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The State of the Art and Science of Coastal Engineering

Field study of contrasting beach recovery processes of observed in Nami-ita and Kiri-kiri coasts after the 2011 Tohoku earthquake

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1. Background

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- The 2011 Tohoku Earthquake tsunami caused significant shoreline retreat along the northern Pacific coast of Japan.
- Beach recovery is one of crucial tasks because the beach provides an important **resource of tourism** and the beach has an important function of **coastal protection**.
- Most of the affected beaches have shown certain recovery while they have not yet fully recovered.
- Nami-ita coast also lost a large part of beach but yields little recovery even six years after the event (Yagisawa et al, 2016).



**How to realize the beach recovery along
Nami-ita coast?
Need any special measures?**



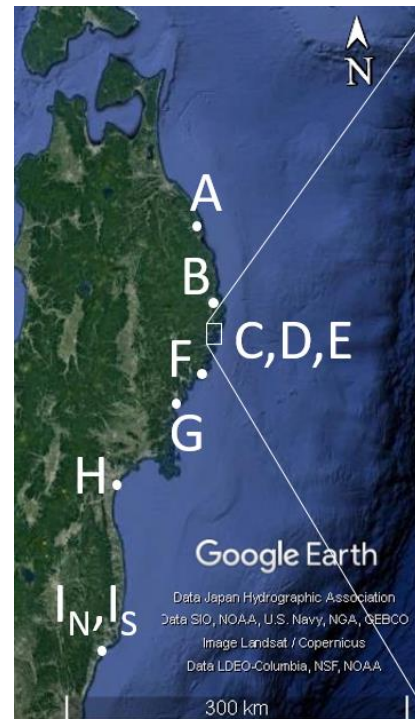
2. Analysis of shoreline change

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Effective beach recovery measures?

Understanding sediment transport characteristics at Nami-ita coast is essential.

- Comparisons of the initial damage and a recovery process of 10 selected beaches along the northeast coast of Japan after the 2011 Tsunami event including Nami-ita coast.



2. Analysis of shoreline change

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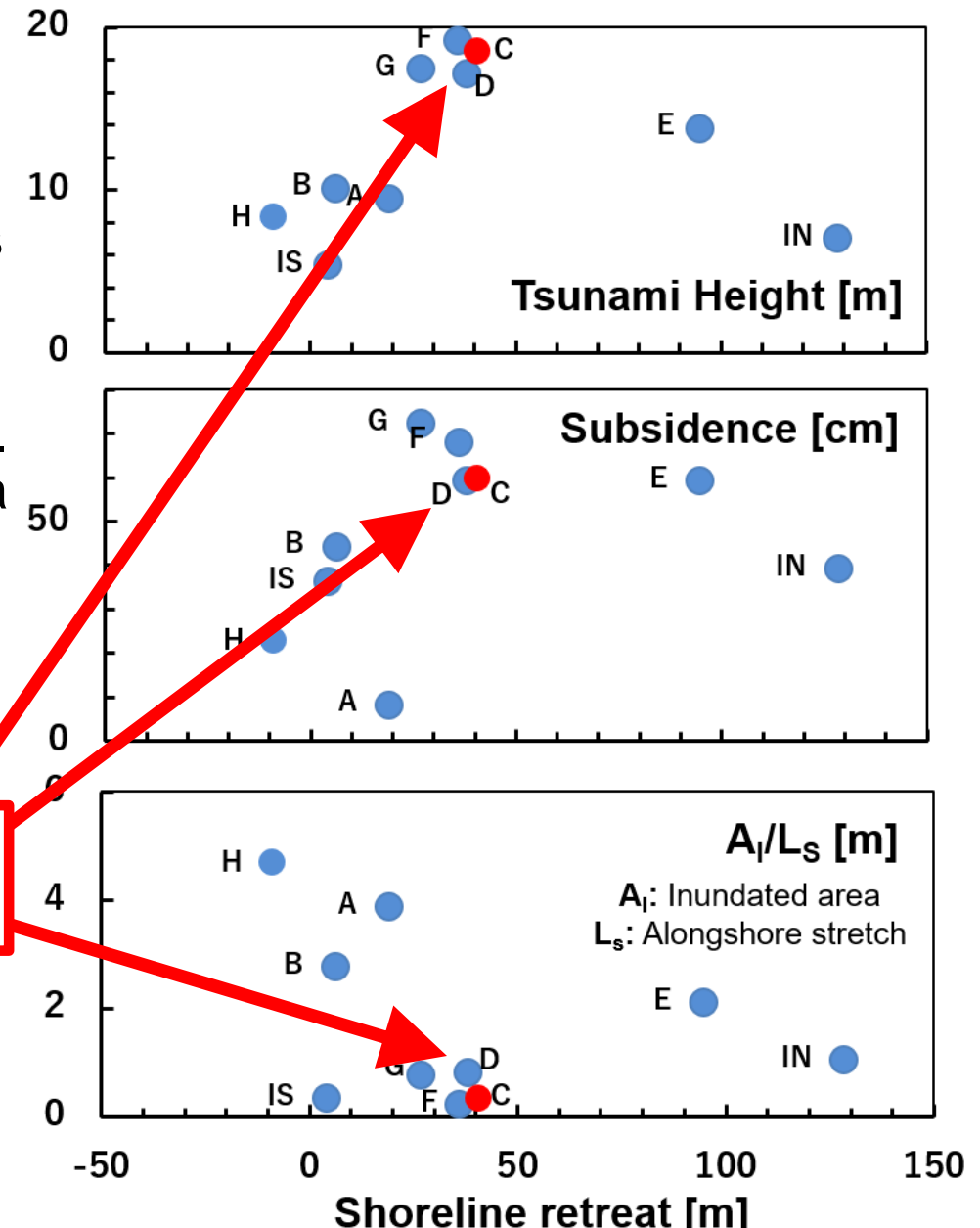
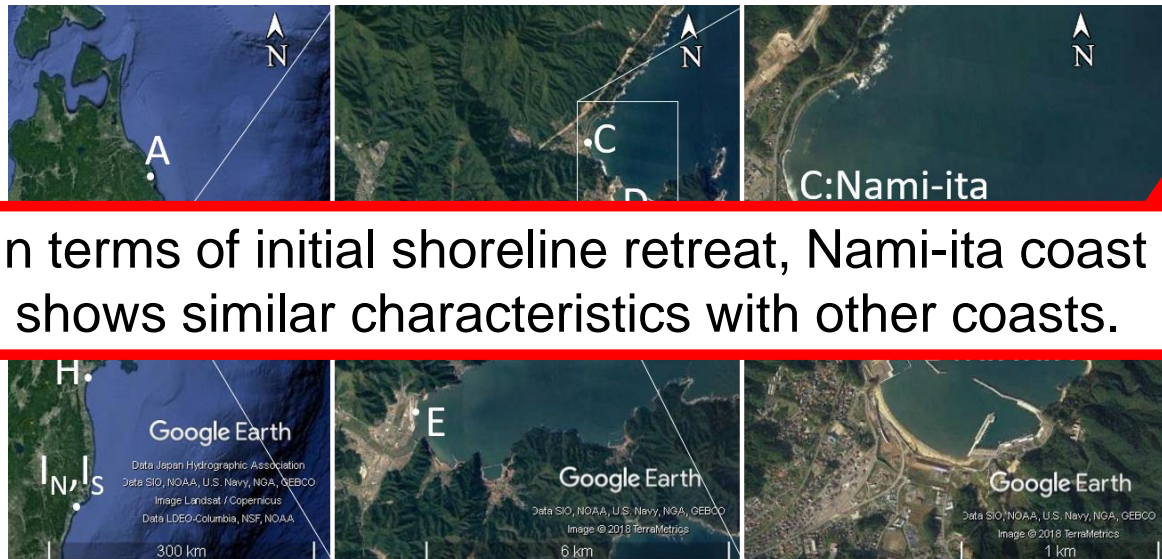
- Satellite images on Google Earth were used.
- GIS was used to rectify the obtained images based on the same geographic coordinate system
- Cross-shore-ward distance from the base line to the shoreline was measured on GIS with alongshore intervals of 50 m.
- Characteristics of the initial shoreline retreat due to the 2011 Earthquake and the post-event recovery process at each coast were compared.
- Initial shoreline retreat was compared with the following parameters related to the 2011 event:
 - H:** tsunami height at the coast
 - S:** land subsidence
 - A_i/L_s** : representative inundation distance.
 - A_i : inundation area,
 - L_s : alongshore stretch of the shoreline



3. Analysis of shoreline change – Initial retreat –

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- Initial shoreline retreat shows clear **positive correlation** with tsunami height and subsidence and **negative correlation** with A_I/L_s .
- Nami-ita coast, C, showed similar characteristics of initial shoreline retreat compared to the other coasts.
- Coasts E and IN showed larger shoreline retreat. Both coasts were near the river mouth and had a lagoon behind the beach.



4. Analysis of shoreline change – post event recovery –

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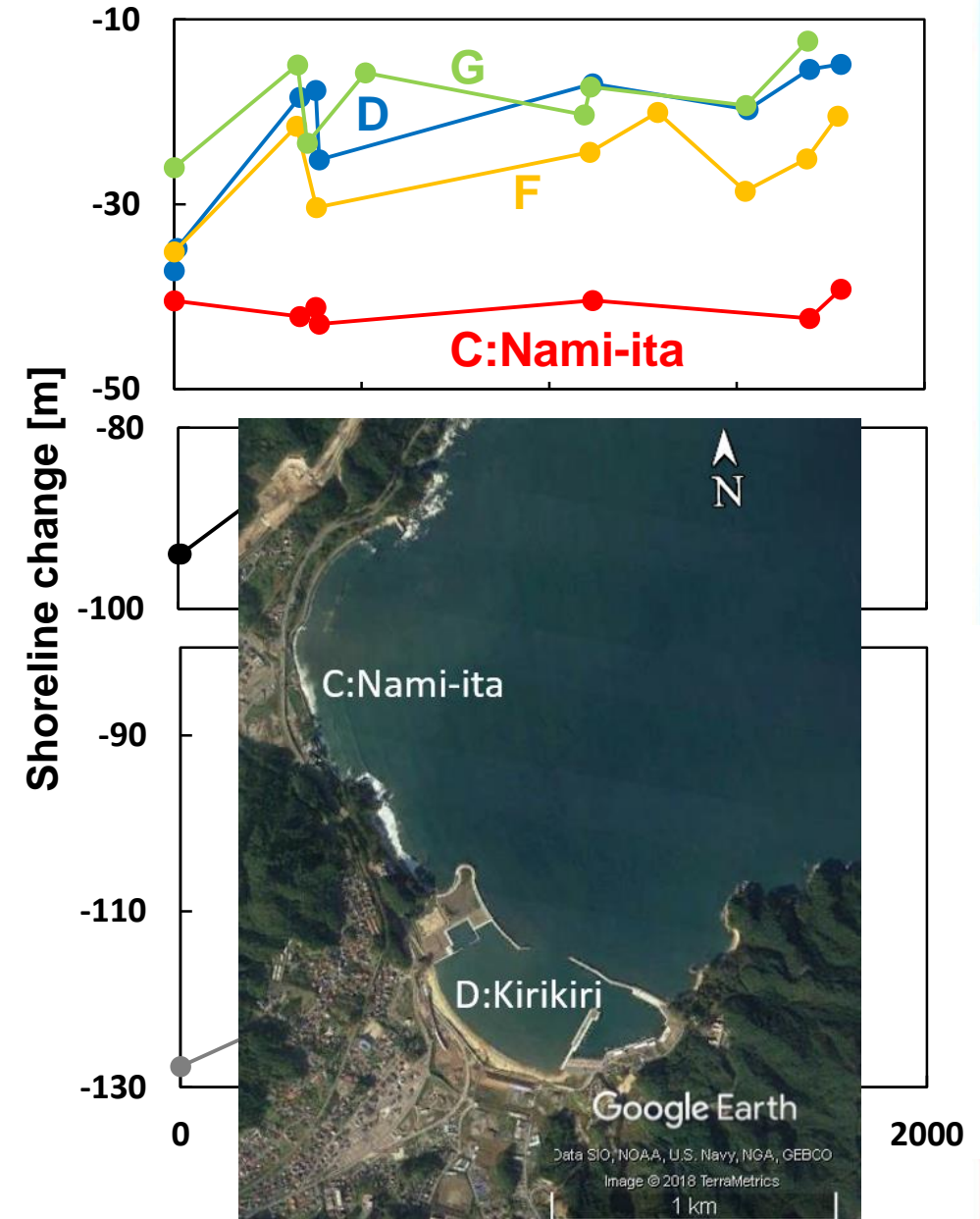
- The initial shoreline retreat of Nami-ita coast was similar to the other coasts.

However

- Recovery process of Nami-ita coast differs from the other coast.
 - Most of the coast:
 - ✓ quick recovery just after the event
 - ✓ gradual recovery after the quick recovery.
 - Nami-ita coast: little recovery.

What makes a difference ?

- Kiri-Kiri coast, D, and Nami-ita coast, C, are located next to each other in the same bay but their recovery characteristics are different.



5. Kiri-Kiri vs Nami-ita

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■ Kiri-Kiri coast

- Kiri-Kiri coast was protected by breakwaters.
- The breakwaters were destroyed by the 2011 tsunami but was reconstructed after the event.
- Collapsed seawall was also reconstructed at the same location.
- The distance between the seawall and the shoreline was around 100 m.
- A **part of beach remained** after the event.
 - ✓ Breakwaters functioned to reduce the offshore-ward loss of sediment due to tsunami?
 - ✓ Milder waves behind the breakwaters enhanced the shoreward sediment transport after the event?
 - ✓ Beach in front of the seawall itself enhanced the recovery?



5. Kiri-Kiri vs Nami-ita

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■ Nami-ita coast

- Nami-ita coast has three detached breakwaters on the north side and no breakwaters in the middle.
- The coast is known to be a good beach for surfing.
- Partially collapsed seawall was reconstructed at the same location.
- The distance between the seawall and the shoreline was 20 to 40 m.
- The **entire beach** was washed out by the event.
- ✓ Nami-ita coast has higher waves than Kiri-Kiri coast.
- ✓ The seawall is exposed to the sea.
- ✓ Reflected waves from the seawall may have significant influence on the shoreward sediment transport.

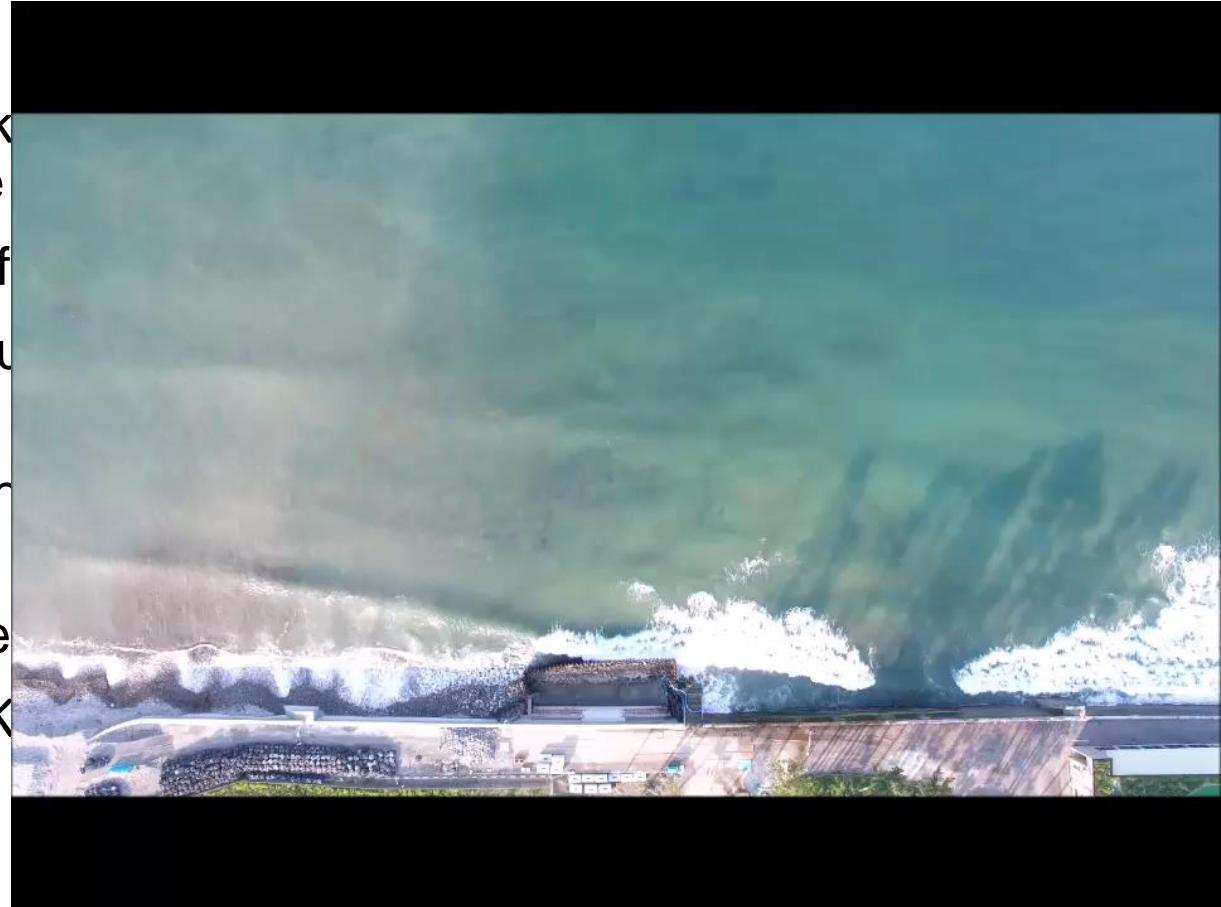


5. Kiri-Kiri vs Nami-ita

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■ Nami-ita coast

- Nami-ita coast has three detached breakwaters on the north side and no breakwaters in the south.
- The coast is known to be a good beach for surfing.
- Partially collapsed seawall was reconstructed at the same location.
- The distance between the seawall and the shoreline was 20 to 40 m.
- The **entire beach** was washed out by the 2011 Tohoku earthquake.
- ✓ Nami-ita coast has higher waves than Kiri-Kiri coast.
- ✓ The seawall is exposed to the sea.
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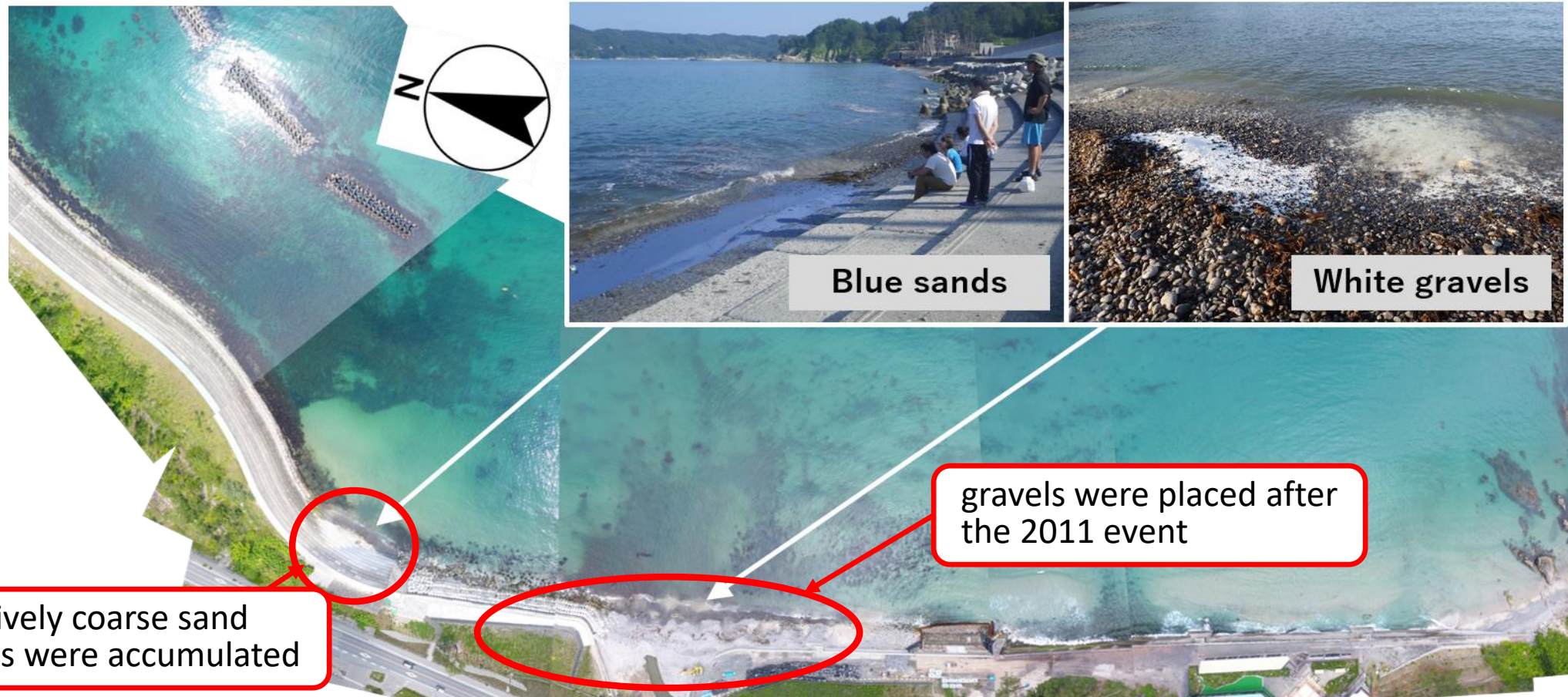
➡ **Is simple beach nourishment effective in Nami-ita coast?**



6. Field experiment at Nami-ita coast

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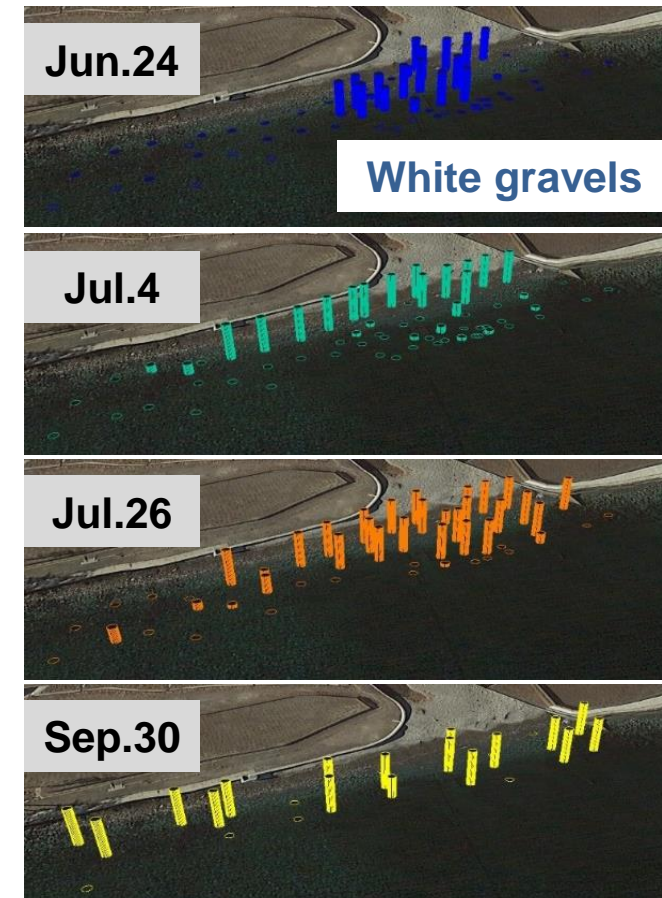
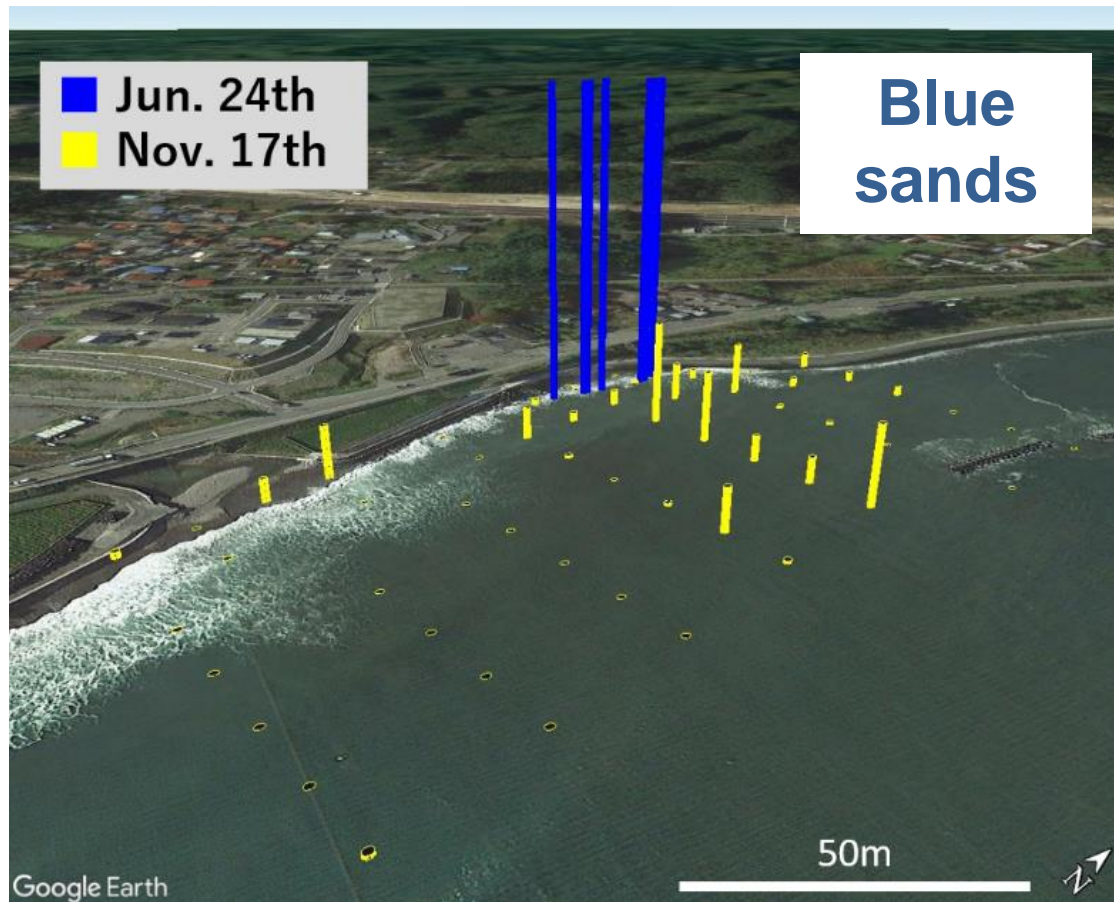
- To investigate the behavior of nourished sediments, sand tracer study was conducted.
- Blue sands ($D_{50} = 0.56$ mm) and white gravels ($D_{50} = 3-5$ mm) were respectively placed as a tracer at the shoreline at the high tide level on June 23rd, 2017.
- The number of tracer grains were counted along the coast.



6. Field experiment at Nami-ita coast

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- Both blue sand and white gravels were transported in the southward alongshore direction.
- A large amount of blue sand was also transported off-shore-ward.
- White gravels showed no off-shore-ward movement and remained near the shoreline.



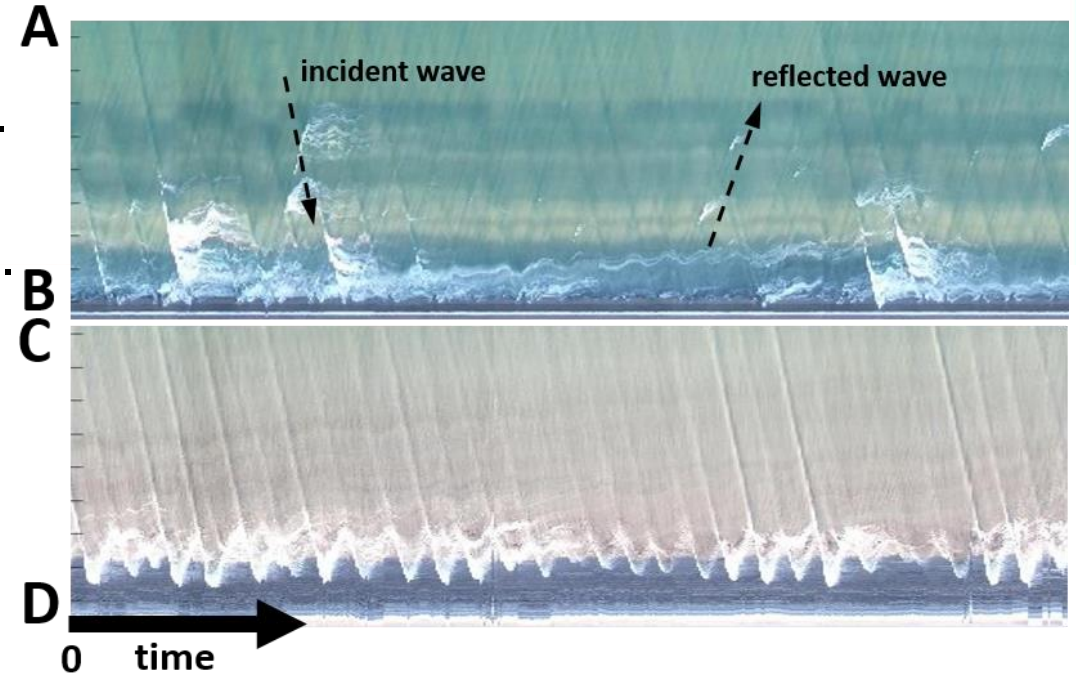
6. Field experiment at Nami-ita coast: summary

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- Sand grains with a grain size of original beach materials are largely transported offshore.
- Gravels ($D_{50} = 3\text{-}5\text{ mm}$) remained on the beach.
- Reflected wave components were smaller in front of the coast where gravels were deposited.



- Partial gravel nourishment may be effective to:
 - (1) enhance the stability of nourished beach;
 - (2) reduce the wave reflection and enhance shoreward transport of offshore sediments.



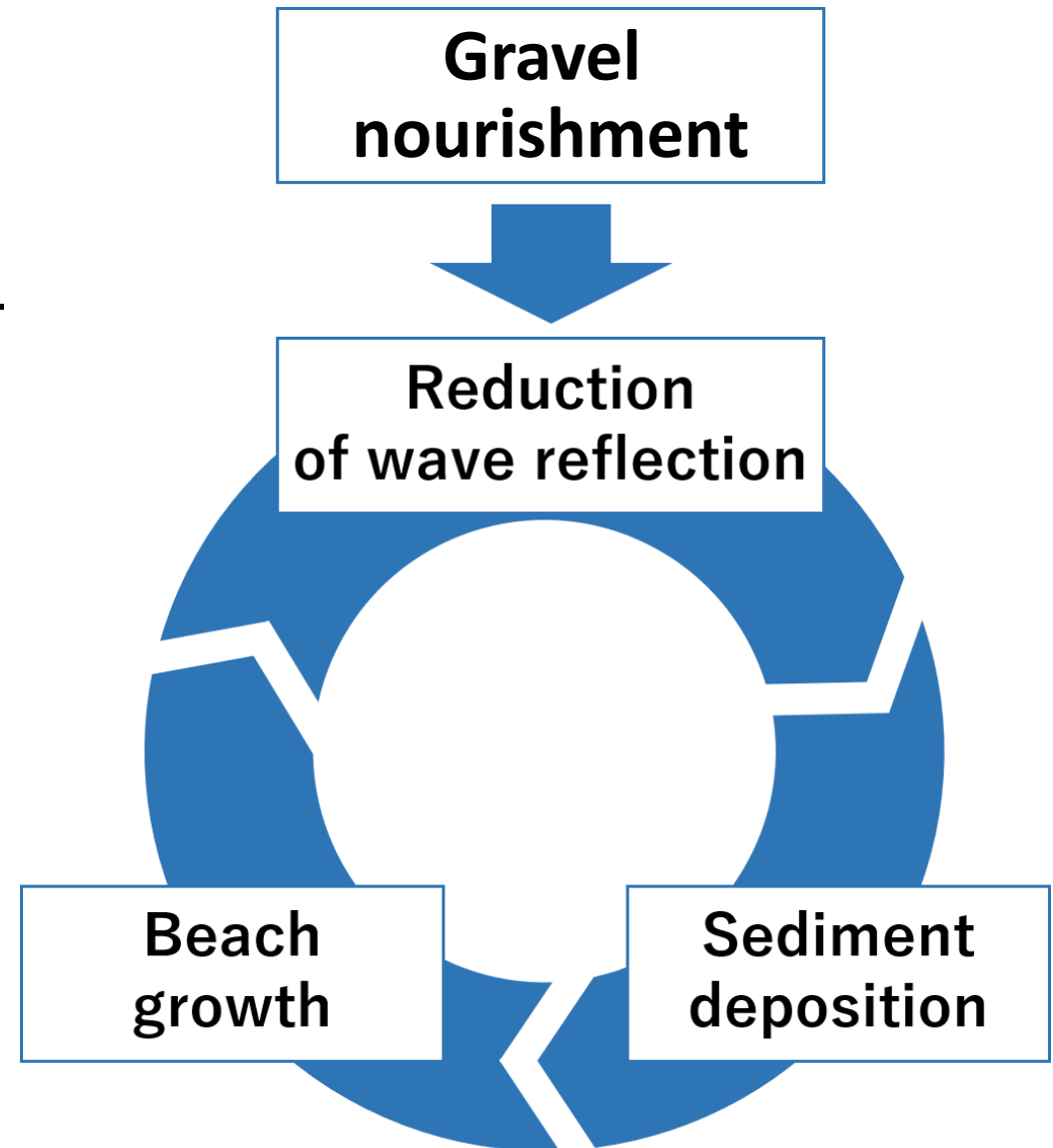
6. Field experiment at Nami-ita coast

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■ Analysis of shoreline change

- Initial shoreline retreat showed positive correlation with tsunami height and land subsidence while it shows negative correlation with representative inundation distance, AI/Ls.
- In most of the coast, retreated shoreline showed relatively quick but a partial recovery after the event.
- Nami-ita and Kiri-Kiri coasts are located next to each other in the same bay but their recovery characteristics were different.
- Nami-ita and Kiri-Kiri are different in nearshore wave conditions and the location of the seawall relative to the original shoreline.
- Significant reflected waves at Nami-ita coast appear to have negative impact on shoreward transport of sediment deposited after the 2011 event.

■ Field experiment at Nami-ita coast

- Tracer gravels remained on the beach while a large amount of tracer sand grains were transported offshore.
- Gravel beach appears to reduce wave reflection from the coast and may accelerate the beach recovery.



Thank you for your attention.

