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Nature-based Solutionとしての海岸砂丘活用を見据えた砂丘-砂浜長期地形変化予測モデルの開発

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- Sandy beaches has been considered as sites of social-economy and culture (McLachlan et al. 2013)
- Complex dynamic of coastal area increase coastal communities' exposure to various hazards (Neumann et al., 2015 ; Refulio-Coronado et al., 2021; Areia et al., 2022)

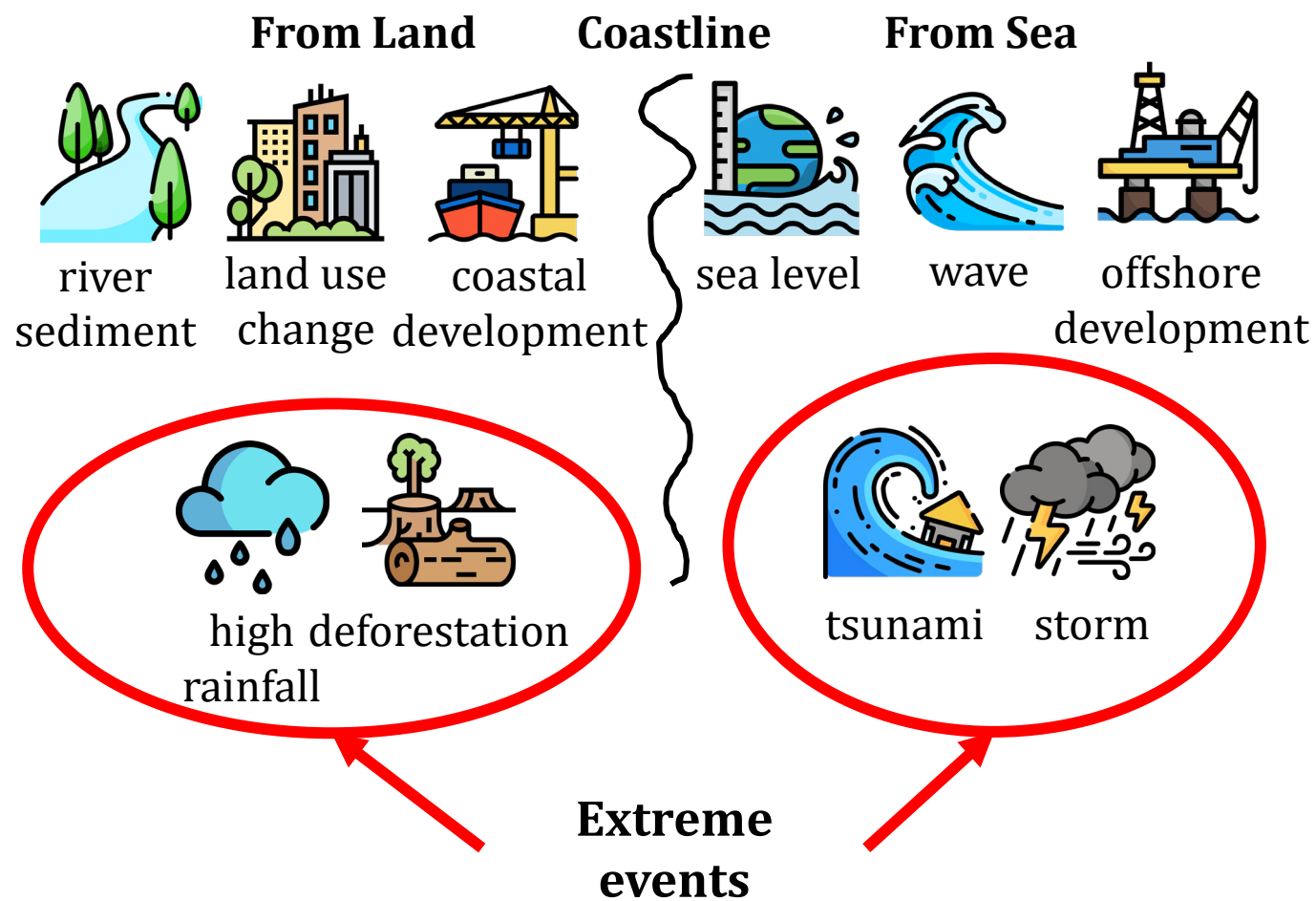
- Integrated grey and green infrastructure (GI) approach has been introduced in recent years (Park et al., 2024; Singvhi et al., 2022)



**The use of sandy beaches
natural landform for
protection**

Forcing factors that influence sandy coasts

(Knight, 2024)





Coastal dunes as one of the sandy beach natural landform act as a **natural barrier** from coastal disaster (Johnston et al., 2023)



Coastal dunes offer a **sustainable and cost-effective solution**, as it can adapt and grow over time



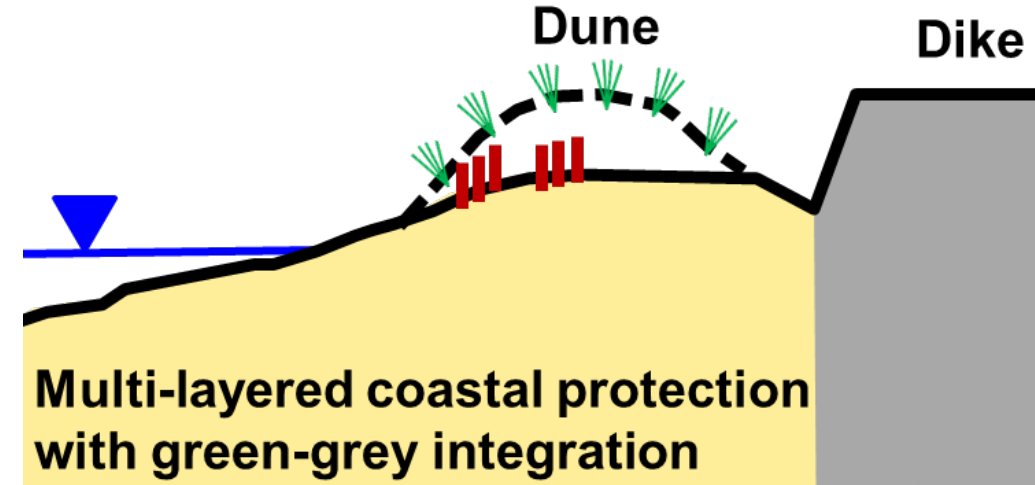
Sand fences are used to control the location and rate of aeolian erosion or deposition (Sherman et al., 2015)



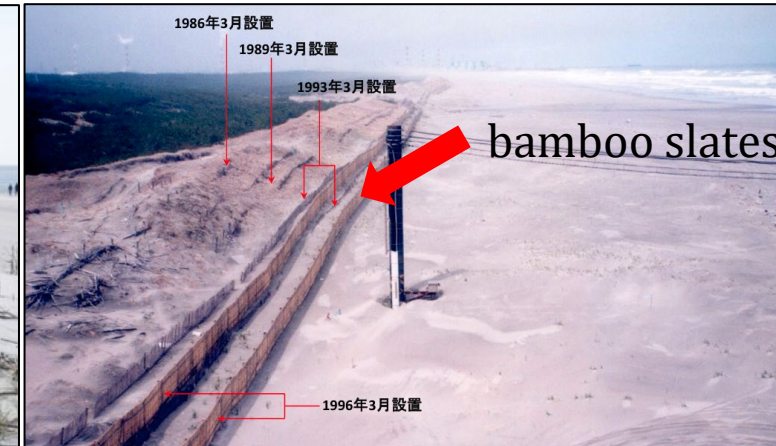
Sand fences are inexpensive and easy to erect by property owners (Jackson & Nordstrom, 2011)



How to explain the formation of dune with sand fence implementation?



Germany, Schleswig-Holstein (North Sea Coast) (Hofstede, 2024)



Japan, Hasaki Beach (HORS, 1996)

Examples of Coastal Dunes



Beach Profile Models	Source	Period	Strength	Weakness	Aeolian Trans.
XBeach	Roelvink et al. (2009)	Short term (hours, day)	Suitable for investigating individual storms and response (Romão et al., 2024; Palalane et al., 2016)	High computational cost (Simmons et al. 2019)	-
SBEACH	Larson et al. (1989)			Insensitive to site-specific parameters (Simmons et al. 2019)	-
LITPACK	DHI (2008)			Detail input data requirement (DHI, 2008)	-
Unibest-TC	Netherlands Delft Hydraulic	Short to medium term		Does not include aeolian processes (Palalane, 2016)	-
LTC	Coelho (2005)	Medium to long term	Combine cross-shore and longshore (Romão et al., 2024)	Assume uniform cross-shore distribution (Coelho, 2013)	-
Delft3D	Delft Hydraulics (1986)	Short to long term	Versatile for hydro-sediment-morphodynamic studies	Requires significant computational resources and expertise to operate	-
Cross-Shore (CS) Model	Larson et al. (2016)	Medium to long term	Simpler and computationally efficient	Semi-empirical model, requiring calibration for site-specific transport parameter	V

Problems

1. The use of coastal dunes as green infrastructure in coastal management strategies needs to account for its morphodynamic behaviour.
2. Incorporating features such as sand-fences to beach profile model has not been studied

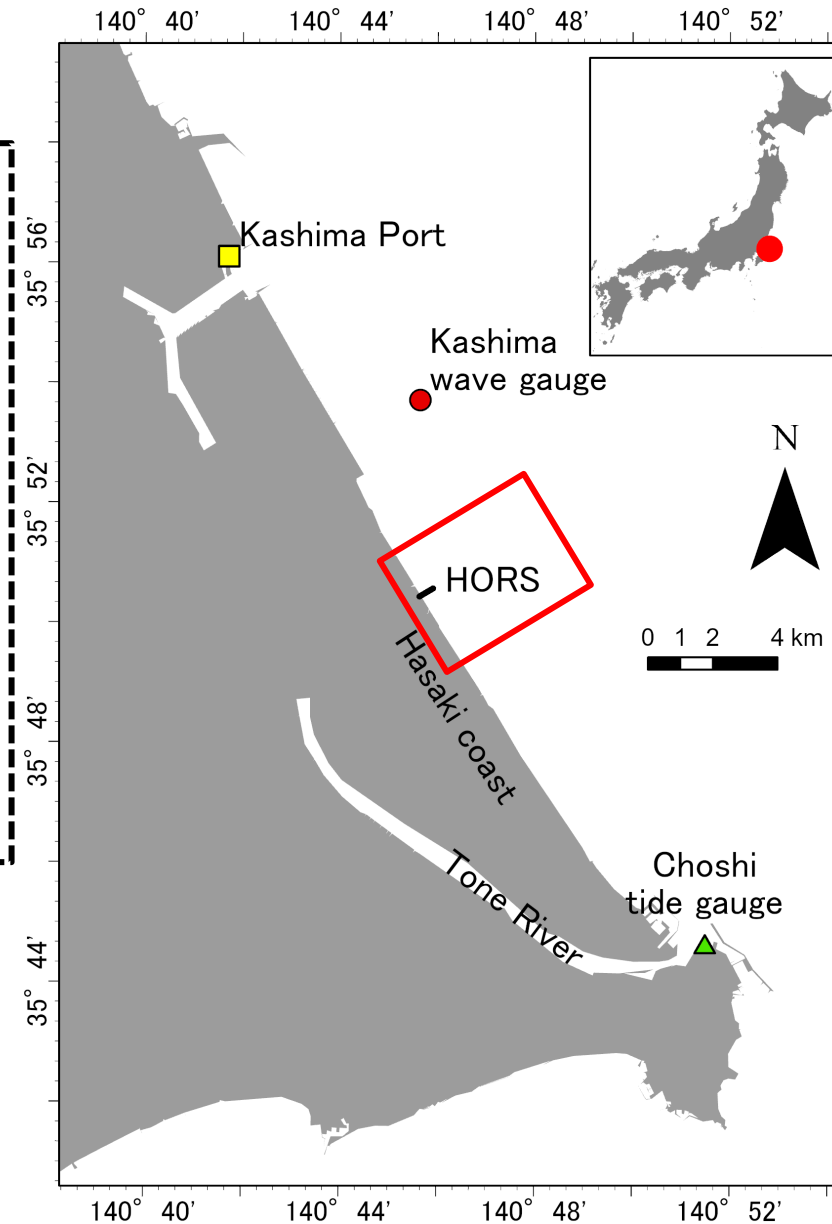
Research Questions

1. How is **the improvement of beach profile model** that incorporates sand-fences?
2. How does sand-fences affect **coastal dunes' evolution** over time?
3. How are the **proposed coastal management strategies** that include coastal dunes as green infrastructure?

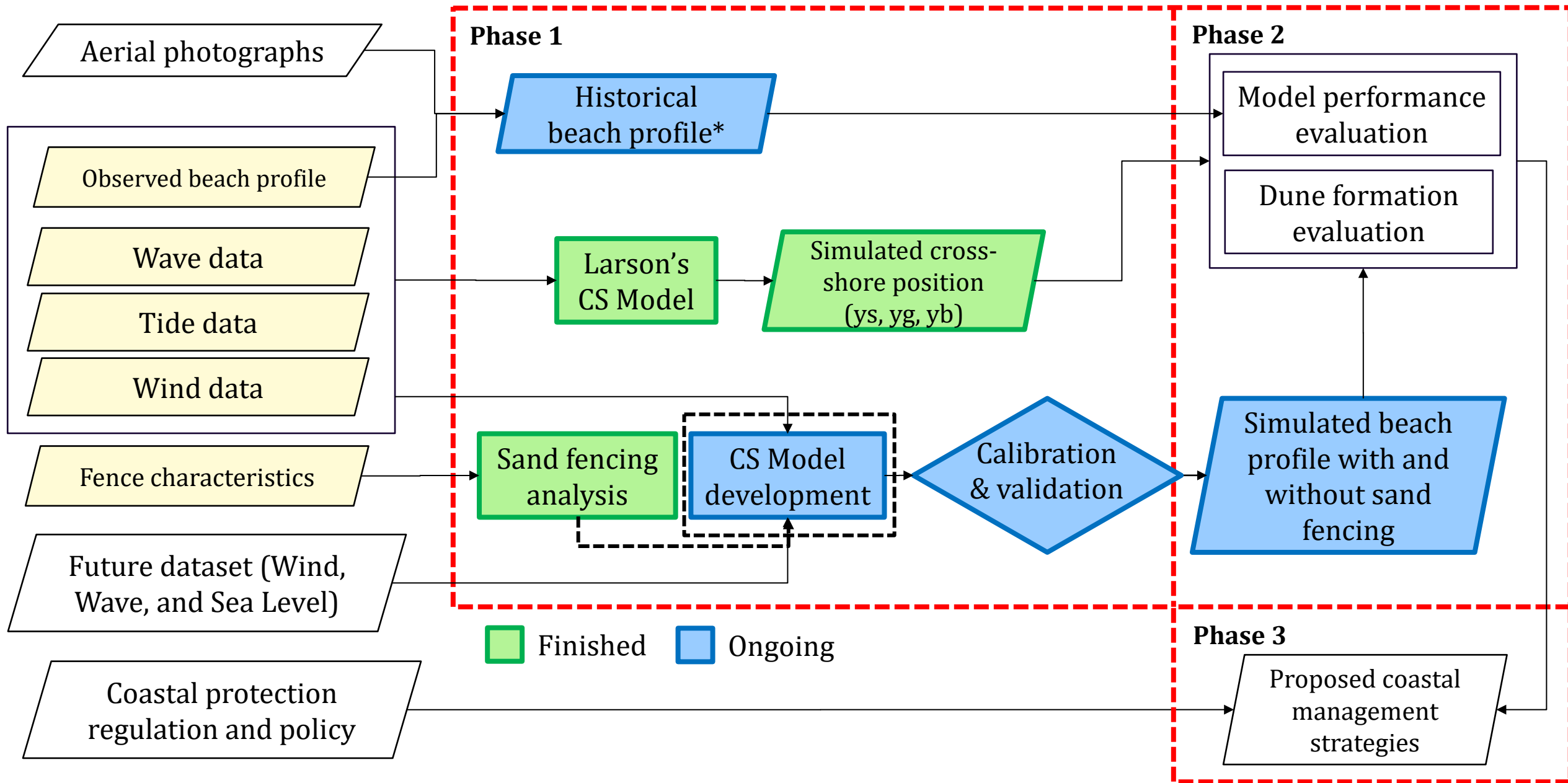
Objectives

Developing a beach profile model with **sand-fences** implementation to evaluate the evolution of coastal dunes over time and propose it as a **green infrastructure** for coastal protection.

- The Hasaki Beach is longshore uniform beach located along the eastern coastline of Ibaraki Prefecture and span about 16 km.
- The Hasaki Oceanographical Research Station (HORS) records beach profiles and other phenomenon for **almost 40 years**.



Source: (Google Earth Pro)



Data	Unit	Temporal Resolution	Spatial Resolution	Data	Source
Beach Profile	m	every weekday except weekend and weekly after 2011	5m	1986-2024	HORS
Wave Height	m	2-hourly	-	1982-2023	NOWPHAS (Kashima & Hitachinaka)
Wave Direction	°	2-hourly	-	1982-2023	NOWPHAS (Kashima & Hitachinaka)
Wind Speed	m/s	2-hourly	-	1991-2008	HORS
Wind Direction	°	2-hourly	-	1991-2008	HORS
Tide Height	m	Hourly	-	1982-2019	JMA (Choshi)
Sediment Dia.	mm	-	-	-	(Katoh et al. 1990)
Fence Character	-	-	-	-	HORS
Aerial Images	-	every 3-5 years	1200 dpi	1983-2012	GSI
Japan DEM	-	-	5m	After 2015	GSI



The use of Unmanned Aerial Vehicles (UAV) and Structure-from-motion (SfM) photogrammetry, allows the generation of high-resolution DSMs, making monitoring coastal dunes more **accessible**.



Several studies have been conducted to use **historical aerial photographs** to produce historical Digital Surface Models (hDSMs)
(Almonacid-Caballer et al, 2025, Mestre-Runge et al., 2023, Carvalho et al., 2020)



Applying SfM to coastal environments presents several challenges. Mainly due to their homogeneous texture, low contrast, and repetitive patterns, which can hinder accurate image matching and surface reconstruction
(Grohmann et al., 2020; Carvalho et al., 2021)

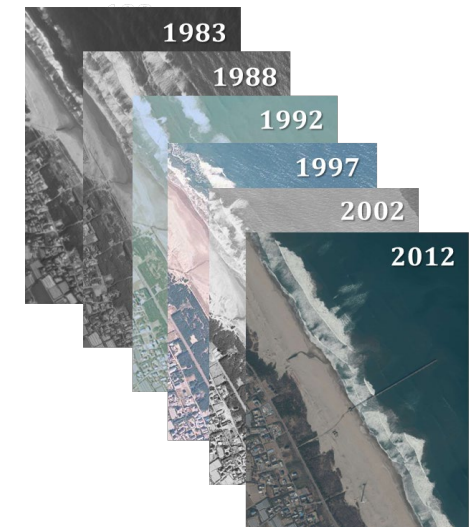


Objective

This research aims to evaluate the **accuracy of decadal-scale changes** in coastal dunes using historical aerial photogrammetry in a data-rich area.

Available Aerial Images in Hasaki

- 1983
- 1988
- 1992
- 1997
- 2002
- 2012

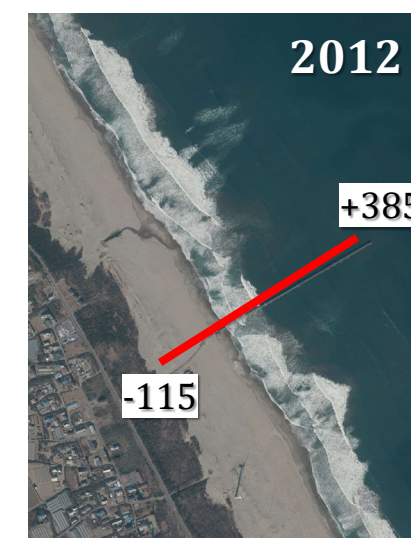
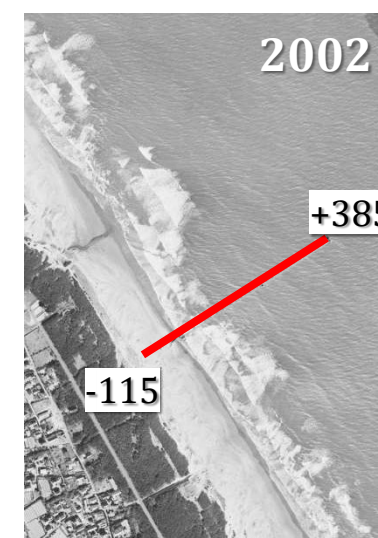
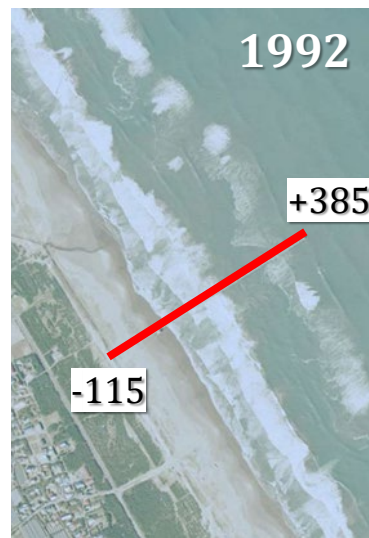
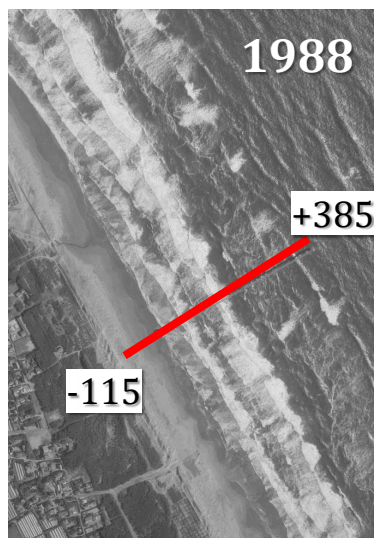


*Notes

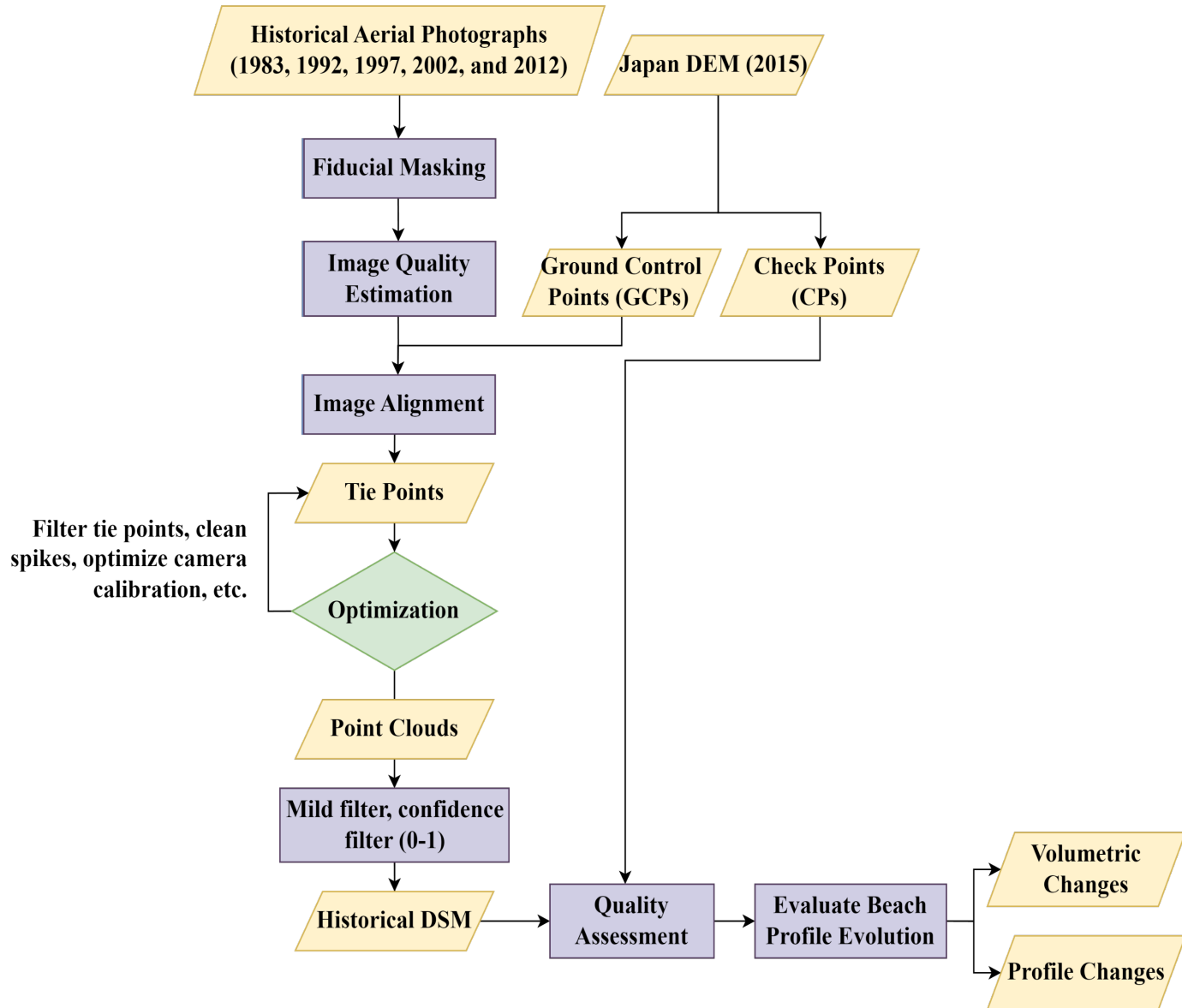
The following result used free available photographs. Higher-quality photographs have been purchased, and improvements are currently in progress.

Aerial images specification

Date of Photo	1983/06/02	1988/05/09	1992/10/10	1997/11/01	2002/10/29	2012/02/21
Shooting altitude (m)	3000	3000	3975	4700	4700	2739
Photographing Scale	1 : 20,000	1 : 20,000	1 : 25,000	1 : 30,000	1 : 30,000	1 : 10,000
Focal Length (mm)	152.54	151.80	153.04	153.75	153.75	100.50
Type	Monochrome	Monochrome	Colour	Colour	Monochrome	Colour

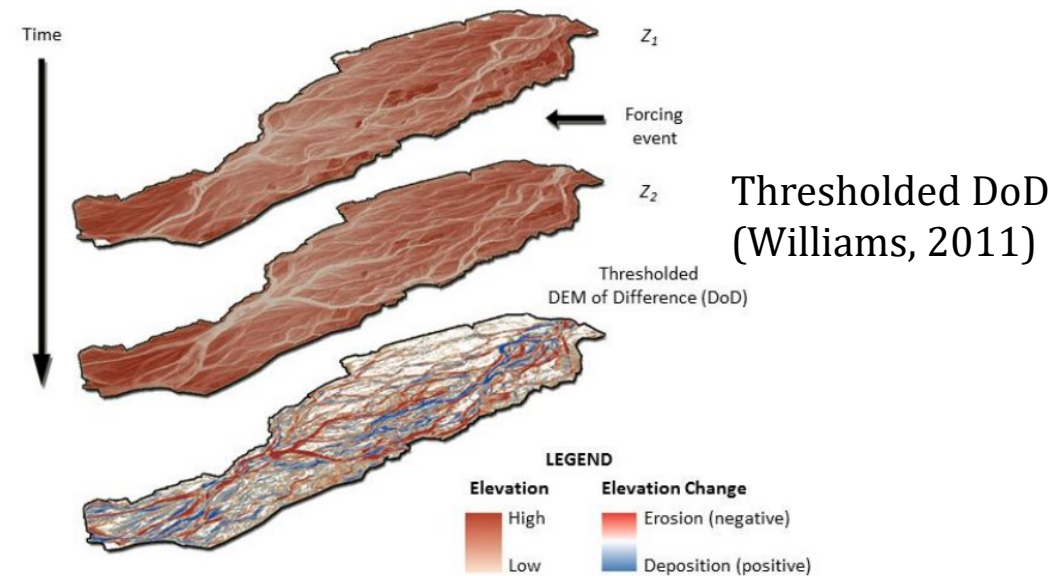


Structure from motion workflow



DEM of Difference (DoD)

Method for calculating terrain change by subtracting a DEM from a reference one, highlighting elevation differences (Williams, 2012).



$$Q_{in} - Q_{out} = \frac{\Delta V_{DOD}}{\Delta t}$$

$$\Delta V_{DOD} = \Sigma V_{Deposition} - \Sigma V_{Erosion}$$

$$LoD = \sqrt{\delta z_1^2 + \delta z_2^2}$$

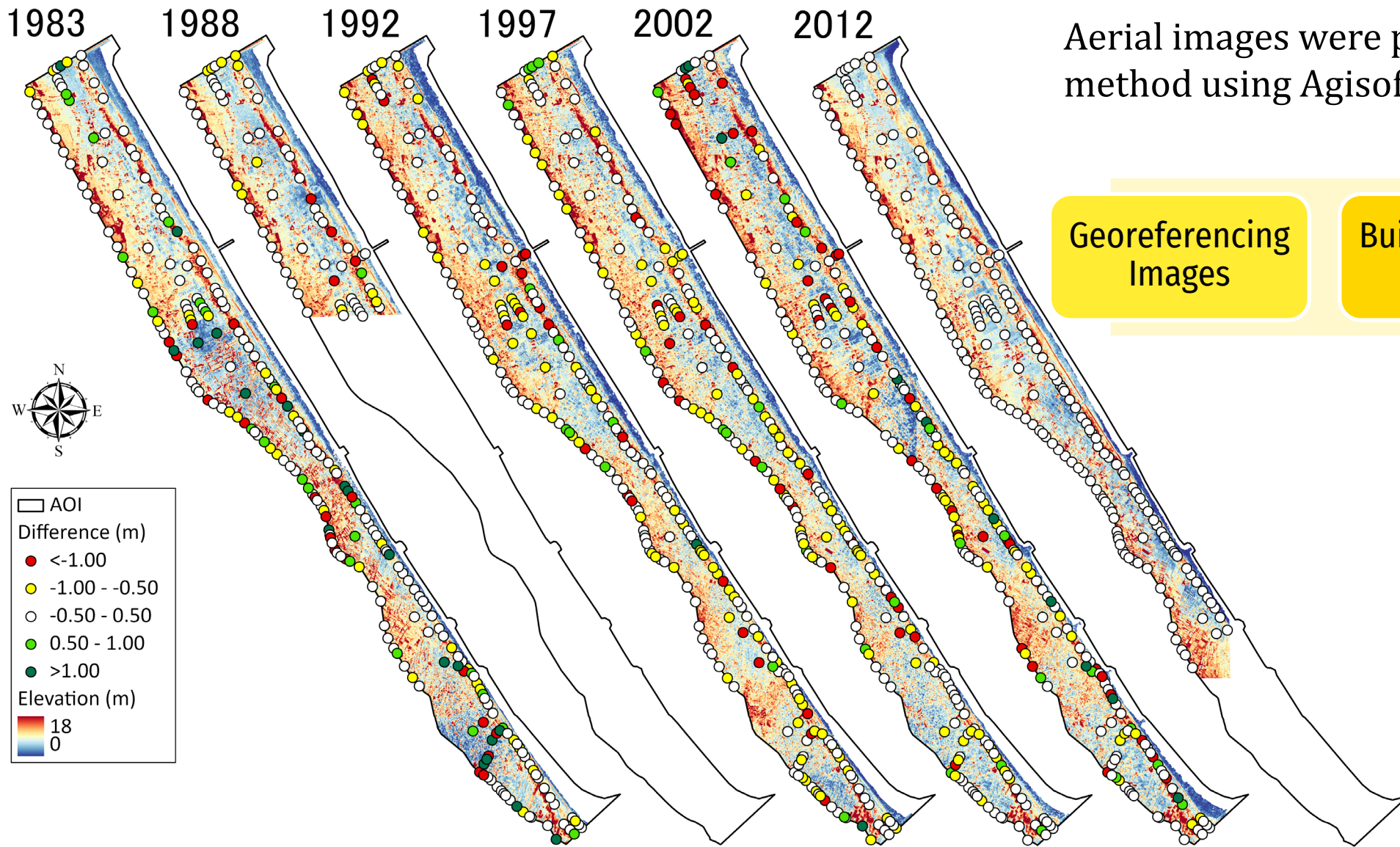


Aerial images were processed using SfM method using Agisoft Metashape software.

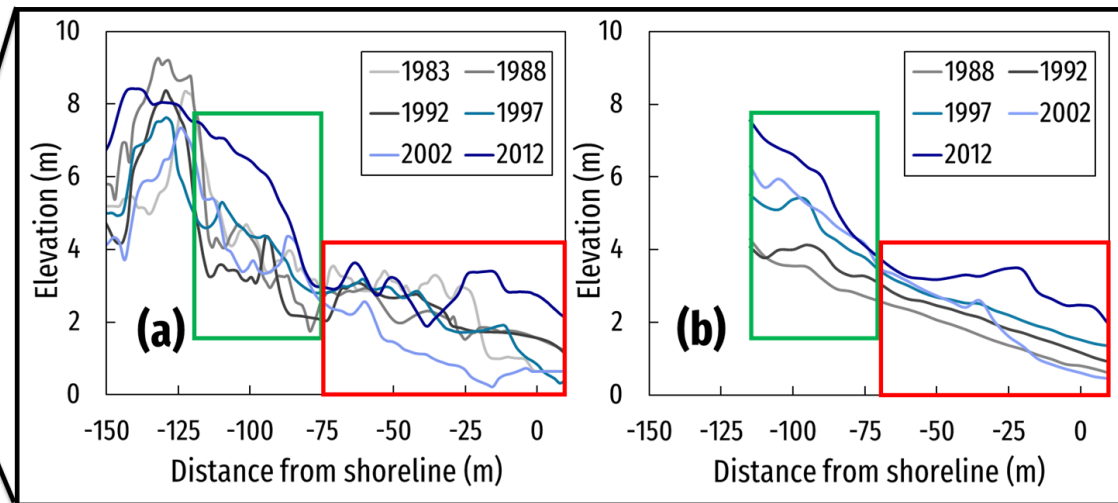
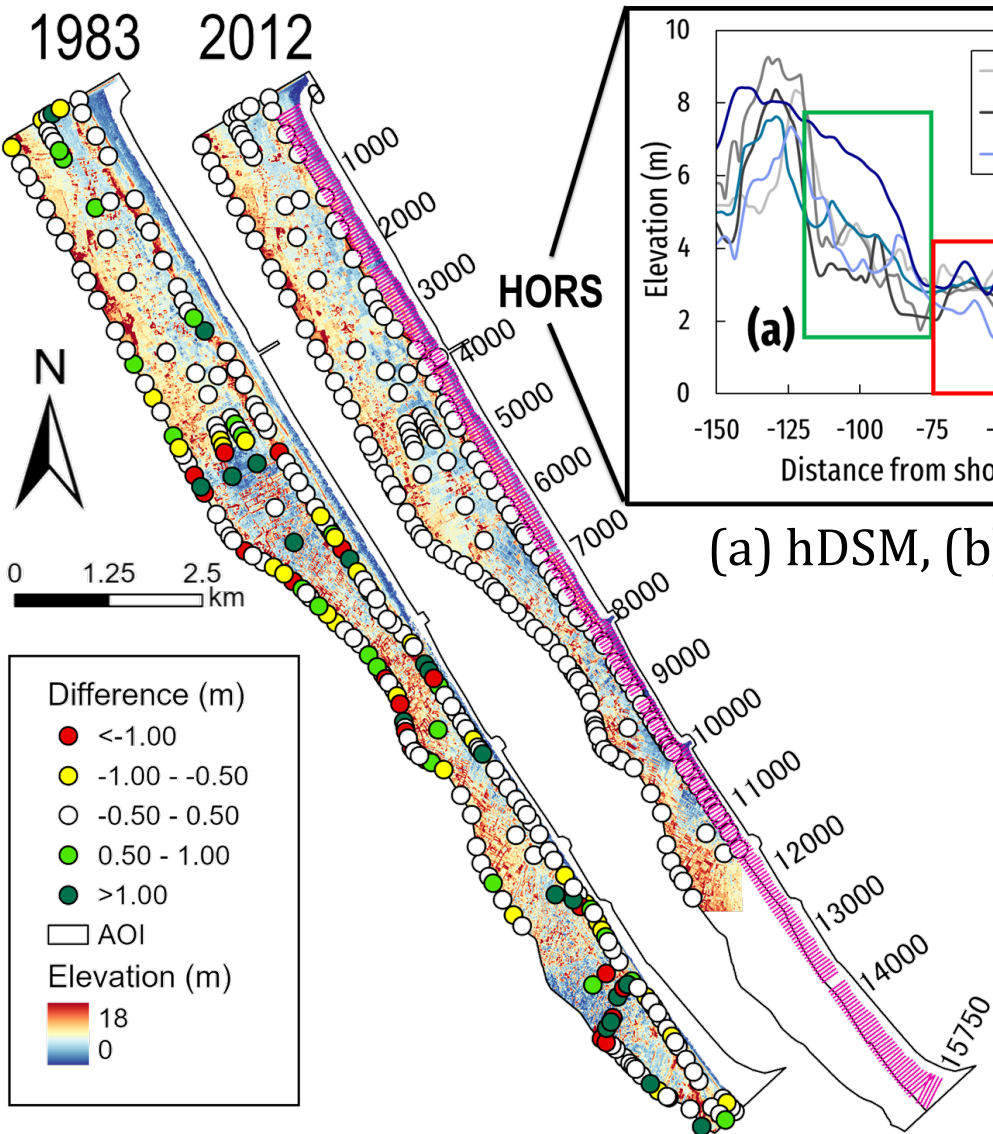
Georeferencing Images

Building Point Clouds

Building Digital Surface Model

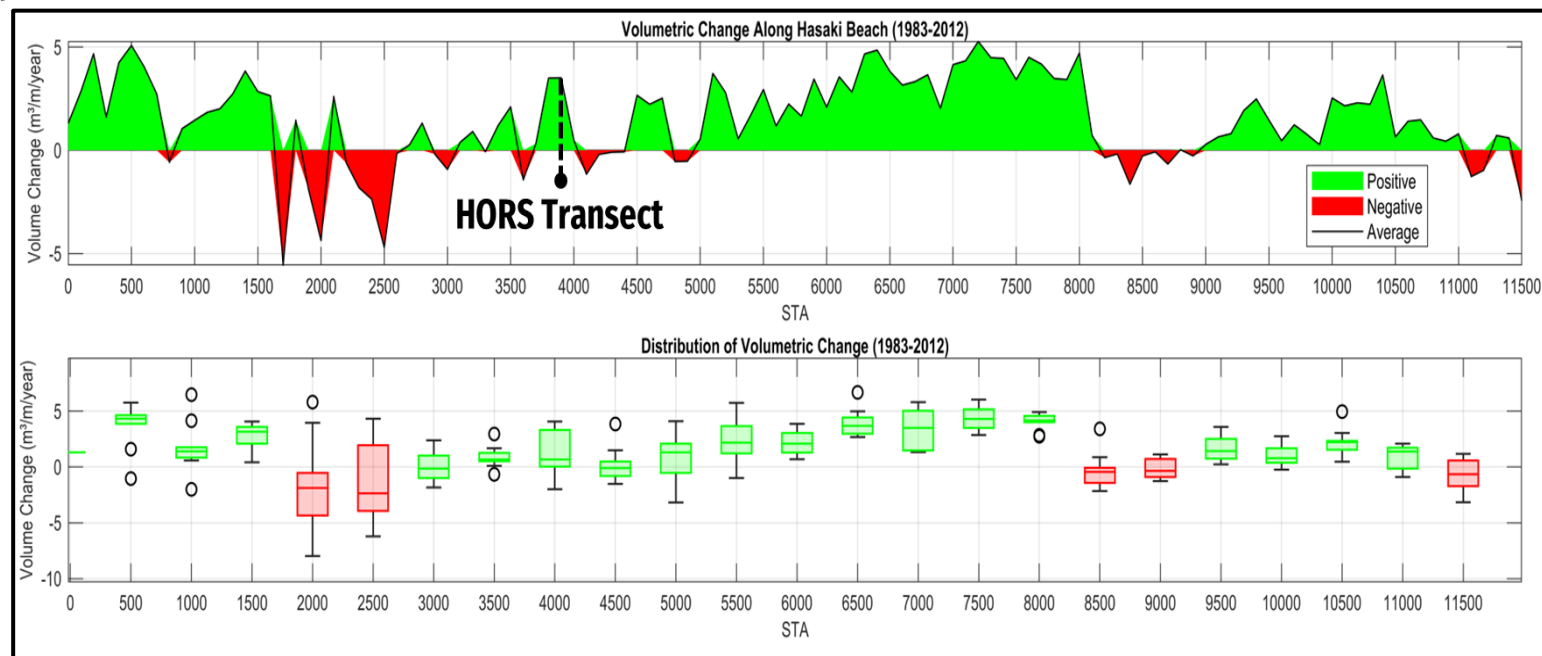


Year	RMSE (m)	MAPE
1983	0.81	12.20%
1988	0.47	7.91%
1992	0.61	10.48%
1997	0.61	9.86%
2002	0.86	13.97%
2012	0.08	0.99%



(a) hDSM, (b) HORS Observation

Year	RMSE (m)	MAPE
1988	0.47	17.05%
1992	0.80	26.33%
1997	0.64	14.31%
2002	1.23	37.53%
2012	0.60	12.54%



CONCLUSIONS

- The coastal dunes at Hasaki Beach show **overall growth**, as revealed by photogrammetry that captures spatial and temporal volumetric changes.
- Careful consideration of **management efforts** and events in the area is needed to better understand the reason for the volumetric changes.
- The accuracy of this method **varies according to the image characteristics, and the difference in elevation**. It shows better accuracy for undulating topography, and worse for flatter area.



The improved result of the profile will be used
to **support the HORS beach profile
observation data** for model development



**Thank you
for your attention**