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The State of the Art and Science of Coastal Engineering

Medium-Term Variation of Bar Movement and its Linkage to Wave Climate

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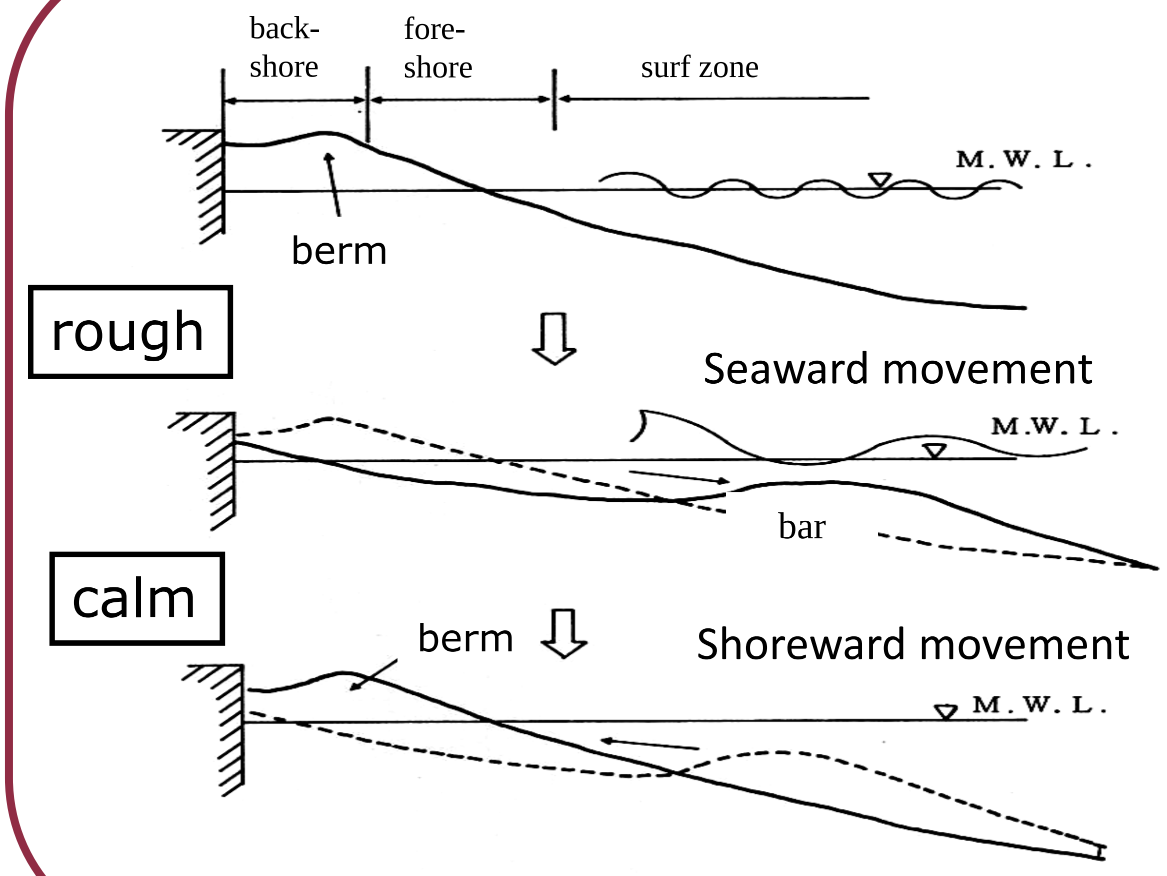
Introduction

- Longshore bars are a common site in sandy beaches which is influential on currents, morphology variations and also on the marine eco system.



- Longshore bar **reacts to the variation of environmental factors** and wave properties like
  - wave height
  - water depth
  - wave period and
  - wave skewness
- It tends to **move seaward or shoreward** while changing its amplitude.

3 Bar migration and linkage to wave climate - Related Studies

- Several studies have been conducted to investigate the **short-term bar migration** and **time-averaged bar migration** properties and their **linkage to wave climate**
- However, only **few studies** have been conducted to investigate **the medium term or long-term bar migration** properties in the **scale of several months to several years** and **their linkage to wave climate**.

Bar migration properties and their linkage to wave climate

Short term (Scale of months)

- Seaward bar migration was **triggered** when **wave height to water depth ratios** are **large** (Sellenger et al.,1985)
- **shoreward migration** of the bar is caused by **shoreward velocity skewness, low undertow velocity and acceleration skewness** (Miller et al, 1990)
- influence of the **wave breaking** on the seaward **bar migration** is **small** (Howd, 1990)

Medium term (Scale of years)

- **bar migration to the equilibrium position** is related to the **largest wave** (Plant et al, 1999 16-year data at Dunk in the United states)
- **bar migration frequency** has **no correlation** with the **bar crest position**, but **weak correlation** with the **bar amplitude** and the **offshore wave energy flux** (Kuriyama et al, 2008 15 years data at Hasaki coast, Japan)

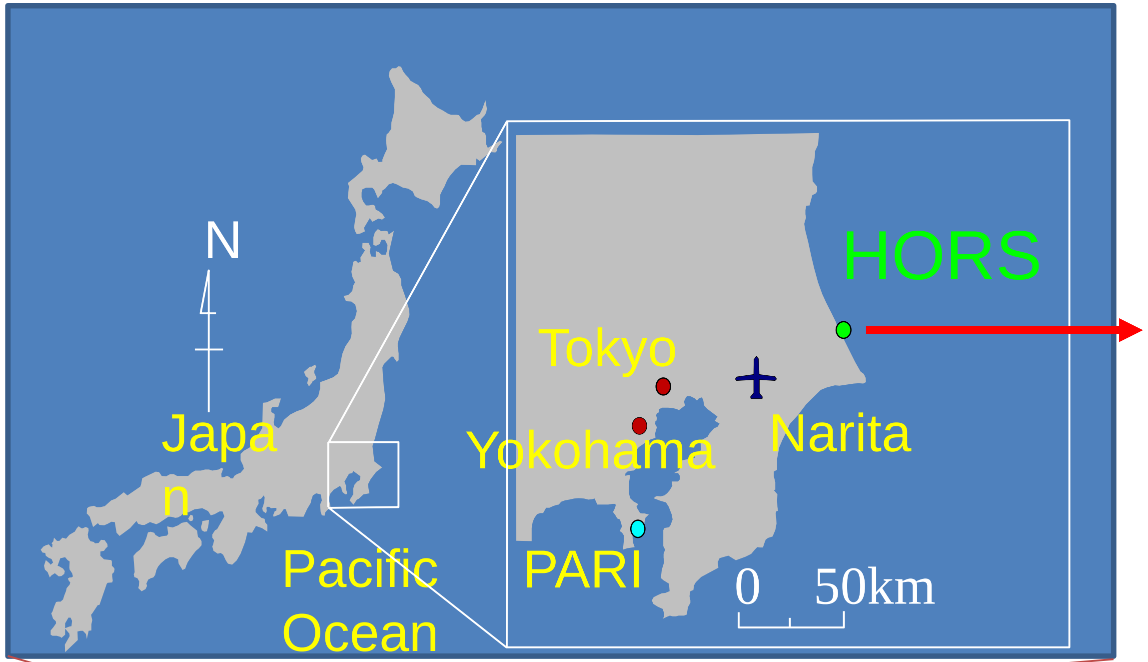
Scope of work

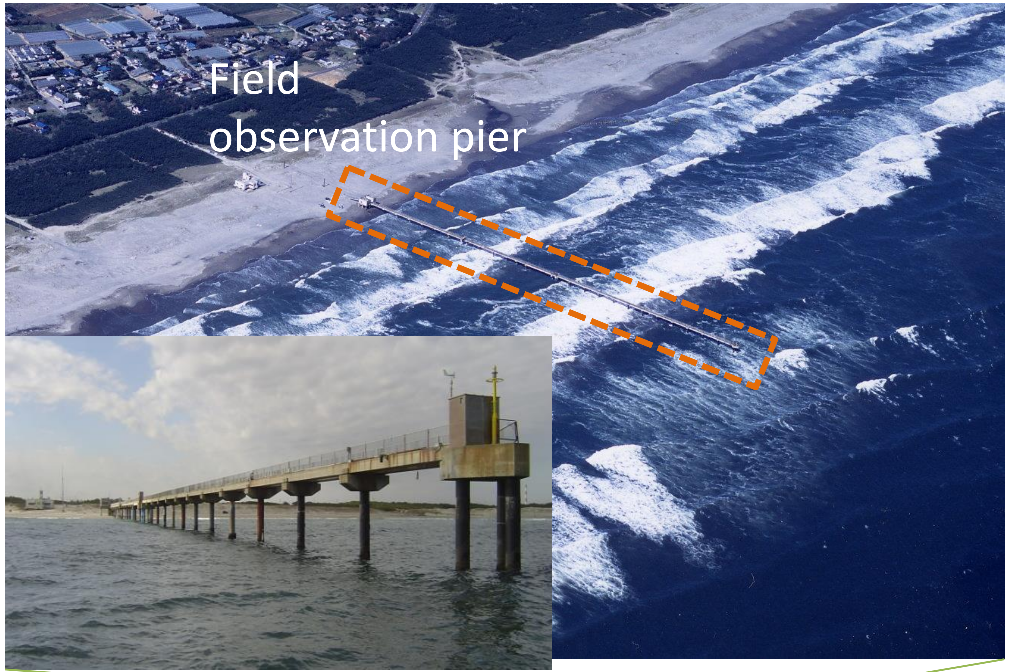
In the present study,
medium-term variations of bar position and bar migration rate and their linkages with environmental factors/wave climate was investigated using the Complex Empirical Orthogonal Function (CEOF) analysis, spectral analysis and beach profile data obtained almost every week for 28 years along a 427-meter-long pier on the Hasaki coast of eastern Japan.

New Data

Different approach

Site and data description





Location

The beach profiles measured at the Hasaki coast which is located in Japan facing the Pacific Ocean

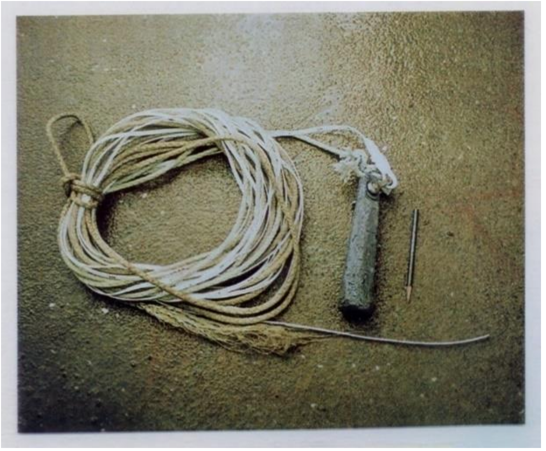
Beach properties

- The median sediment diameter of the area is 0.18 mm
- High, mean and low water levels are 1.25 m, 0.65m,and −0.20m, respectively
- Beach profile is almost uniform alongshore

Beach profile measurements

The 427-m long field observation pier of Hazaki Oceanographic Research Station (HORS) was used to measure the beach profiles

Site and data description



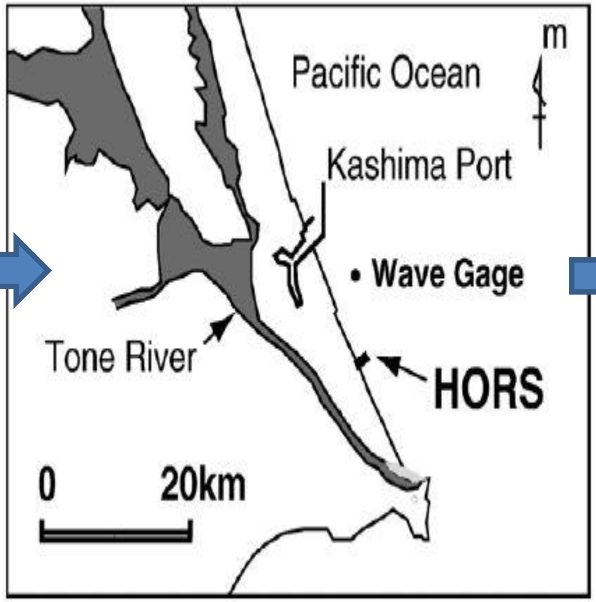
Beach profiles measuring technique and frequency

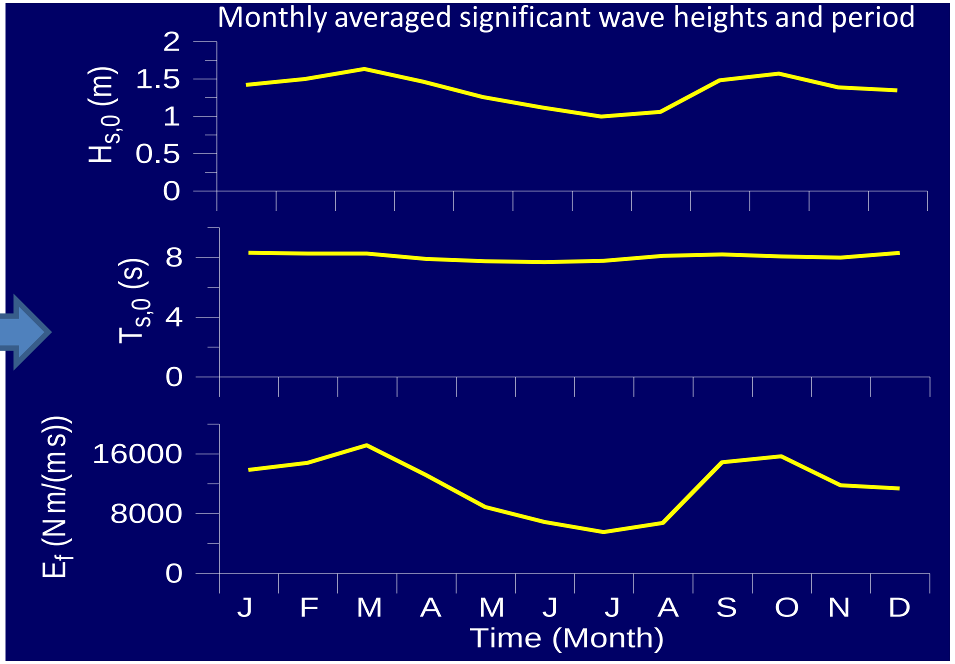
Beach profiles at every 5-m interval using a rope with graduated depth making and a 5-kg lead from the pier once a week from March 1986 to November 2014

Wave height measurements

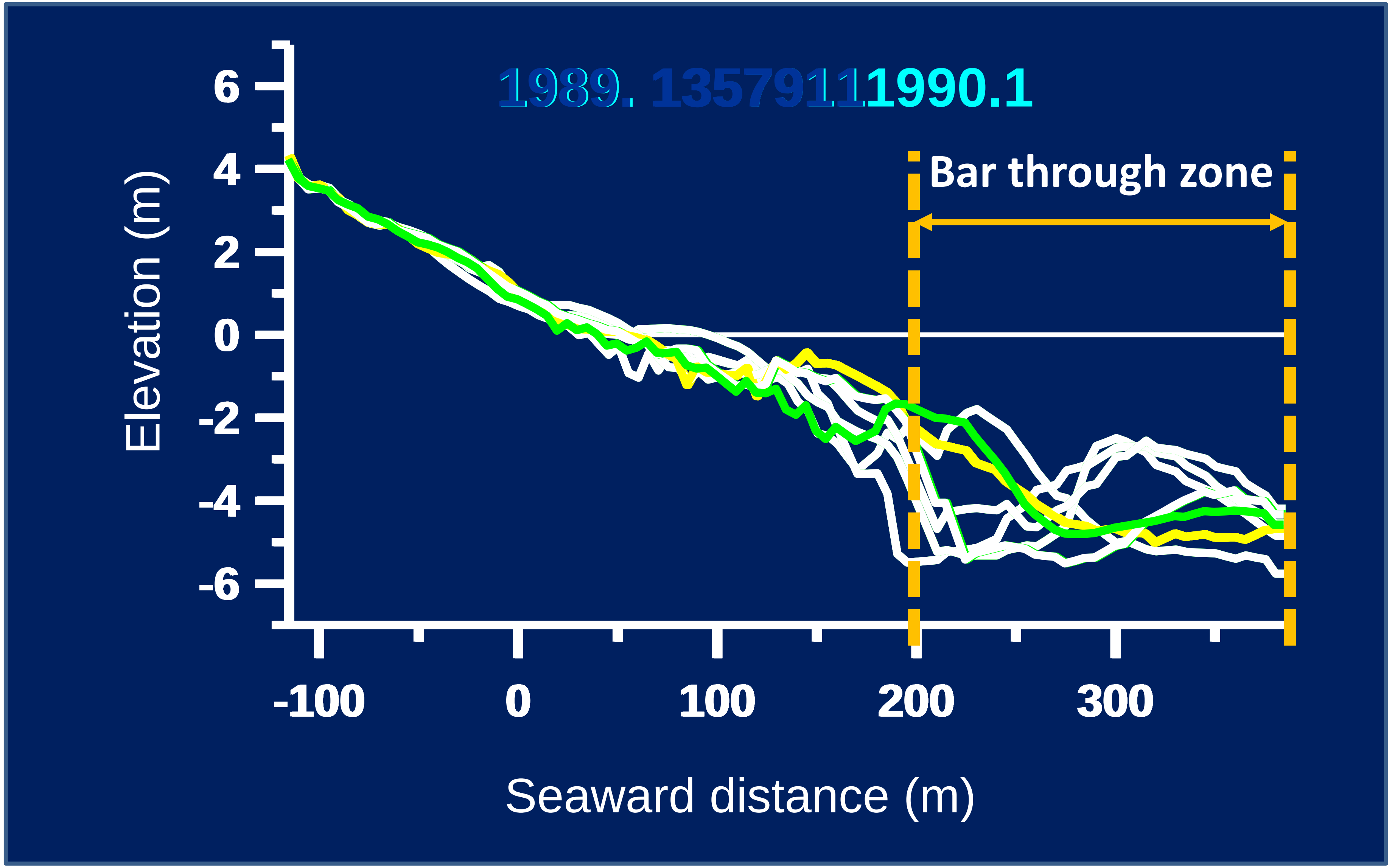
Deepwater waves were measured at a water depth of about 24 m with an ultrasonic wave gage for 20 min every 2 h throughout the investigation period

Location of wave height measurements

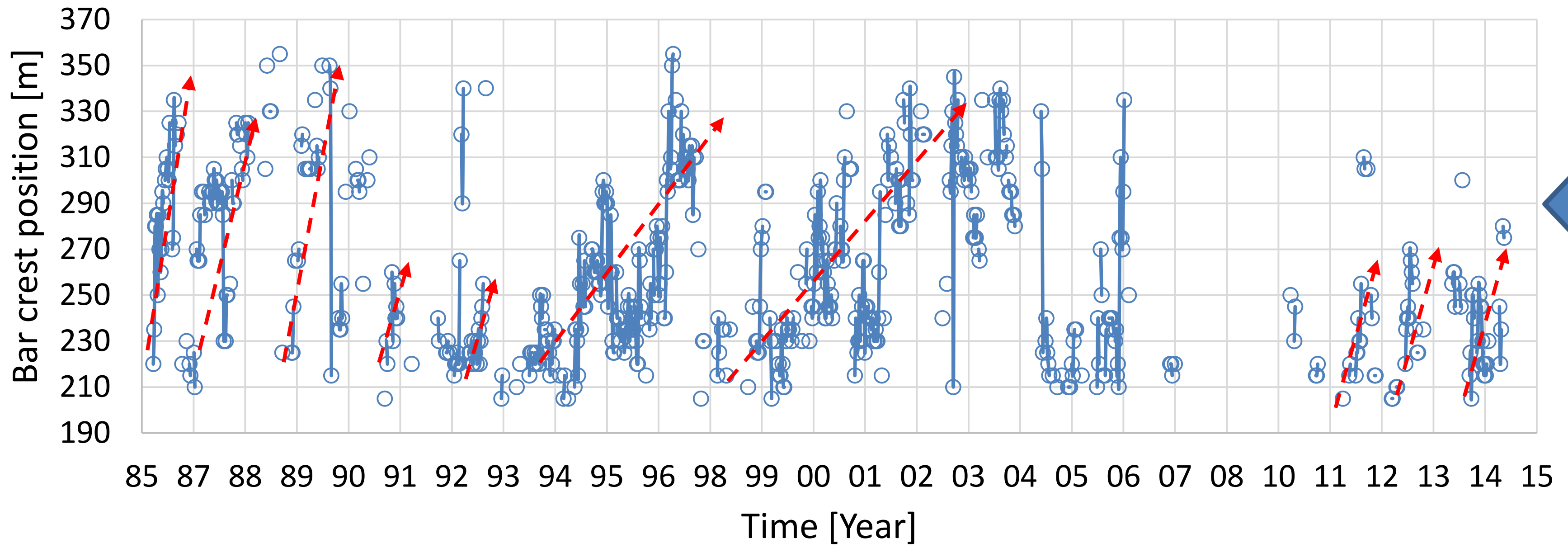




Seaward movement of the bar



Variation of bar crest position



Bar crest variation in the bar-trough zone (the seaward distance is from 205m to 400m)

- Most of the time during the **observed 28 years** bar movement is in the **seaward direction**.
- **Up to 1993** the bar moved **seaward** with a duration **time of about 1 year**. After that, apart from the minor fluctuations, **seaward bar migration** can be seen with a duration **time of about 5 years** up until 2004.
- **After 2006** relatively **small seaward bar migration** was observed with a **duration time of 1 year**.

Empirical Orthogonal Function analysis

Spatial variation of the deviation

$$z = [z_1 \quad z_2 \quad \dots \dots z_p] = \begin{bmatrix} z_1(1) & z_2(1) & . & z_p(1) \\ z_1(2) & z_2(2) & . & z_p(2) \\ . & . & . & . \\ . & . & . & . \\ z_1(n) & z_2(n) & . & z_p(n) \end{bmatrix}$$

Temporal variation of the deviation

Spatial and Temporal variation of deviation of beach profile from the mean ($n \times p$)

- The covariant of matrix is $p \times p$ symmetric $\widehat{C_{zz}} = \frac{1}{n-1} z^T z$
- An eigen decomposition of a square matrix is always possible

$\widehat{C_{zz}} = U\Gamma U^T = \sum_{k=1}^{k=p} \gamma_k U_k U_k^T$ Where; U – eigen vector ($1 \times n$)

- Calculation of principle components

$$\mathrm{A} = \mathrm{zU} \ (n \times p \text{ matrix})$$

- In conclusion, the data matrix of size $n \times p$ can be re written as a sum of p modes. In other words any observation at location j at time step n is the sum of p terms

$$z_j(n) = \sum_{k=1}^{p} A_k(n) U_{jk}$$

Complex Empirical Orthogonal Function (CEOF) analysis

- To analyze available data **meaningfully** Complex Empirical Orthogonal Function (CEOF) analysis was applied. **The results of this analysis were used to relate bar crest position and wave conditions**

Complex Empirical Orthogonal Function (CEOF) analysis was applied to decompose the complex deviation

Any connection with bar migration properties???

$$Z(x,t) = z(x,t) + i\hat{z}(x,t)$$

$$Z(x,t) = \sum_n (C_{nr}(t) + iC_{ni}(t))(e_{nr}(x) - ie_{ni}(x))$$

$$\varphi(t) = \arctan\left(\frac{C_{nr}(t)}{C_{ni}(t)}\right)$$

Complex deviation *Z(x,t)* from the mean beach profile.

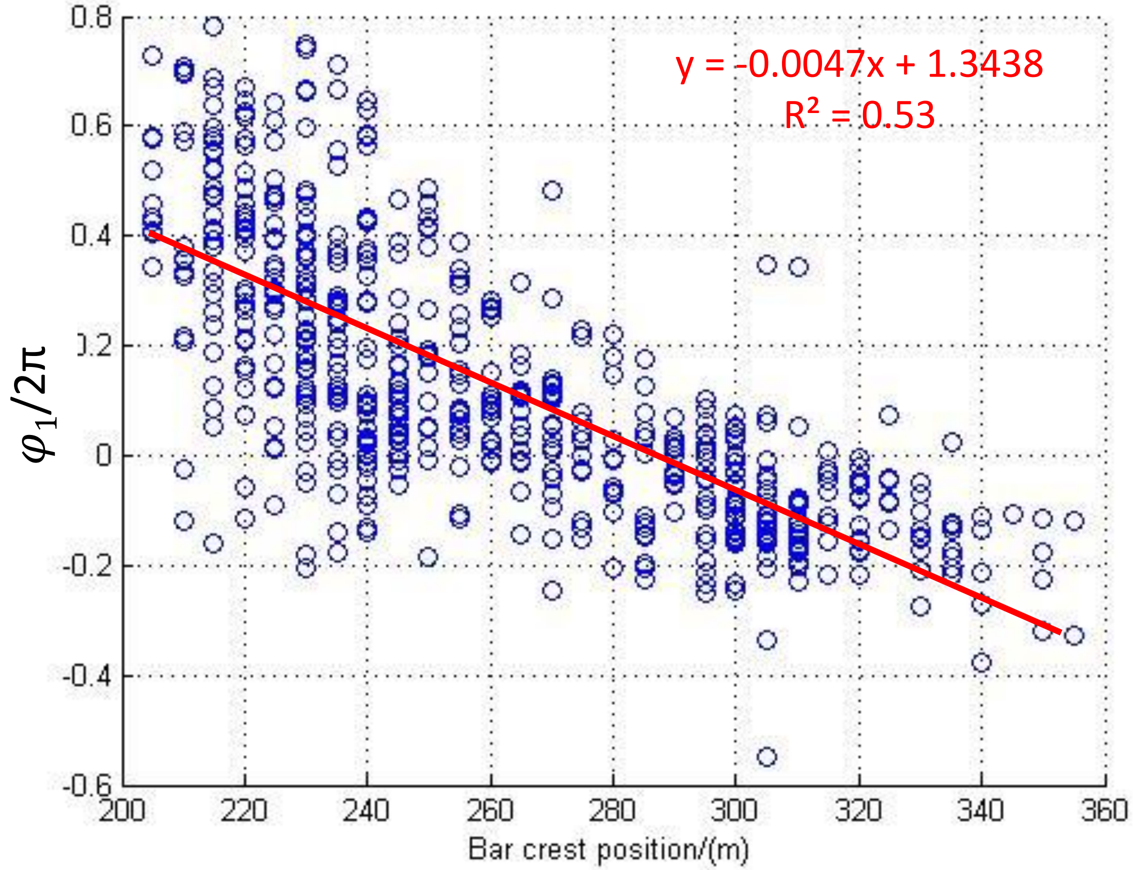
z(x,t)- deviation from mean beach profile

$\hat{z}(x,t)$ – Hilbert transformation of *z(x,t)*

$C_{nr}(t)$ and $C_{ni}(t)$ – real and imaginary parts of the complex temporal coefficient

The value of $\varphi(t)$ express the temporal variation phase of the elevation change (first mode)

Bar migration rate

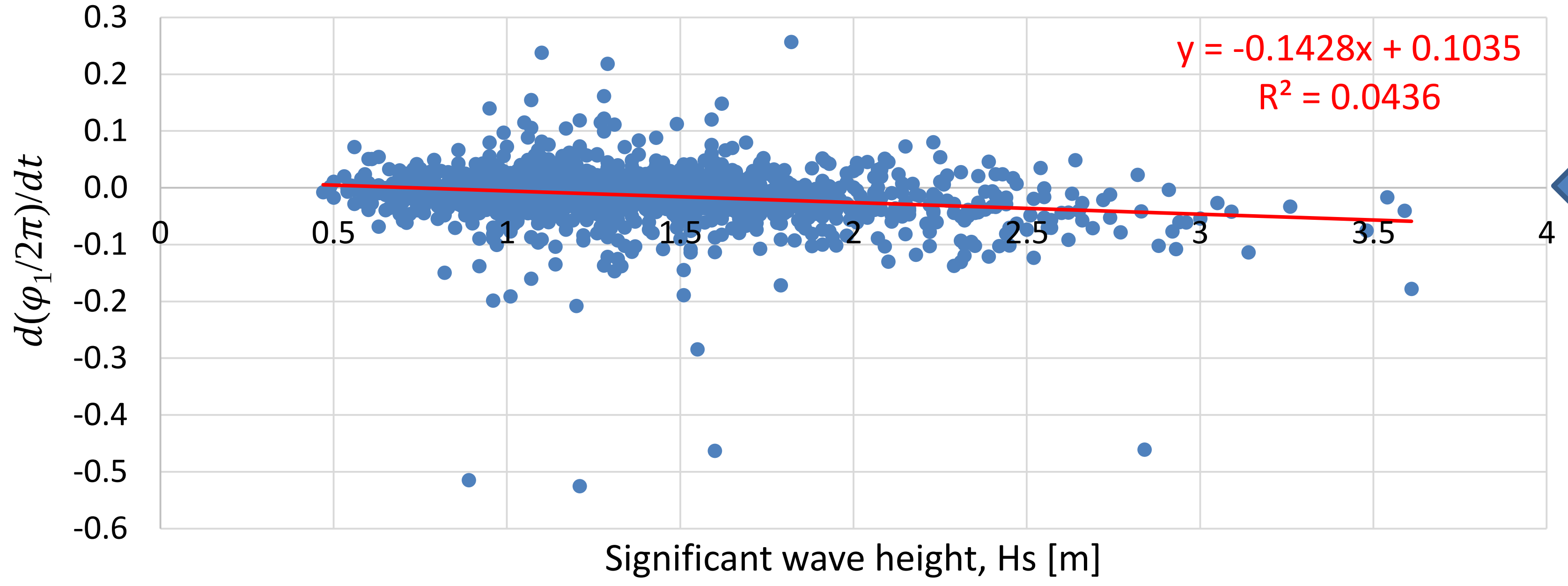


Temporal variation phase of the elevation change (φ_1) vs Bar crest position

- Strong correlation between temporal variation phase of the elevation change ($\varphi_1/2\pi$, from the first mode) and bar crest position can be observe
- This result indicates that $\varphi_1/2\pi$ represents a surrogate for the bar crest position, and $d(\varphi_1/2\pi)/dt$ represents the bar migration rate (duration time of the bar migration cycle)
- The seaward bar migration is represented by a negative value of $d(\varphi_1/2\pi)/dt$

Linkage between bar behavior with wave climate

Linear Regression Analysis

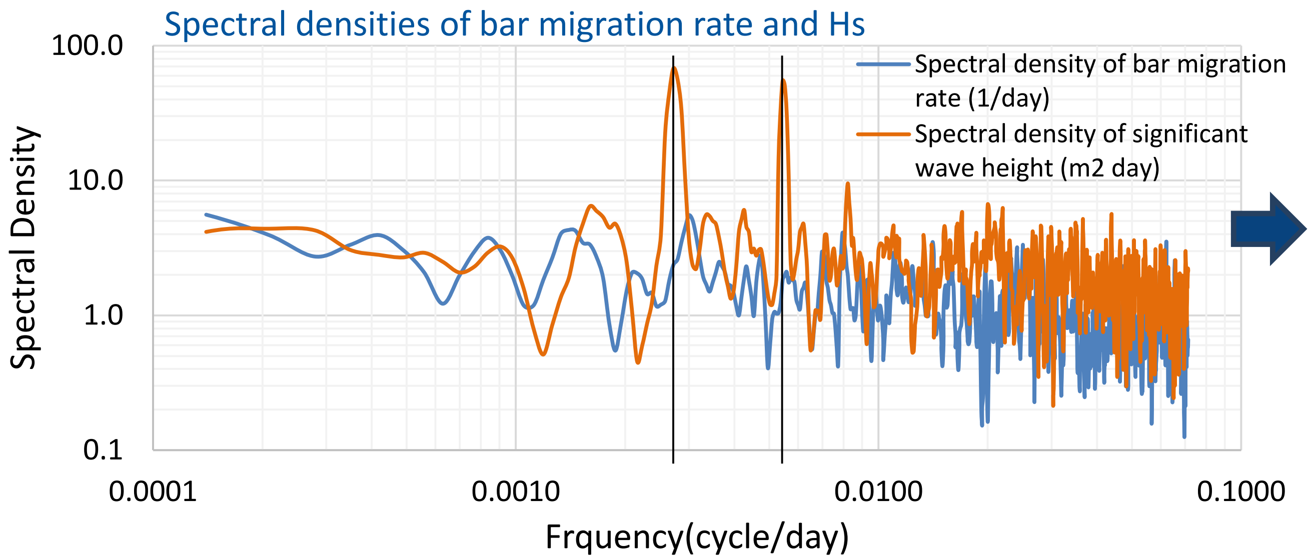


The correlation between the bar migration rate $d(\varphi_1/2\pi)/dt$, and H_s representing the weekly averaged significant wave height

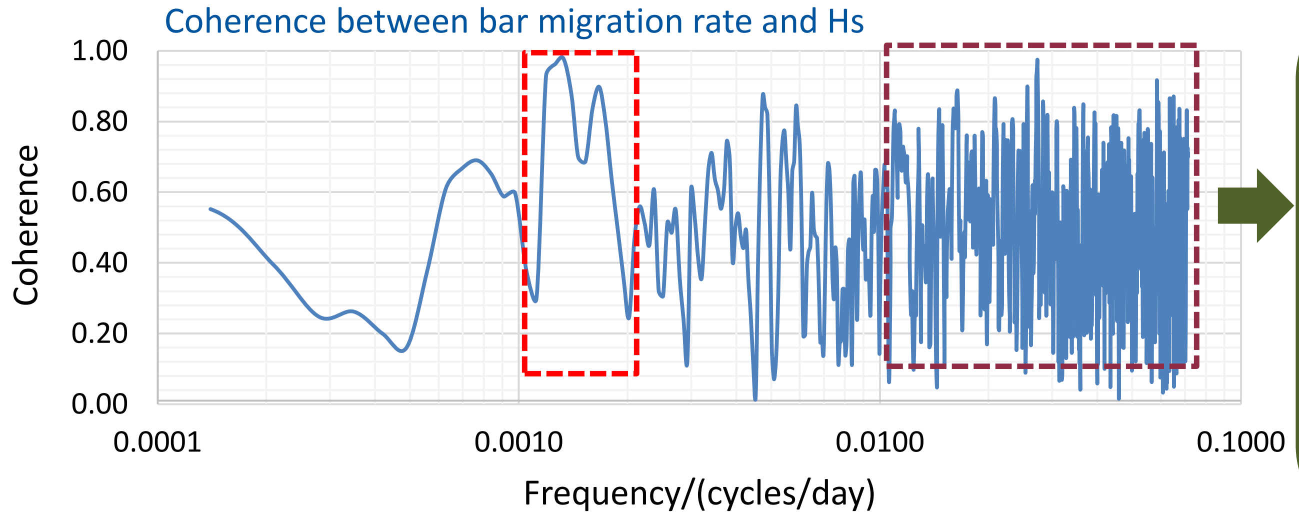
- **Pearson's correlation coefficient** between two variables = -0.209 (-1 being the perfect correlation) **weak negative correlation** with **significant wave height,** H_s considering all 28 years data
- This result indicates **that seaward bar migration rate** increases with increasing wave height

Linkage between bar behavior with wave climate

Cross spectral analysis



- Spectral analysis shows that the temporal variation of **bar migration rate** has **no significant peaks**
- Temporal variation of H_s **has peaks at about 1 year** (f=0.002 cycle/day) and **about 6 months** (f= 0.0045 cycle/day)
- Spectral densities of both H_s and bar migration rate are relatively small in high frequencies.



- From the **coherence between** H_s and bar migration rate, **high correlation** can be seen between **f= 0.0007 and 0.0015 cycle/day**.
- Majority of **short period components** (periods with less than 100 days) show **coherence values as high as 0.8**, even though the coherence value changes radically in high frequencies.

Conclusions

- **Seaward movement** of the bar was observed in the most of the time **during observed 28 years**

- **From the CEOF** analysis, it was found out that $\boldsymbol{\varphi_1(t)}$ **is a good representative** of **bar crest position** and thus **seaward bar migration rate** can be represented by $\boldsymbol{d(\varphi_1/2\pi)/dt}$

- **Bar migration rate** $\boldsymbol{d(\varphi_1/2\pi)/dt}$ does **not** have a **strong correlation** with **significant wave height (H_s)** at Hasaki coast

- **Cross spectral analysis** shows that the majority of **short period components of H_s** and **bar migration rate** have **high coherence** values indicating the possibility of a **linear relationship** between short period components of H_s and bar migration rate

Thank you very much