Eleventh Meeting of the ICG/PTWS Regional Working Group on Tsunami Warning and Mitigation System in the South China Sea Region, 25-26th September 2023, Guangzhou, China

Response review of 2022 Tonga volcanic tsunami

Lining Sun
South China Sea Tsunami Advisory Center
National Marine Environmental Forecasting Center

1 Response review

2 Tsunami wave analyzation

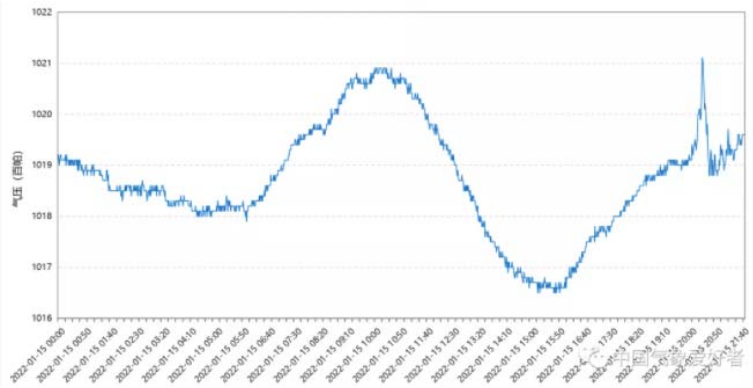
3 Lessons learned

4 Research on volcanic&landslide tsunami

5 Volcanic Eruption Monitoring and Tsunami Wave Alarm Software

Overview

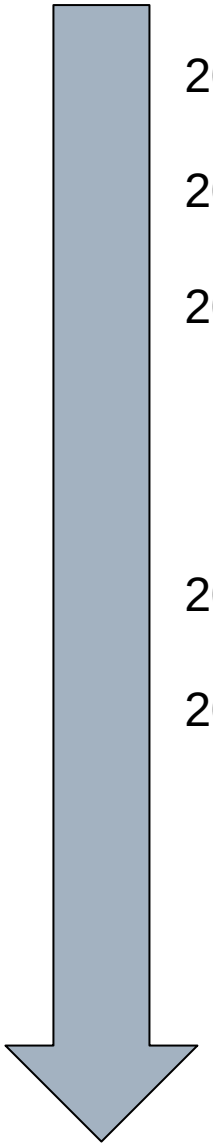
Original Time：2022-01-15 04:27 (UTC)
Epicenter：20.5° S，175.4° W
Eruption Type：Plinian
VEI：5-6



Atmospheric pressure station lie in Guangdong

- The tsunami hit Tabu Island about 20 minutes after the eruption,and finally reached to far away areas in Pacific region.
- The volcanic eruption caused changes in atmospheric pressure, with weather stations along China's coast picking up changes of 1-2 hPa.

Response to Tonga Tsunami



2022-01-15 04:27 Volcanic Eruption

2022-01-15 11:30 SCSTAC Manually Issued 1st Tsunami Message

2022-01-15 20:21 PTWC 1st(No.7) Tsunami Message Received

-the PTWC manually issued 6 messages through the backup listserv since the in-place dedicated messaging software did not have the flexibility to manually add basin-wide messages for non-earthquakes. But the backup listserv did not work

2022-01-16 02:46 PTWC Final Tsunami Message Received

2022-01-16 03:30 SCSTAC Manually Issued 2st Tsunami Message

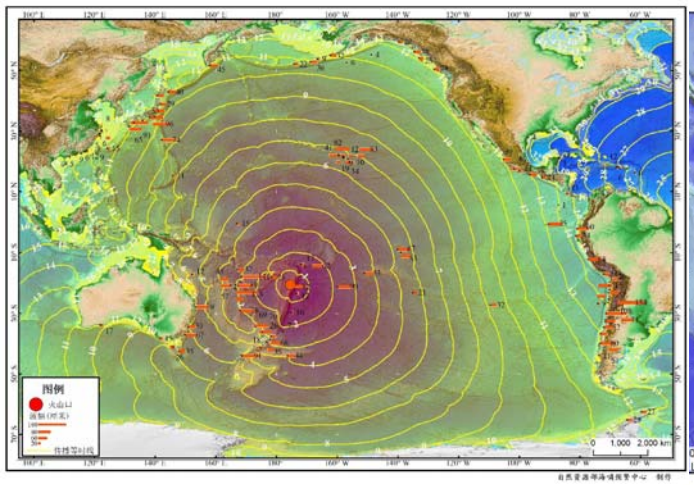
Response to Tonga Tsunami

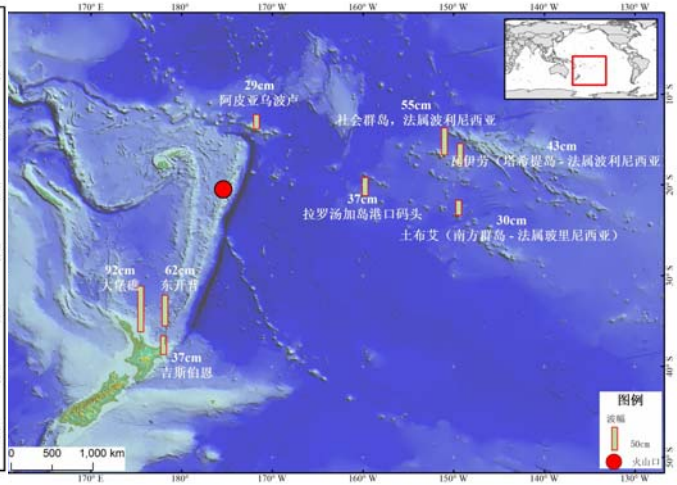
1st Tsunami Message issued on 01-15 11:30 (UTC)

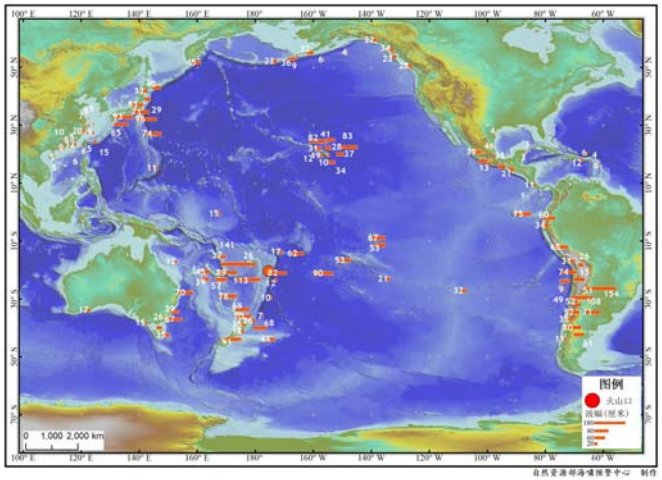
- The volcanic eruption caused a local tsunami
- Tsunami wave obseravtions around Tonga Island
- No tsunami threat to China

2nd on 01-16 03:30 (UTC)

- The volcanic eruption caused a trans-oceanic tsunami
- Tsunami obseravtions all around Pacific reigion
- Tsunami waves observed in China, but no catastrophic impact





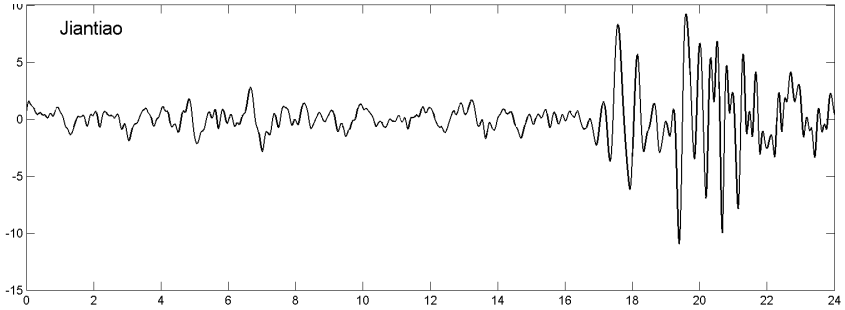


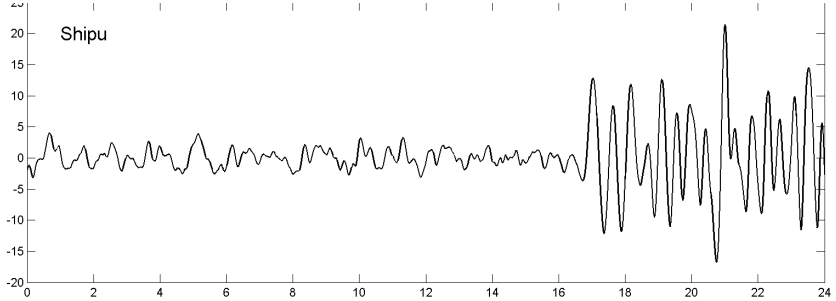
Obseravtion of tsunami waves in China Mainland(partial gauge stations)

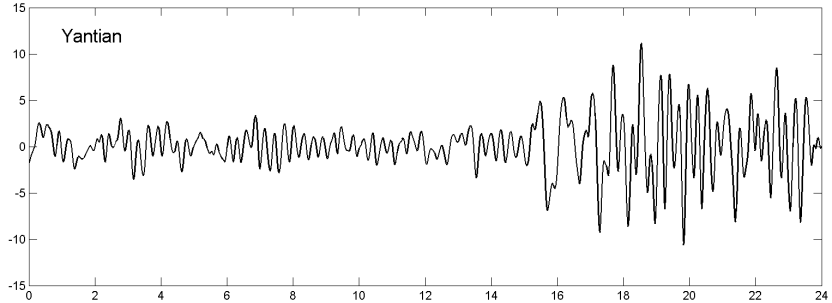
2nd Tsunami Message issued on 01-16 03:30(UTC)

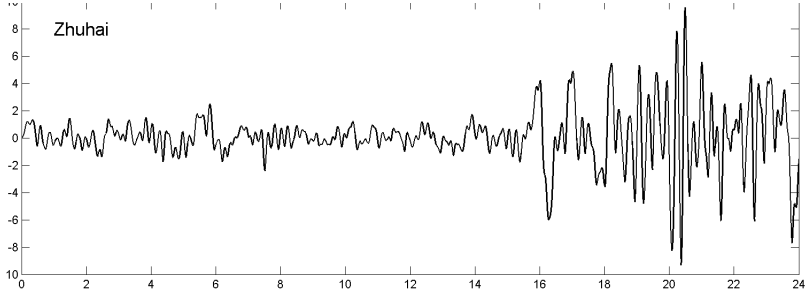
- Maximal tsuname wave observed in Shipu,Zhejiang,about **22cm**.

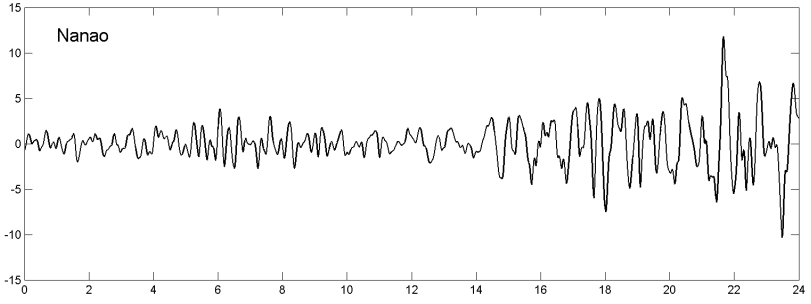
gauge	loation	time of measure (UTC)	maximum tsunami height (cm)
Jiantiao	Zhejiang	15 19:55	9
Shipu	Zhejiang	15 20:55	22
Zhuhai	Guangdong	15 20:30	9
Yantian	Guangdong	15 18:20	10
Nanao	Guangdong	15 21:40	12











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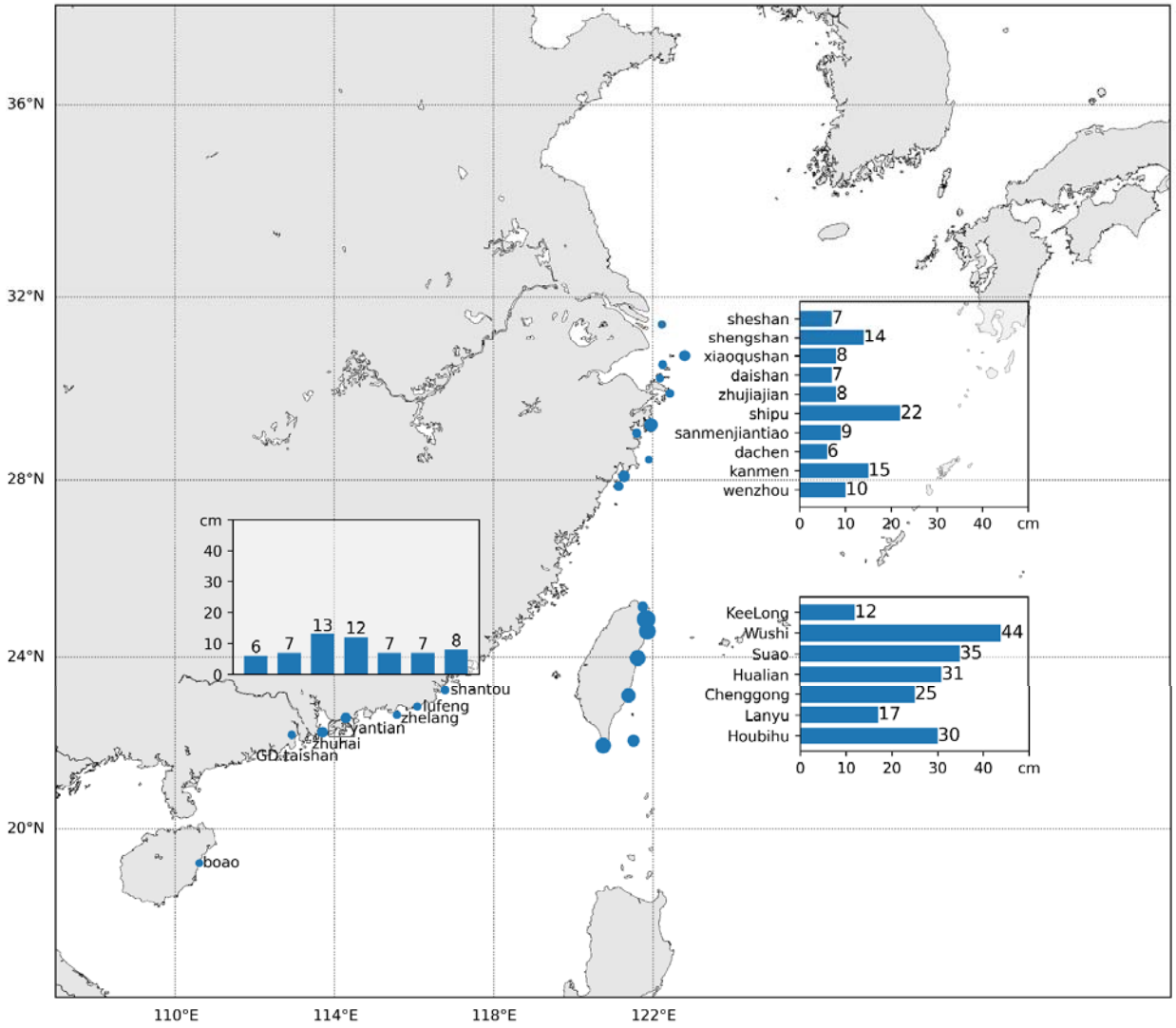
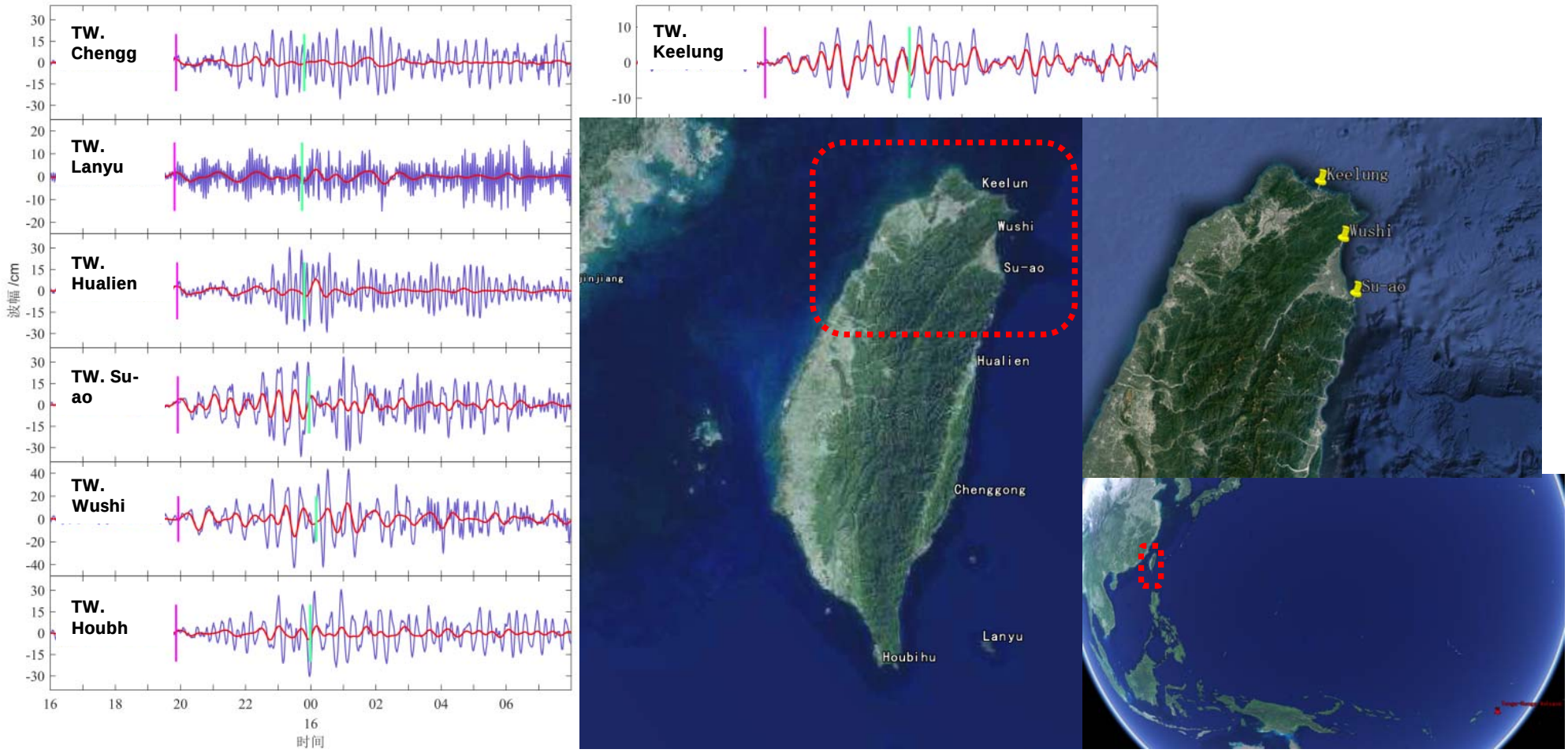
Amplitude along the Coast of China

- The largest wave amplitude monitored in Taiwan was 44 cm, which appeared at the Wushi Tide Gauge Station in Yilan County.
- The maximum wave amplitude in China Mainland is just 22 cm in Shipu of Zhejiang Province.



Wang, Z. et al. How did the Tonga volcanic tsunami on January 15, 2022, affect Chinese coasts? Science China Earth Sciences 66, (2023).

Leading wave in China



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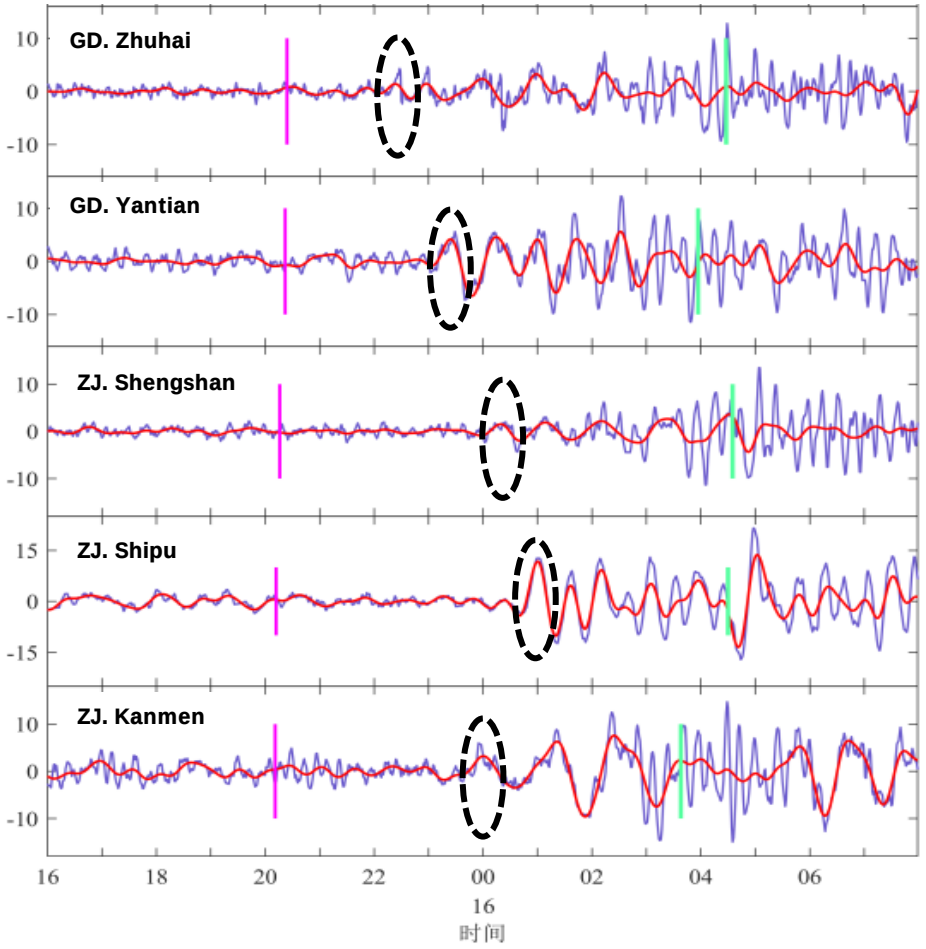

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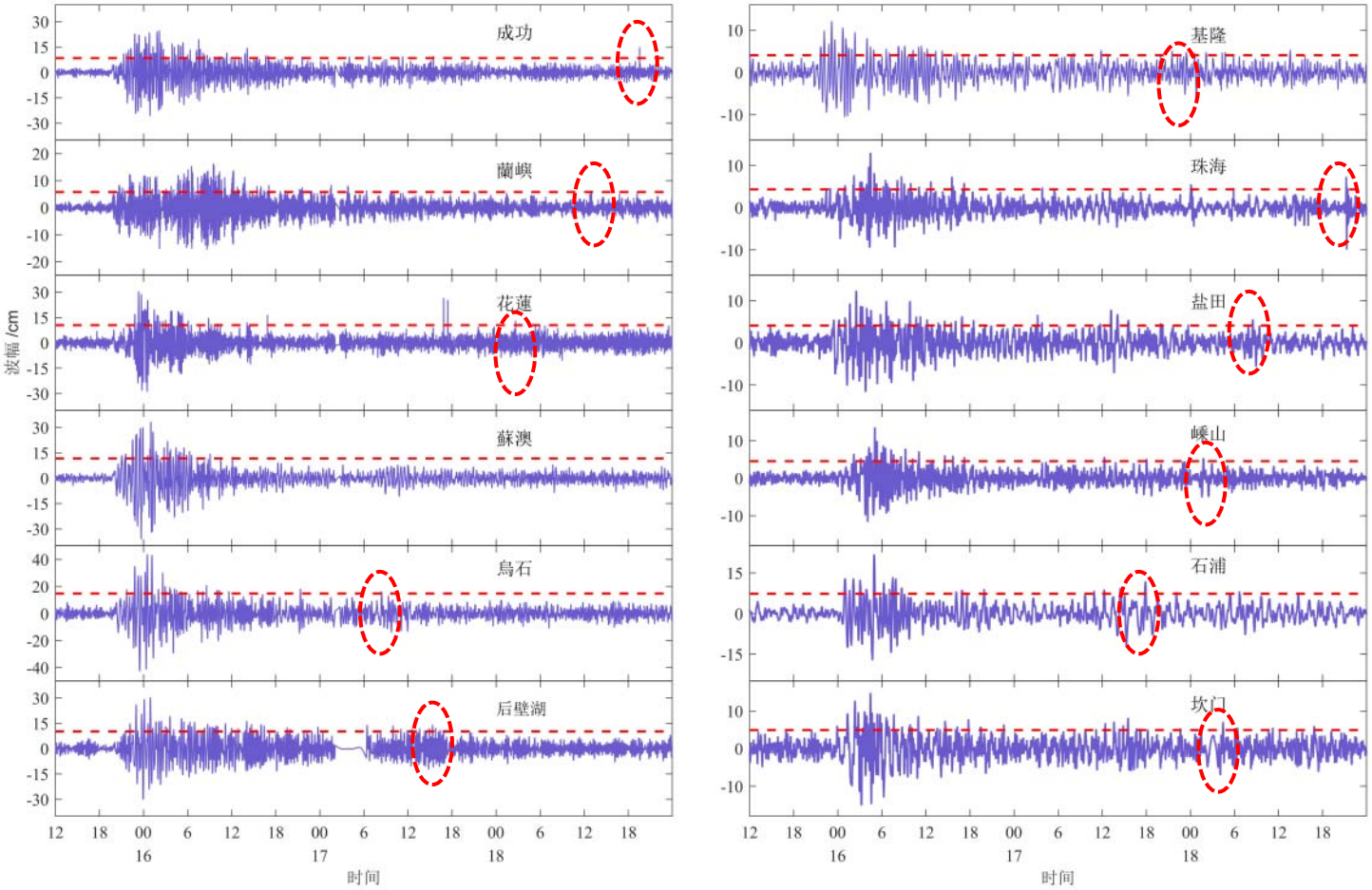
Long duration of the sea-level fluctuations in the Coast of China

If the energy of the tsunami wave monitored by a station is attenuated by 2/3 as the criteria, the duration of the tsunami impact exceeded 36 hours except Su-ao, and some of them even exceeded 48 hours.



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Lessons learned

1.Traditional earthquake tsunami monitoring methods cannot detect tsunamis caused by volcanoes, landslides and other factors

2.A more dense water level monitoring network on a global scale can effectively detect the generation of tsunamis caused by volcanoes and landslides

3.The generation mechanism and propagation dynamics of tsunamis caused by volcanoes, landslides and other factors need further study

4.The tsunami dissemination system needs to be further optimized

5.Enhance public awareness of tsunami prevention, and carry out tsunami evacuation drills regularly to reduce casualties

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Source Mechanisms of Volcanic Tsunamis

- Low frequency, but more serious
- The process is very complex, especially for large-scale volcanic eruptions, which may be continuous and accompanied by various movement mechanisms:
- Pyroclastic flow（20%, Force of pyroclastic flows generated by the eruption）
- Landslide（15%, Massive submarine/slope landslides or debris avalanches ）
- Collapse（10%, Sudden collapse of the caldera or subsidence）
- Submaine explosion（25%, Underwater volcanic explosions）
- Earthquake（ <20%, Volcanic earthquakes, ground deformation）
- Shock wave（5%, Shock waves associated with volcanic explosion）
- Others（i.e., Tsunamis Due to Avalanches of Hot Rock, Tsunamis Due to Lahars Entering the Sea, Tsunamis Due to Lava Avalanching into Water ）

Inferred source mechanisms of volcanic tsunamis

Source mechanisms	% of events	Source volume (km^3)	Volume flux (m^3/s)	Wave height[a] (m)	Travel distance (km)
Underwater explosion	25	<1	$<10^9$	<10	<200
Pyroclastic flow	20	1–200	10^5–10^8	<30	<300
Earthquake	<20			<15	<500
Flank failure	15	1–500	10^5–10^6	<100?	<6000
Caldera subsidence	10	1–100	10^6–10^8	<20	<200
Air wave	5			<3	>1,000
Lahar	<5	<1	$<10^5$	<3	<10
Collapse of lava bench	<1	<0.01	$<10^6$	<2	<10

[a] Wave height at the shoreline

- shock waves, lahars and collapses of lava bench can give birth to tsunamis with wave heights of more than 3 m
- Pyroclastic flows, flank failures and caldera subsidence are the only source mechanisms likely to imply volumes larger than 1 km^3

Volcanic tsunami: a review of source mechanisms, past events and hazards in Southeast Asia

Research on potential mechanism of Palu tsunami

1.Okada uniform slip model & Finite Fault Model to calculate the initial sea surface deformation

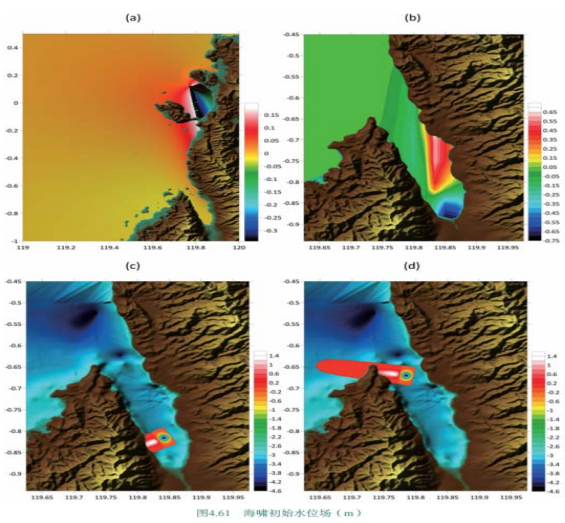
2.Geowave to calculate the initial sea surface by landslide

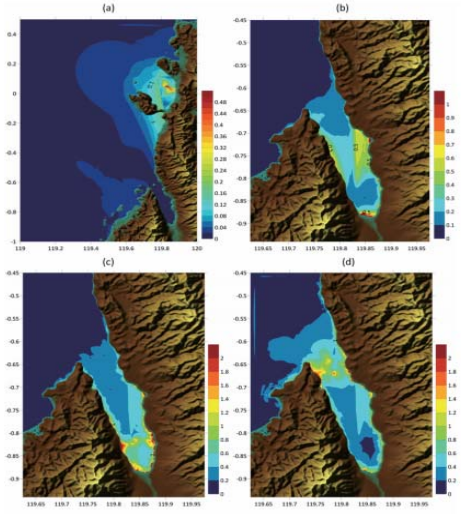
3.Funwave to simulate the tsunami propagation

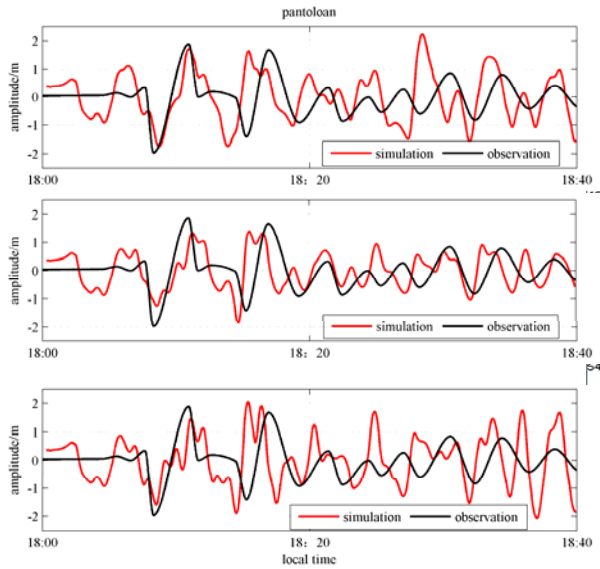
4.The earthquake is not likely to generate a destructive tsunami in Palu

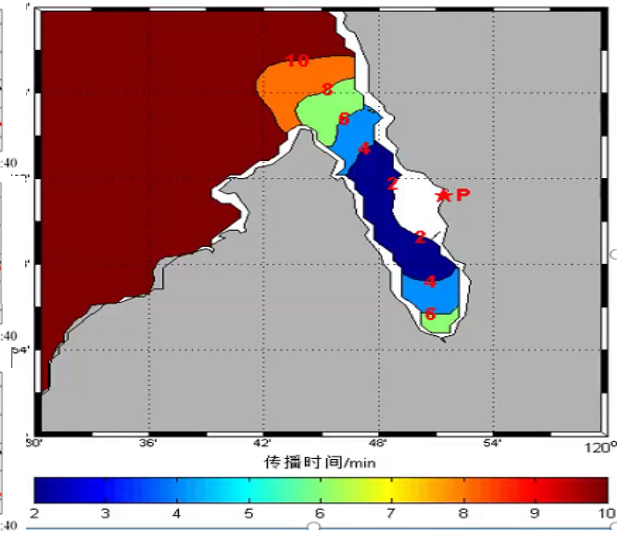
5.Field survey indicates landslides in Palu

6.Numerical simulation results fit well with the TTT&tsuanmi waves in Pantoloan Gauge









Landslide tsunami risk assessments in SCS

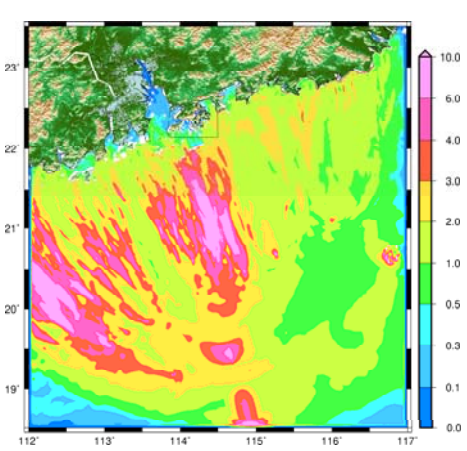
1.Evaluate potential submarine landslide parameters based on collected data

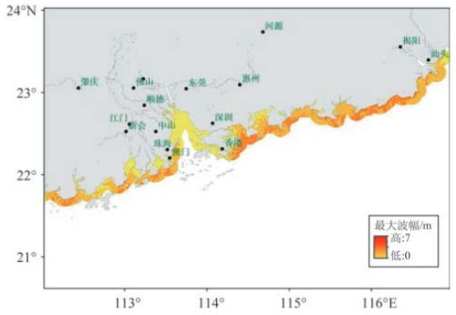
2.Simulate the generation and propagation of the tsunami with Numerical model

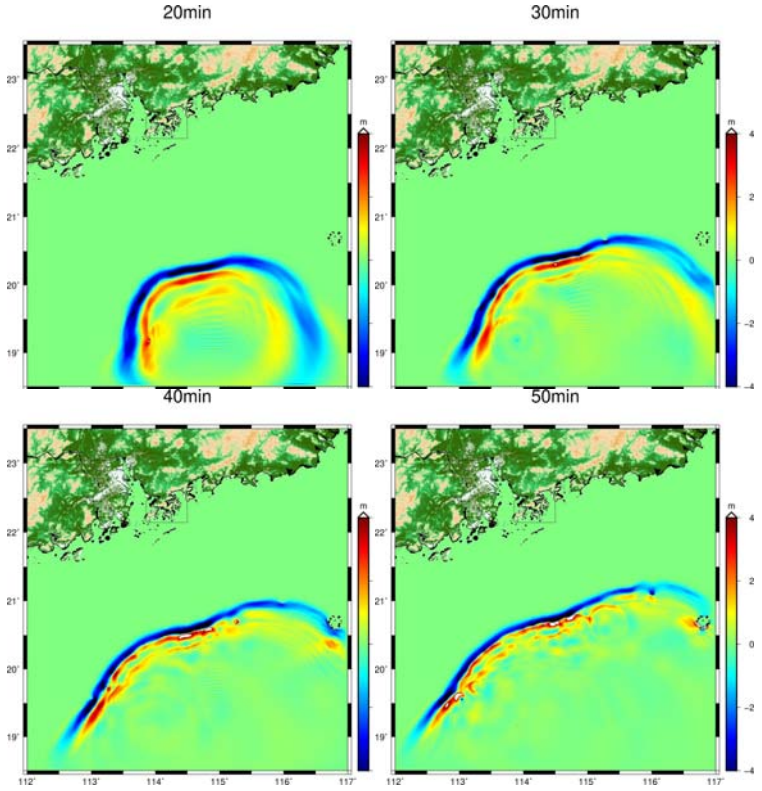
3.Worst Case Scenario:
4h to reach the coast
Max.Amp along the coast: 3m
Max.Amp in deep ocean: 6m

4.Max.Amp
Shantou & Shanwei : 2-3m
Hongkong & Shenzhen : ~2m
Macao & Zhuhai : ~1m

depth	slope angel	length	thickness	width	density
1350m	3.5°	60000m	62.5m	48000m	1900kg/m^3







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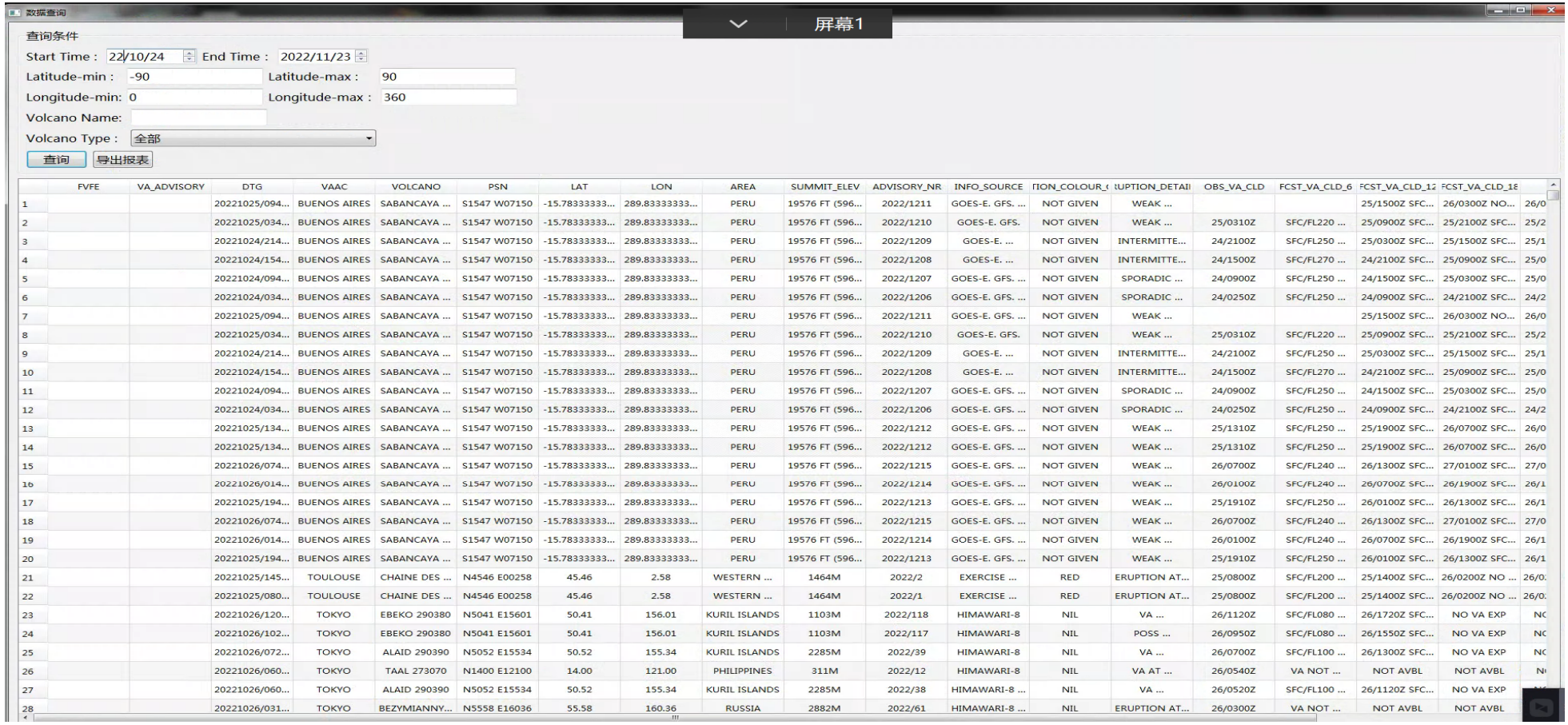
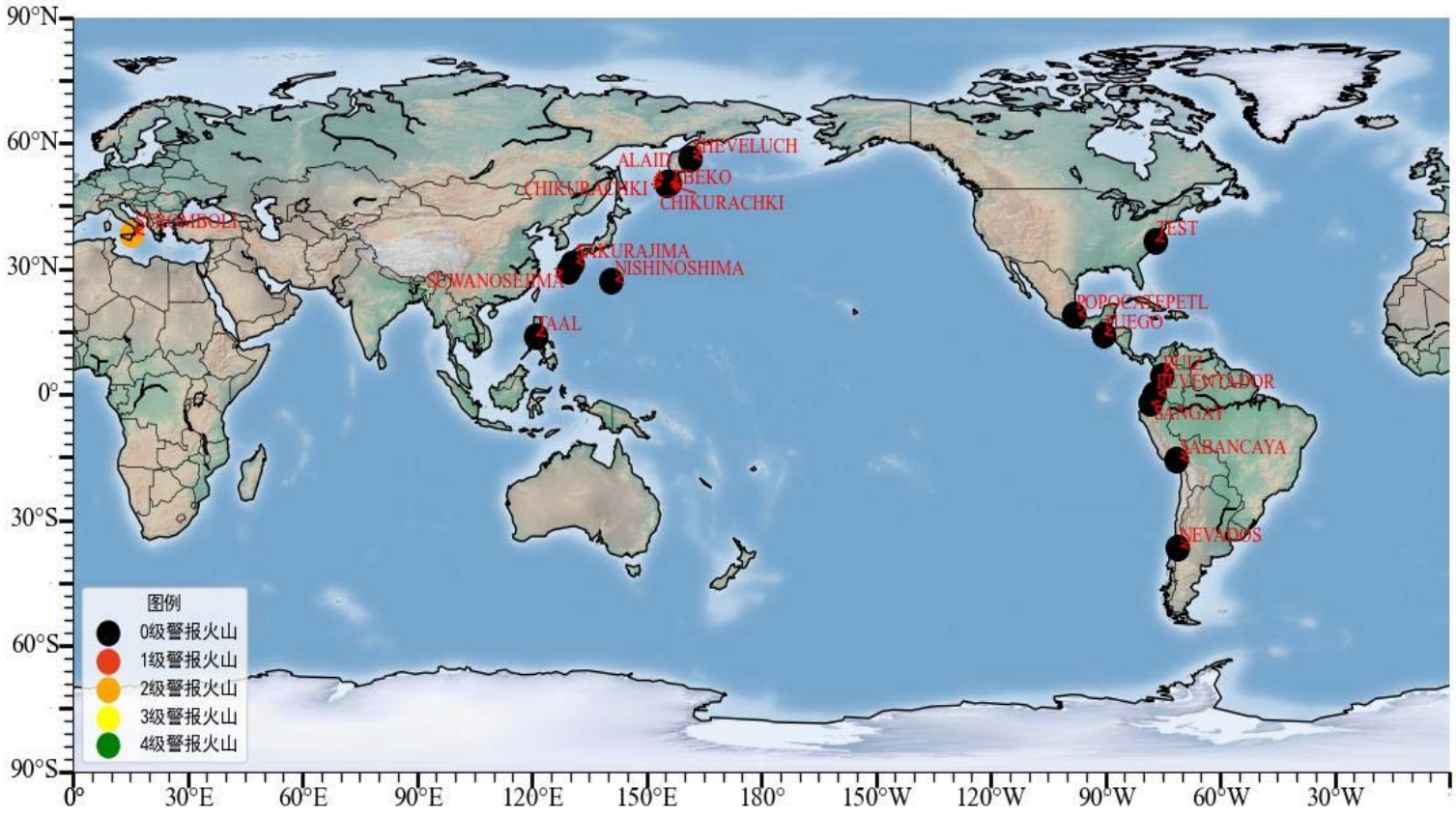
Volcanoic Eruption Information

Historical volcanic events

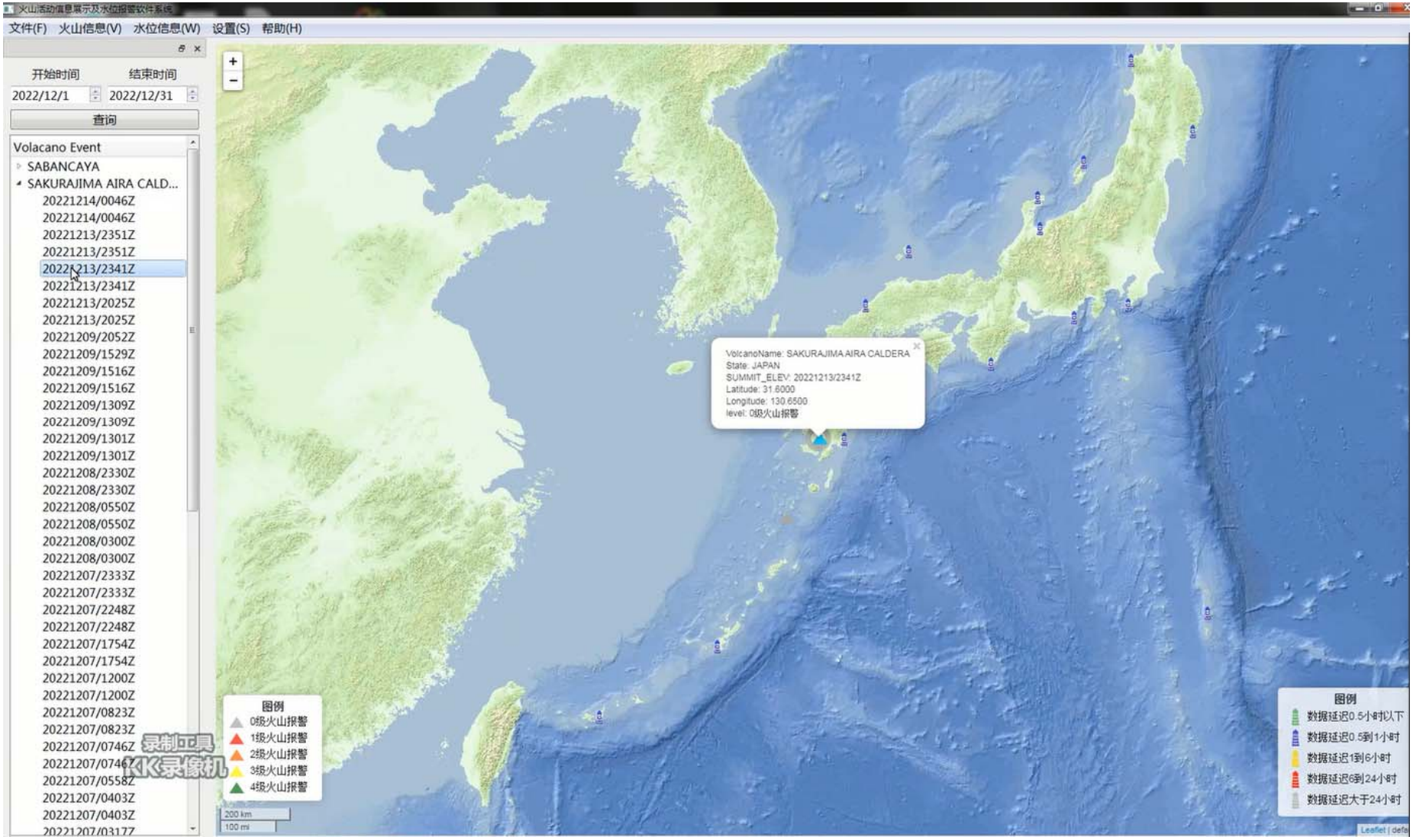


	FVFE	VA_ADVISORY	DTG	VAAC	VOLCANO	PSN	LAT	LON	AREA	SUMMIT_ELEV	ADVISORY_NR	INFO_SOURCE	TION_COLOUR_(	UPTION_DETAI	OBS_VA_CLD	FCST_VA_CLD_6	FCST_VA_CLD_12	FCST_VA_CLD_18	
1			20221025/094...	BUENOS AIRES	SABANCAYA ...	S1547 W07150	-15.78333333...	289.83333333...	PERU	19576 FT (596...	2022/1211	GOES-E. GFS. ...	NOT GIVEN	WEAK ...			25/1500Z SFC...	26/0300Z NO...	26/0
2			20221025/034...	BUENOS AIRES	SABANCAYA ...	S1547 W07150	-15.78333333...	289.83333333...	PERU	19576 FT (596...	2022/1210	GOES-E. GFS.	NOT GIVEN	WEAK ...	25/0310Z	SFC/FL220 ...	25/0900Z SFC...	25/2100Z SFC...	25/2
3			20221024/214...	BUENOS AIRES	SABANCAYA ...	S1547 W07150	-15.78333333...	289.83333333...	PERU	19576 FT (596...	2022/1209	GOES-E. ...	NOT GIVEN	INTERMITTE...	24/2100Z	SFC/FL250 ...	25/0300Z SFC...	25/1500Z SFC...	25/1
4			20221024/154...	BUENOS AIRES	SABANCAYA ...	S1547 W07150	-15.78333333...	289.83333333...	PERU	19576 FT (596...	2022/1208	GOES-E. ...	NOT GIVEN	INTERMITTE...	24/1500Z	SFC/FL270 ...	24/2100Z SFC...	25/0900Z SFC...	25/0
5			20221024/094...	BUENOS AIRES	SABANCAYA ...	S1547 W07150	-15.78333333...	289.83333333...	PERU	19576 FT (596...	2022/1207	GOES-E. GFS. ...	NOT GIVEN	SPORADIC ...	24/0900Z	SFC/FL250 ...	24/1500Z SFC...	25/0300Z SFC...	25/0
6			20221024/034...	BUENOS AIRES	SABANCAYA ...	S1547 W07150	-15.78333333...	289.83333333...	PERU	19576 FT (596...	2022/1206	GOES-E. GFS. ...	NOT GIVEN	SPORADIC ...	24/0250Z	SFC/FL250 ...	24/0900Z SFC...	24/2100Z SFC...	24/2
7			20221025/094...	BUENOS AIRES	SABANCAYA ...	S1547 W07150	-15.78333333...	289.83333333...	PERU	19576 FT (596...	2022/1211	GOES-E. GFS. ...	NOT GIVEN	WEAK ...			25/1500Z SFC...	26/0300Z NO...	26/0
8			20221025/034...	BUENOS AIRES	SABANCAYA ...	S1547 W07150	-15.78333333...	289.83333333...	PERU	19576 FT (596...	2022/1210	GOES-E. GFS.	NOT GIVEN	WEAK ...	25/0310Z	SFC/FL220 ...	25/0900Z SFC...	25/2100Z SFC...	25/2
9			20221024/214...	BUENOS AIRES	SABANCAYA ...	S1547 W07150	-15.78333333...	289.83333333...	PERU	19576 FT (596...	2022/1209	GOES-E. ...	NOT GIVEN	INTERMITTE...	24/2100Z	SFC/FL250 ...	25/0300Z SFC...	25/1500Z SFC...	25/1
10			20221024/154...	BUENOS AIRES	SABANCAYA ...	S1547 W07150	-15.78333333...	289.83333333...	PERU	19576 FT (596...	2022/1208	GOES-E. ...	NOT GIVEN	INTERMITTE...	24/1500Z	SFC/FL270 ...	24/2100Z SFC...	25/0900Z SFC...	25/0
11			20221024/094...	BUENOS AIRES	SABANCAYA ...	S1547 W07150	-15.78333333...	289.83333333...	PERU	19576 FT (596...	2022/1207	GOES-E. GFS. ...	NOT GIVEN	SPORADIC ...	24/0900Z	SFC/FL250 ...	24/1500Z SFC...	25/0300Z SFC...	25/0
12			20221024/034...	BUENOS AIRES	SABANCAYA ...	S1547 W07150	-15.78333333...	289.83333333...	PERU	19576 FT (596...	2022/1206	GOES-E. GFS. ...	NOT GIVEN	SPORADIC ...	24/0250Z	SFC/FL250 ...	24/0900Z SFC...	24/2100Z SFC...	24/2
13			20221025/134...	BUENOS AIRES	SABANCAYA ...	S1547 W07150	-15.78333333...	289.83333333...	PERU	19576 FT (596...	2022/1212	GOES-E. GFS. ...	NOT GIVEN	WEAK ...	25/1310Z	SFC/FL250 ...	25/1900Z SFC...	26/0700Z SFC...	26/0
14			20221025/134...	BUENOS AIRES	SABANCAYA ...	S1547 W07150	-15.78333333...	289.83333333...	PERU	19576 FT (596...	2022/1212	GOES-E. GFS. ...	NOT GIVEN	WEAK ...	25/1310Z	SFC/FL250 ...	25/1900Z SFC...	26/0700Z SFC...	26/0
15			20221026/074...	BUENOS AIRES	SABANCAYA ...	S1547 W07150	-15.78333333...	289.83333333...	PERU	19576 FT (596...	2022/1215	GOES-E. GFS. ...	NOT GIVEN	WEAK ...	26/0700Z	SFC/FL240 ...	26/1300Z SFC...	27/0100Z SFC...	27/0
16			20221026/014...	BUENOS AIRES	SABANCAYA ...	S1547 W07150	-15.78333333...	289.83333333...	PERU	19576 FT (596...	2022/1214	GOES-E. GFS. ...	NOT GIVEN	WEAK ...	26/0100Z	SFC/FL240 ...	26/0700Z SFC...	26/1900Z SFC...	26/1
17			20221025/194...	BUENOS AIRES	SABANCAYA ...	S1547 W07150	-15.78333333...	289.83333333...	PERU	19576 FT (596...	2022/1213	GOES-E. GFS. ...	NOT GIVEN	WEAK ...	25/1910Z	SFC/FL250 ...	26/0100Z SFC...	26/1300Z SFC...	26/1
18			20221026/074...	BUENOS AIRES	SABANCAYA ...	S1547 W07150	-15.78333333...	289.83333333...	PERU	19576 FT (596...	2022/1215	GOES-E. GFS. ...	NOT GIVEN	WEAK ...	26/0700Z	SFC/FL240 ...	26/1300Z SFC...	27/0100Z SFC...	27/0
19			20221026/014...	BUENOS AIRES	SABANCAYA ...	S1547 W07150	-15.78333333...	289.83333333...	PERU	19576 FT (596...	2022/1214	GOES-E. GFS. ...	NOT GIVEN	WEAK ...	26/0100Z	SFC/FL240 ...	26/0700Z SFC...	26/1900Z SFC...	26/1
20			20221025/194...	BUENOS AIRES	SABANCAYA ...	S1547 W07150	-15.78333333...	289.83333333...	PERU	19576 FT (596...	2022/1213	GOES-E. GFS. ...	NOT GIVEN	WEAK ...	25/1910Z	SFC/FL250 ...	26/0100Z SFC...	26/1300Z SFC...	26/1
21			20221025/145...	TOULOUSE	CHAINE DES ...	N4546 E00258	45.46	2.58	WESTERN ...	1464M	2022/2	EXERCISE ...	RED	ERUPTION AT...	25/0800Z	SFC/FL200 ...	25/1400Z SFC...	26/0200Z NO ...	26/0
22			20221025/080...	TOULOUSE	CHAINE DES ...	N4546 E00258	45.46	2.58	WESTERN ...	1464M	2022/1	EXERCISE ...	RED	ERUPTION AT...	25/0800Z	SFC/FL200 ...	25/1400Z SFC...	26/0200Z NO ...	26/0
23			20221026/120...	TOKYO	EBEKO 290380	N5041 E15601	50.41	156.01	KURIL ISLANDS	1103M	2022/118	HIMAWARI-8	NIL	VA ...	26/1120Z	SFC/FL080 ...	26/1720Z SFC...	NO VA EXP	NO
24			20221026/102...	TOKYO	EBEKO 290380	N5041 E15601	50.41	156.01	KURIL ISLANDS	1103M	2022/117	HIMAWARI-8	NIL	POSS ...	26/0950Z	SFC/FL080 ...	26/1550Z SFC...	NO VA EXP	NO
25			20221026/072...	TOKYO	ALAID 290390	N5052 E15534	50.52	155.34	KURIL ISLANDS	2285M	2022/39	HIMAWARI-8	NIL	VA ...	26/0700Z	SFC/FL100 ...	26/1300Z SFC...	NO VA EXP	NO
26			20221026/060...	TOKYO	TAAL 273070	N1400 E12100	14.00	121.00	PHILIPPINES	311M	2022/12	HIMAWARI-8	NIL	VA AT ...	26/0540Z	VA NOT ...	NOT AVBL	NOT AVBL	N
27			20221026/060...	TOKYO	ALAID 290390	N5052 E15534	50.52	155.34	KURIL ISLANDS	2285M	2022/38	HIMAWARI-8 ...	NIL	VA ...	26/0520Z	SFC/FL100 ...	26/1120Z SFC...	NO VA EXP	
28			20221026/031...	TOKYO	BEZYMIANNY...	N5558 E16036	55.58	160.36	RUSSIA	2882M	2022/61	HIMAWARI-8 ...	NIL	ERUPTION AT...	26/0300Z	VA NOT ...	NOT AVBL	NOT AVBL	

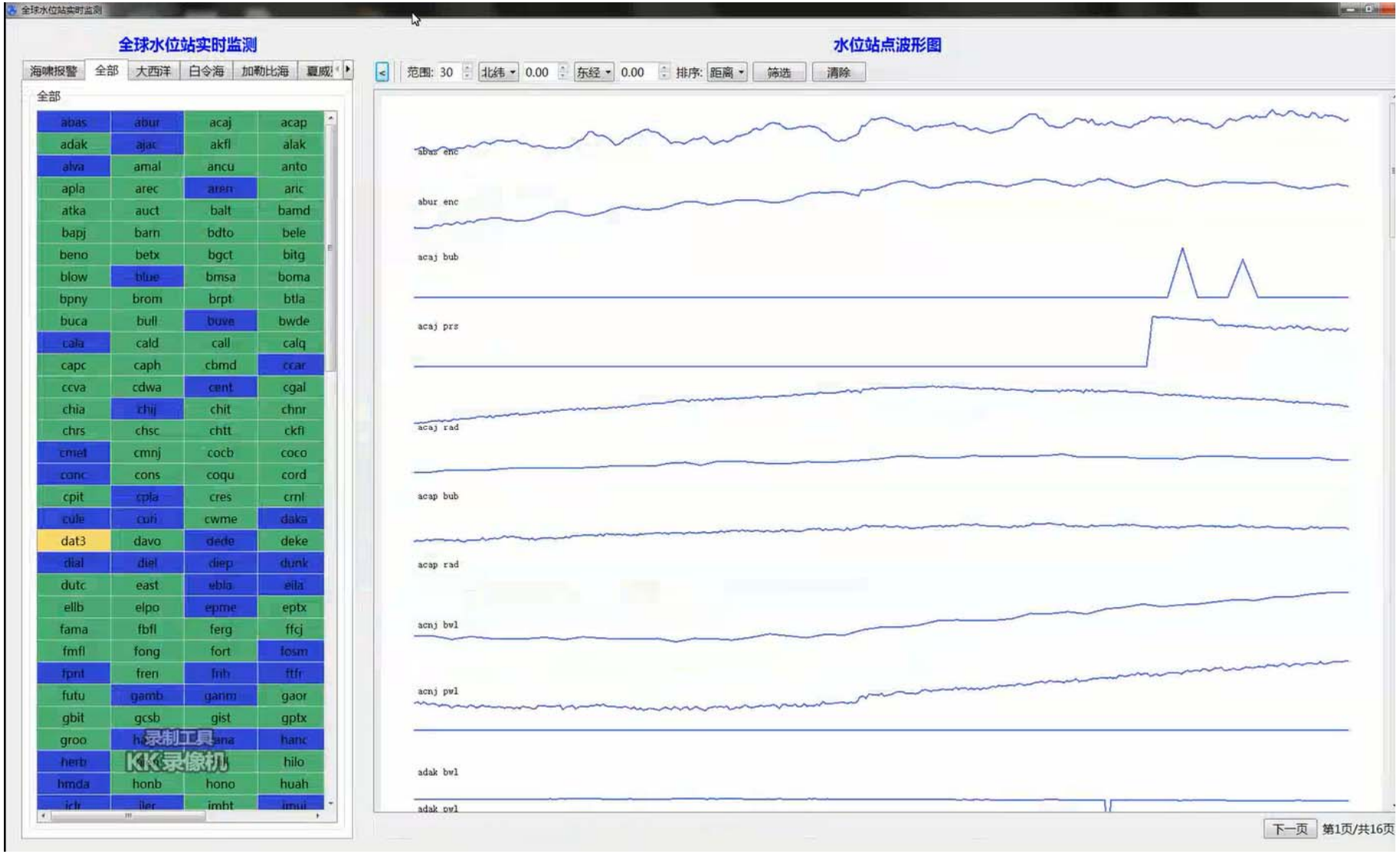
Volcanoic Eruption Information



Volcanoic Eruption Information

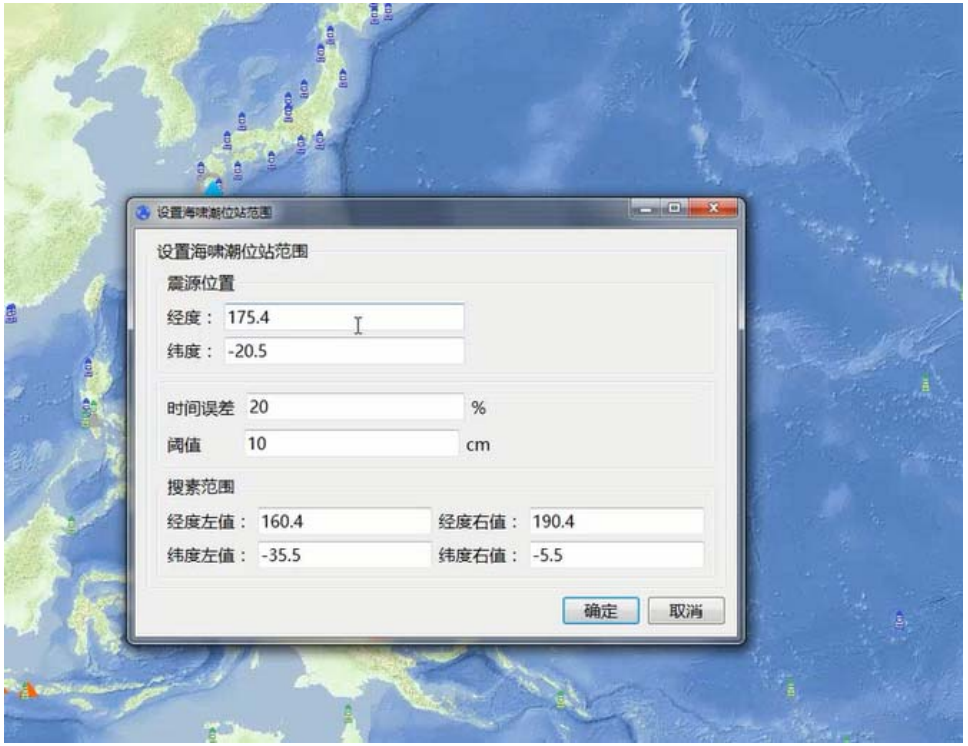


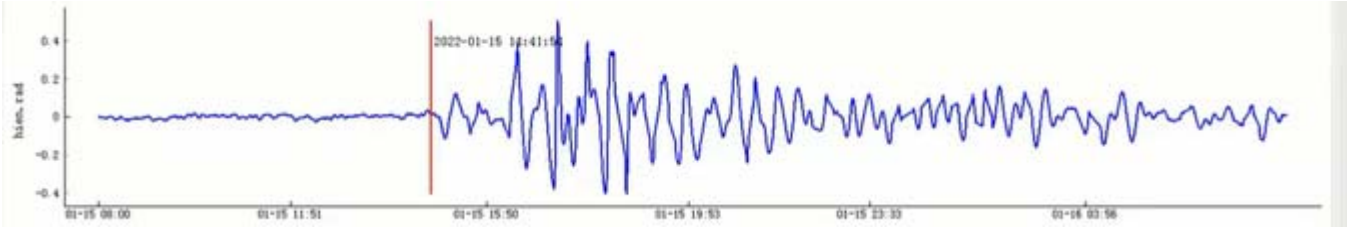
Sealevel Data

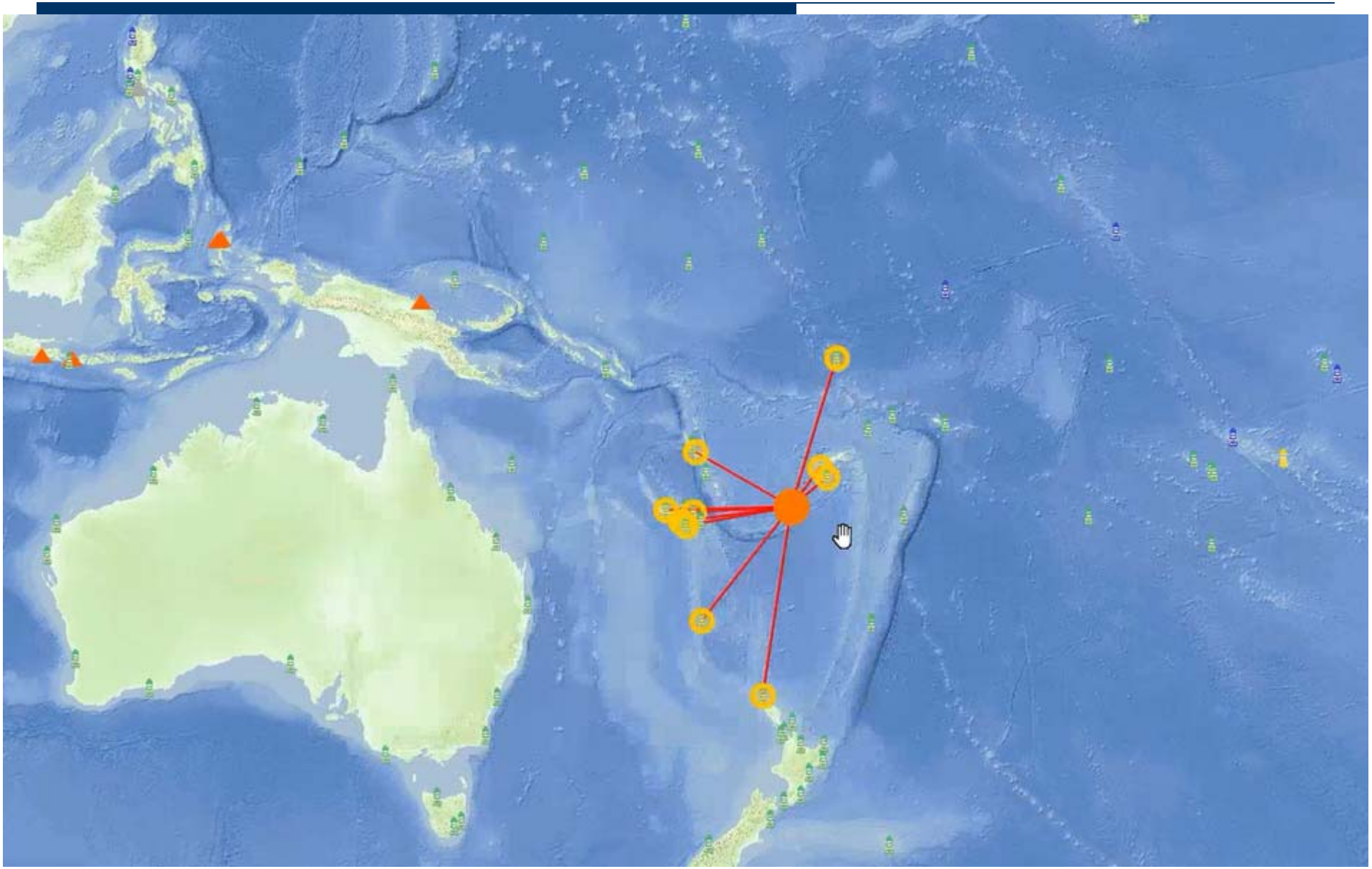


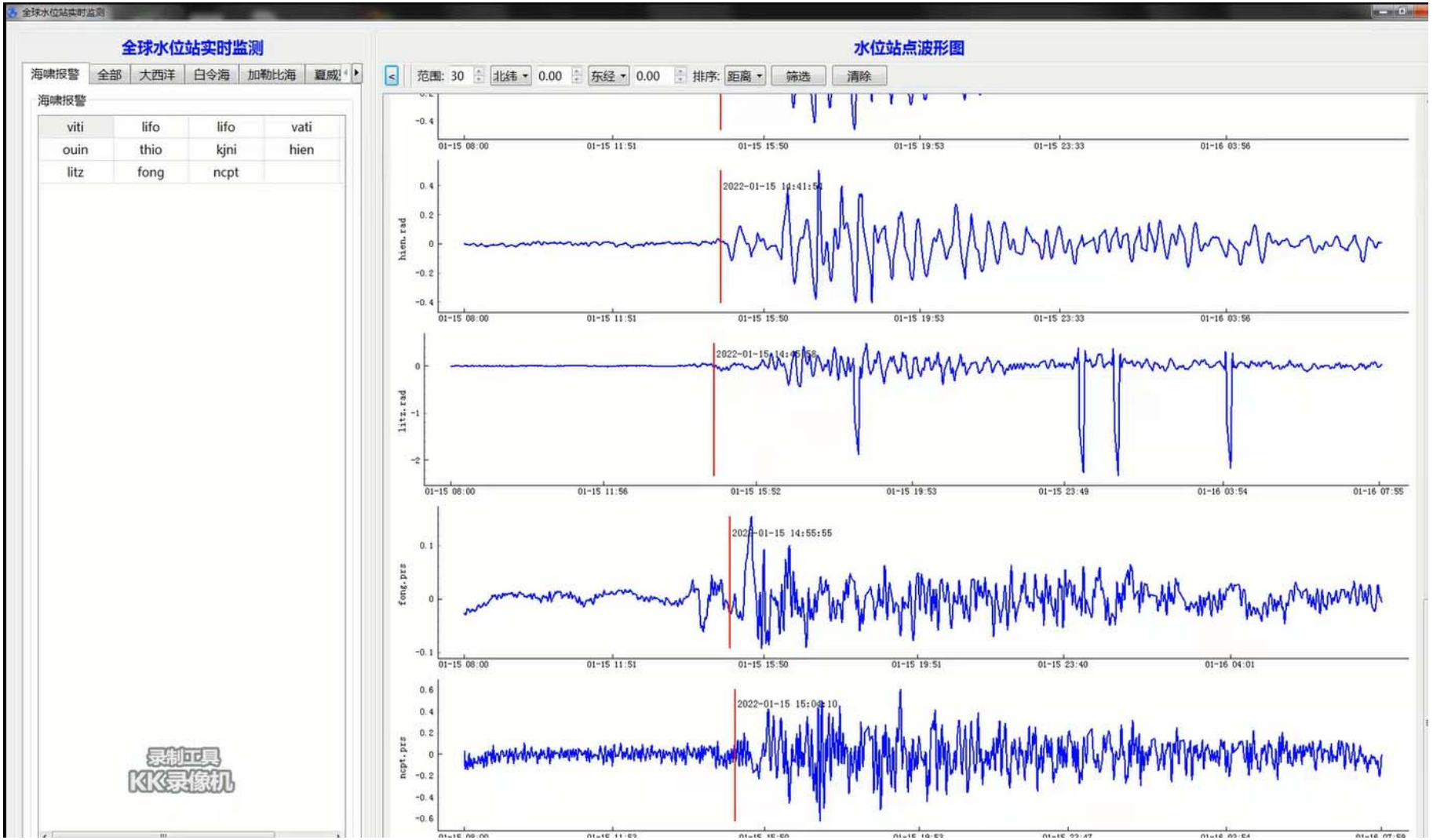
Tsunami wave alarm

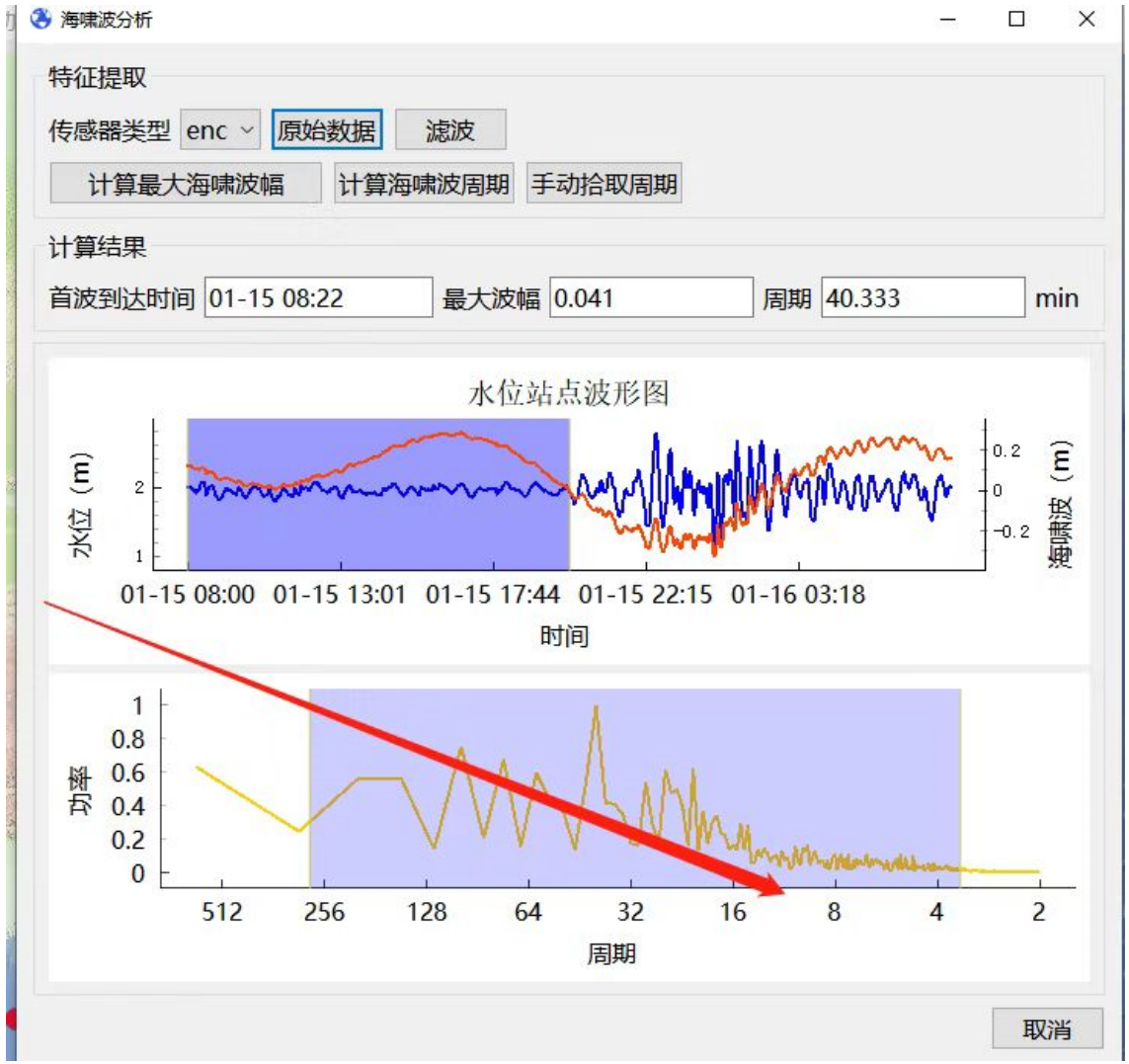
1. In the specified area（default ±15°）
2. tsunami wave over threshold value（default 10cm）
3. observed tsunami wave arrival time matches the calculated time





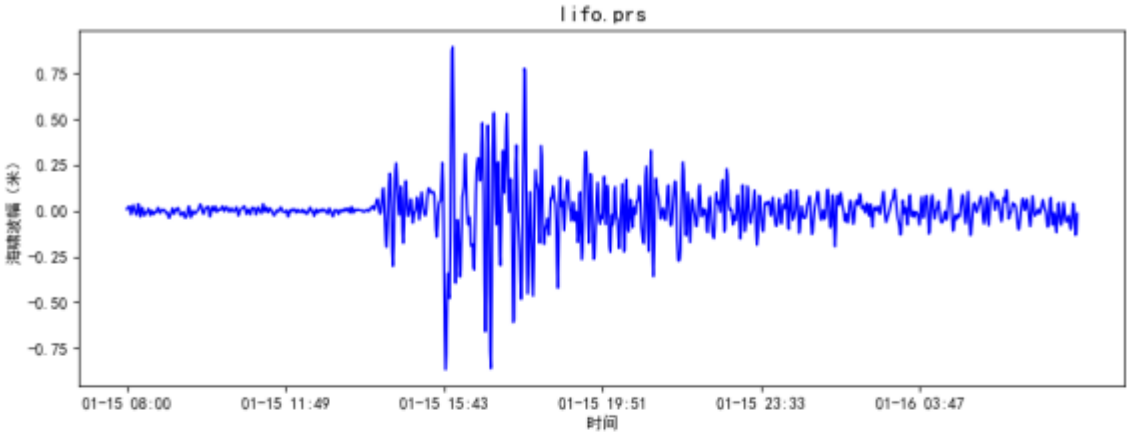


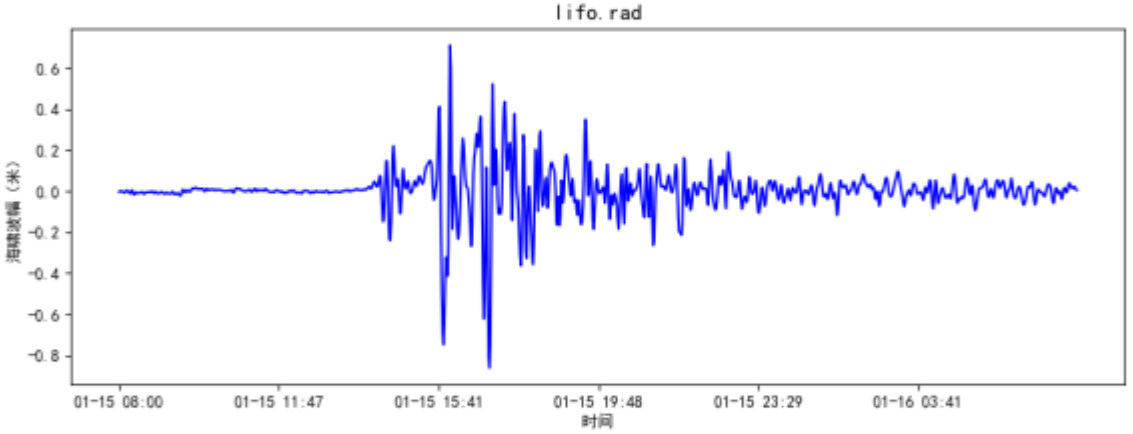

全球水位站实时监测
海啸报警
全部
大西洋
白令海
加勒比海
夏威
海啸报警
viti lifo lifo vati
ouin thio kjni hien
litz fong ncpt
水位站点波形图
范围: 30
北纬
0.00
东经
0.00
排序:
距离
筛选
清除
hien.rad
litz.rad
fong.prs
ncpt.prs
2022-01-15 14:41:54
2022-01-15 14:55:55
录制工具
KK录像机

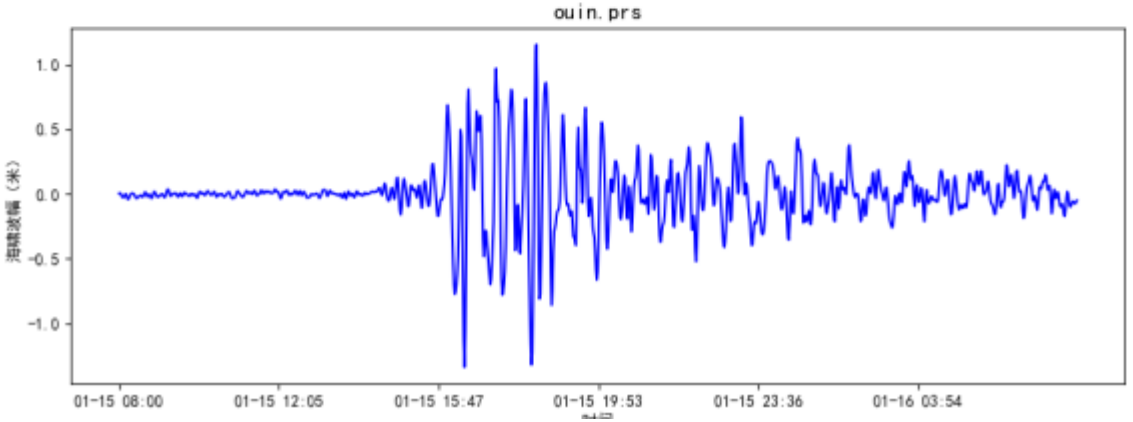

海啸波分析
特征提取
传感器类型
enc
原始数据
滤波
计算最大海啸波幅
计算海啸波周期
手动拾取周期
计算结果
首波到达时间
01-15 08:22
最大波幅
0.041
周期
40.333
min
水位站点波形图
水位（m）
海啸波（m）
01-15 08:00
01-15 13:01
01-15 17:44
01-15 22:15
01-16 03:18
时间
功率
周期
取消

Tsunami Report

潮位站（缩写）	经度	纬度	最大海啸波幅达到时间	最大海啸波幅(m)	最大海啸波幅对应周期(min)
lifo	167.2787° E	20.9185° S	01-15 15:54	0.974	9.95
lifo	167.2787° E	20.9185° S	01-15 15:56	0.806	9.9
vati	177.7611° E	17.3978° S	01-15 12:12	1.002	9.57
ouin	166.6833° E	21.9829° S	01-15 17:11	0.712	9.9
ouin	166.6833° E	21.9829° S	01-15 17:11	0.816	9.9
hien	164.9422° E	20.6929° S	01-16 02:40	0.514	10.1
hien	164.9422° E	20.6929° S	01-16 03:07	0.5	10.1
fong	179.1952° E	8.5025° S	01-15 11:38	0.802	11.0
nept	173.0487° E	34.4148° S	01-16 02:38	1.203	11.66







Thank You