel element 8 x 22.5m

管节断面：两孔一管廊 Section of tunnel element: two–bore and one middle gallery

海水
淤泥
粘土及粉质粘土
砂

1:7
1:3
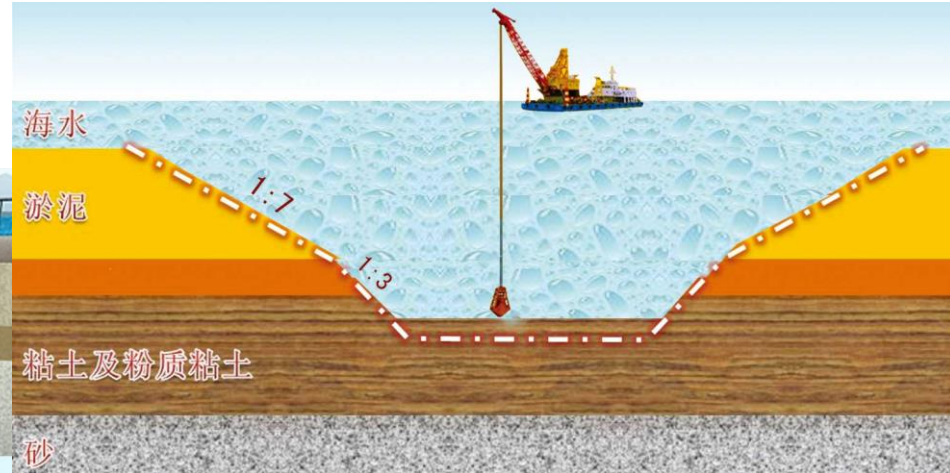
中交一体船出坞

中交一体船浮运

中交一体船沉管安装

保利长大船出坞

拖轮辅助浮运

沉管安装

▶ Needs for ocean and weather forecasts

➤ **Weather**

Typhoon, winter storm, strong convection one

➤ **Waves**

Large wind waves/swells, ship-wakes, freak waves

➤ **Currents**

Large river flux in rainy season, high speed flow near trench bed

➤ **Sediments**

Sedimentation in trench, failure of the trench slope

Prediction is needed for decision-making, such as determining an appropriate window according to wind, wave, current and sediment conditions.

Tube transportation

Tube installation

The system-overview

MOS method

Regular observations

龙穴船厂气象站
西人工岛气象站
桂山牛头岛气象站
2号浮标
1号浮标
3号浮标
4号浮标
西人工岛观测站
桂山牛头岛观测站

Wave current buoy

Weather Station
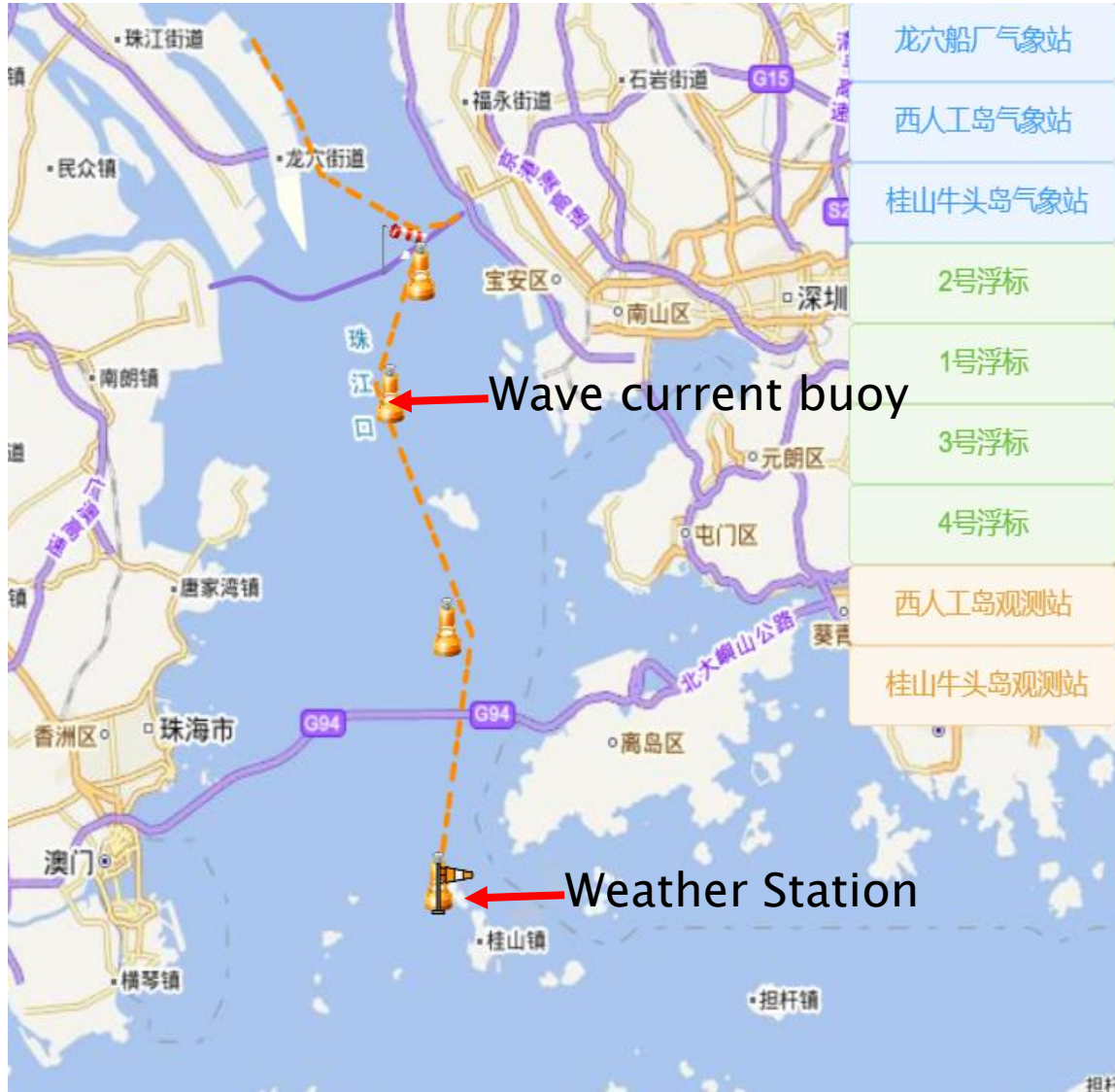
In-situ observations during installation

160m

ADCP5   ADCP1

40 m

津安3   待安管节   津安2

ADCP2

ADCP3
直读式海流计
CTD
浊度计

160m

ADCP7
CTD
测量船
1002

Far field surveying vessel
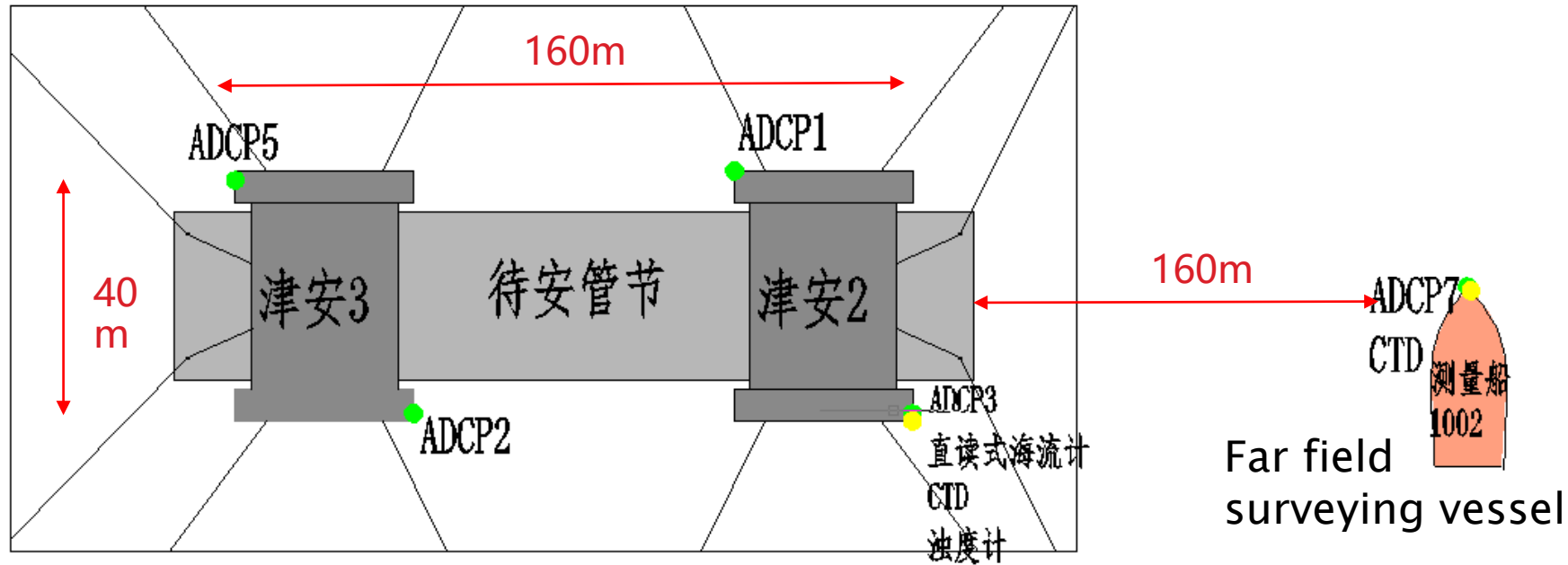
> **Current observation per minute**
> **CTD with turbidity sensor per hour**

Obs Point 5

1002_20160511_0252 density
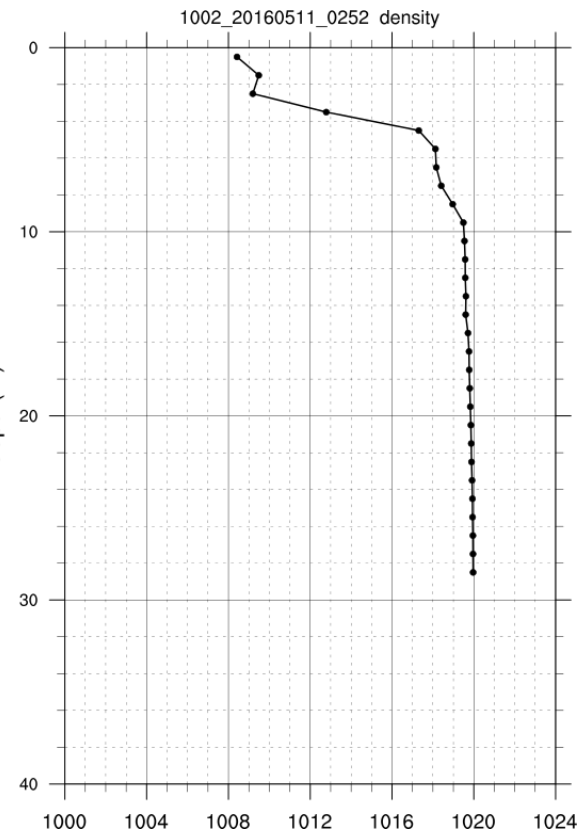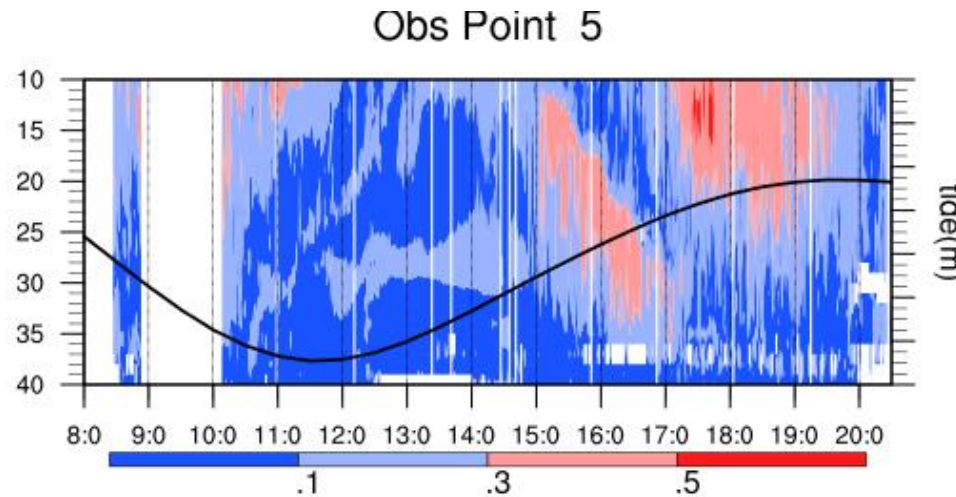
Large instantaneous near bottom flow observed in the trench
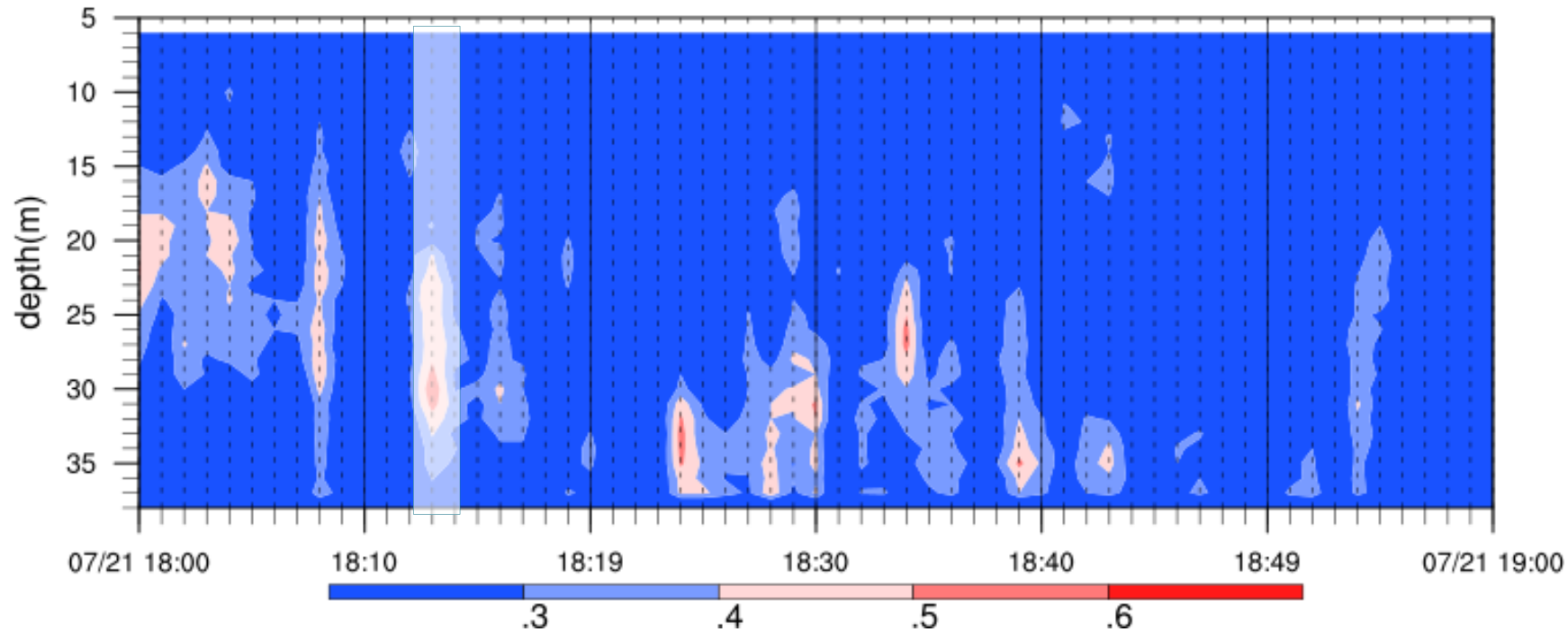
Depth:30~40m
Magnitude: >0.5m/s
Duration:3 minutes

The numerical models
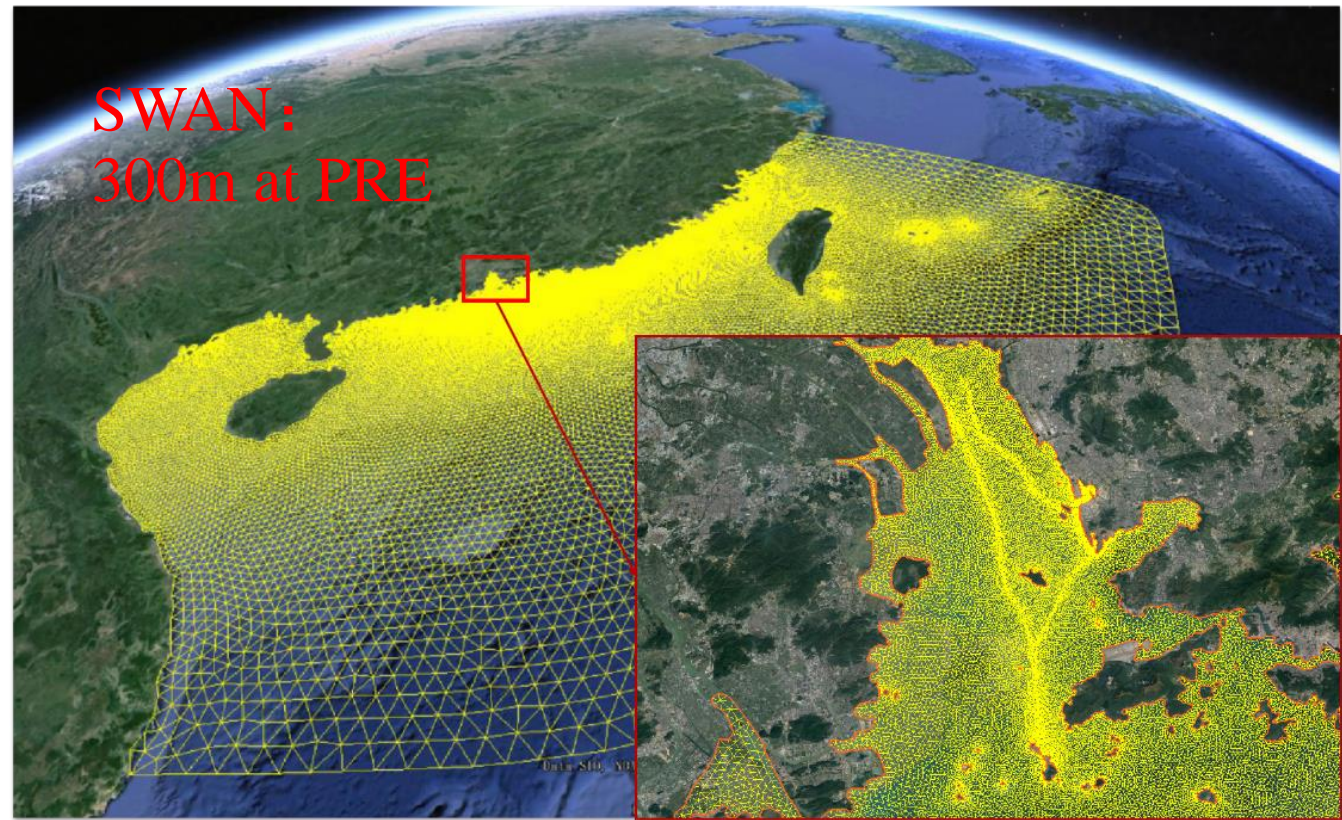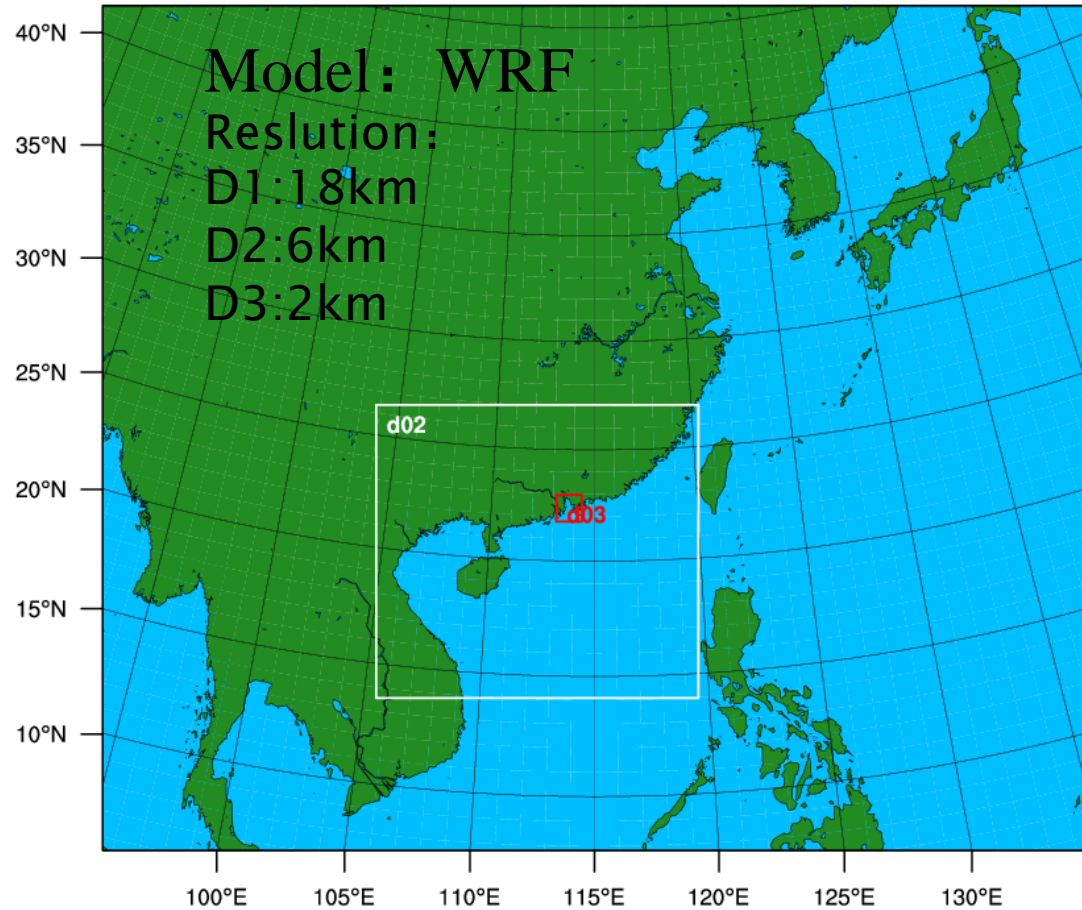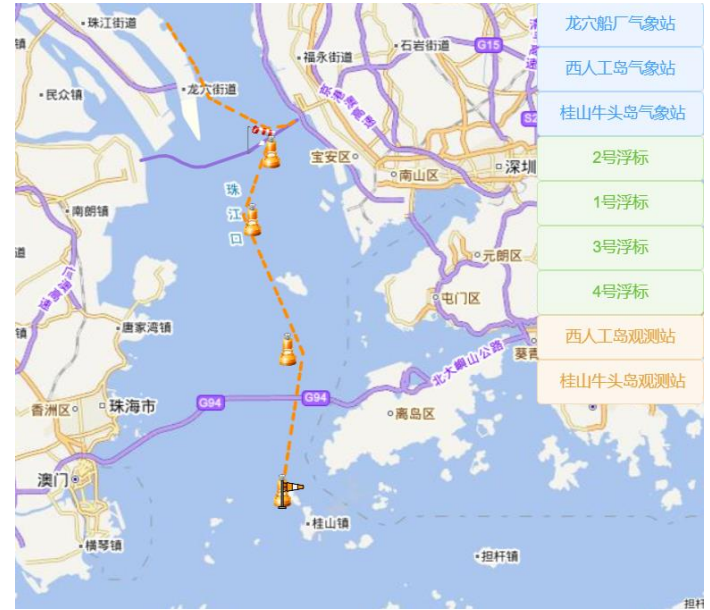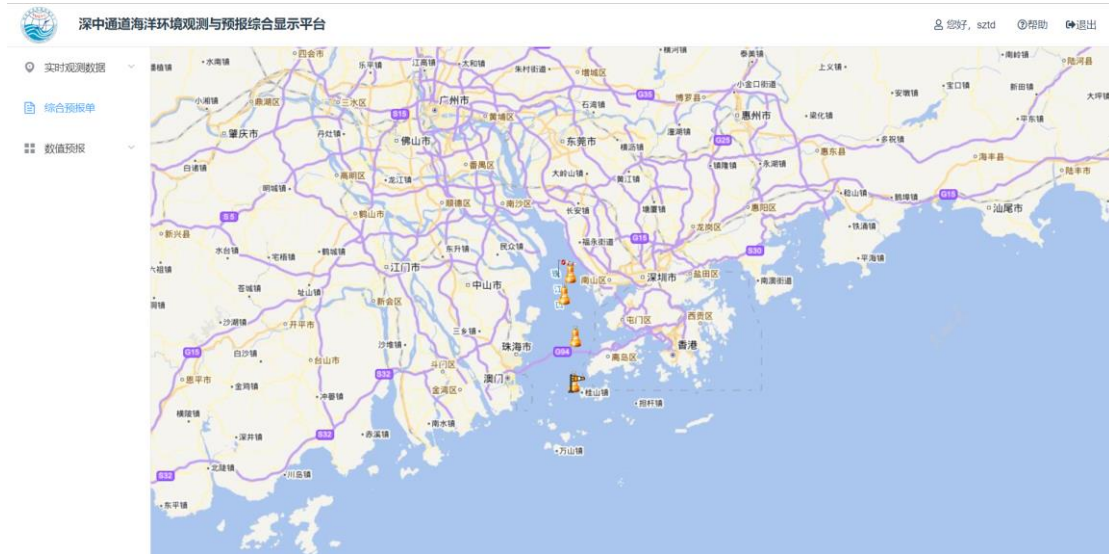
Model：WRF
Reslution：
D1:18km
D2:6km
D3:2km

d02

d03

SWAN：
300m at PRE

Data visualizations

浮标 1 层级 3 起止时间 2019-06-05 00:00:00 - 2019-06-09 00:00:00 查询

海流流速

流速(m/s) ●流速

1,294
1,200
900
600
300
15

06-05 2019 　 06-06 2019 　 06-07 2019 　 06-08 2019 　 06-09 2019

时间

潮位计 平台潮位计 起止时间 2019-06-04 00:00:00 - 2019-06-11 00:00:00 查询

平台潮位

潮位(cm) ●潮位

220
200
150
100
50
0
-50
-63

06-04 2019 　 06-05 2019 　 06-07 2019 　 06-09 2019 　 06-10 2019

海浪数值预报产品

起报日期 2019-06-27
数值产品 ☑有效波高 ☐浪向
预报时次 ●
0 24 72 96 120 144 168
加载

0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 浪

海流数值预报产品

起报日期 2019-06-30
垂直层级 1
数值产品 ☑流场 ☐盐度 ☐水位
预报时次 ●
0 4 8 12 16 20 24
加载

数值产品 ☐气压场 ☐风场 ☑降水
预报时次 ●
0 24 48 96 120 144 168
加载

0.2 1.0 2.0 5.0 10 20 30 50 70 100 降水

未来24小时流场时间序列图

水位(m)

1.2
0.9
0.6
0.3
0
-0.3
-0.6
-0.9

流速: 0.14m/s
流向: 316.61°
水位: 0.57m

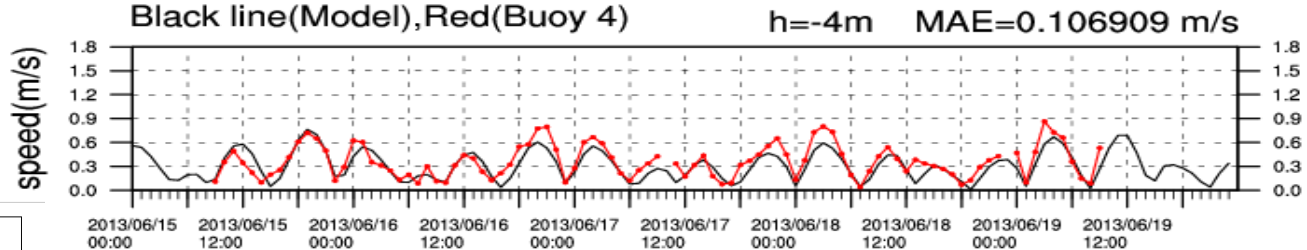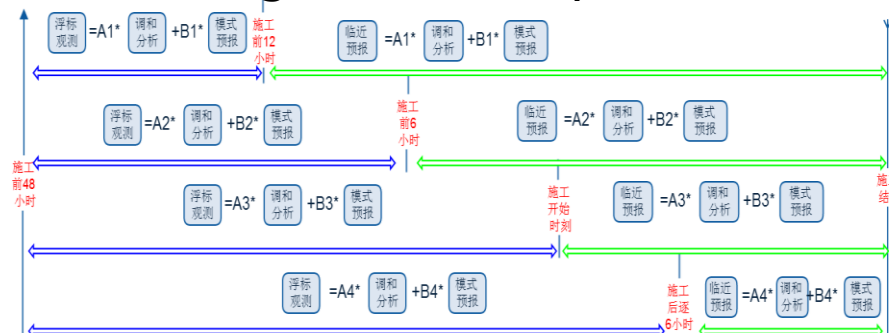0 　 5 　 10 　 15 　 20 　 25

预报时次(h)
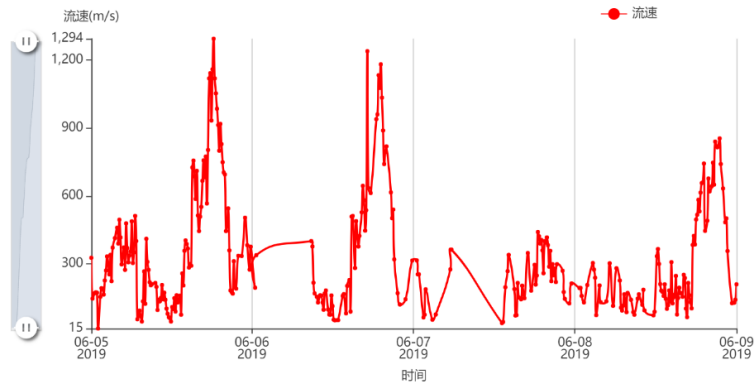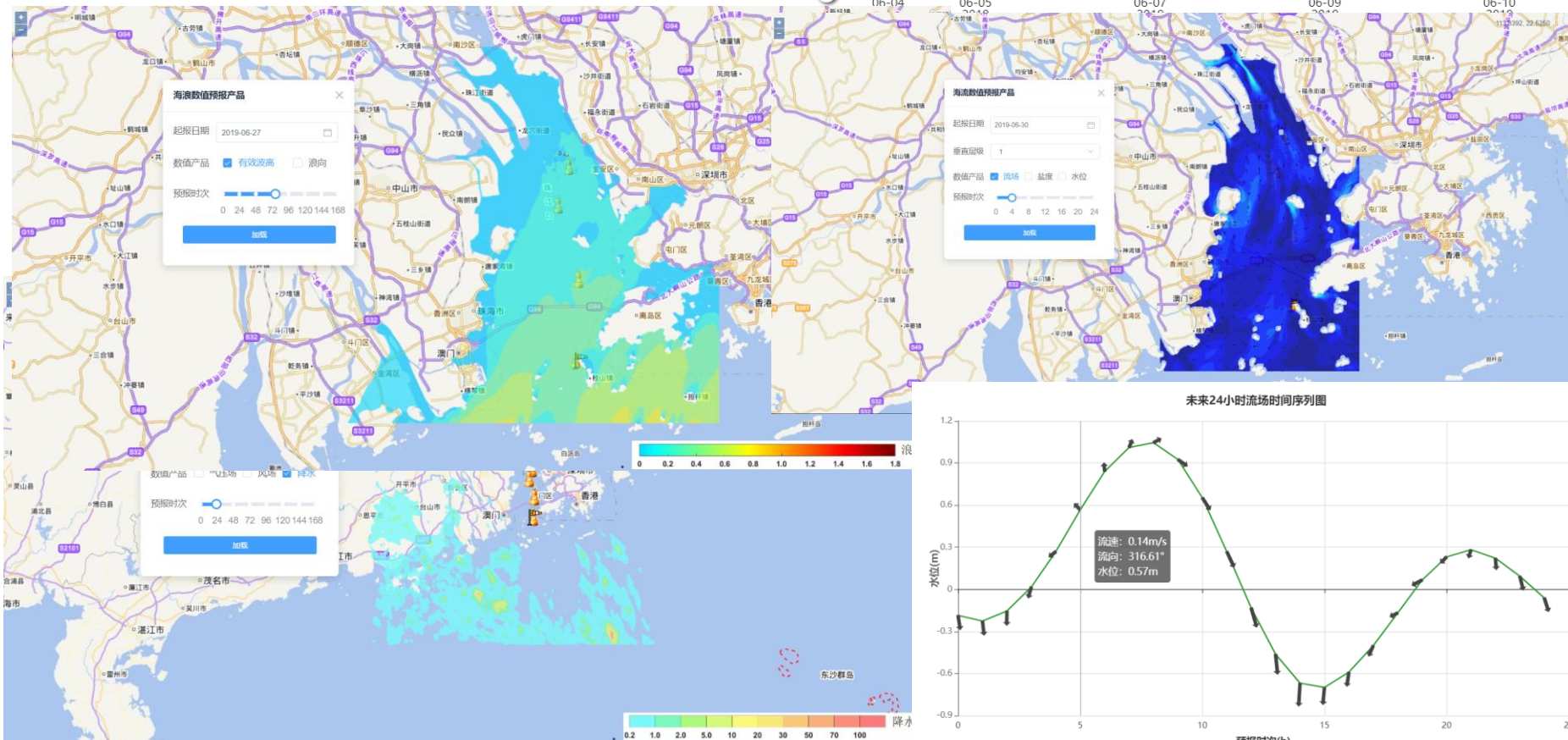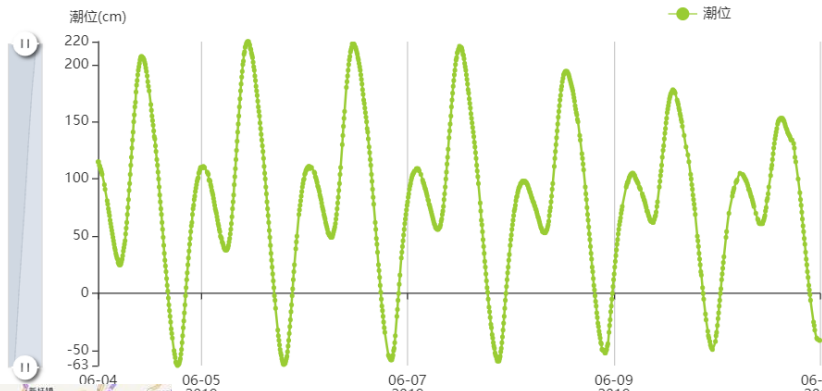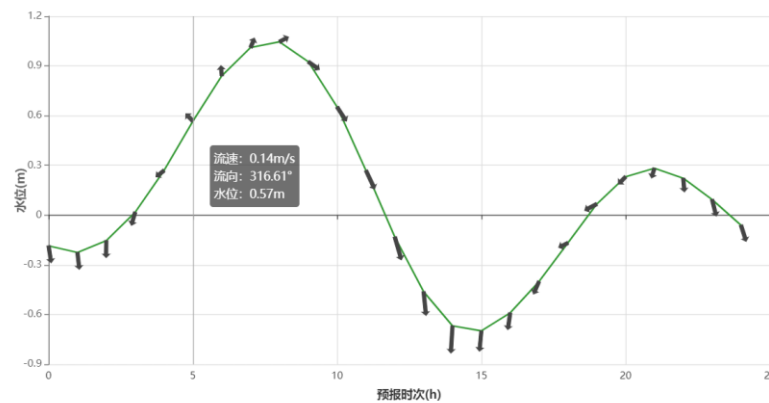
Currents-the model grids

nesting

4m

10m
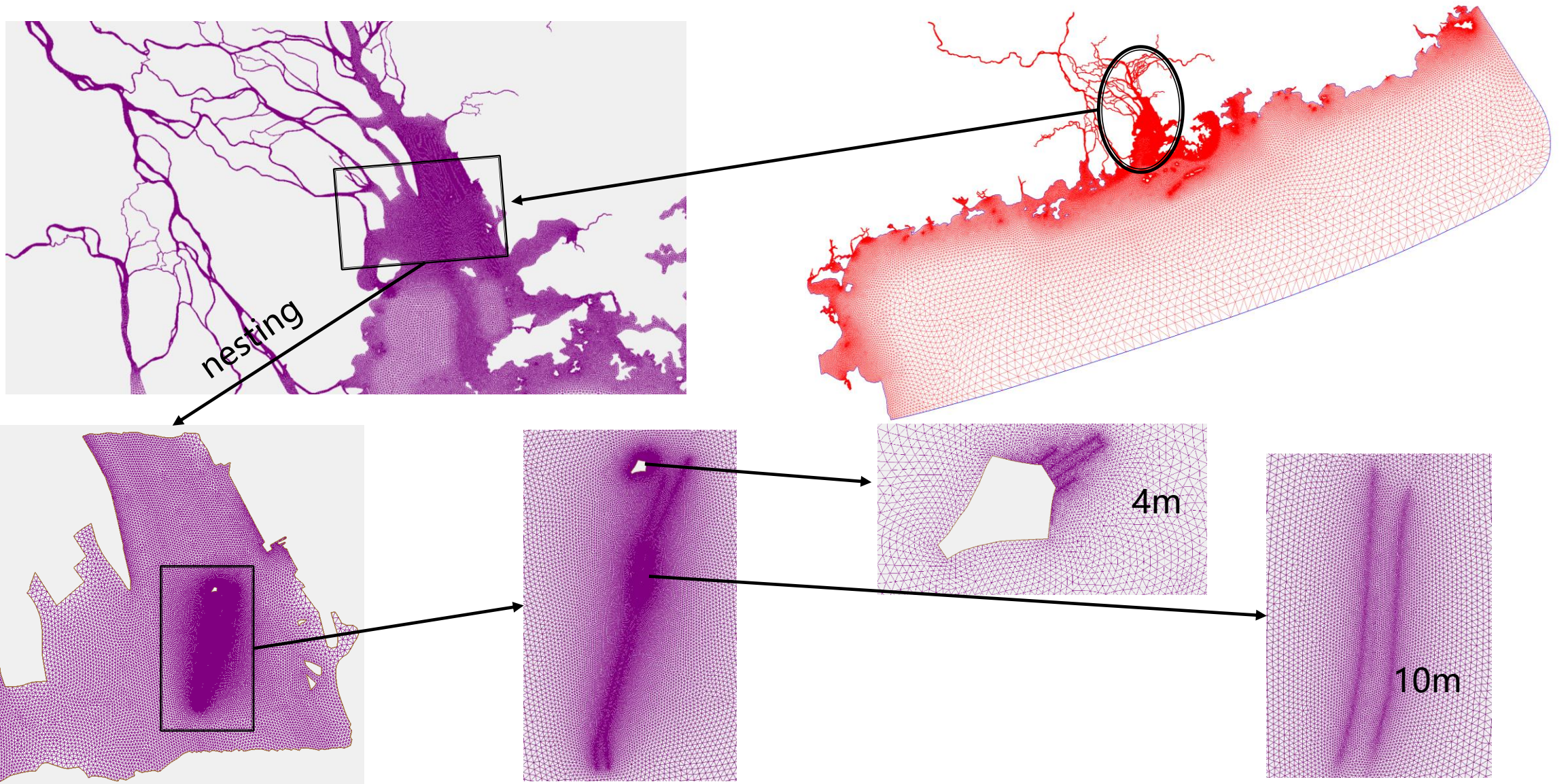
Model validation

Elevation
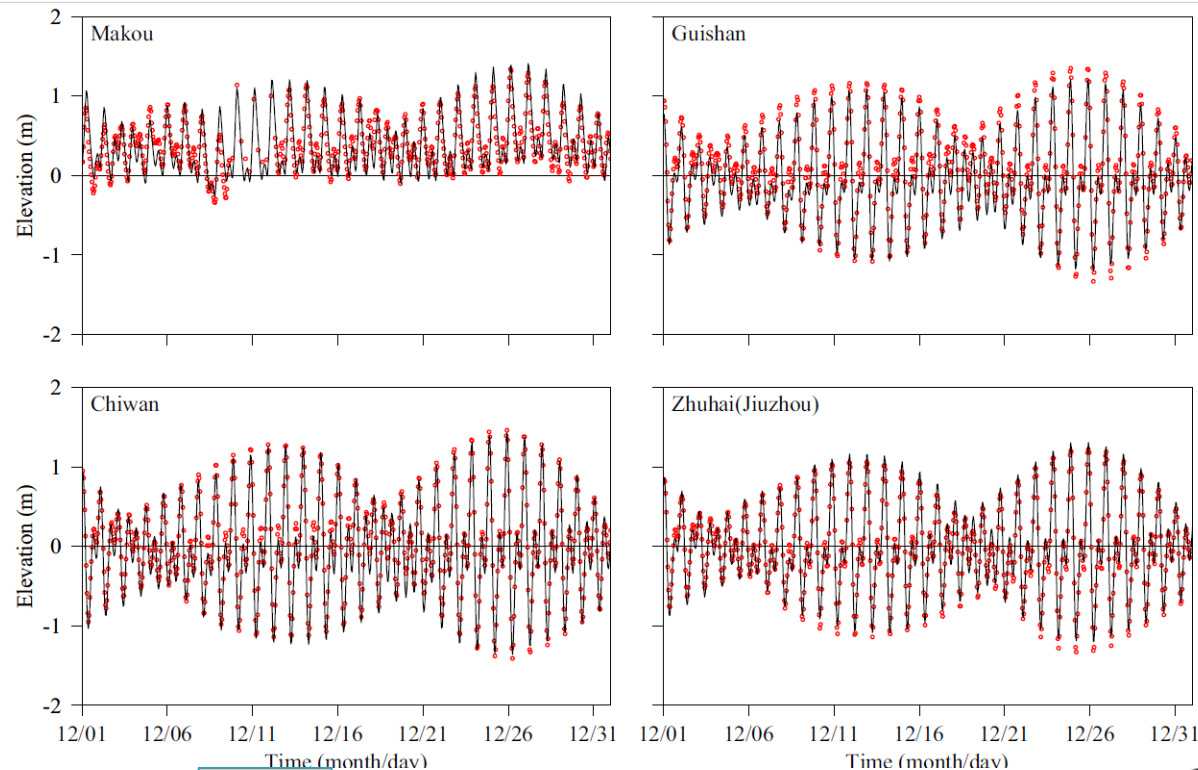
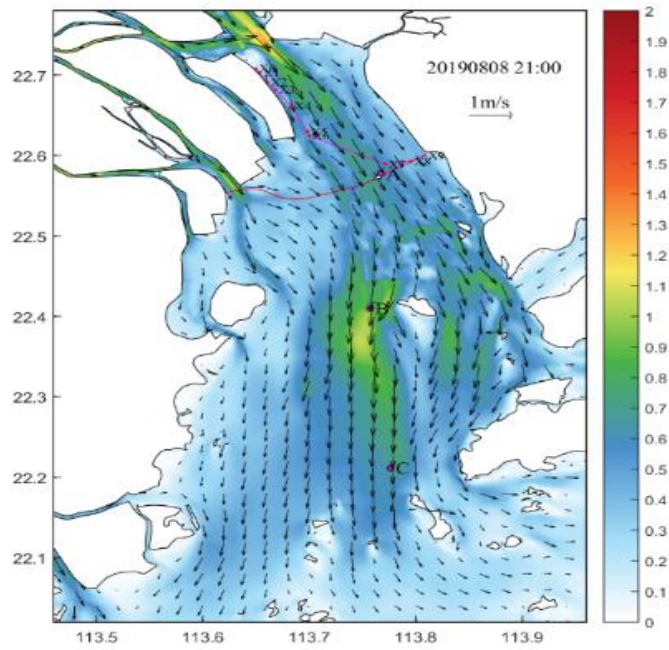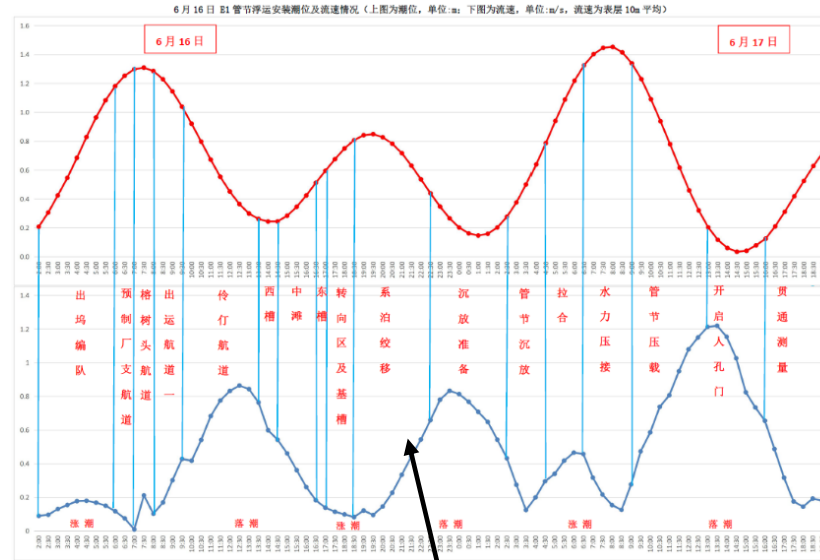obs =A* harmonic +B* prediciton
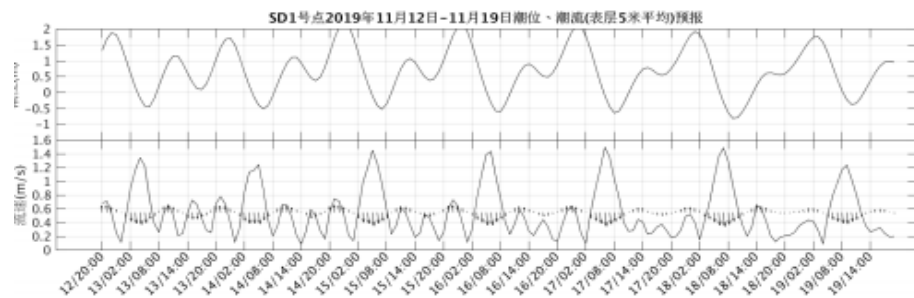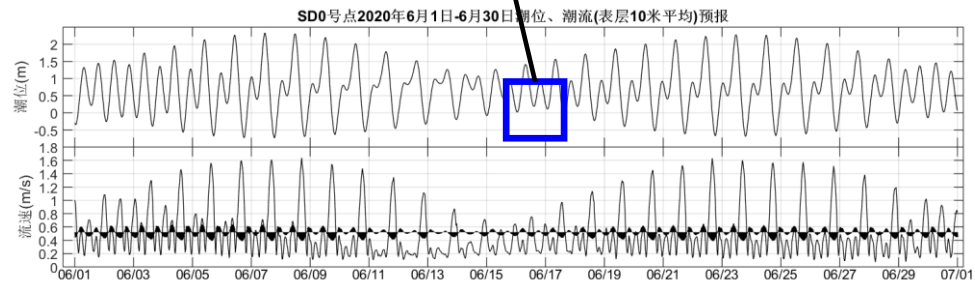
Regression analysis
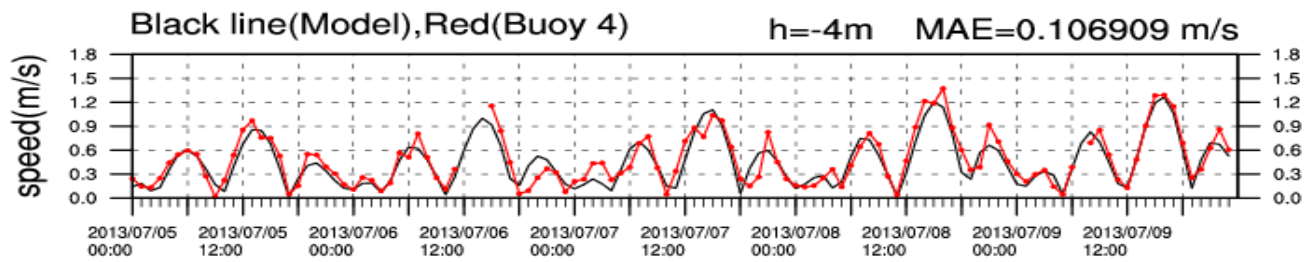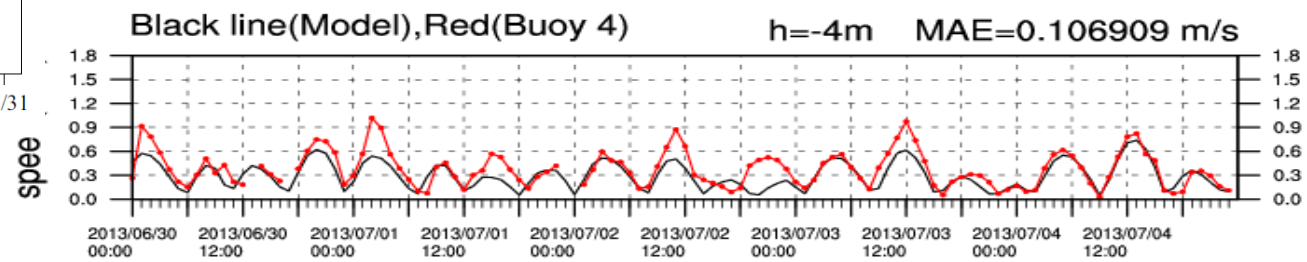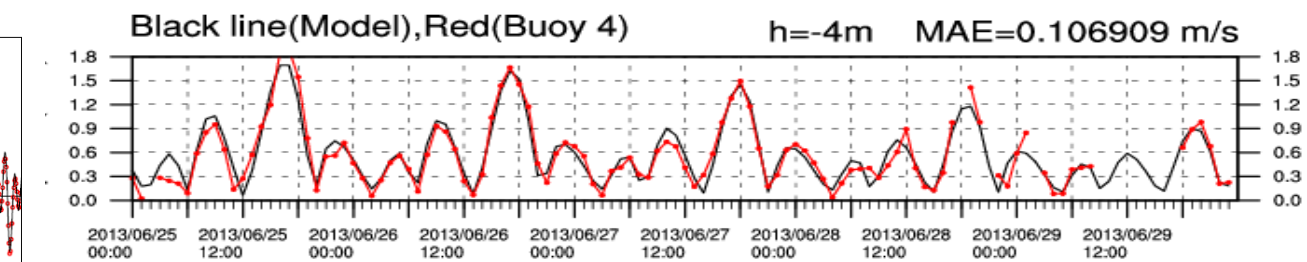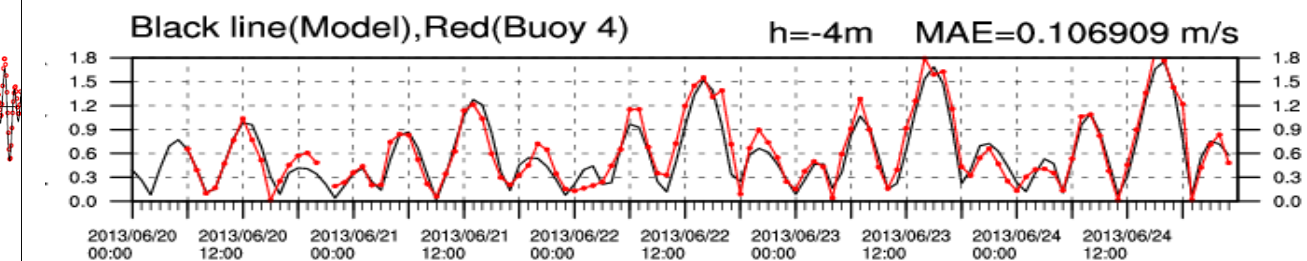
Currents-prediction products

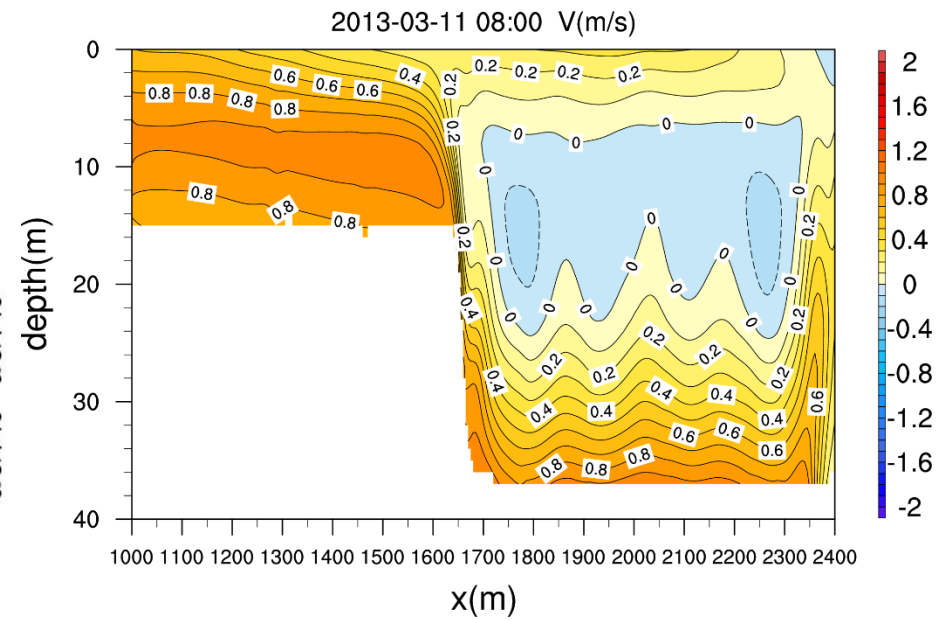Flow field

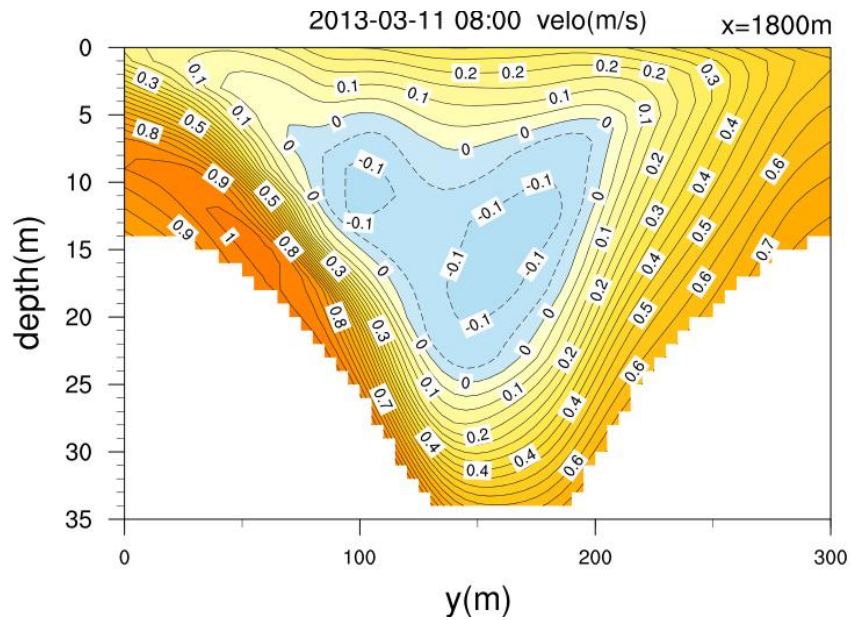Prediction along the route

7 days forecasts

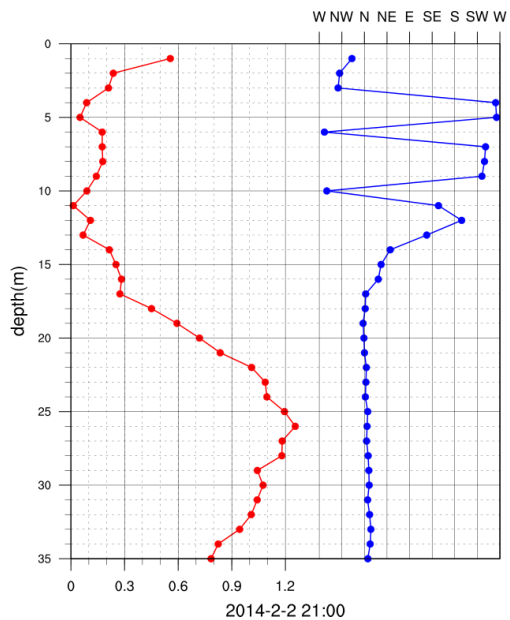Monthly prediction

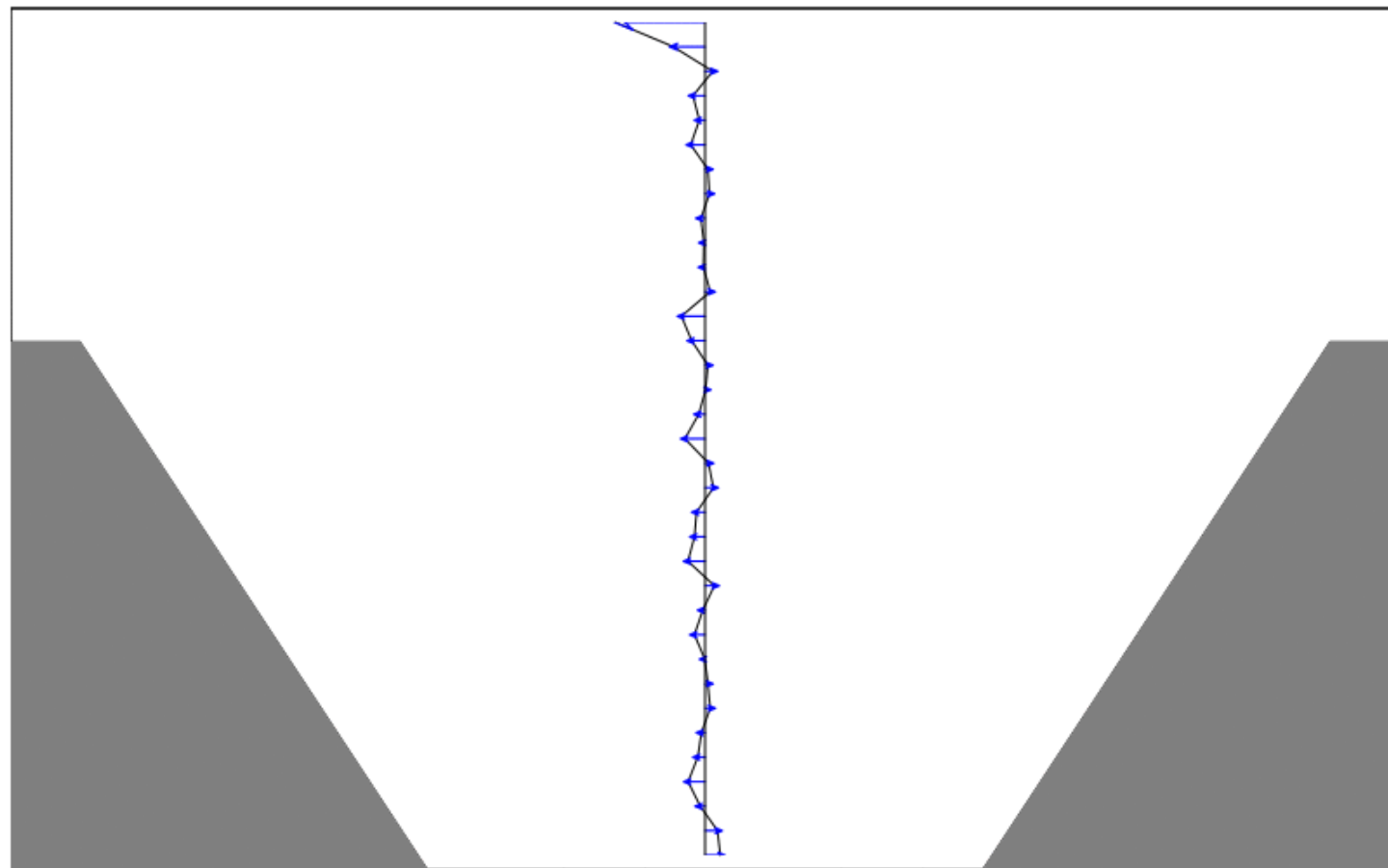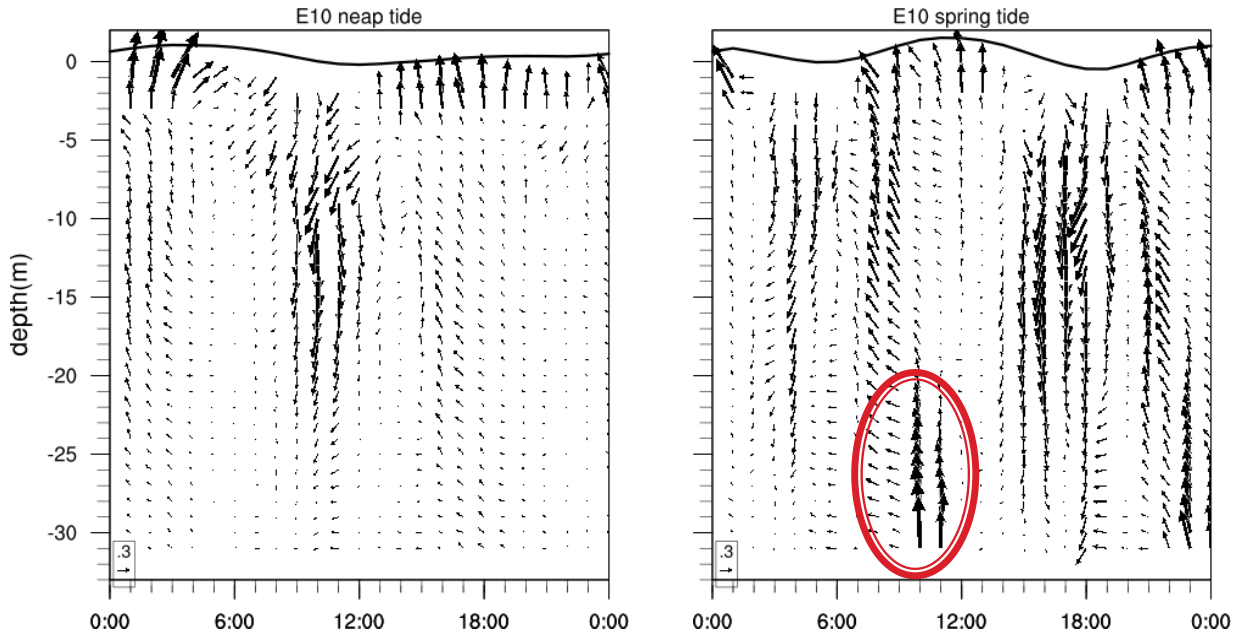# Currents-trench products
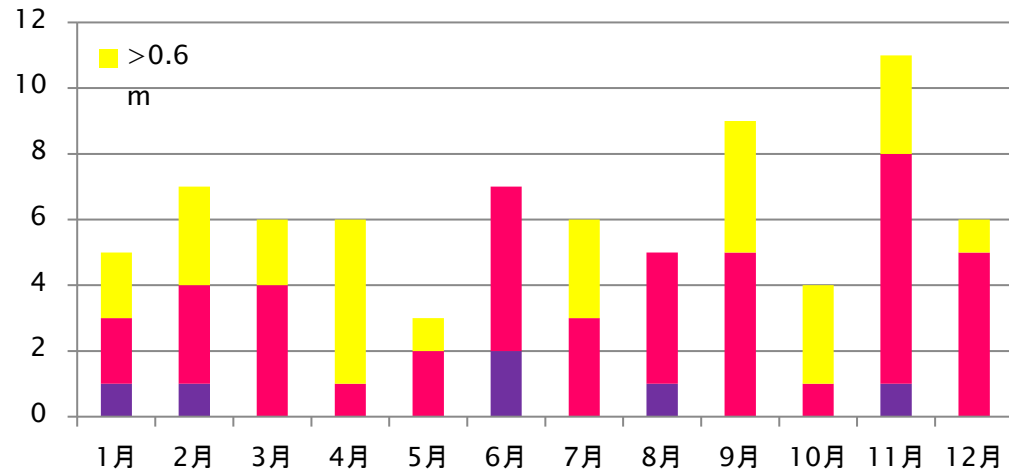
20140118 14:00
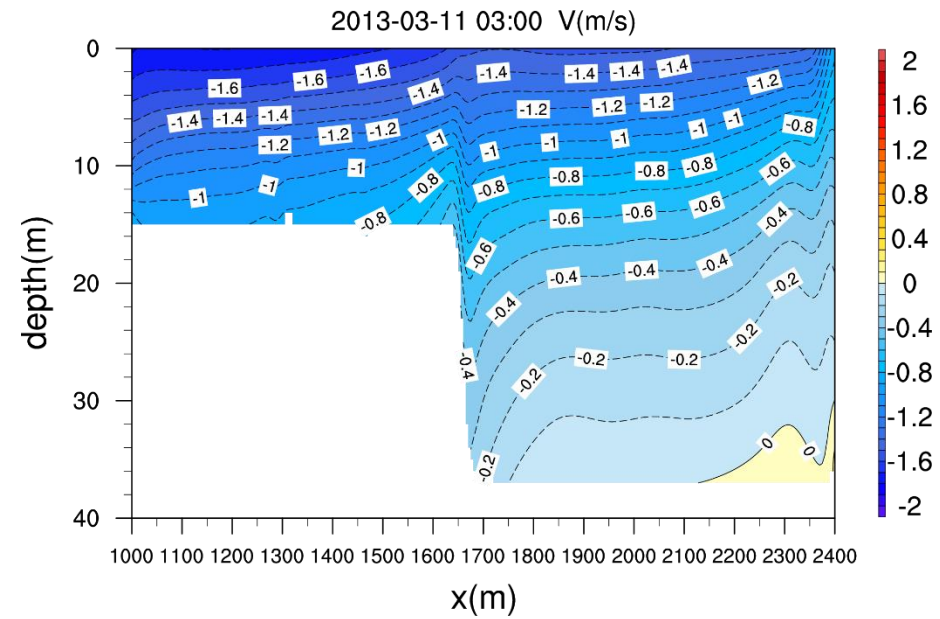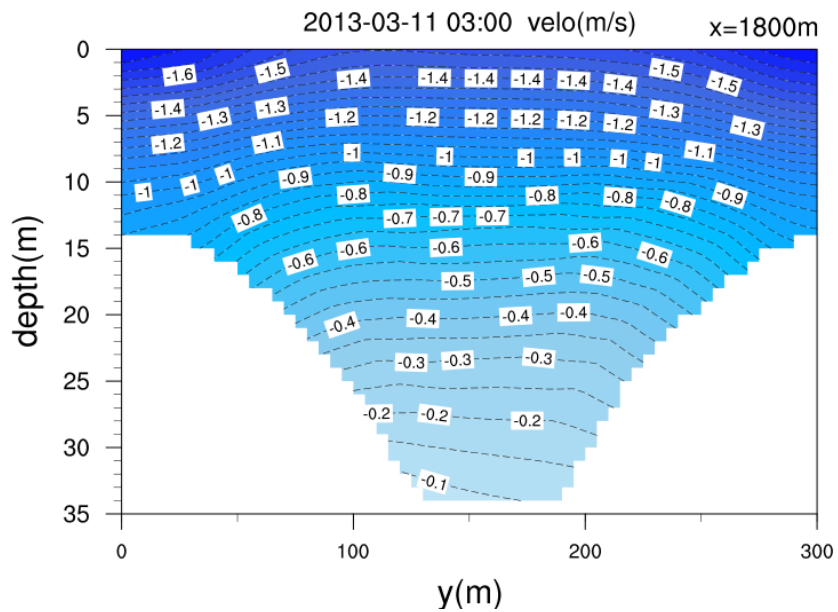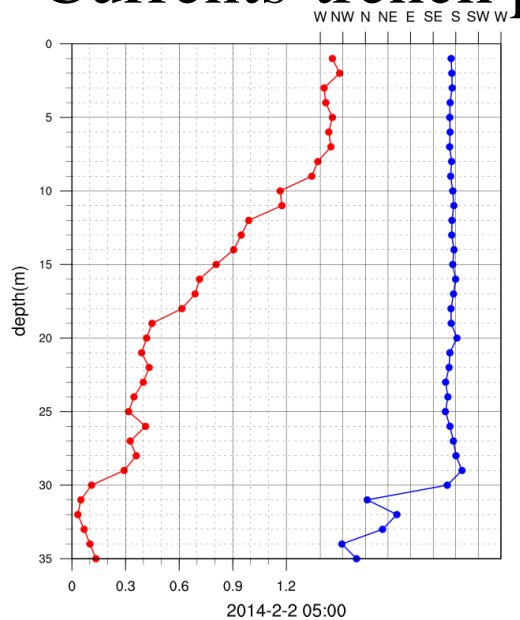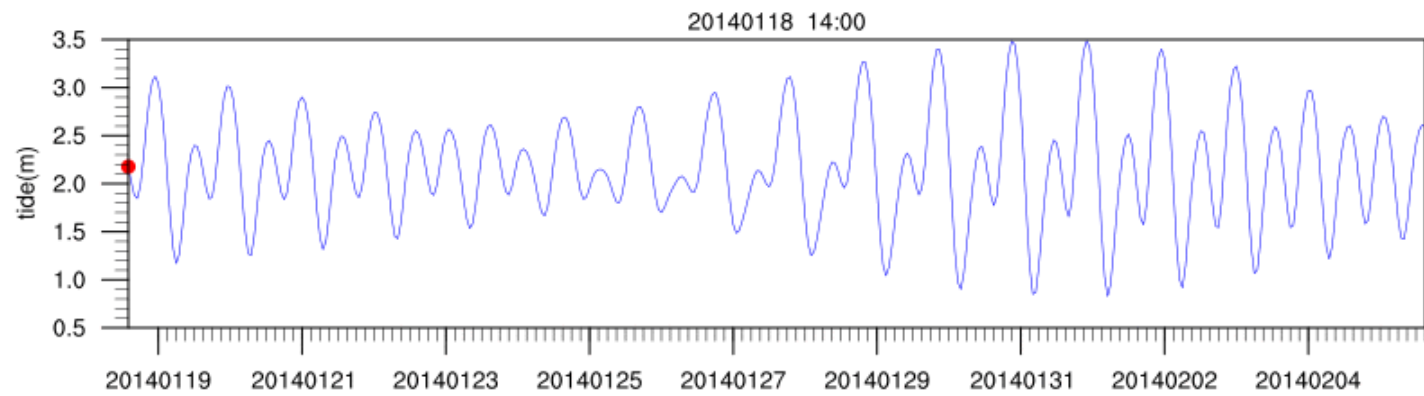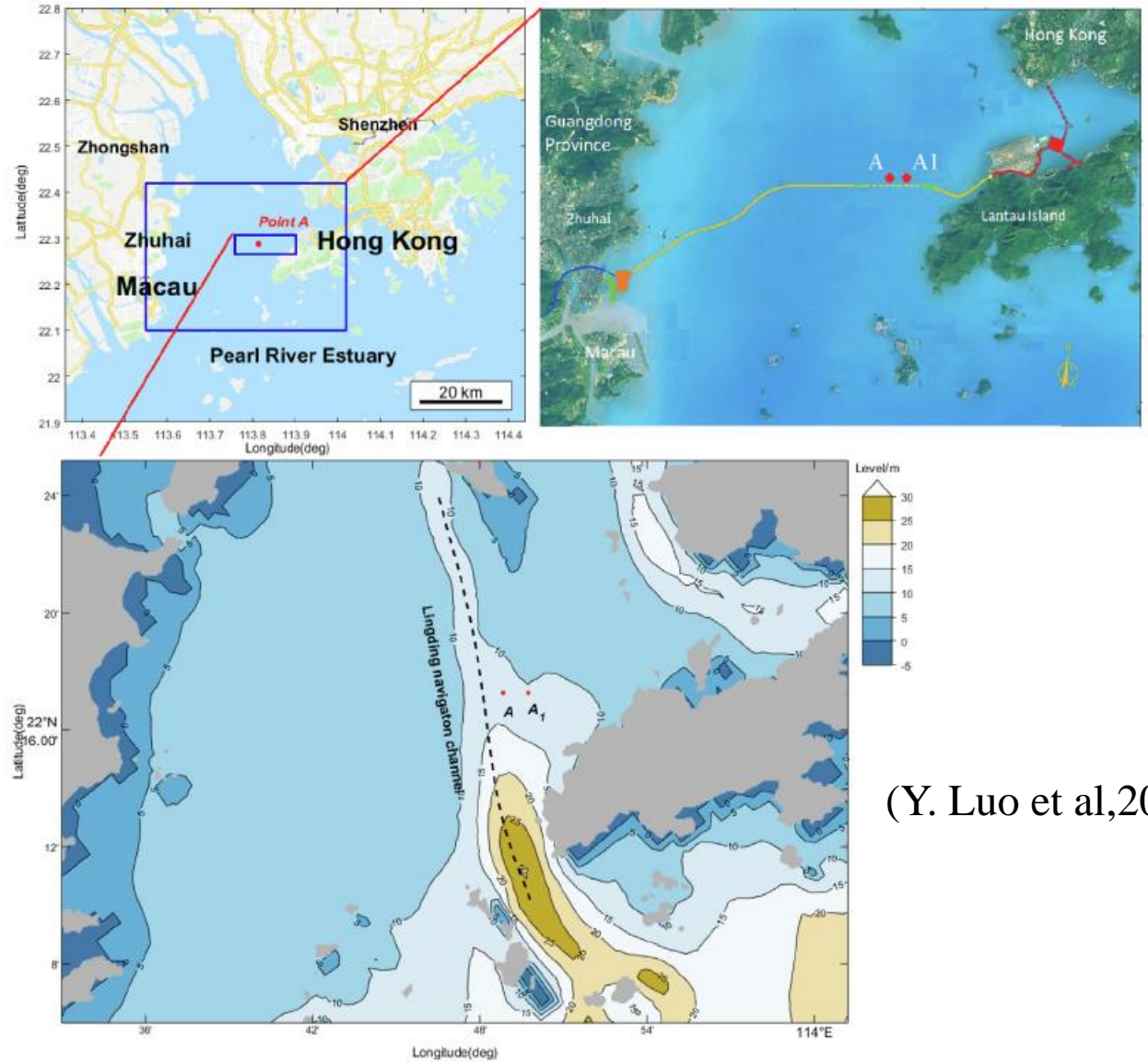
Currents- large near bottom flow in trench
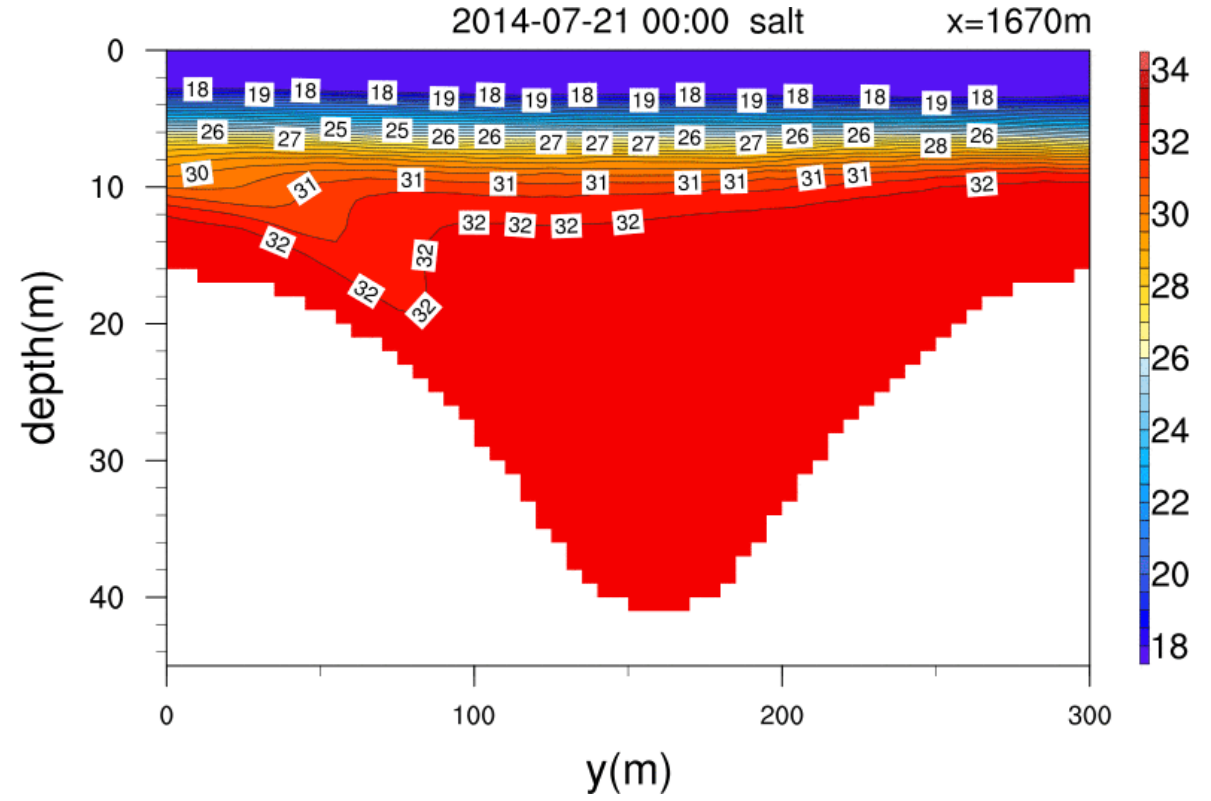
Disastrous waves

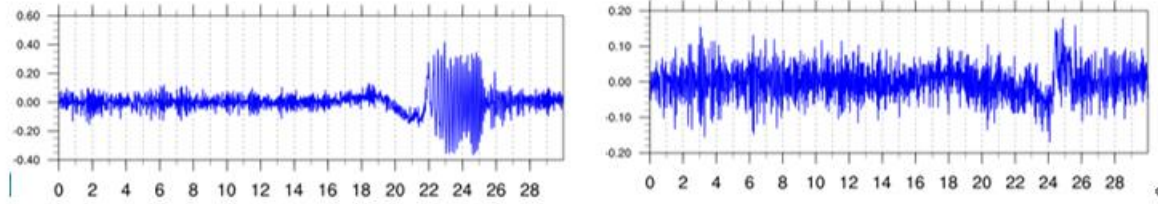### Number of occurrences in the year 2016
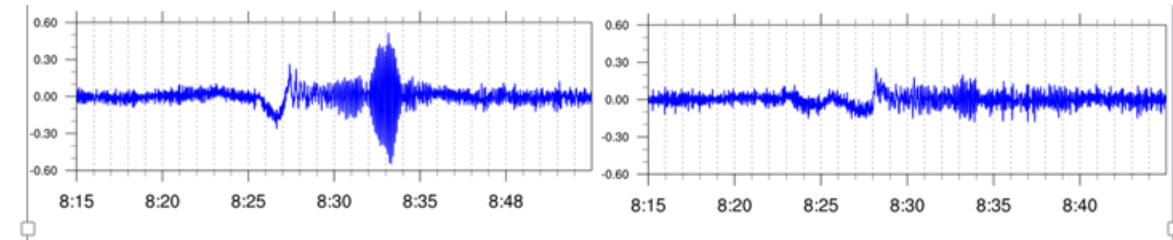

Observation sites
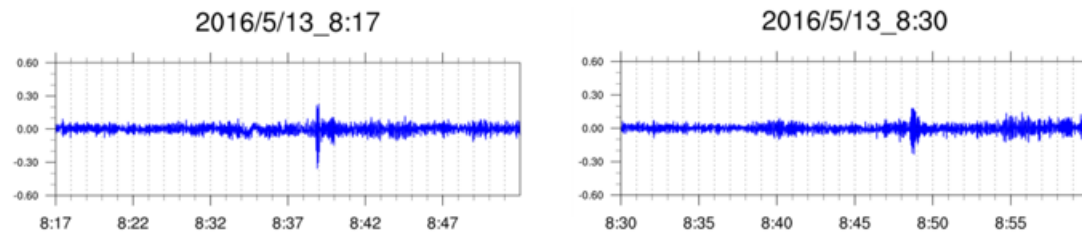

(Y. Luo et al,2022)
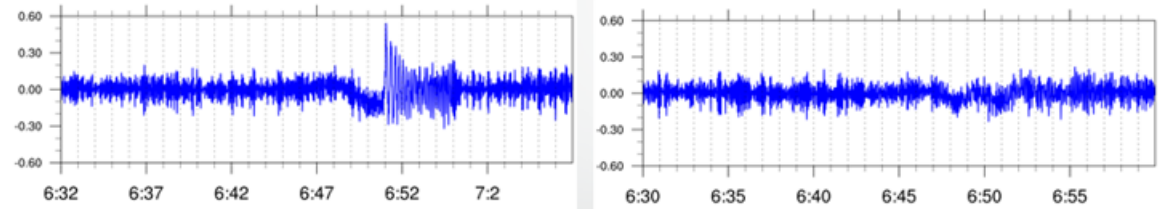
Examples

Pre installation
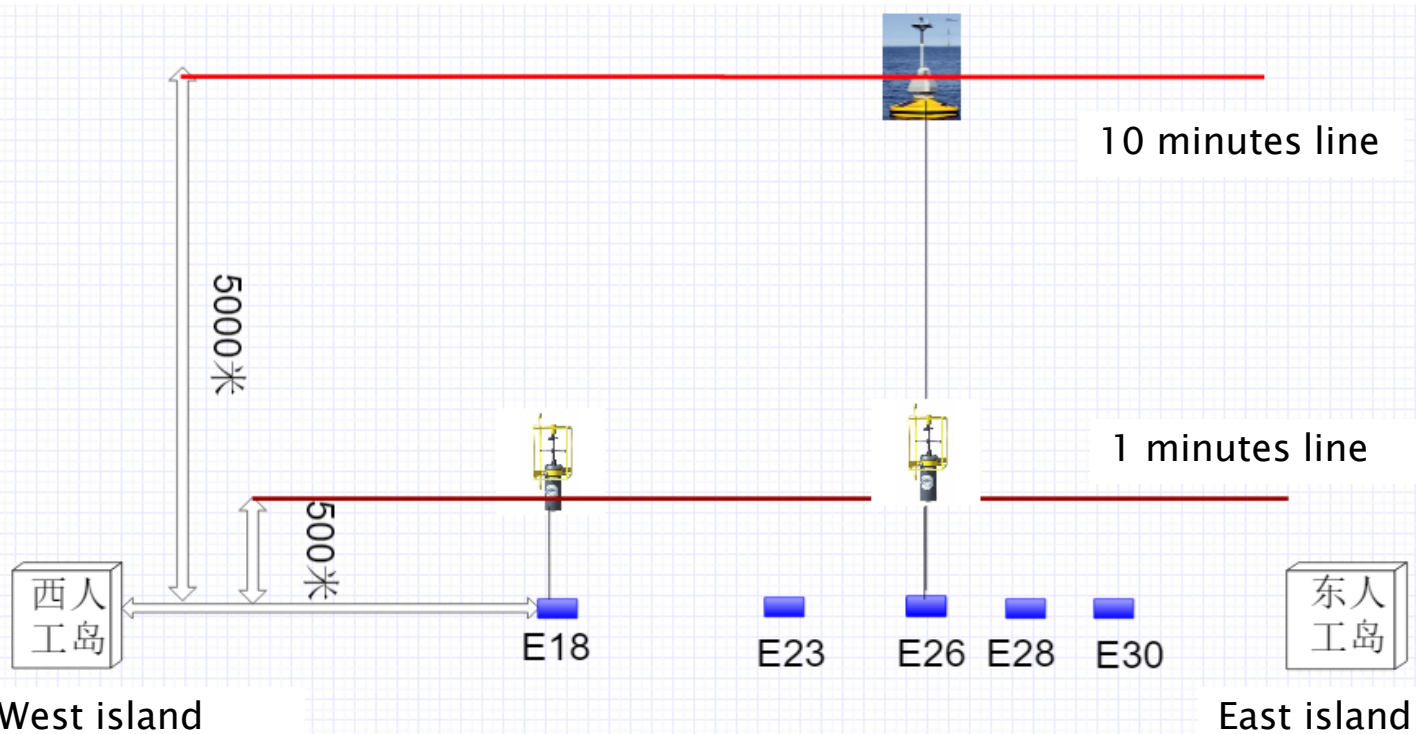

Left:A right:A1

Left:A right:A1

During installation

Left:A right:A1
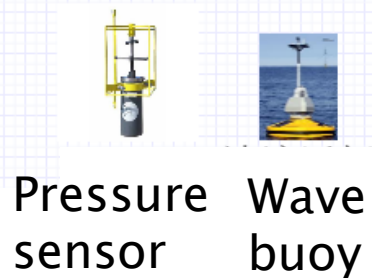
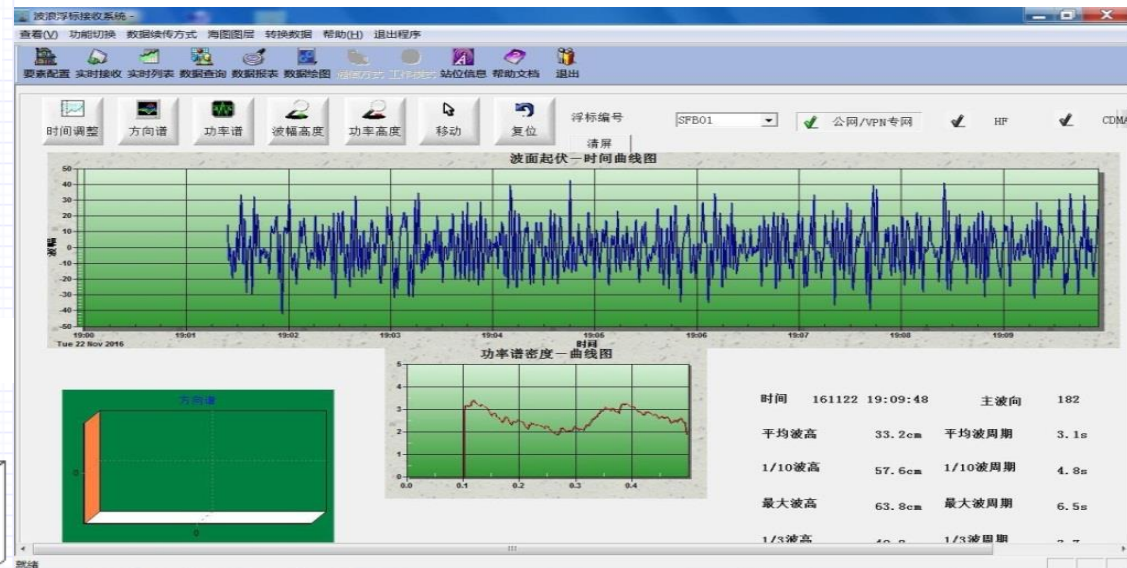Left:A right:A1

Monitoring and warning systems

Monitoring system

Analyzing software

10 minutes line

1 minutes line

5000米

500米

西人工岛

东人工岛

West island

East island

E18

E23

E26 E28 E30

Pressure sensor

Wave buoy

▶ Summary

- The high spatial and temporal resolution monitoring and modeling framework is vital for applying ocean prediction in coastal engineering

- The forecasting products should meet the needs of the user and solve the problems they encounter

Future efforts:

- Couple the circulation model with a watershed model

- Couple CFD model to simulate near-field flow around the tube

- Apply AI techniques to identify the freak waves or ship-wakes

Thank you!

谢 谢！