

Improvement on The **H**amaoka **T**sunami **O**bservation and **P**rediction **S**ystem (**HTOPS**) in Hamaoka Nuclear Power Plant

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Chubu Electric Power Co., Inc.
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1. Introduction

Chubu Electric Power Co., Inc. (**CHUBU**) and
Hamaoka Nuclear Power Plant (**HAMAOKA**)

2. The Hamaoka Tsunami Observation and Prediction System (**HTOPS**)

3. Idea of a New Tsunami Prediction Method

4. Summary

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2. The Hamaoka Tsunami Observation and Prediction System (HTOPS)

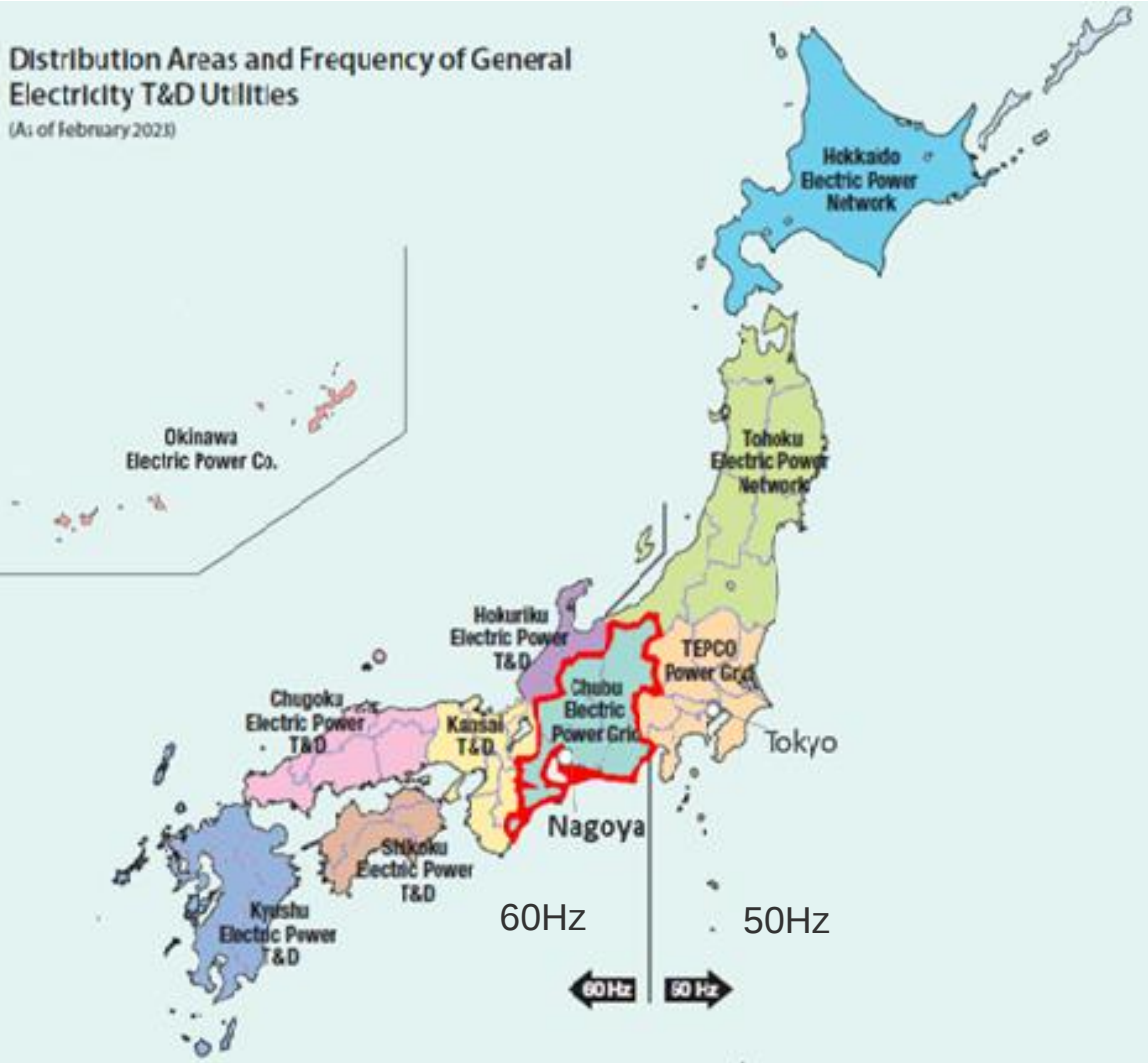
3. Idea of a New Tsunami Prediction Method

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Chubu Electric Power Co., Inc. (CHUBU)



Distribution Areas and Frequency of General Electricity T&D Utilities
(As of February 2023)

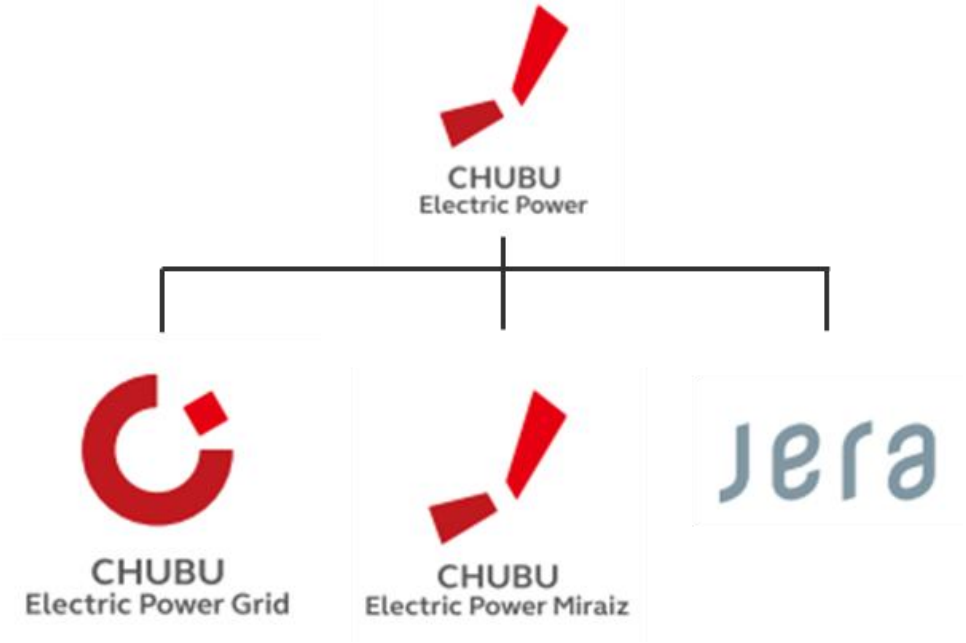


Source: JEPIC “The Electric Power Industry in Japan 2024”

Corporate Philosophy

Chubu Electric Power Group delivers the energy that is indispensable to people’s lives and so contributes to the development of society.

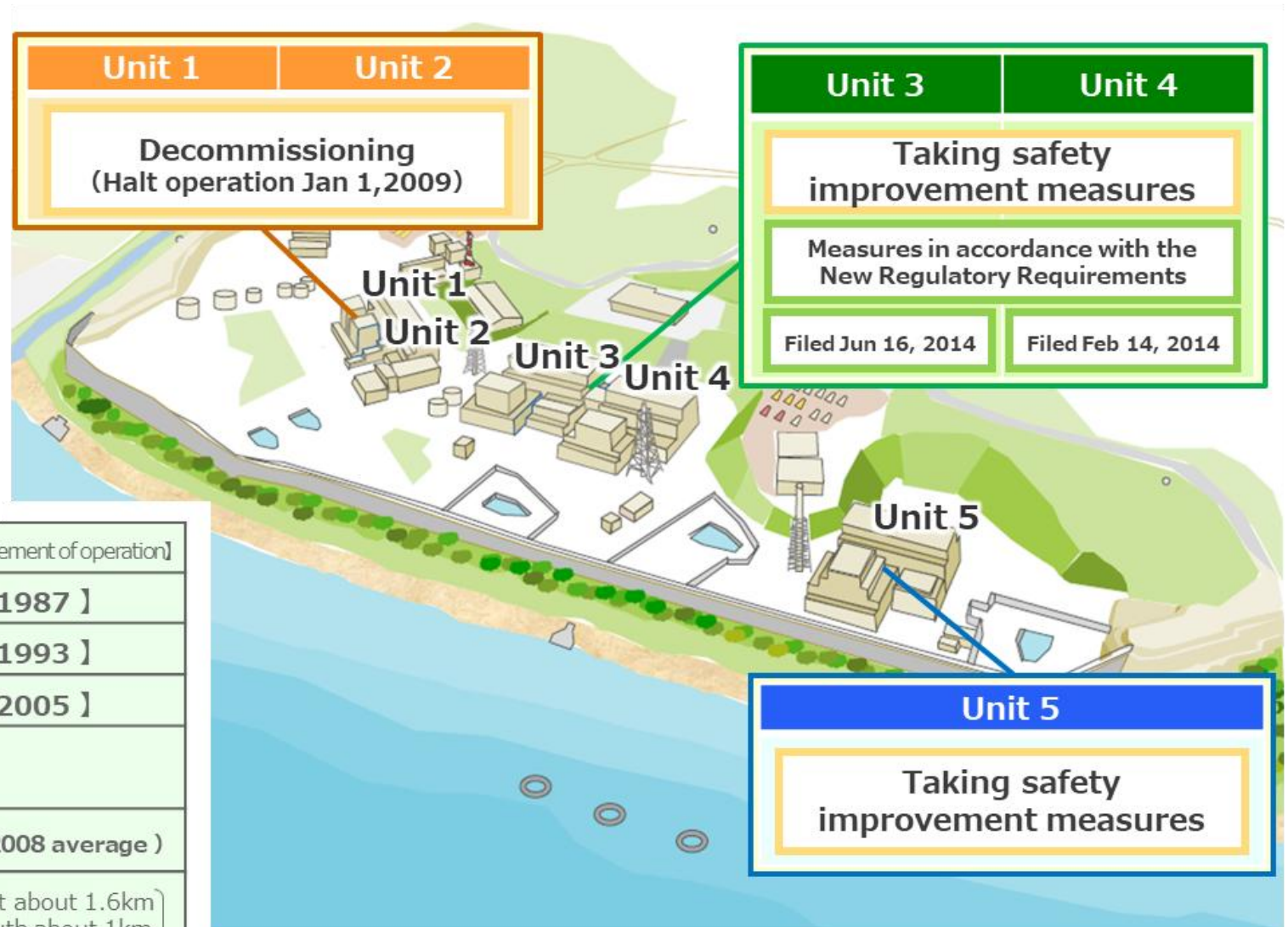
Corporate Group Structure



Hamaoka Nuclear Power Plant (HAMAOKA)



	Power output [Commencement of operation]	
Unit 3	1,100 MW	【 1987 】
Unit 4	1,137 MW	【 1993 】
Unit 5	1,380 MW	【 2005 】
Total output	3,617 MW	
Annual electricity (actual)	22,057,000 MWh (2006-2008 average)	
site area	about 160 hectares (East-West about 1.6km North-south about 1km)	



Countermeasures against Earthquakes & Tsunamis

Equipment Measures

<Earthquake>

- Pipe Support Remodeling

<Power Supply>

- Gas Turbine Generator
- AC Power Supply Car

<Tsunami>

- Protection Wall
- Overflow Prevention Wall
- Watertight Door

<Feed Water>

- Emergency Water Storage Tank
- Feed Water Car

<Heat Removal>

- Emergency Sea Water Intake System

Strengthen On-site Responsiveness

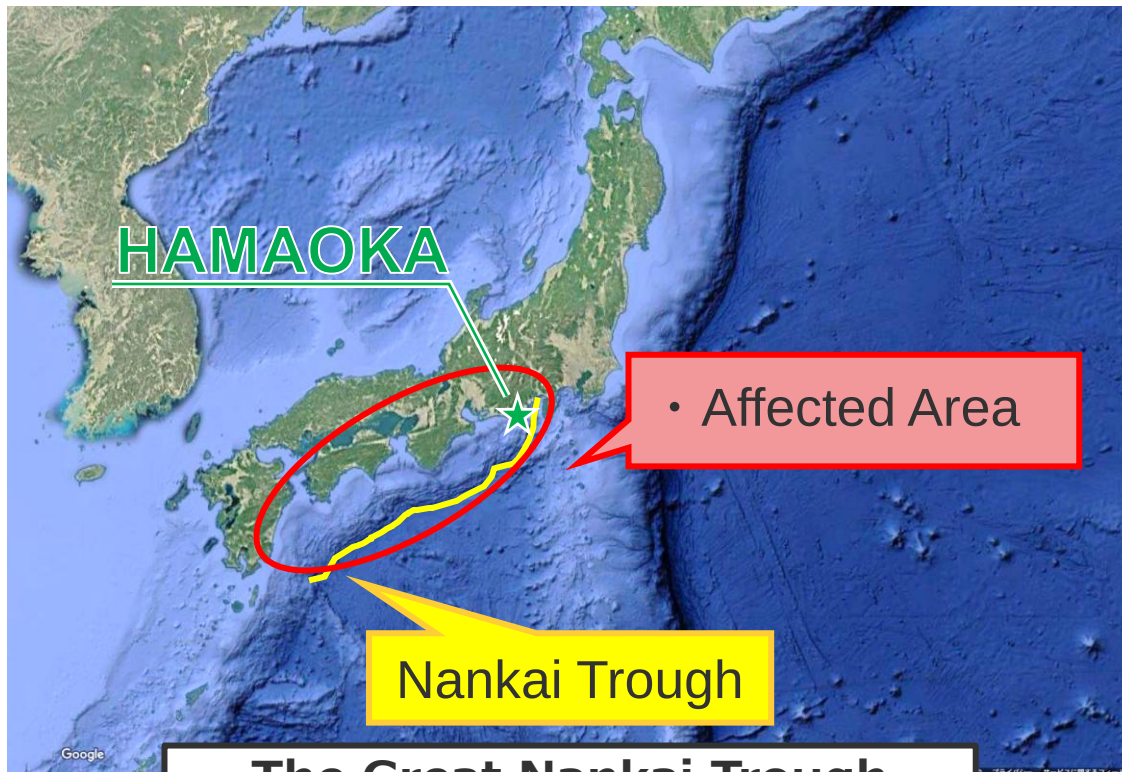


Tsunami Protection Wall
(22m above sea level, 1.6km long)
(16m above ground level)

The Great Nankai Trough Earthquake and Tsunami

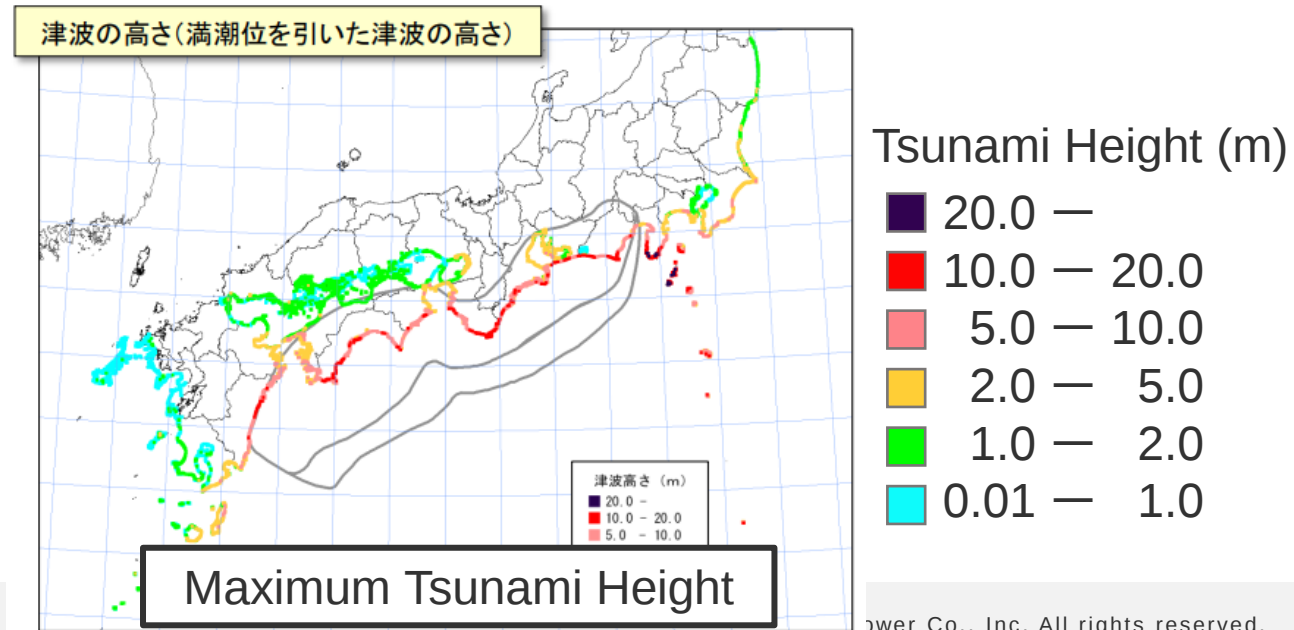
- The Great Nankai Trough Earthquake and Tsunami could be one of the worst disaster in Japan.
- It has occurred about every 100 years in the past, and CHUBU assumes that the tsunami will come to HAMAOKA.
- The Japanese government is simulating the earthquakes and tsunamis and calculating the damage.

【Assumption】



The Great Nankai Trough
Earthquake and Tsunami

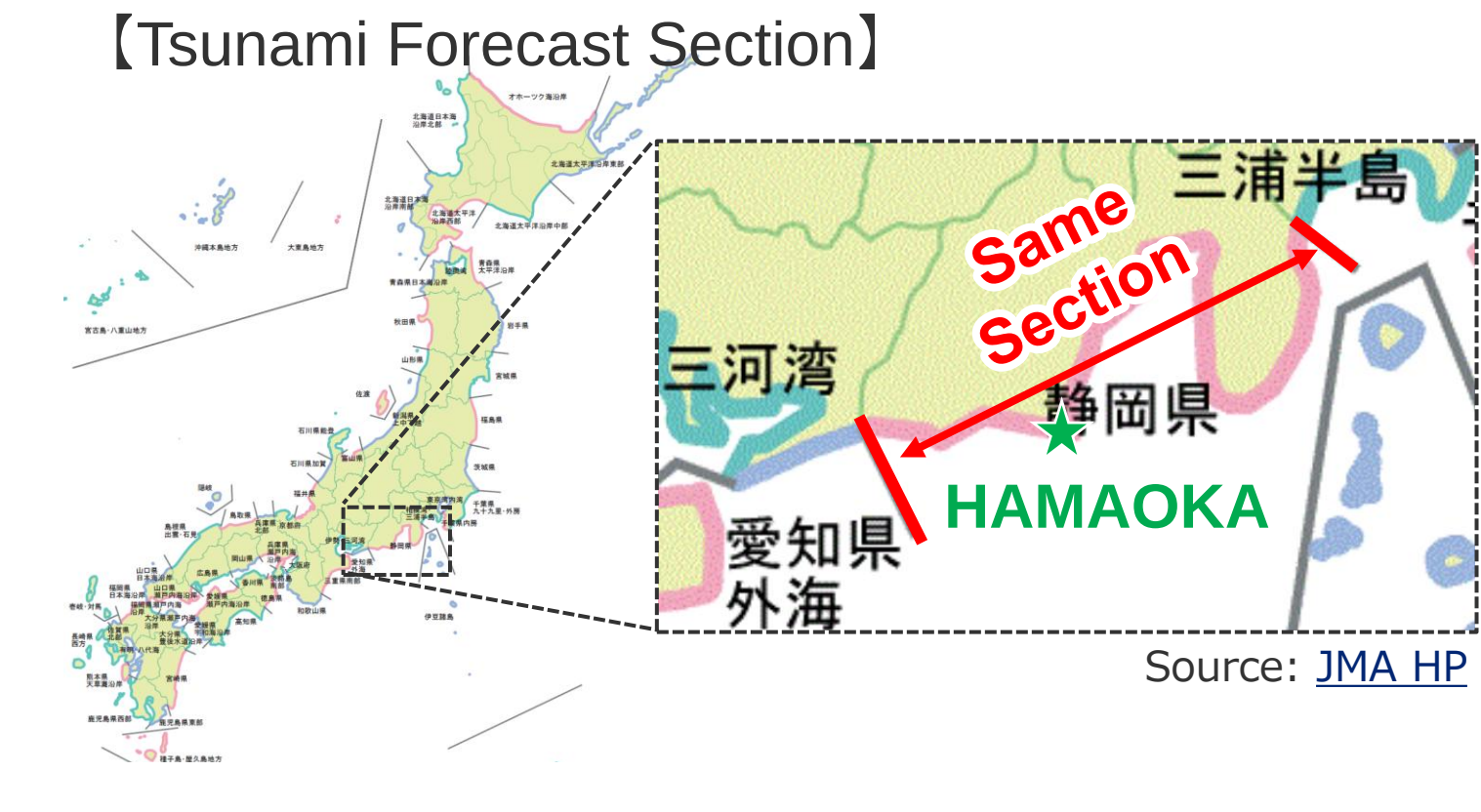
- Magnitude: M9.1
- Maximum Tsunami Height: 31m@Shimoda
(Maximum Tsunami Height: 19m@HAMAOKA)
- the number of deaths: 298,000
- the number of buildings destroyed/burned: 2,350,000



Tsunami Warning by Japan Meteorological Agency

【Operation of Tsunami Warning in Japan】

- The Japan Meteorological Agency (JMA) issues Tsunami Warning within 3 minutes of an earthquake.
- Since its section for tsunami warnings are relatively large in size, we cannot get detailed tsunami information.
- Therefore, CHUBU has developed a brand-new tsunami observation and prediction system.



【Types of Tsunami Warning】

	Estimated maximum tsunami height	
	Numerical announcement	Massive Earthquake
Major Tsunami Warning	$10\text{m} < h$ $5\text{m} < h < 10\text{m}$ $3\text{m} < h \leq 5\text{m}$	Huge
Tsunami Warning	$1\text{m} < h \leq 3\text{m}$	High
Tsunami Advisory	$0.2\text{m} \leq h \leq 1\text{m}$	—

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The Current Tsunami Prediction System

- CHUBU has developed a brand-new tsunami observation and prediction system called "**The Hamaoka Tsunami Observation and Prediction System (HTOPS)**" in 2020.
- HTOPS consists of DONET, Oceanographic Radar, and GPS buoys as observation equipment.

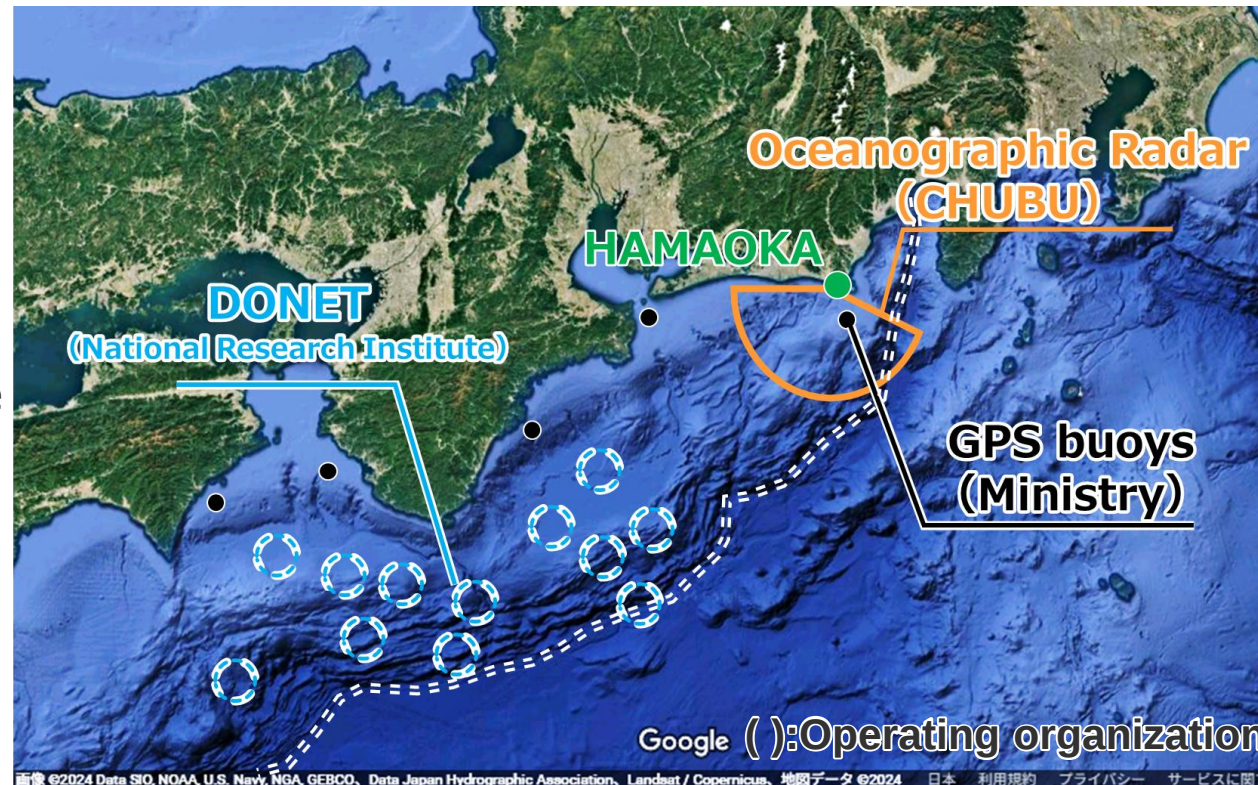


Pressure Gauge
measures water Pressure



Seismometer
measures acceleration

Source: National Research Institute
for Earth Science and Disaster Resilience



Location of observation equipment

**The world's first installed
tsunami monitoring radar**



Oceanographic Radar
measures sea surface
current velocity



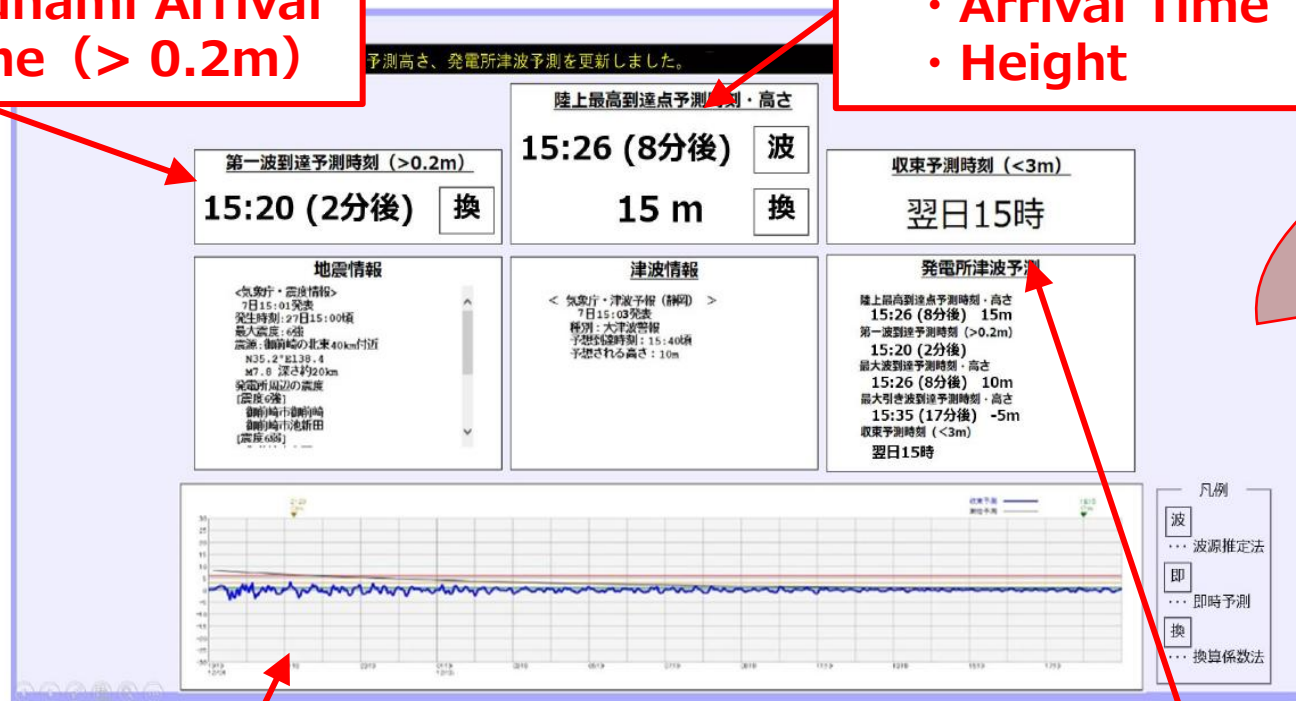
GPS buoy
measures water level
Source: Ministry of Land, Infrastructure
, Transport and Tourism

The Current Tsunami Prediction System

- HTOPS predicts maximum tsunami height, tsunami arrival time and disappearance time in front of HAMAOKA.
- HTOPS aims to support the head of HAMAOKA to make decision for refuge.

**Tsunami Arrival
Time (> 0.2m)**

Maximum Tsunami
• Arrival Time
• Height



HTOPS Display

**Tsunami
Waveform**

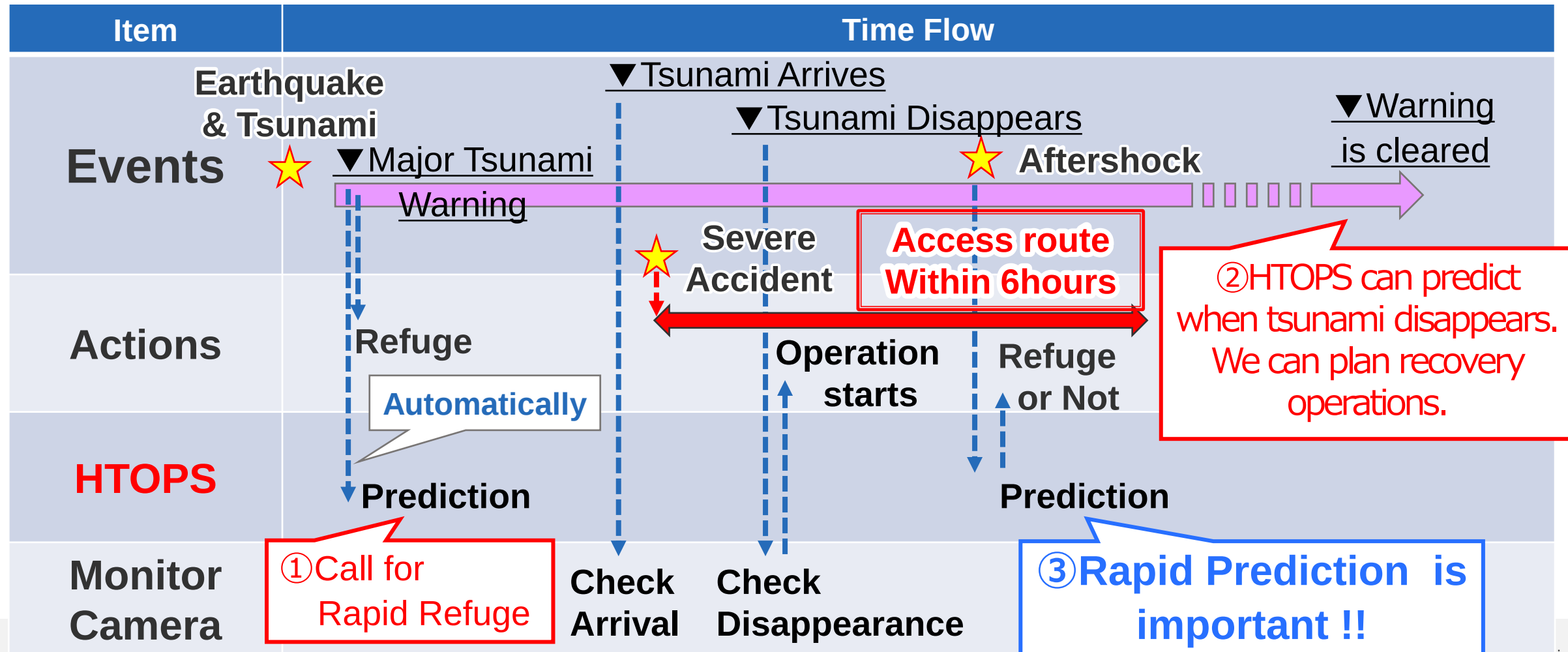
**Tsunami Disappearance
Time (< 3.0m)**



Comprehensive Exercise

"Function" and "Issue" of HTOPS

Functions: Assistance in ①rapid refuge, ②Planning recovery operations
Issues : ③If tsunamis occur far from equipment, it takes to predict them

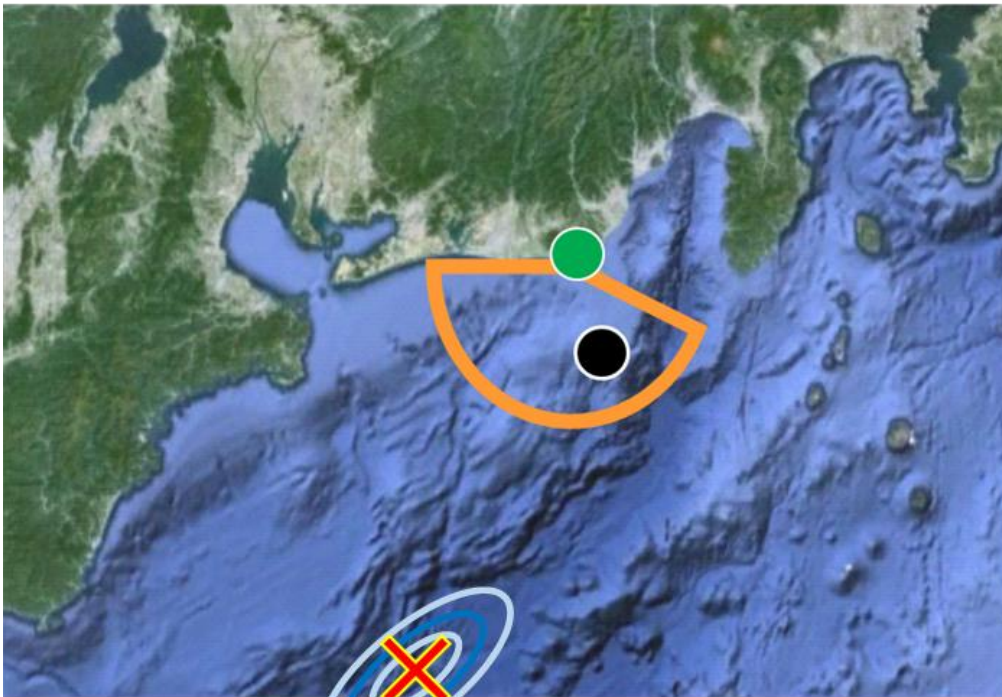


Prediction Flow and Research Issues

【Prediction Flow】

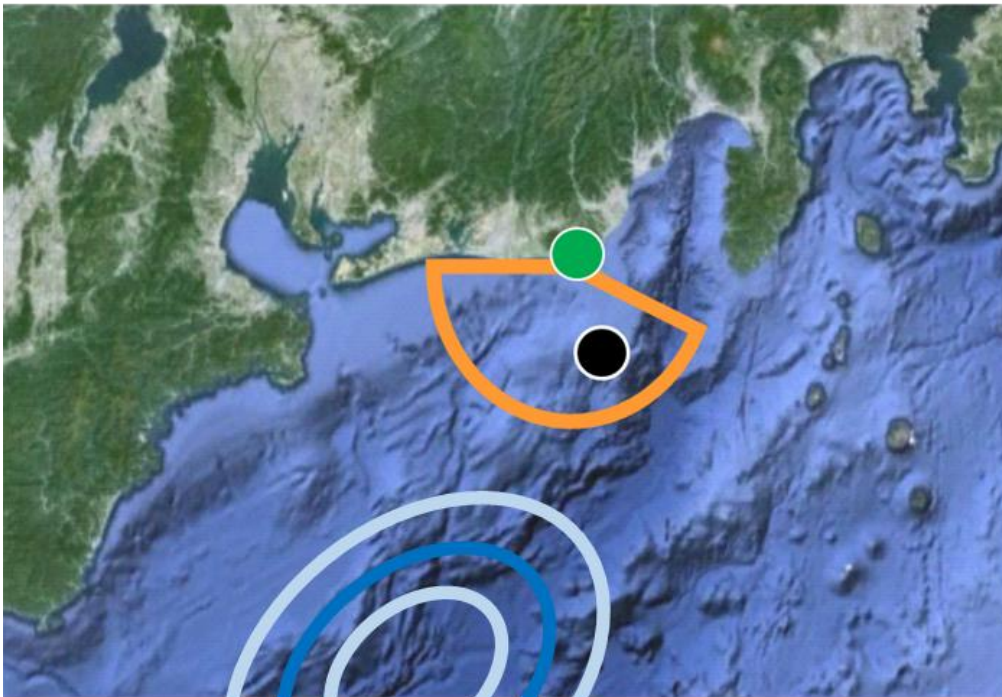
Tsunami
Occurs

Tsunami
arrives



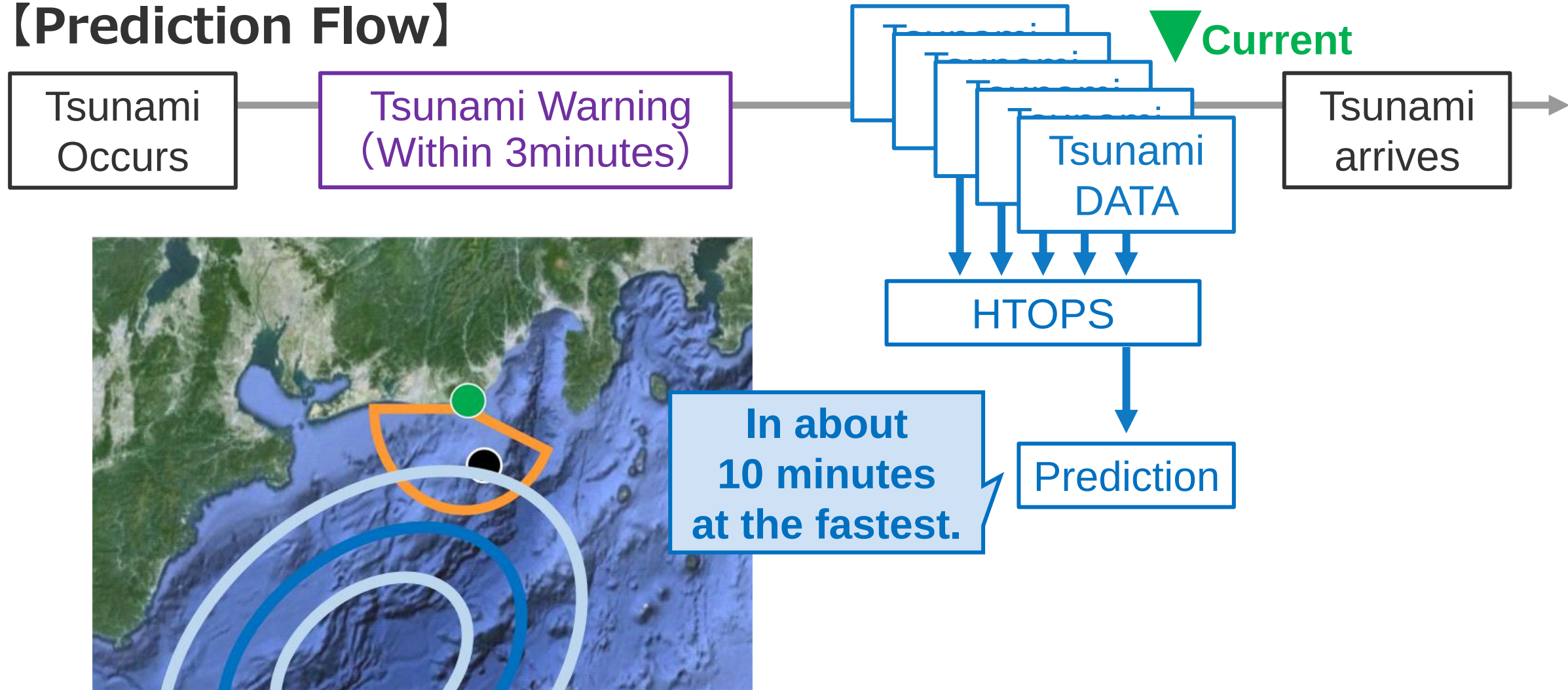
Prediction Flow and Research Issues

【Prediction Flow】 ▼Current



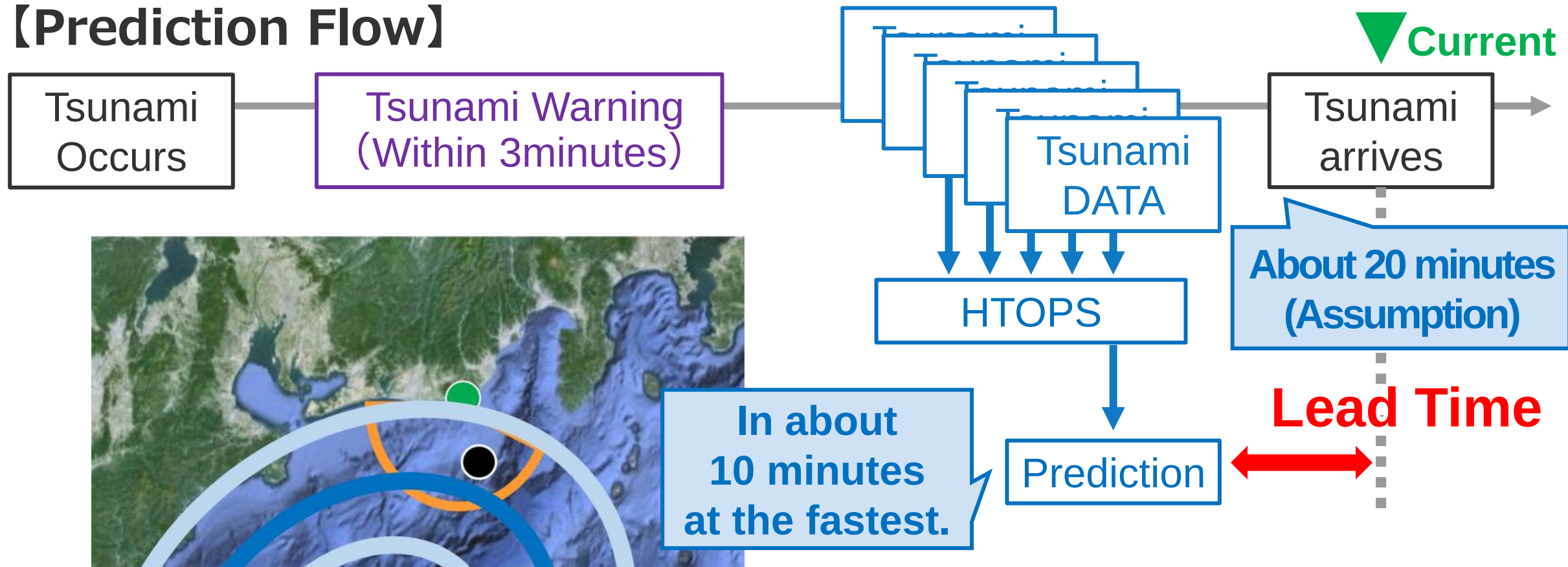
Prediction Flow and Research Issues

【Prediction Flow】



Prediction Flow and Research Issues

【Prediction Flow】



Because it takes time to observe the tsunami, We cannot secure sufficient Lead Time.

➡ Is there any information that can be used for rapid tsunami prediction?
What Natural Phenomena occur with tsunamis?

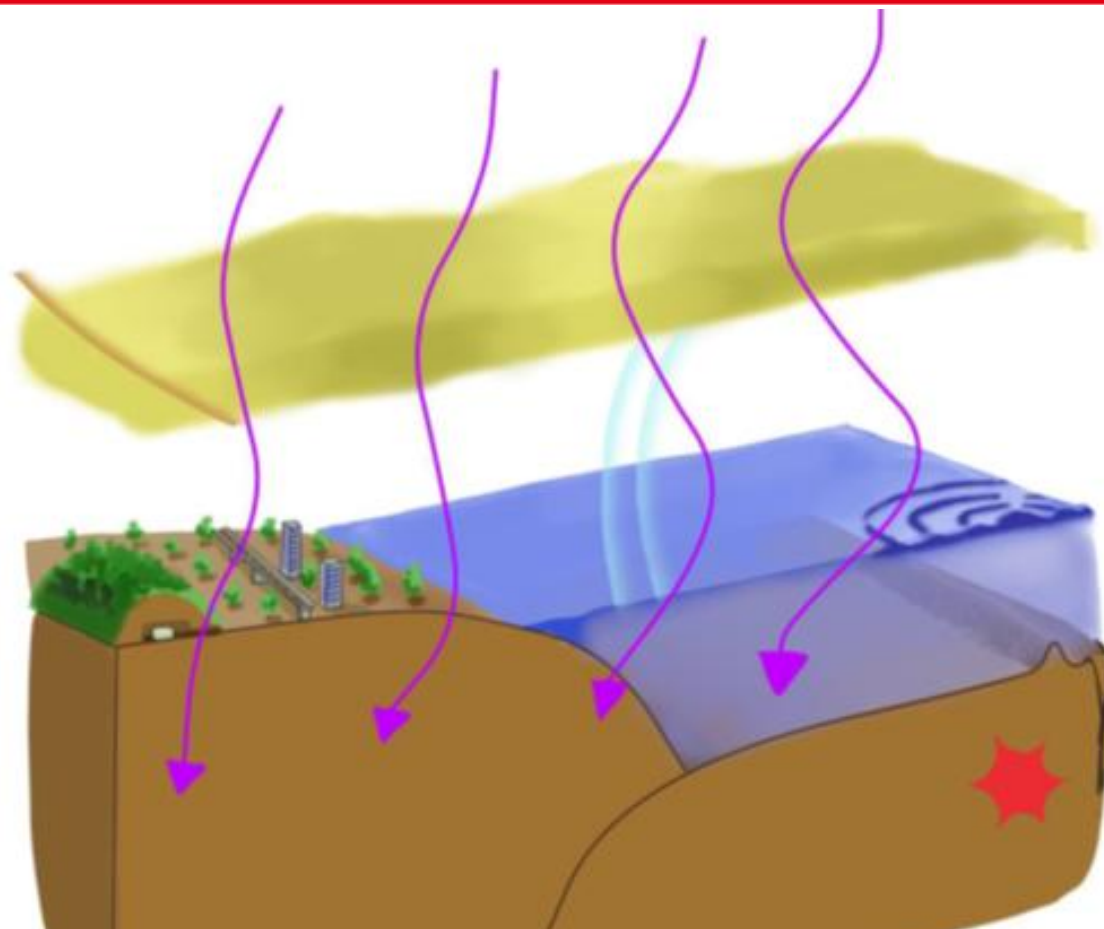
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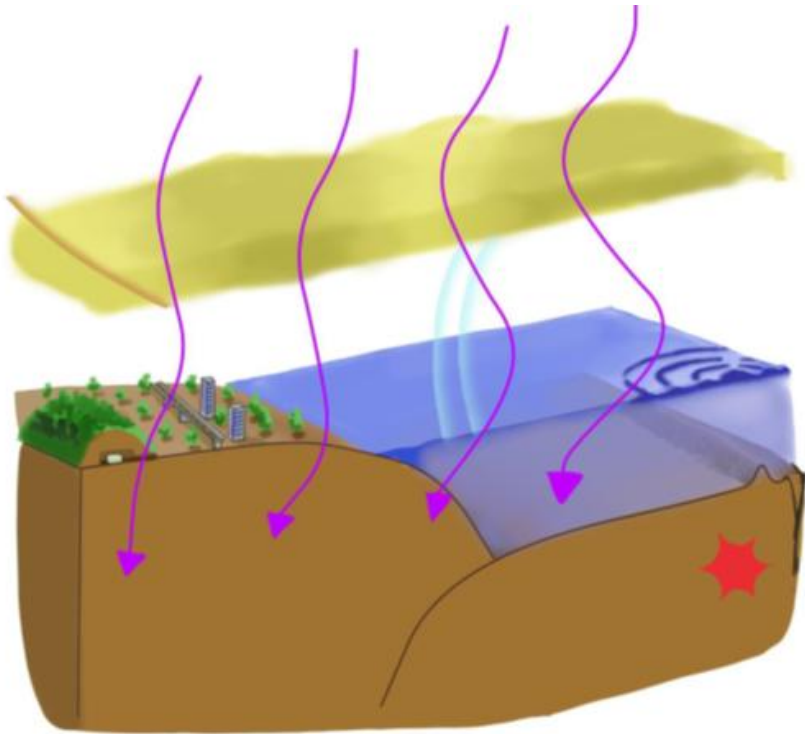
Earthquake
▼
Water Pressure Fluctuation
▼
Tsunami
▼
Infrasound Wave
▼
Ionospheric Hall
▼
Magnetic field fluctuations

We are considering whether natural phenomena that occur with tsunamis can be used for tsunami prediction.

Infrasound Wave is suitable for rapid tsunami prediction and highly feasible.

Infrasound Wave is ultra-low frequency sounds below the audible range, also known as micro-pressure vibrations.

【How fast Infrasound Wave travels?】

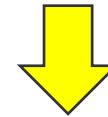


○Earthquake

○Rising sea levels

How long does it take to travel 100km*?

* Distance between the assumed tsunami epicenter and Hamaoka

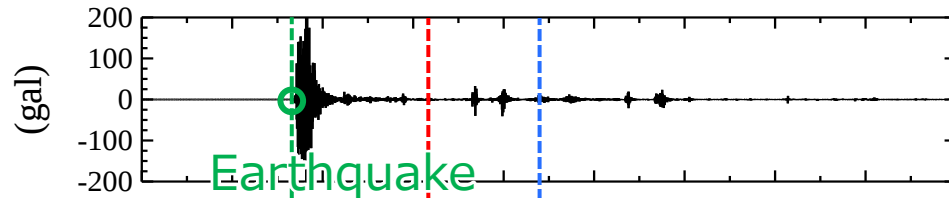


Tsunami	Average 300km/h →in 20 minutes
Infrasound Wave	Speed of sound:1200km/h →in 5 minutes

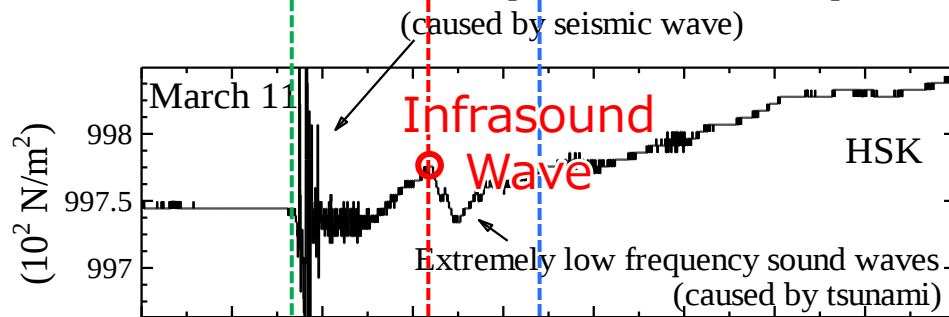
Observation of Infrasound Wave of the Great East Japan Earthquake and Tsunami (2011.3.11)

【Observation】

Acceleration (at Hosokura)



Infrasound Wave (at Hosokura)



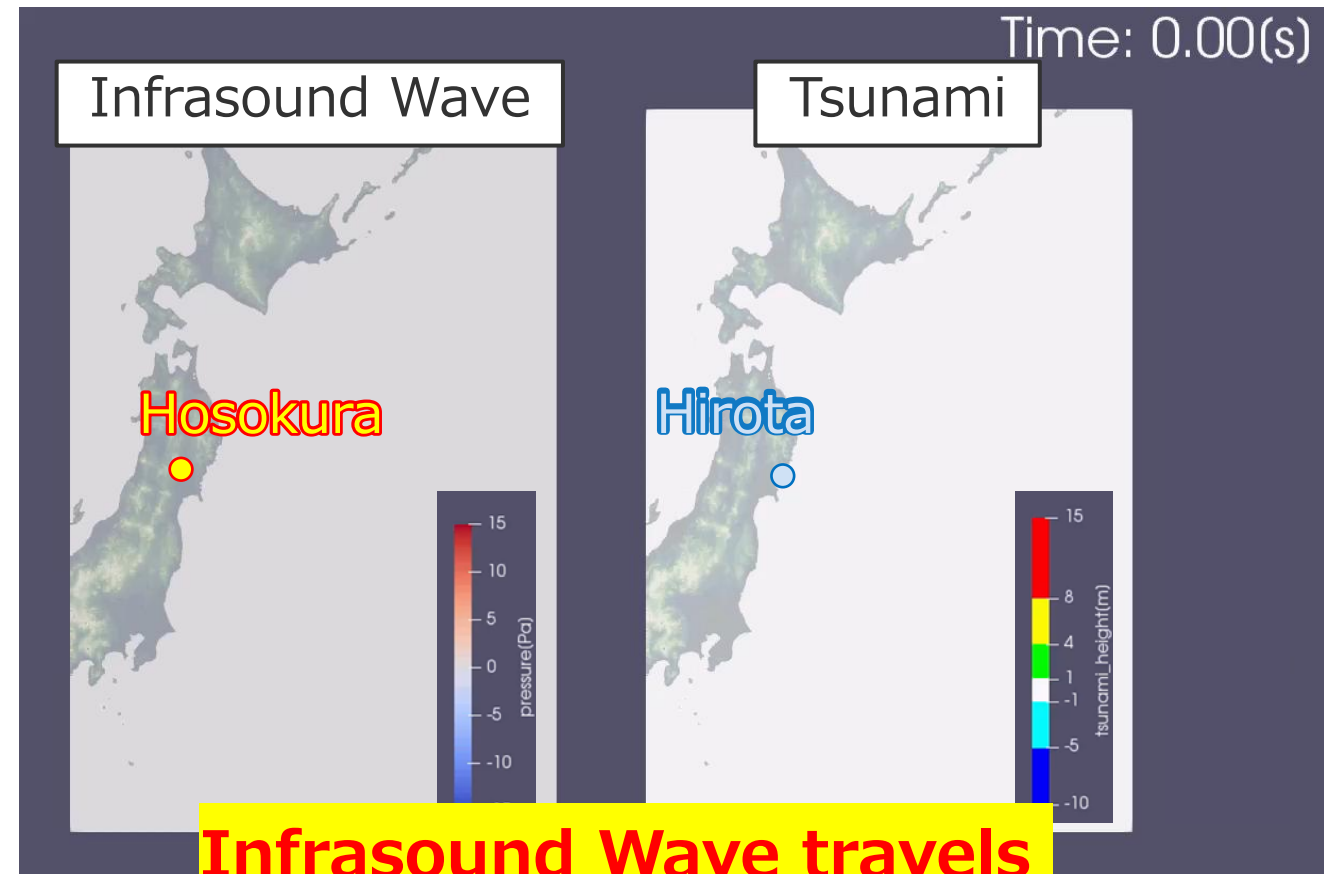
Sea level (at Hirota)



Infrasound Wave is observed 15 minutes before the tsunami

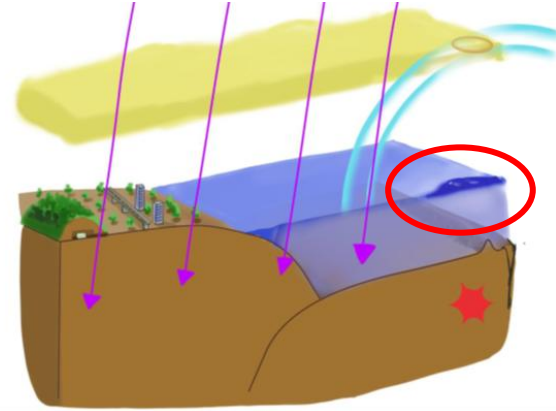
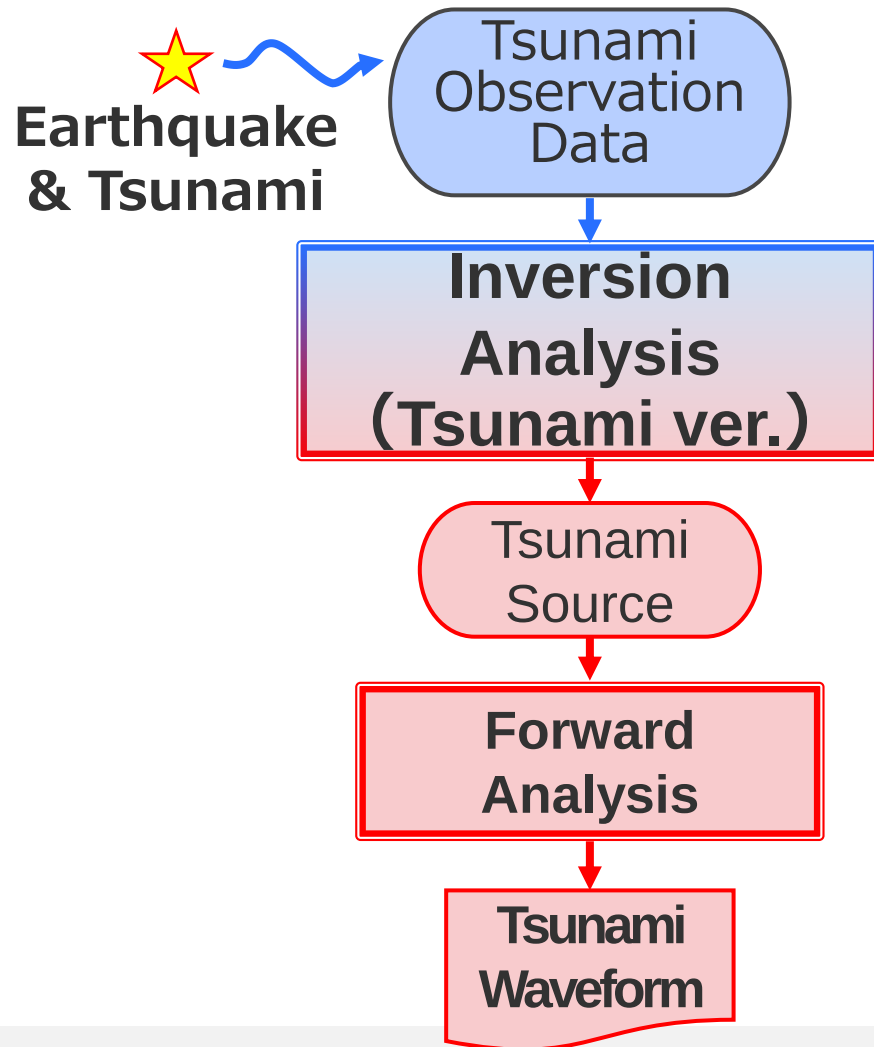
【Numerical Analysis】

Fault Model: the Great East Japan Earthquake



Infrasound Wave travels faster than tsunamis.

Tsunami Prediction Flow (Current Method)



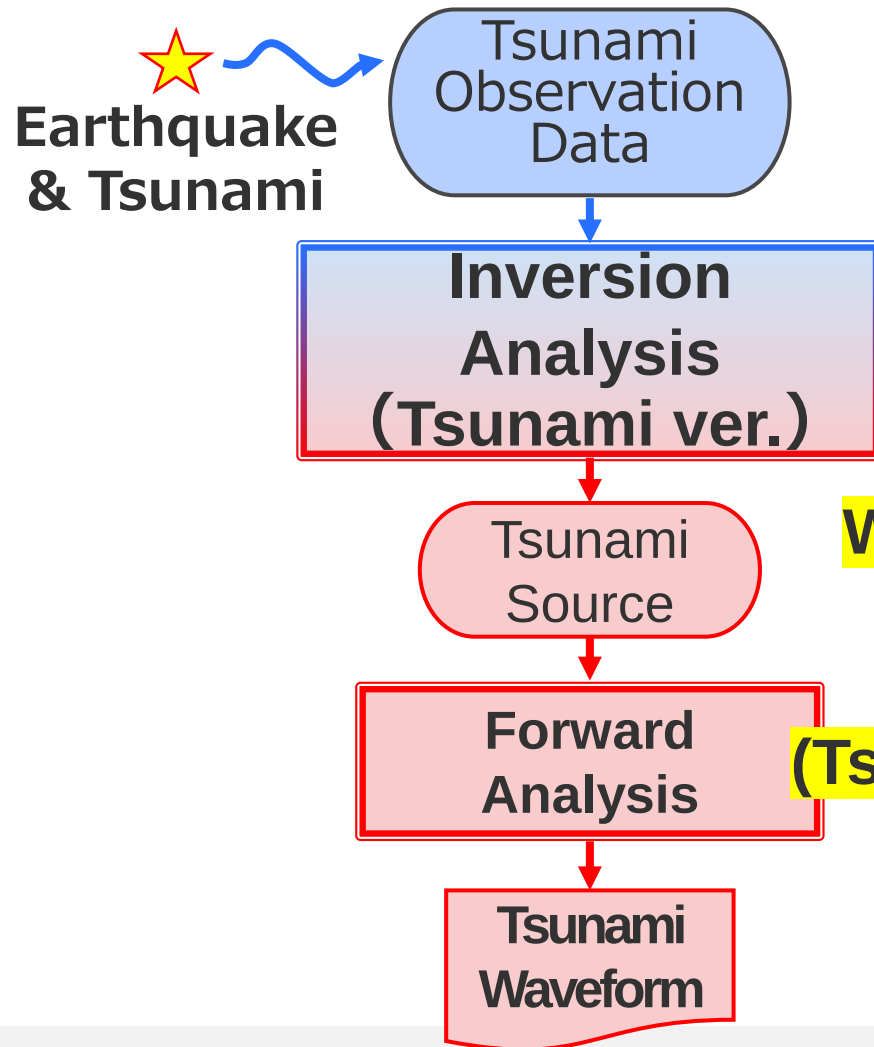
Tsunami Source

The location of the tsunami origin and the sea surface displacement

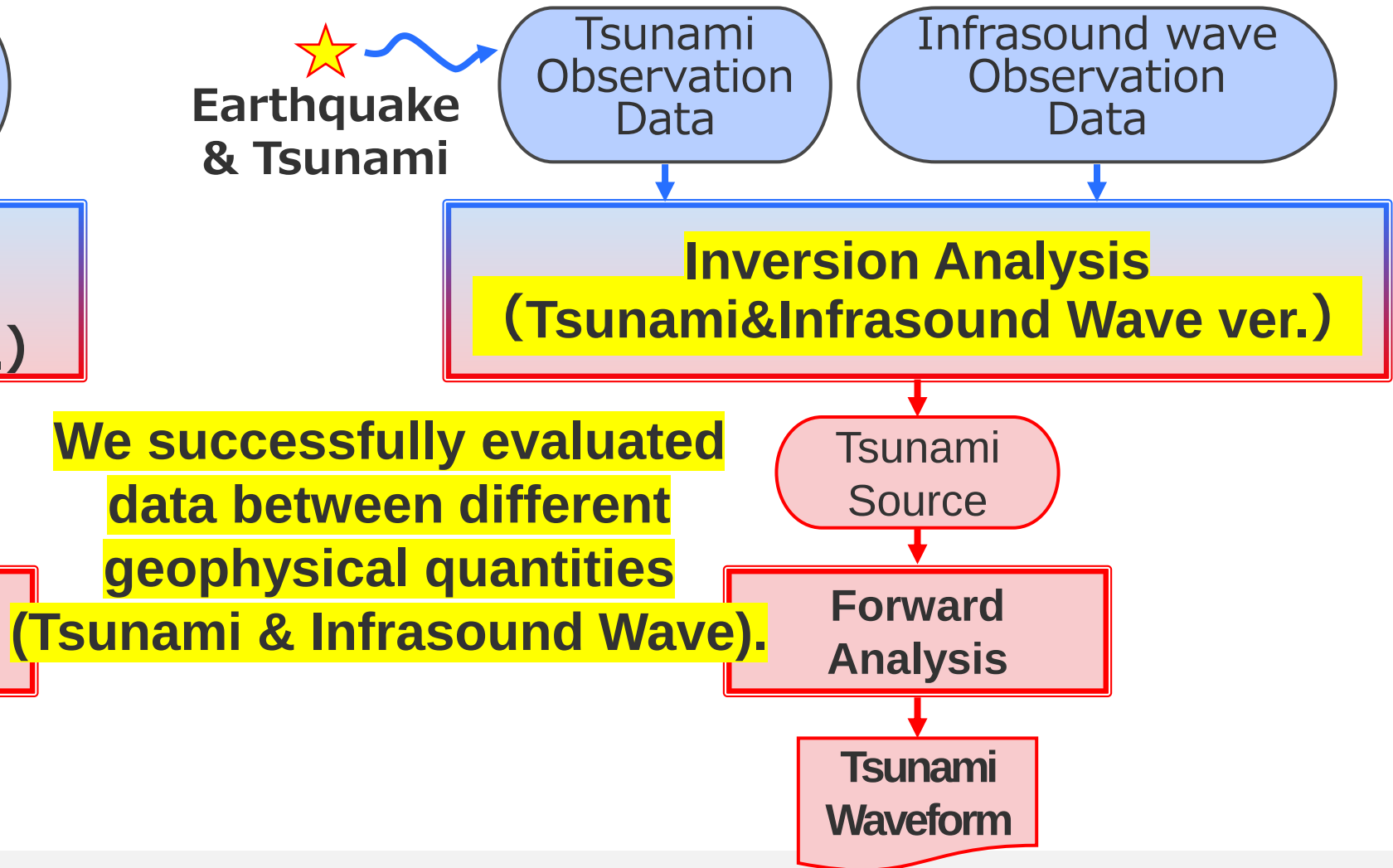
Inversion Analysis (Tsunami ver.)	Analyze the initial tsunami source from tsunami observation data at multiple observation points Input : Tsunami Observation Data Output : Tsunami Source
Forward Analysis	Numerically analyze the travel of tsunamis Input : Tsunami Source Output : Tsunami Waveforms at HAMAOKA front and various observation points

Tsunami Prediction Flow (New Method)

【Current Method】



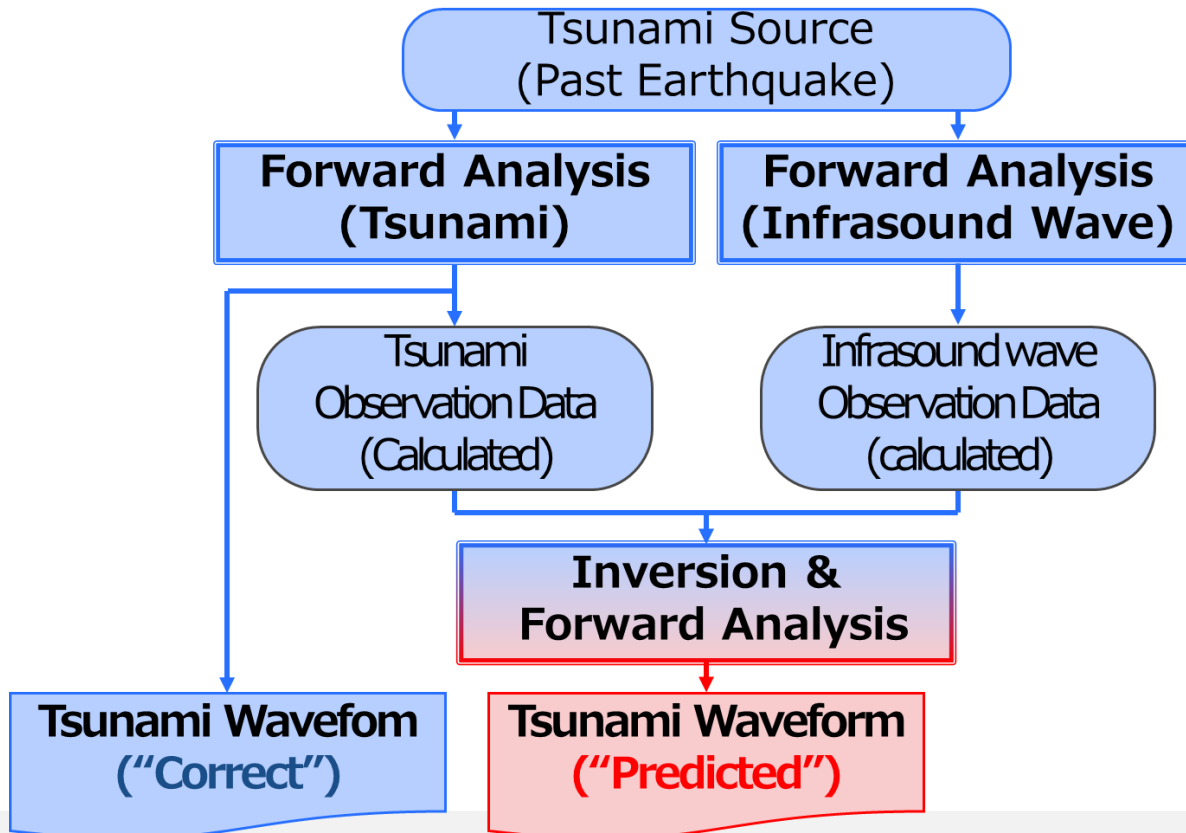
【Developed Method】



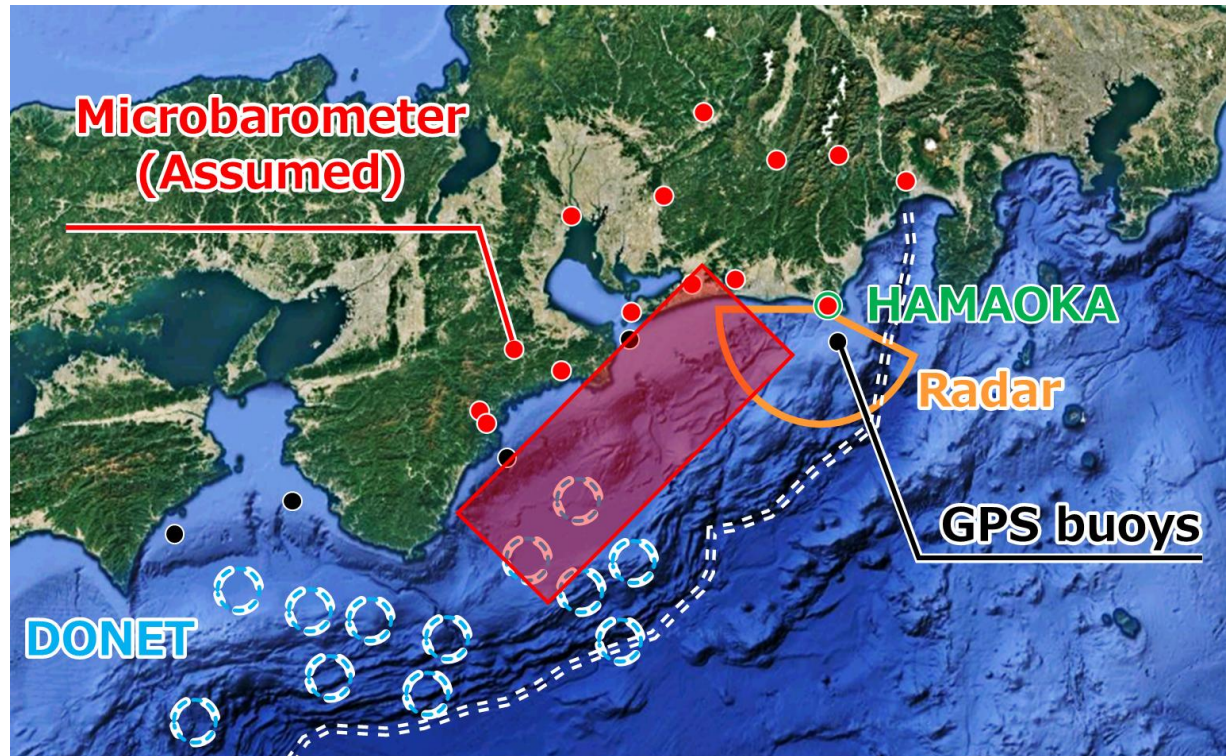
Verification (Accuracy & Lead Time)

Using a past earthquake as a model case, the observed data at each observation location is numerically generated. Therefore, We performed tsunami predictions using the current and developed methods and verified the prediction accuracy and lead time.

【Verification Flow】

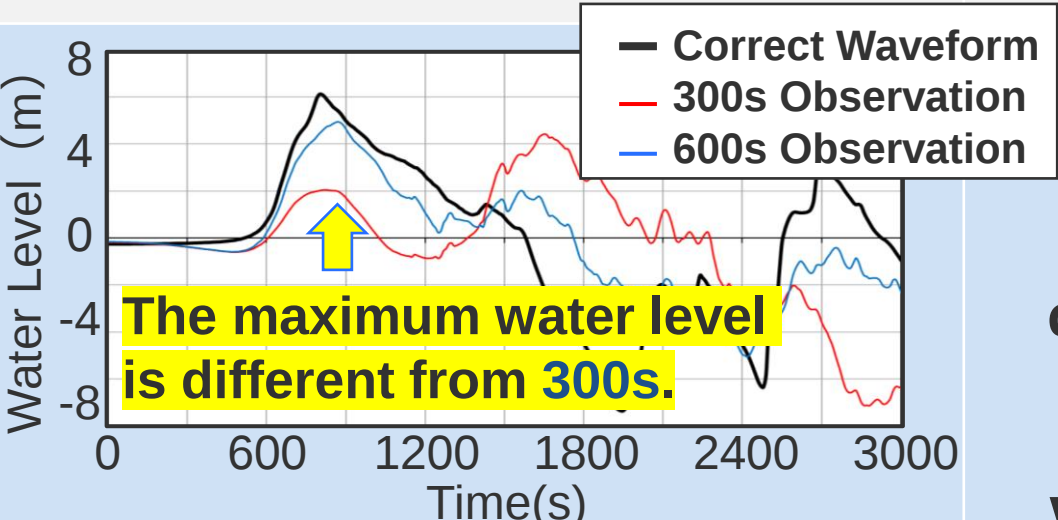
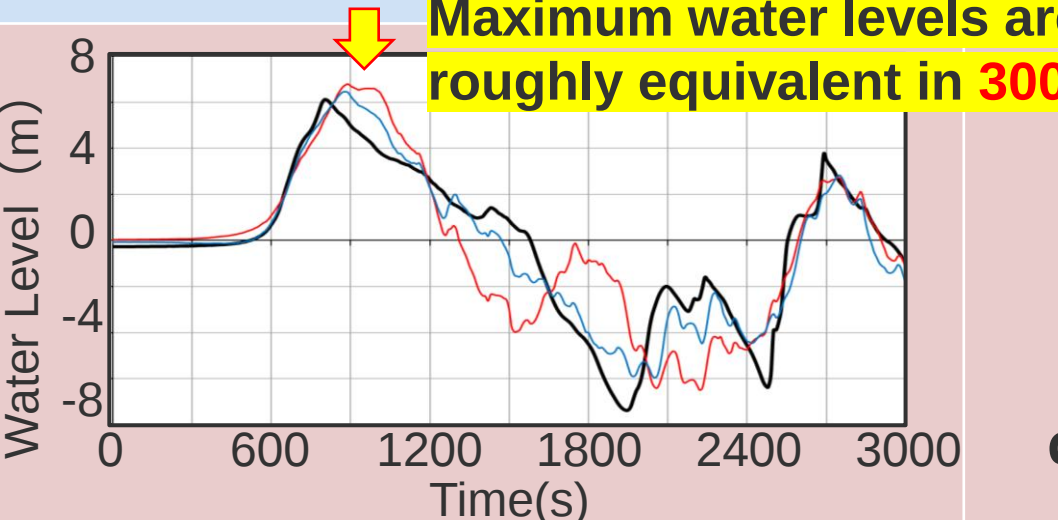


【Location of Equipment & Fault】



 : Fault location

Verification results (Comparison of Accuracy)

	Waveform in HAMAOKA	300s observation	600s observation	Lead Time
(only Tsunami) Current	 — Correct Waveform — 300s Observation — 600s Observation The maximum water level is different from 300s.	× 66% difference from the correct waveform	○ 19% difference	
(Tsunami & Infrasonic Wave) Developed	 Maximum water levels are roughly equivalent in 300s.	○ 10% difference	◎ 6% difference	

Verification results (Comparison of Lead Time)

	Waveform in HAMAOKA	300s observation	600s observation	Lead Time
(only Tsunami) Current	— Correct Waveform — 300s Observation — 600s Observation The maximum water level is different from 300s.	× 66% difference from the correct waveform	○ 19% difference	200s (800-600)
(Tsunami & Infrasound Wave) Developed	Maximum water levels are roughly equivalent in 300s. 800 The developed method allows for lead times 2.5 times longer than current methods.	○ 10%	◎ 6%	500s (800-300)

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- ◆ We operate tsunami observation and prediction system named **“HTOPS”**, which stands for **“The Hamaoka Tsunami Observation and Prediction System”**.
- ◆ We have developed **a method to predict tsunamis earlier by utilizing Infrasound Wave**, which travels faster than tsunamis.
- ◆ The developed method has **the potential to predict tsunamis earlier and with greater accuracy than current methods**.

In the future, we plan to improve the fault model to increase the prediction accuracy of the developed method and introduce it into HTOPS around 2027.