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The State of the Art and Science of Coastal Engineering

Analysis of Wave Characteristics for Design and Construction of Offshore Wind Power Plant

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OUTLINE

Introduction

---Offshore wind power plant in Japan

---Purpose

Wave characteristics in east side of Japan

Construction simulation using wave characteristics

Summary

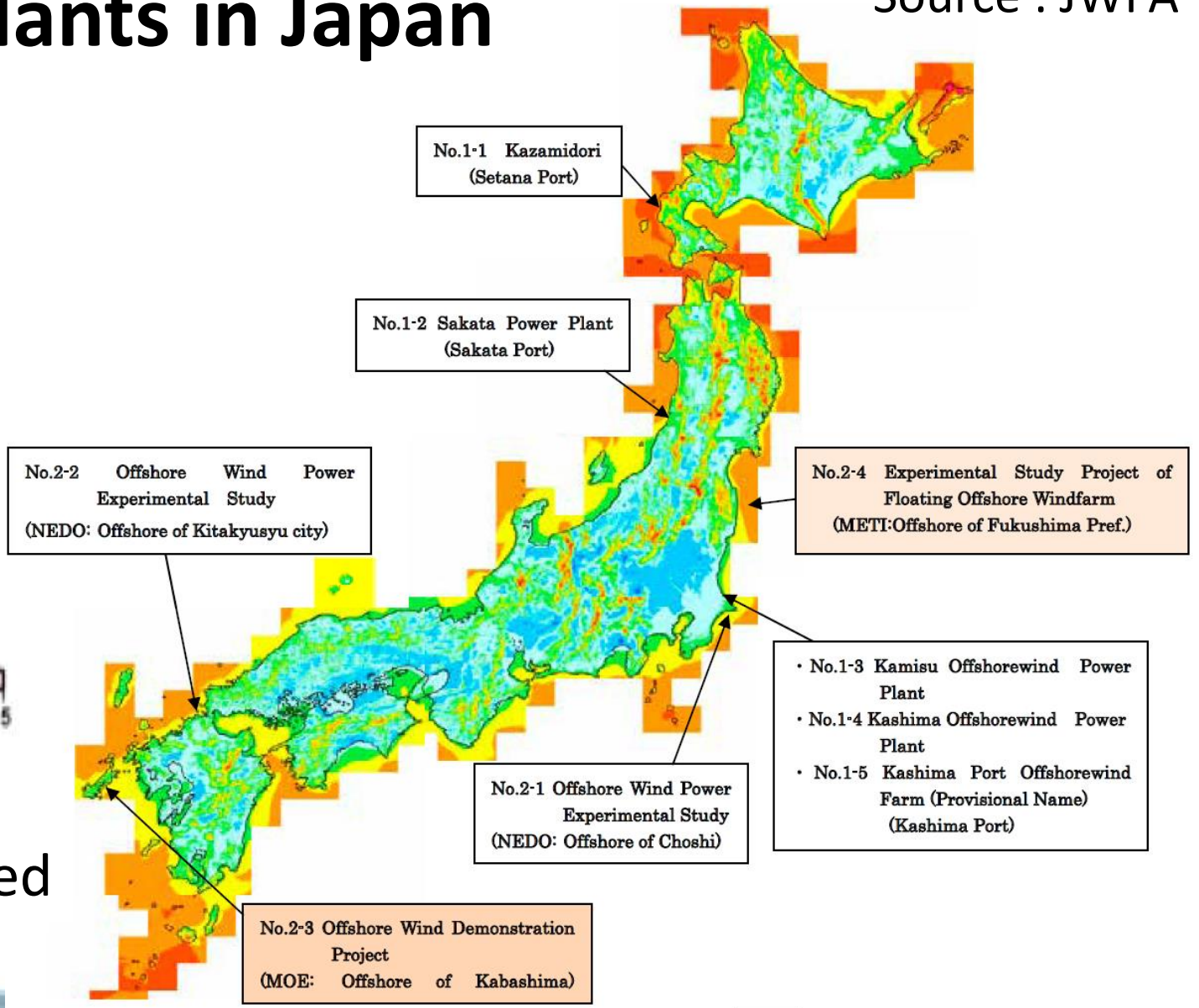
Offshore Wind Power Plants in Japan

Source : JWPA

- Many suitable area for offshore wind power plant

[m/s]

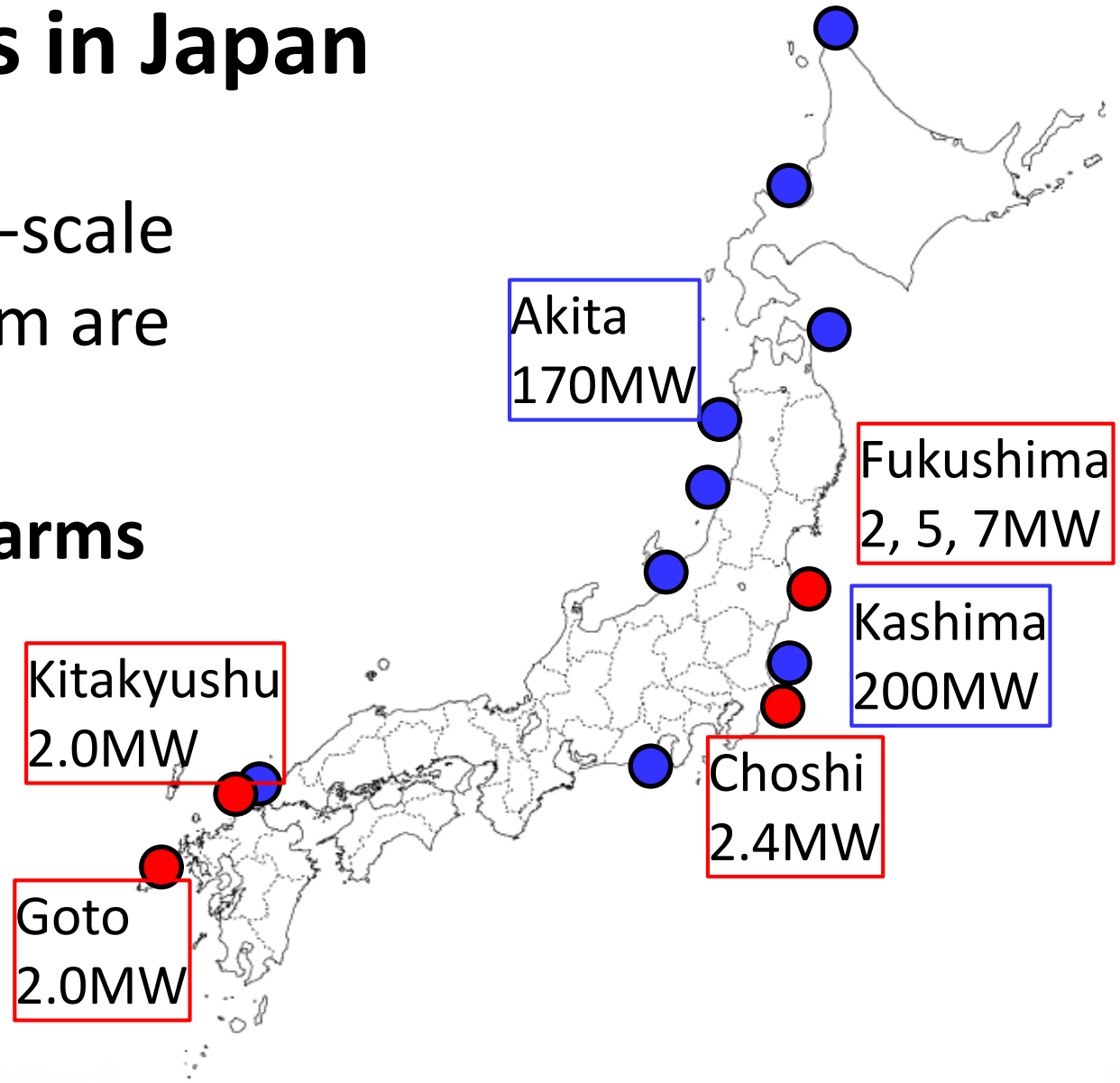
Annual mean wind speed



Offshore Wind Power Plants in Japan

- **Proving research projects** for full-scale introduction of offshore wind farm are being carried out.
- Consideration of **offshore wind farms** are under way in several areas.

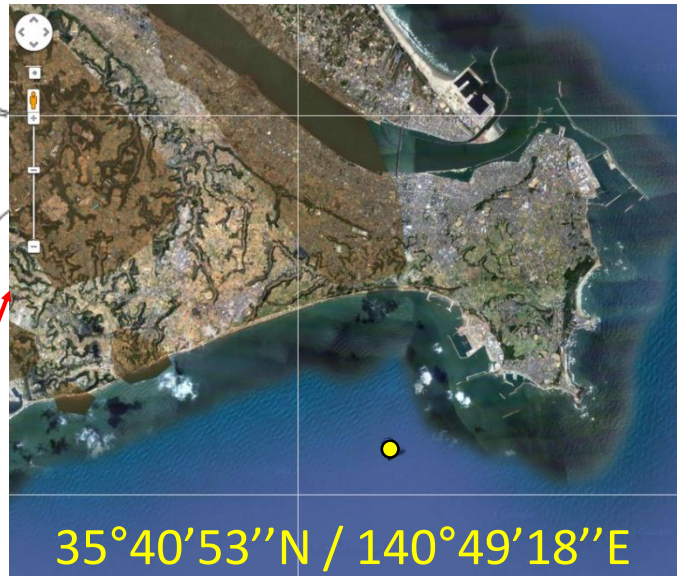
➢ Compared to Europe, full-scale introduction in Japan seems to be delayed.



Offshore Wind Power Plants in Japan

- Severe natural conditions
  - Low pressure affects continually in winter on the Sea of Japan side.
  - Many typhoons attack in summer and autumn on the Pacific side.
    Swell due to typhoon in remote area is also problem for construction offshore.

Purpose

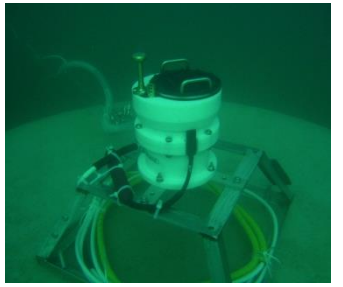


- We measured the wave condition offshore Choshi during the proving research project.
- We aim to establish the design and construction of offshore wind farm adapted to Japan using the obtained data.



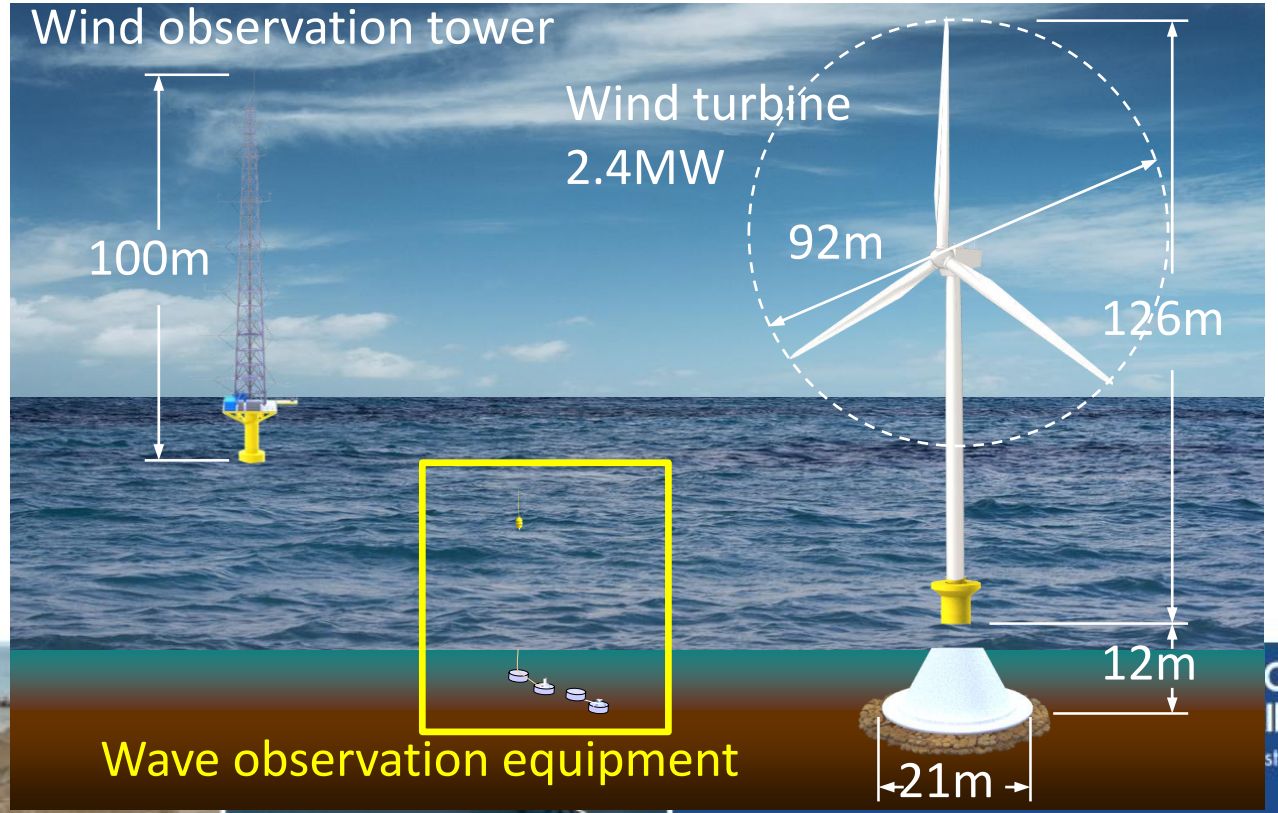

Proving Research Offshore Choshi

ultrasonic-type wave gauge



ADCP

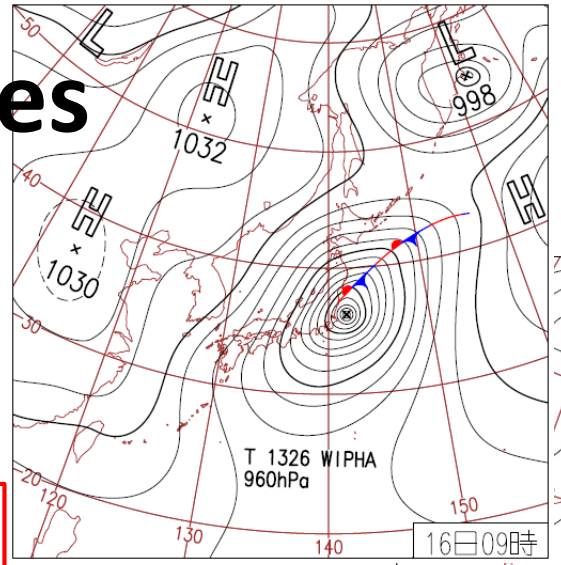
- "Research and Development of Offshore Wind Power Generation Technology" funded by New Energy and Industrial Technology Development Organization (NEDO).
- **Ultrasonic-type wave gauge** and **Acoustic Doppler Current Profiler**
- Successive measurement **from Jan, 2010 to Dec, 2016**
- Water depth: **11m**
- Distance from land: **3km**



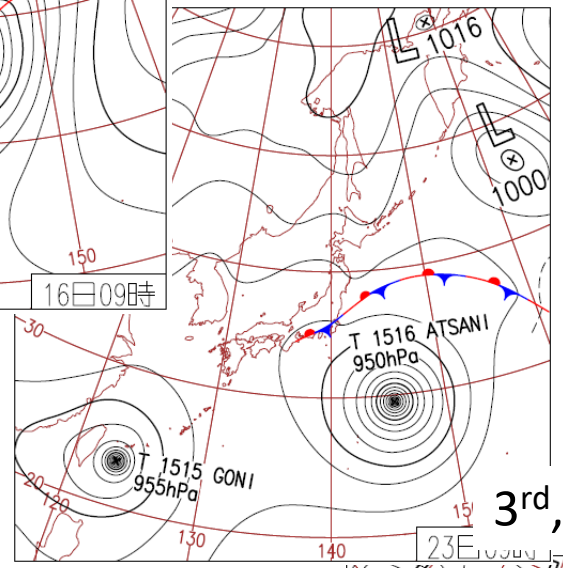
Characteristics of High Waves

Top 10 event (2010~2016)

Rank	$H_{1/3}$ (m)	$T_{1/3}$ (s)	Date and time	Weather condition
1	6.39	11.0	10/16 /2013 09:00	Typhoon 1326
2	6.27	12.9	08/22/2015 20:40	Typhoon 1516
3	6.02	9.3	02/09/2014 00:20	Low pressure
4	5.95	9.8	04/07/2013 03:20	Low pressure
5	5.76	10.8	02/15/2014 14:40	Low pressure
6	5.66	10.6	10/06/2014 13:20	Typhoon 1418
7	5.59	11.0	09/21/2011 20:40	Typhoon 1115
8	5.50	8.9	12/03/2010 09:20	Low pressure
9	5.46	10.5	08/17/2016 01:40	Typhoon 1607
10	5.42	9.7	12/11/2015 13:40	Low pressure

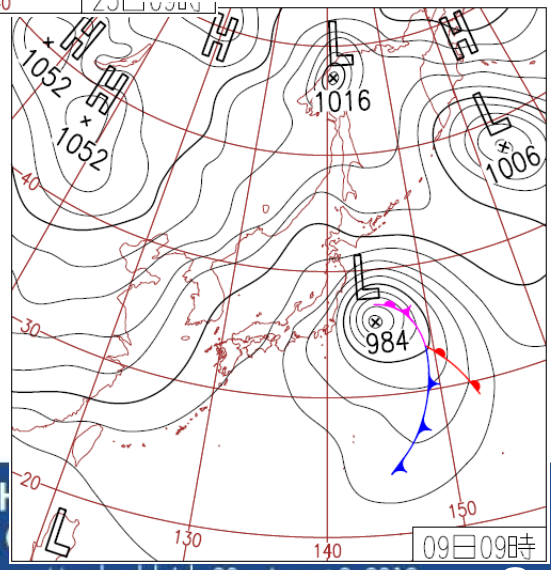


1st , Typhoon 1326



2nd, Typhoon 1

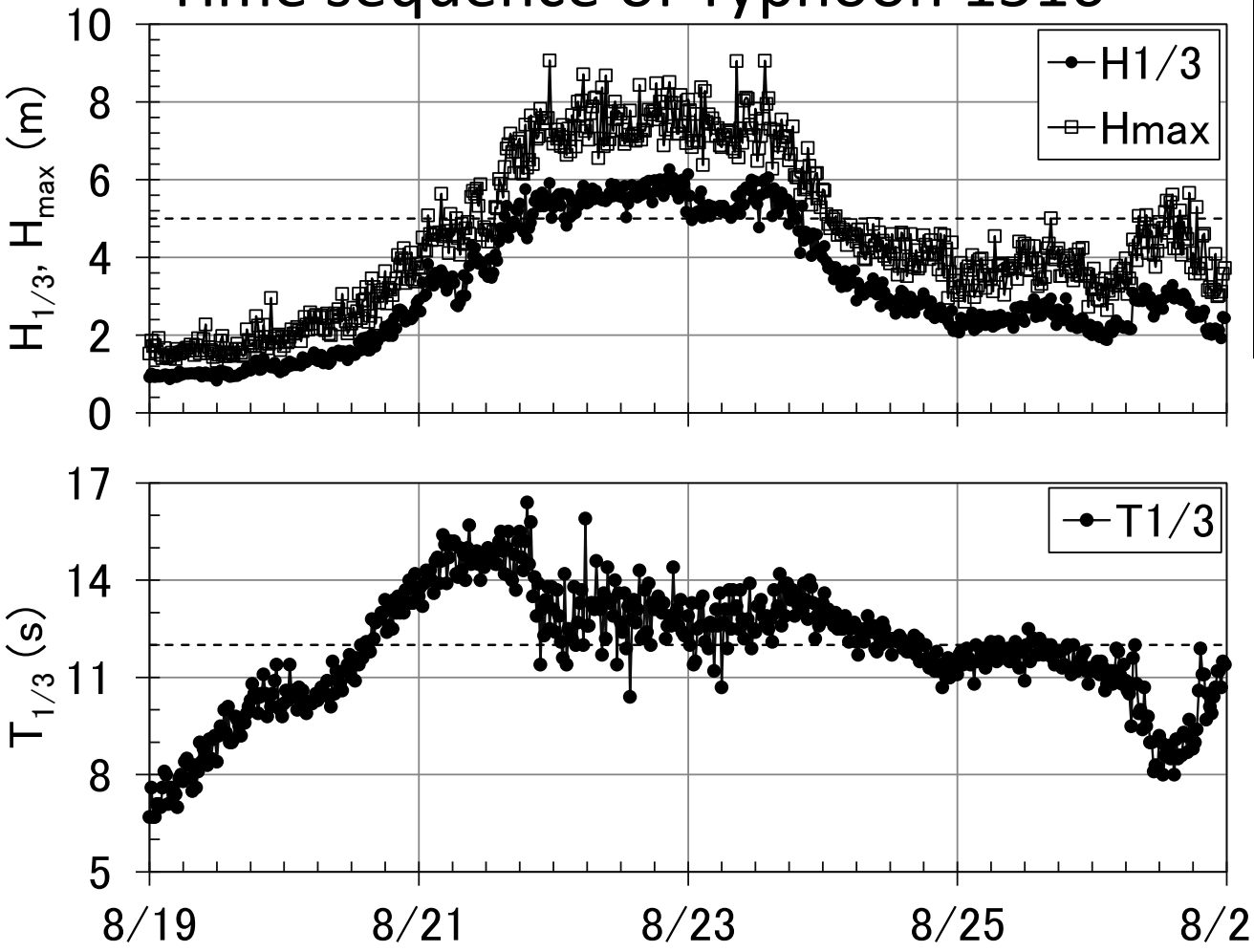
3rd, Low pressure

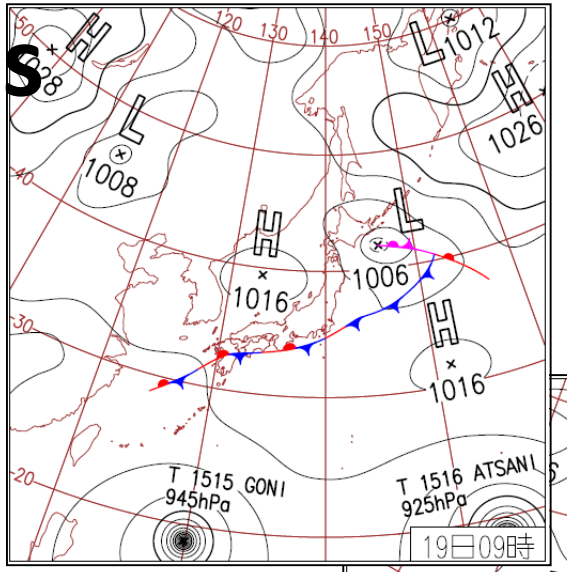


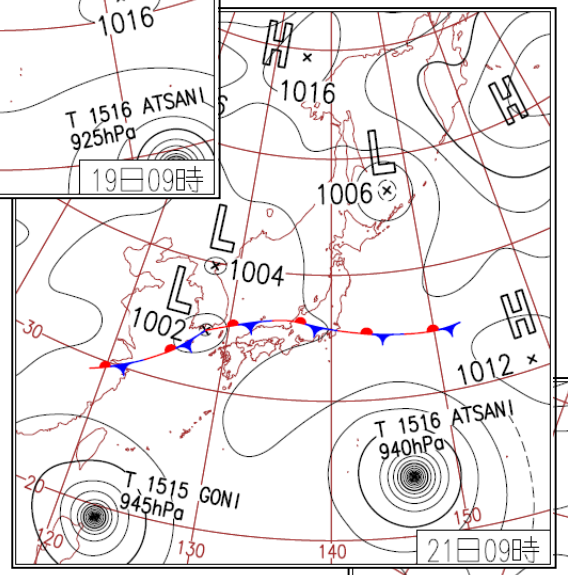
Source : Japan Meteorological Agency

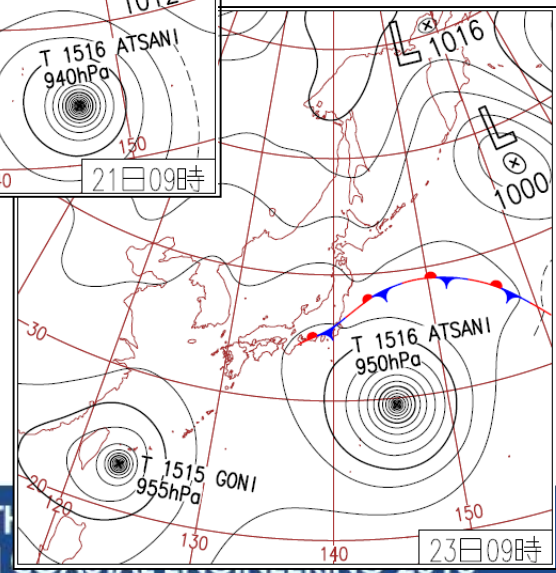
Characteristics of High Waves

Time sequence of Typhoon 1516



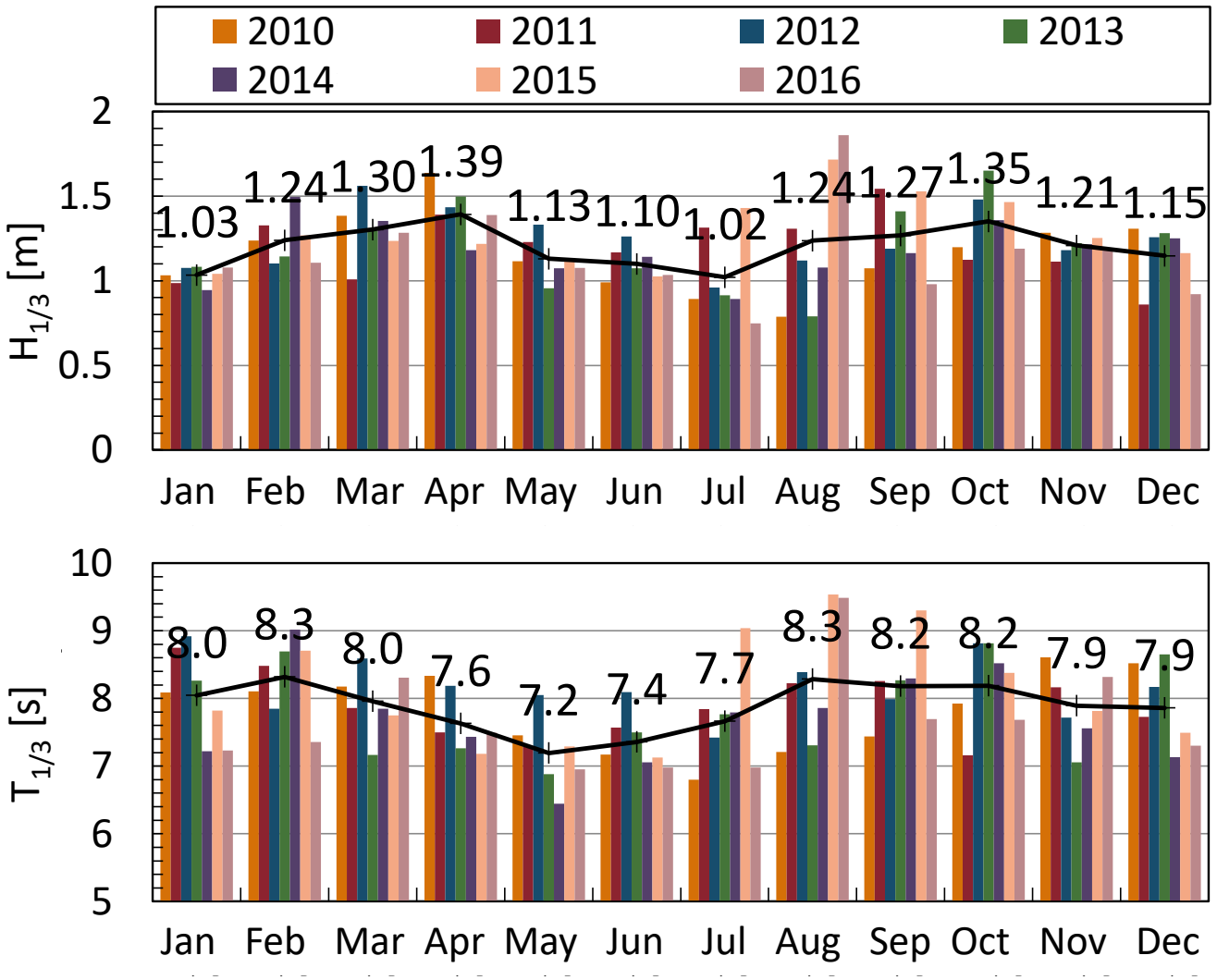






Source :
Japan Meteorological Agency

Monthly Wave Characteristics



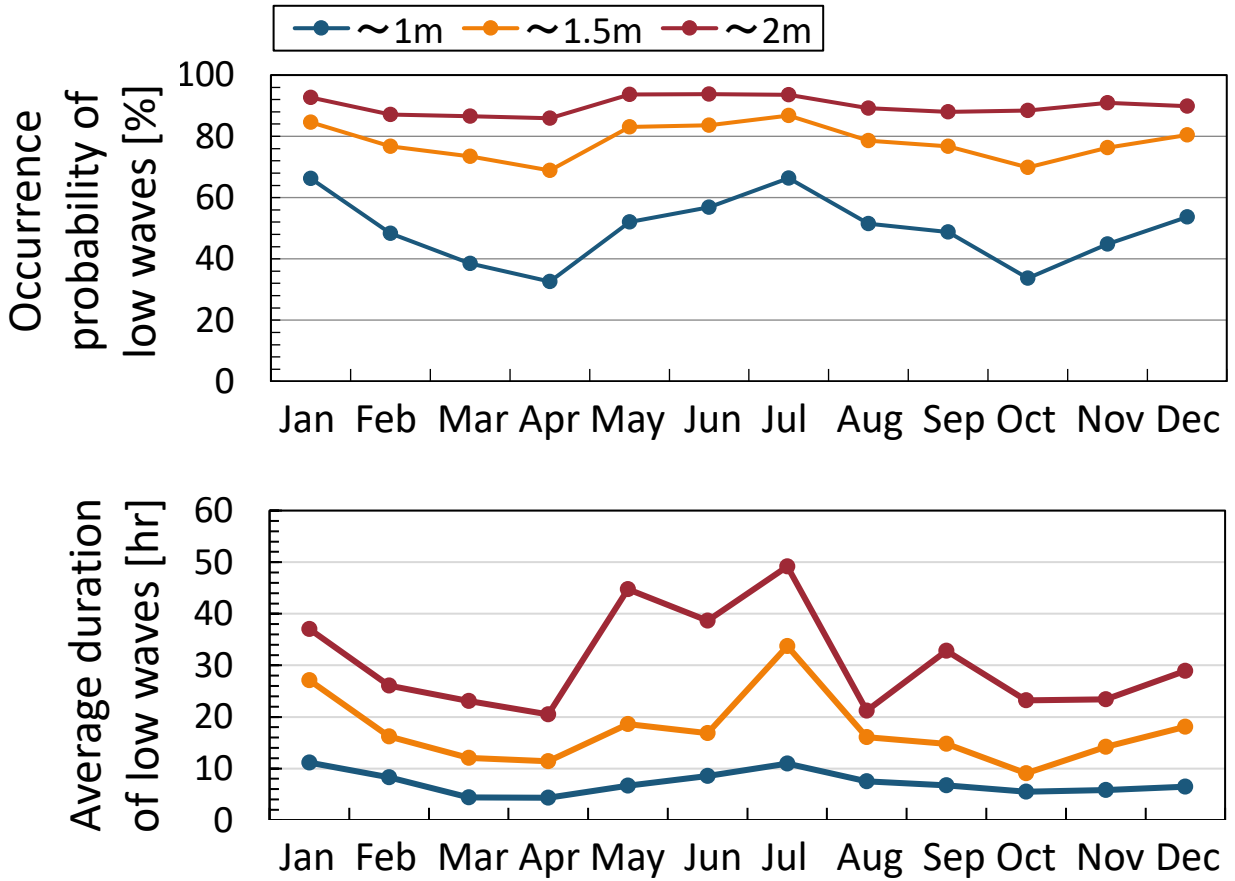
Monthly average of $H_{1/3}$ and $T_{1/3}$

- Knowing monthly characteristics is important for construction planning.

✓ $H_{1/3}$ are comparatively small in summer and winter.

✓ Variation in summer is large due to typhoon season.

Characteristics of Low Waves



- ✓ Probability of wave height under 1m is high in summer and winter, but probability of wave height under 1.5m is less-seasonal.
- ✓ The average duration doubles comparing under 1m with under 1.5m.
- ➡ Appropriately setting the conditions for efficient construction planning

Construction Simulation

Method

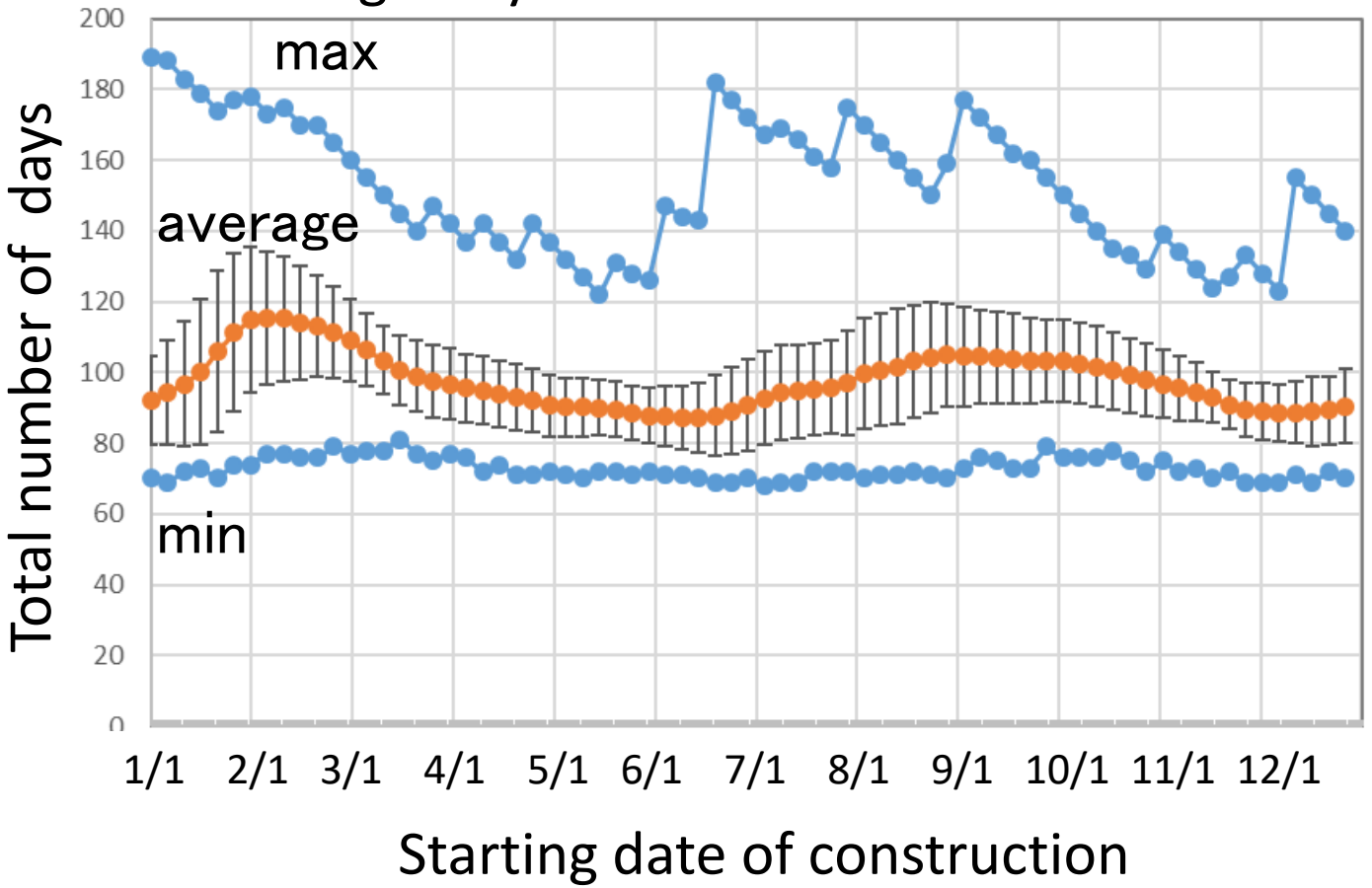
1. Modeling of construction step and each wave condition
2. Monte Carlo simulation using monthly occurrence probability and duration probability of low waves

Modeling in case of gravity foundation

	Work	Required days	Workable wave condition
1	Dredging and riprap	25 days	$H_{1/3}$<1.0m Time : 6am~3pm
2	Installation of foundation	2 days	$H_{1/3}$<0.75m Time: 6am~6pm
3	Scour protection	11 days	$H_{1/3}$<1.0m Time : 6am~3pm
4	Installation of tower	30 days	$H_{1/3}$<3.0m Time : 6am~3pm

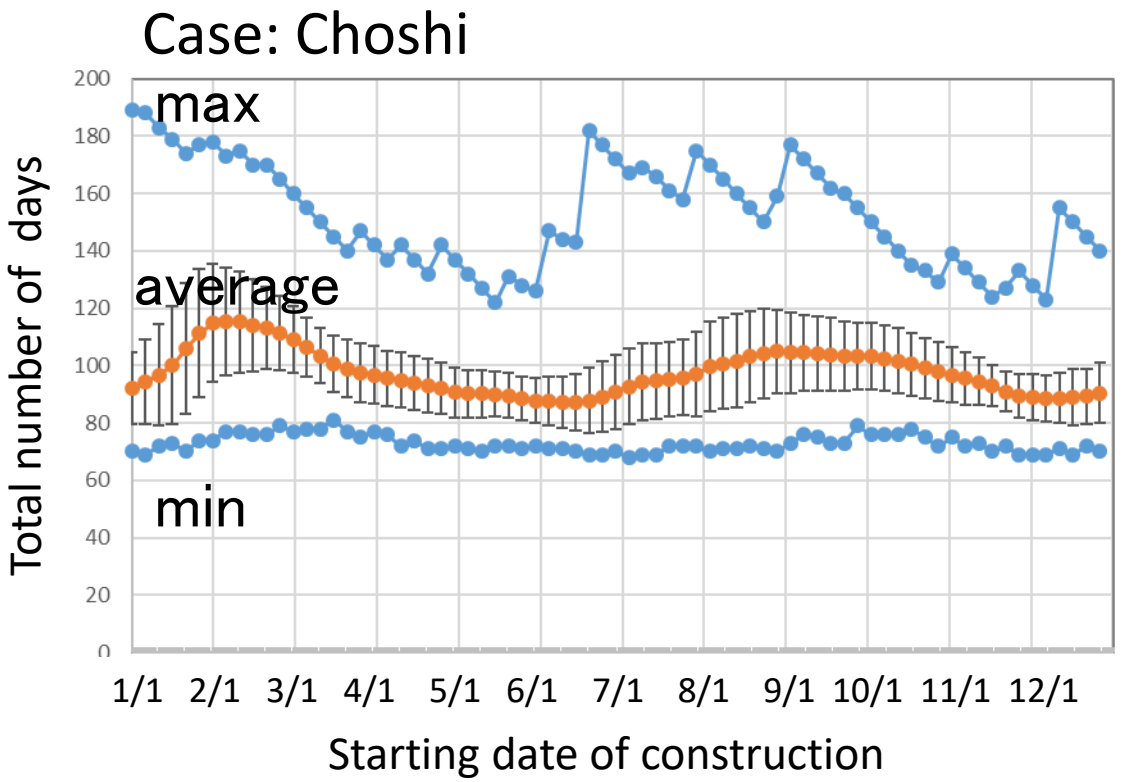
Construction Simulation

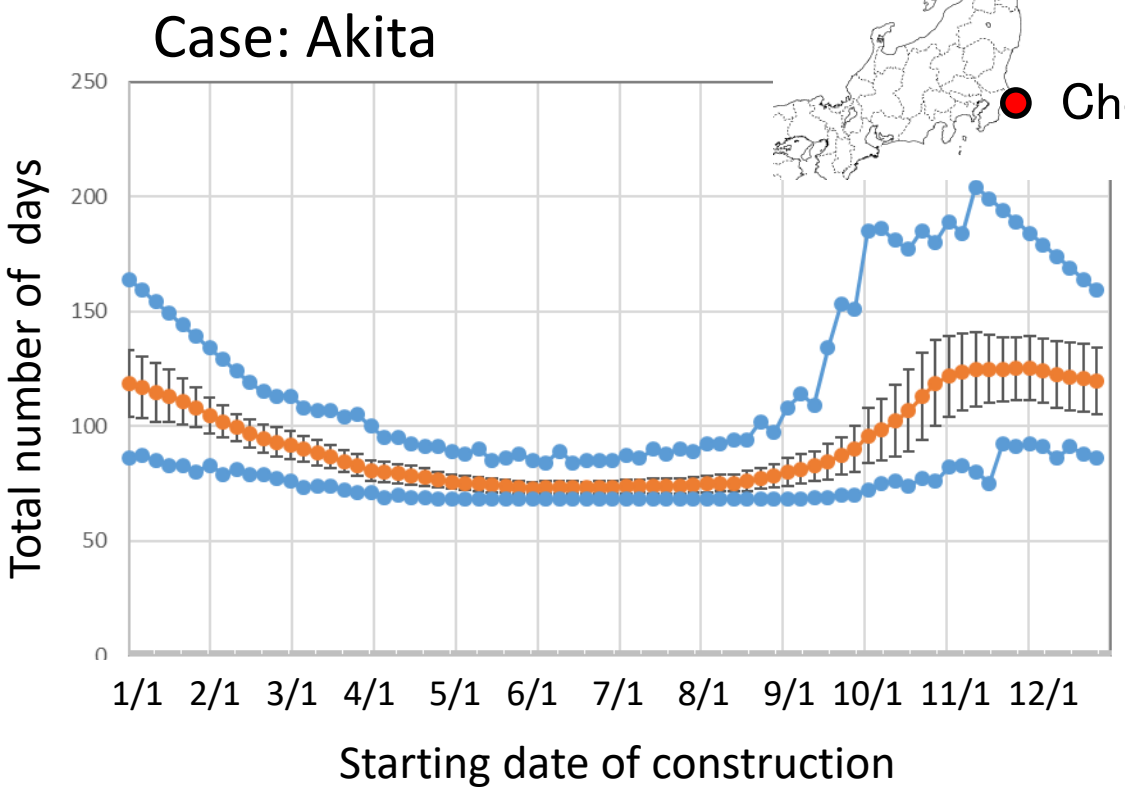
Case: A gravity foundation in Choshi

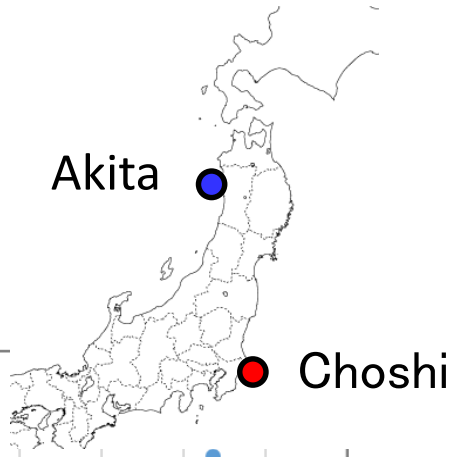


- ✓ The average of total number of days is shortest when starting in mid-June. But the maximum is large, therefore there is a risk the total construction cost become high.
- ✓ When starting in May, the total days is a little bit longer, but the maximum is not so large, it seems to be the best choice.

Construction Simulation







- Construction simulation can be carried out, if the construction model is set appropriately, regardless of the location, the foundation type, and the number of wind turbines.

Summary

- Using the wave data obtained from the proving project of offshore Choshi wind power plant, we understand the wave characteristics of offshore Choshi.
  - ✓ We propose a construction simulation method for planning an efficient construction plan using the occurrence characteristics of low waves.
  - ✓ By using this method it is possible to make a construction plan with consideration of risk.

Thank you for your attention