THE RELATION BETWEEN PROPAGATION PATHS OF BAROMETRIC WAVES OVER THE EAST CHINA SEA AND SEA-LEVEL FLUCTUATIONS OFF THE WEST COAST OF KYUSHU, JAPAN

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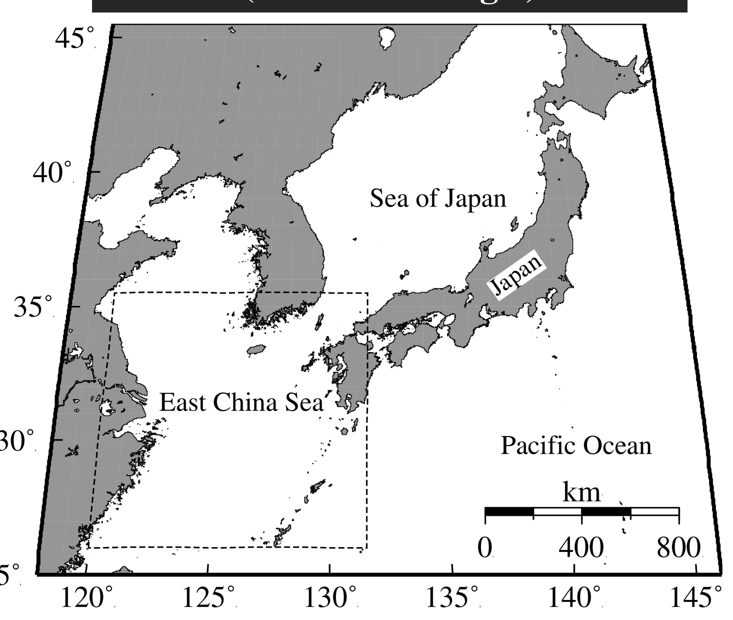
1.INTRODUCTION

A meteotsunami is a phenomenon similar to earthquake-generated tsunamis which is caused by the progress of atmospheric disturbances.

/ **Over outer seas**: Resonance occurs when the speed of atmospheric disturbances coincides with the speed of ocean waves =>**Meteotsunami**.

/ **At semi-closed waters:** Strong amplification occurs when the period of ocean waves matches the natural period of the waters. This amplification can result in damage such as coastal flooding. =>**Secondary undulations**

Location of the study area (dashed rectangle)



Secondary undulations, locally called "**Abiki**", are frequently observed off the west coast of Kyushu from winter to spring.

Cause of the long-period waves; Pressure disturbances over the East China Sea (Odamaki et al., 1982; Hibiya and Kajiura, 1982).

ex.) Secondary undulation with total amplitude of about 3 m at Kami-Koshiki Island in 2009.

Photos by the Kami-Koshiki branch office of the Satsuma-Sendai City.

If occurrences of secondary undulations could be predicted, it would be possible to mitigate damage.

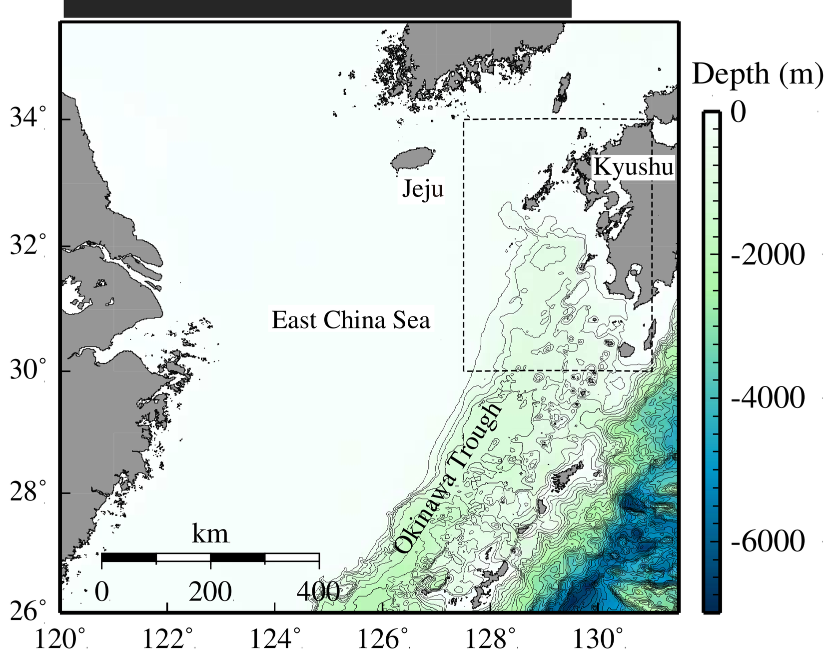
The relationship between the propagation path of barometric waves in the East China Sea and the characteristics of sea level fluctuations along the Kyushu coast was investigated by numerical analyses.

2. OUTLINE OF NUMERICAL CALCULATIONS

2.1 Setting of domain and boundary.

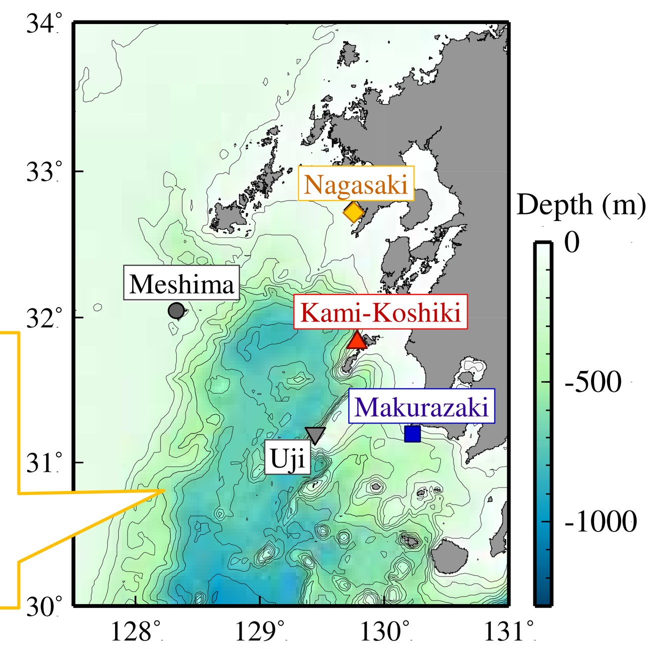
The Princeton Ocean was used for numerical analyses.

Calculational domain



/ The sizes of Δx and Δy: 1/30 º.
/ The time intervals: 0.5 s for the external mode
2.0 s for the internal mode
/ The salinity and water temp.: 34 and 20 ºC
/ Open boundaries: Radiation condition
/ Land boundaries: Complete reflection condition

Sea-level monitoring points



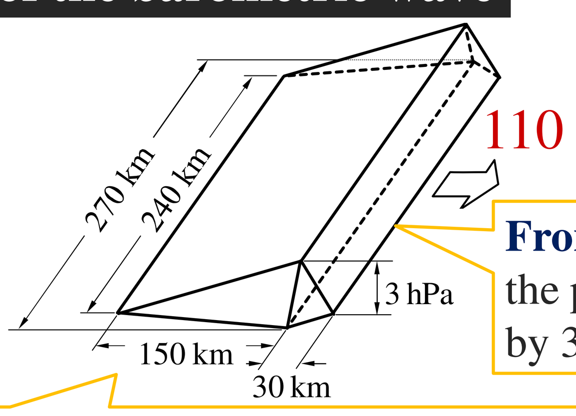
Nagasaki, **Kami-Koshiki**, and **Makurazaki**; Sites where secondary undulations occur frequently.

Meshima and **Uji**; Front-line sites for detecting long-period waves from the East China Sea.

=>**Sea level fluctuations caused by the propagation of barometric waves in the domain were evaluated.**

2.2 Modeling of barometric waves.

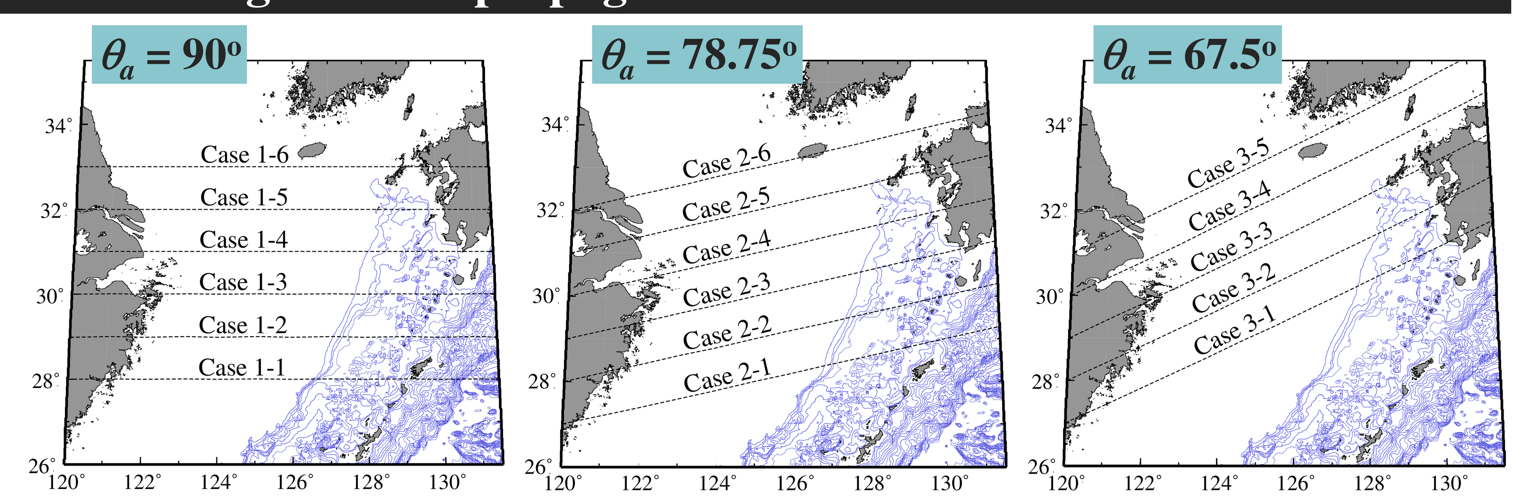
Shape of the barometric wave



Front of the crest: the pressure increases by 3 hPa in the 30 km

Behind the cres: The pressure decreases to the background pressure in the 150 km

Azimuth angles of the propagation directions of the barometric waves



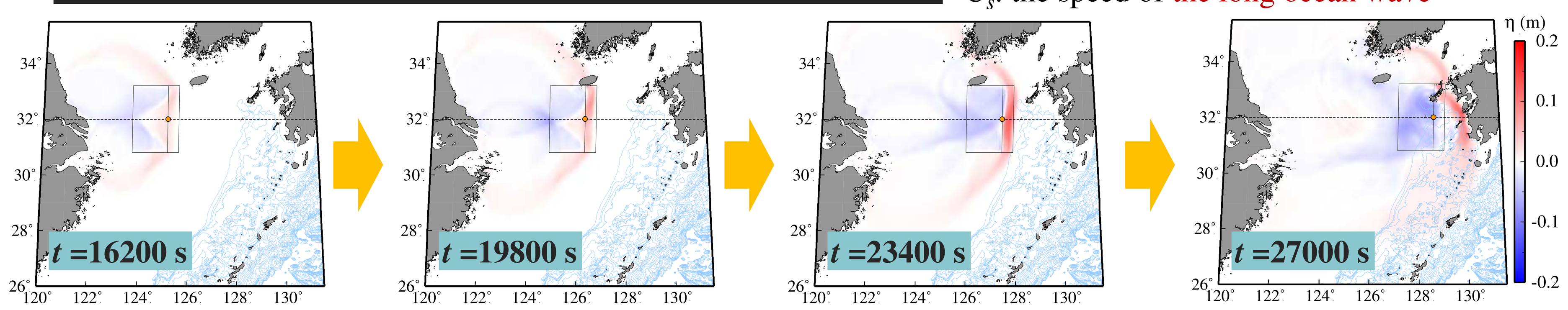
Cases No. : the first number corresponds to azimuth angle
the second number corresponds to latitude.

3. CALCULATION RESULTS

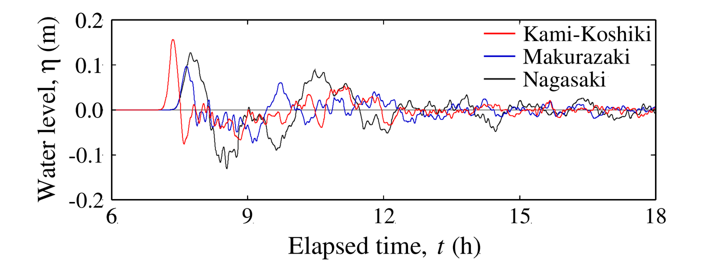
3.1 Behavior of water surface disturbances induced by barometric waves.

Example of sea level fluctuation (η) in Case 1-5.

C_a: the speed of the barometric wave
C_s: the speed of the long ocean wave



The η at each monitoring point



Before the barometric wave reaches the Okinawa Trough

/ $C_a \approx C_s$ on the west side of the Okinawa Trough
The disturbance η gradually increases (Proudman Resonance).
/ $C_a > C_s$ on the west side of the Okinawa Trough
The disturbance η can't propagate forward.

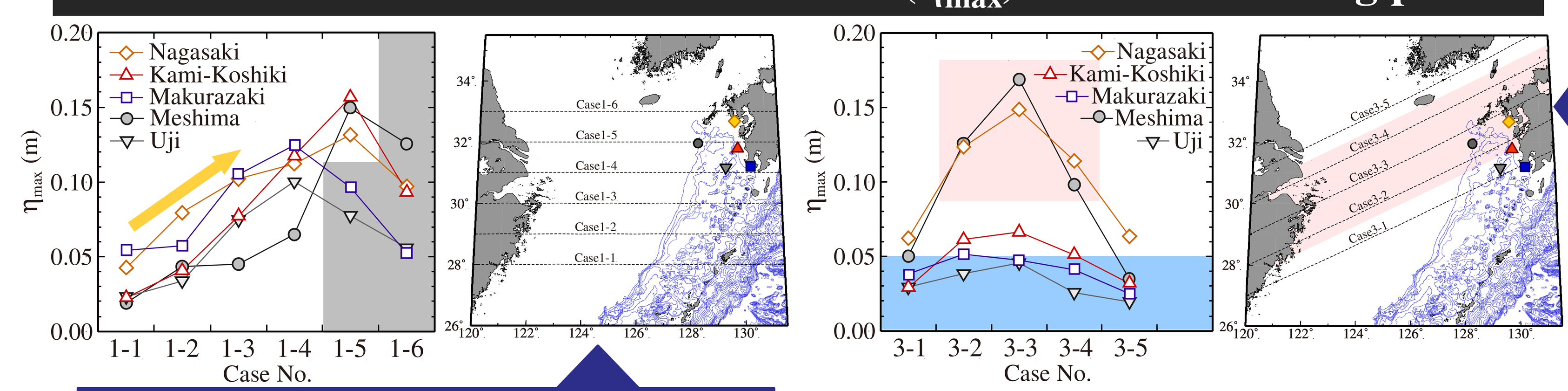
After the barometric wave reaches the Okinawa Trough

/ $C_a < C_s$ over the Okinawa Trough
The sea level disturbance starts propagating ahead of the barometric wave.

The barometric wave propagating over the East China Sea generate strong enough oscillations of the sea surface to cause a secondary undulation.

3.2 Relationship between barometric wave path and magnitude of water surface disturbance.

Maximum values of sea level fluctuation (η_{max}) at the monitoring points



The barometric wave travels toward E

/ The higher the latitude at which the barometric wave passes, the larger the η_{max} become as long as the barometric wave passes through the trough.

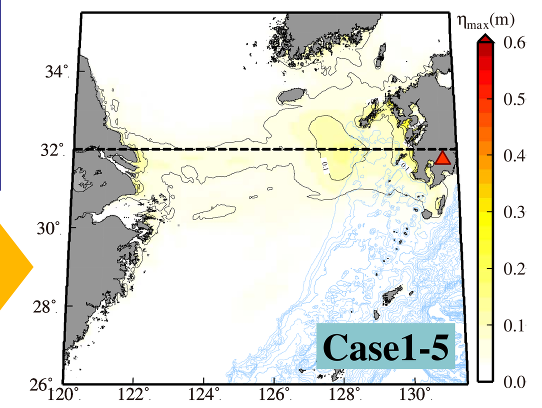
/ Reflection is less likely to occur.
/ Most of the wave energy reaches the Kyushu coast.

The barometric wave travels toward ENE

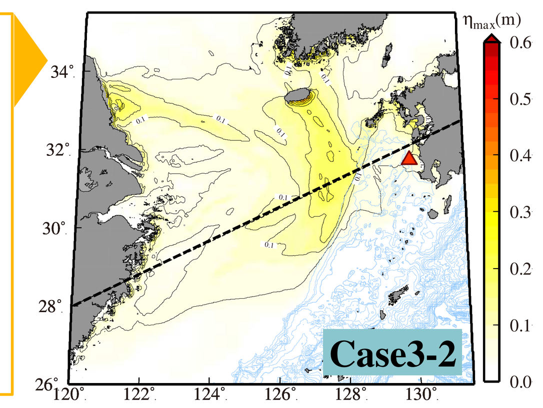
/ **Kami-Koshiki**, **Makurazaki**
The values of η_{max} remain at around 0.05 m.
/ Meshima, **Nagasaki**
The values of η_{max} are large in Cases 3-2 to 3-4.

Why isn't the η_{max} off Kami-Koshiki same magnitude as that off Nagasaki ?

Spatial distribution of maximum values of sea level fluctuation (η_{max}).



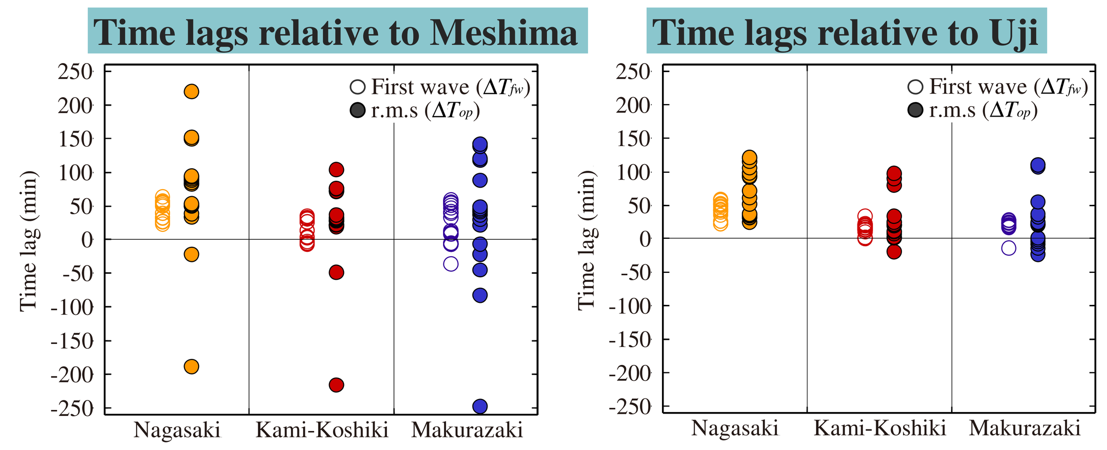
/ The influence of the water surface disturbance extends to Jeju and the coast of China due to strong reflection at the trough.
/ The energy of waves reaching the area east of the Okinawa trough is smaller.



3.3 Relationship between barometric wave path and arrival time of water surface disturbance.

Time lags between the occurrence of sea level fluctuations at each monitoring point

ΔT_{fw}: The time lags of the arrival time (T_{fw}) of the first wave.
ΔT_{op}: The time lags of the times (T_{op}) that the r.m.s. values of the η become maximum.



/ **Nagasaki**, **Kami-Koshiki**: There are no significant differences between the ΔT_{fw} values relative to Meshima and those relative to Uji.
/ **Makurazaki**: The ΔT_{fw} values relative to Uji tended to be smaller than those relative to Meshima. (just because Makurazaki is closer to Uji.)

/ The variability of ΔT_{op} became larger than the ΔT_{fw}.
/ The variations are larger when Meshima is used as a reference.

There are cases where the T_{op} at Meshima is delayed by 3–4 h relative to that along the coast of Kyushu, when the barometric wave passed through low latitudes.

4.CONCLUSIONS

1) The behavior of the water surface waves caused by the barometric wave propagation to the east of the Okinawa trough drastically changes depending on the position and angle at which the barometric wave passes through the Okinawa trough.
=>That brings about a great difference in the magnitude of water level fluctuations occurring along the coast of Kyushu Island.

2) The time lag between the peak time of water level fluctuations off the Kyushu Island (Meshima and Uji) and that in the coastal areas of Kyushu Island also varies greatly depending on the propagation path of the barometric wave.
=>There might be cases where the peak of water level fluctuation Meshima is around 3-4 hours behind the coastal areas of Kyushu Island.

3) Meshima can be a useful monitoring site for early detection of long-period waves that cause secondary undulations on the west coast of Kyushu Island. There are cases where it is difficult to detect long-period waves with high accuracy in advance though.
=>It is considered that it is preferable to perform monitoring not only on Meshima but also on multiple sites east of the Okinawa Trough.