Dominant Wave Height Estimation Based on Spectral Analysis for Coastal Erosion Monitoring System in Real Time

28 November 2023

18th iSAI-NLP-AIoT

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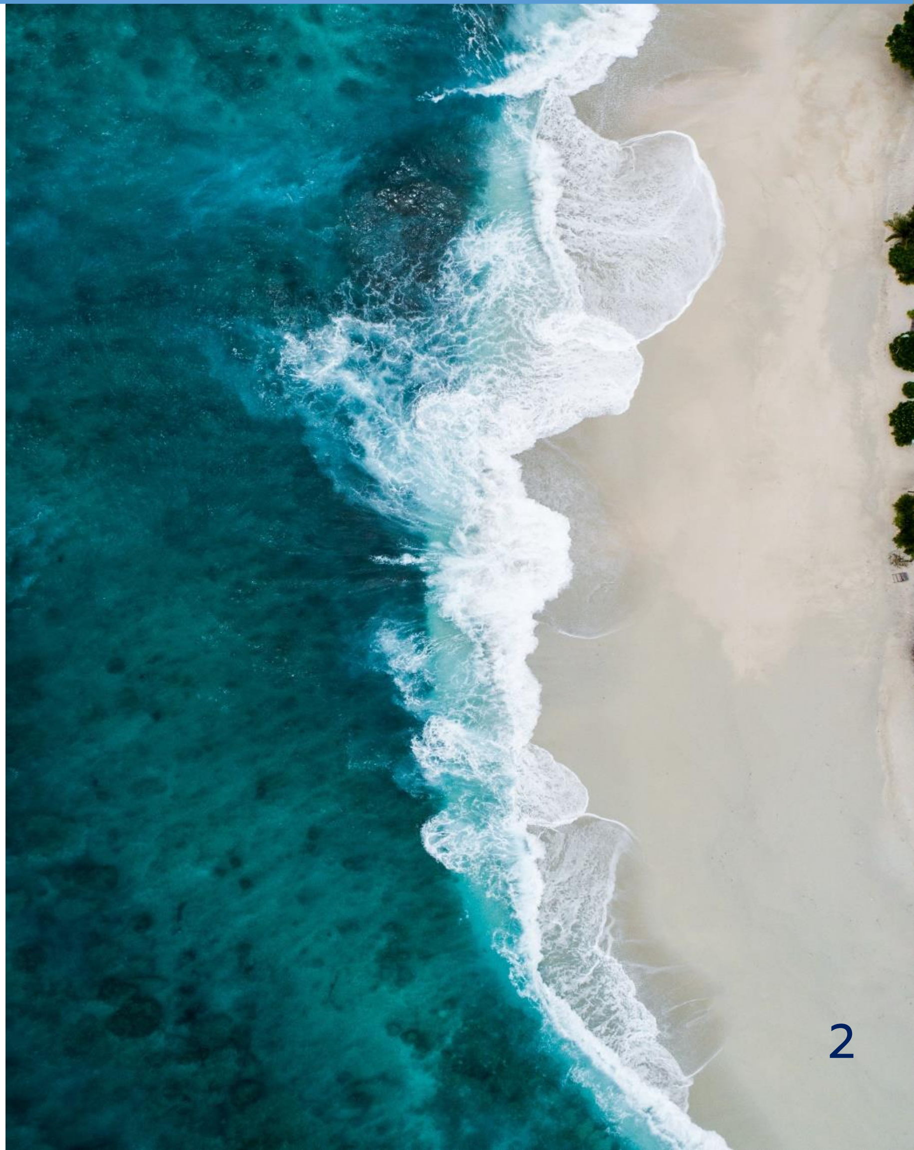
Background

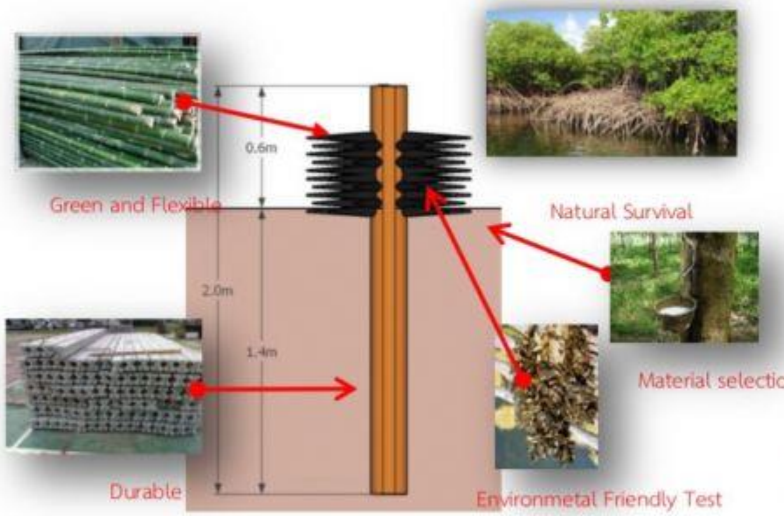
- 10% of world's population lives in coastal areas less than 10 meters above sea level and 40% lives within 10 km of the coast.
- 70% of sandy beaches are retreating.
- Thailand has a coastline of around 3,000 km long, and many communities along the shores experience the coastal erosion problem.



Coastal Erosion

- Loss or displacement of land along the coastline due to the action of wind, wave, currents, tides, wind-driven water, waterborne ice, runoff of surface waters, storm, groundwater seepage, etc.
- Breaking waves release their energy, creating turbulent water. The turbulence disturbs the bottom sediments, and the moving water of the broken wave can then move those sediments.

Countermeasure



C-Aoss

ชั้นระดับการ
ตกตะกอน
ที่หนาแน่นมาก

Bamboo fend

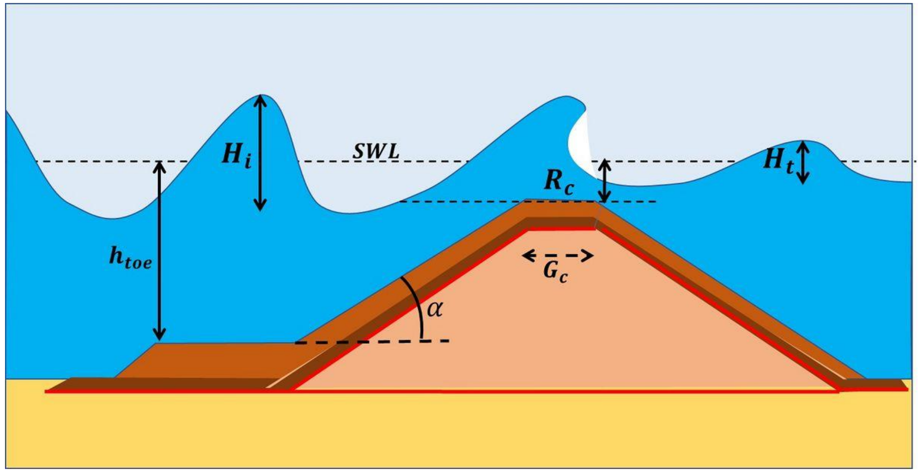
Breakwater

Image Source: DMCR, NSTDA

Wave Transmission Coefficient

NECTEC a member of NSTDA

Wave transmission over a submerged breakwater at Mandara beach, Alexandria (Egypt). The yellow arrows indicate the location of rip currents.



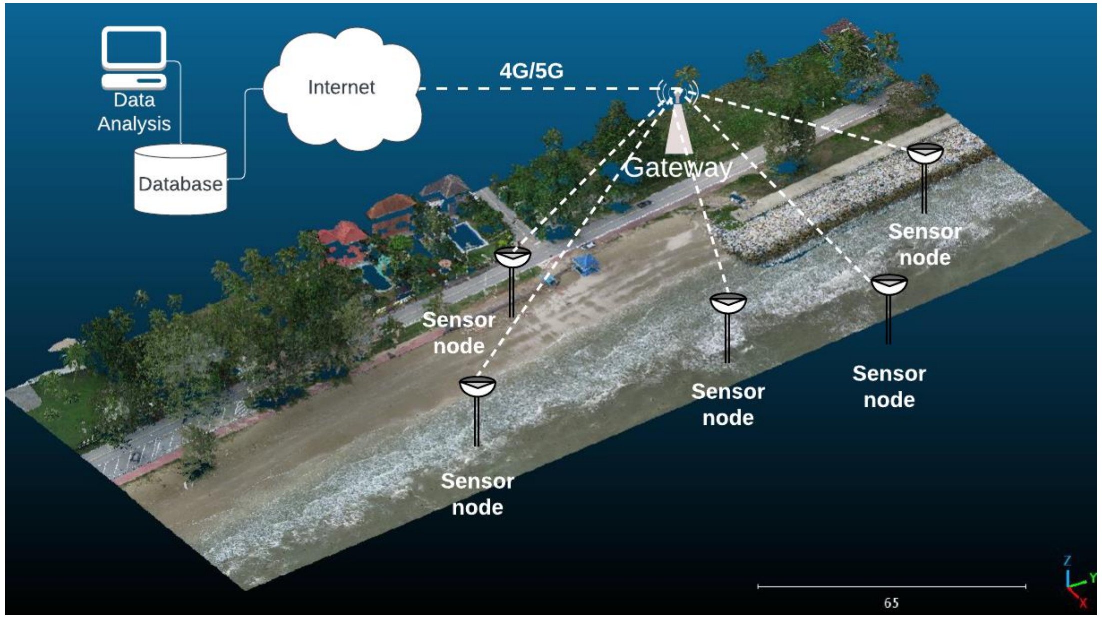
Transmitted wave

$$K_t = \frac{H_t}{H_i}$$

Incoming wave

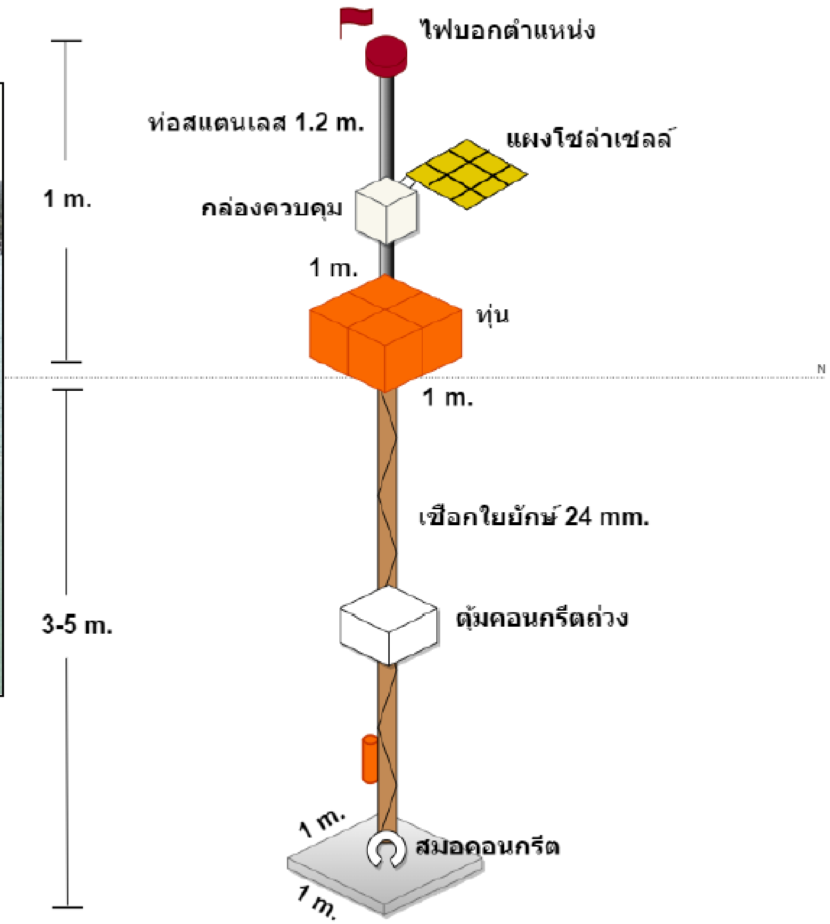
Image Source: coastalwiki.org

WSN



Data Analysis
Database
Internet
4G/5G
Gateway
Sensor node
Sensor node
Sensor node
Sensor node
Sensor node
65

OPPO A53



ไฟบอกตำแหน่ง
ท่อสแตนเลส 1.2 m.
แผงโซล่าเซลล์
กล่องควบคุม
1 m.
1 m.
ทุ่น
1 m.
เชือกใยยักษ์ 24 mm.
ตุ้มคอนกรีตถ่วง
3-5 m.
1 m.
สมอคอนกรีต
1 m.

Weather station + CCTV

สถานีวัดสภาพอากาศ หมายเลข 1

วิสาหกิจชุมชนประมงเรือเล็กเก้ายอด
ต.ปากน้ำ อ.เมืองระยอง จ.ระยอง

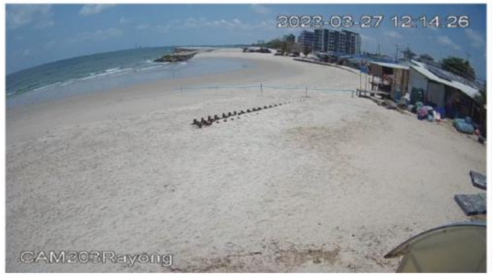
สถานีวัดสภาพอากาศ หมายเลข 2

ฟาร์มทะเลตัวอย่างในสมเด็จพระนางเจ้าสิริกิติ์ พระบรมราชินีนาถ บ้านดอนช่องแคบ ต.บางแก้ว อ.บ้านแหลม จ.เพชรบุรี

Time	Temperature	Humidity	Light	Rain Guage	Wind Speed	Wind Direction	Max Wind Speed	Wind Level
06-Mar-23 15:29	29.7 °C	59.2 %H	61634 lux	0 mm	3.5 m/s	169 °	6.3 m/s	3
06-Mar-23 15:24	30.0 °C	60.3 %H	63745 lux	0 mm	3.7 m/s	167 °	6.3 m/s	3
06-Mar-23 15:19	30.0 °C	59.3 %H	65126 lux	0 mm	3.7 m/s	187 °	6.3 m/s	3

มุมมองภาพ

จุดติดตั้งที่ 3 รัฐวิสาหกิจชุมชนประมงเรือเล็กเก้ายอด จ.ระยอง
ละติจูด 12°39'44.26"น ลองจิจูด 101°14'55.07"ตะวันออก



มุมมองภาพ

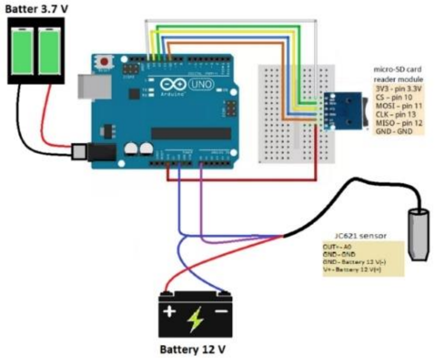
จุดติดตั้งที่ 4 รัฐวิสาหกิจชุมชนประมงเรือเล็กเก้ายอด จ.ระยอง
ละติจูด 12°39'45.32"น ลองจิจูด 101°14'51.69"ตะวันออก

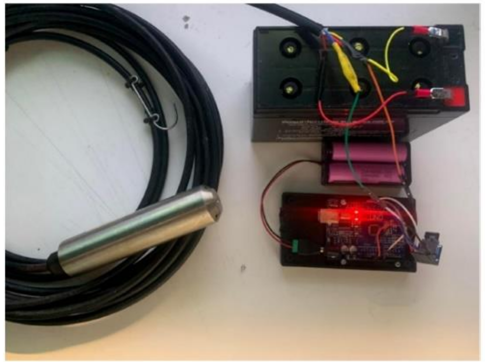
Objective

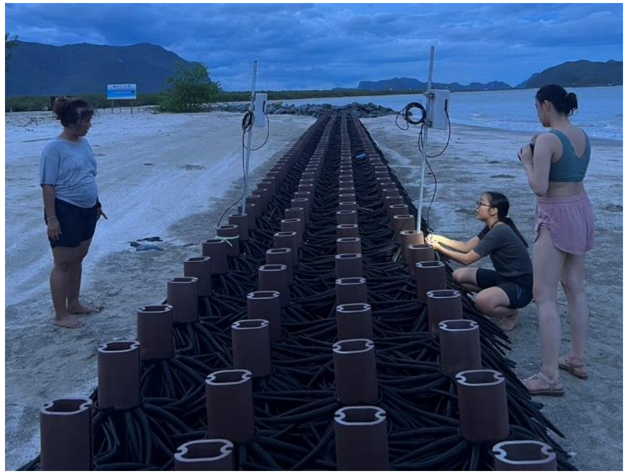
- To develop a sensor node that monitors the water surface level in real-time or near-real-time and to estimate the dominant wave height (spectral wave height) from time series data

Data Collection

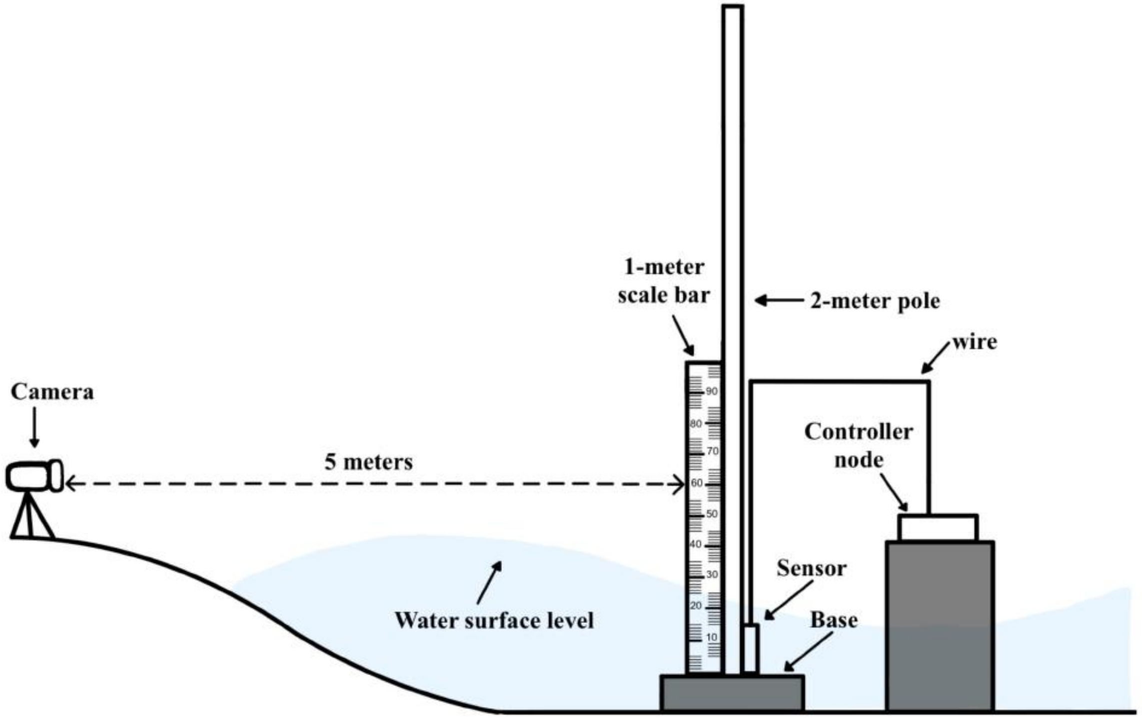
- ❑ 29 June 2023, @Khao-Sam-Roi-Yot national park, Pachuapkhirikhun province
- ❑ Sampling = 28 Hz (i.e., 1,680 datapoints/minute)
- ❑ 35-minute time series (segmented into 35 1-minute time series)
- ❑ VDO frame rate = 25 frames/second



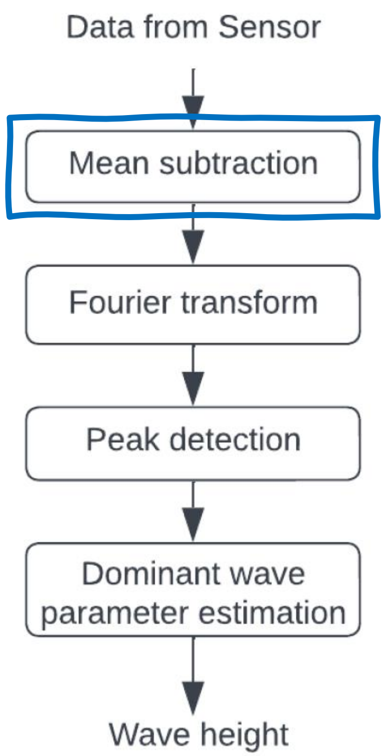


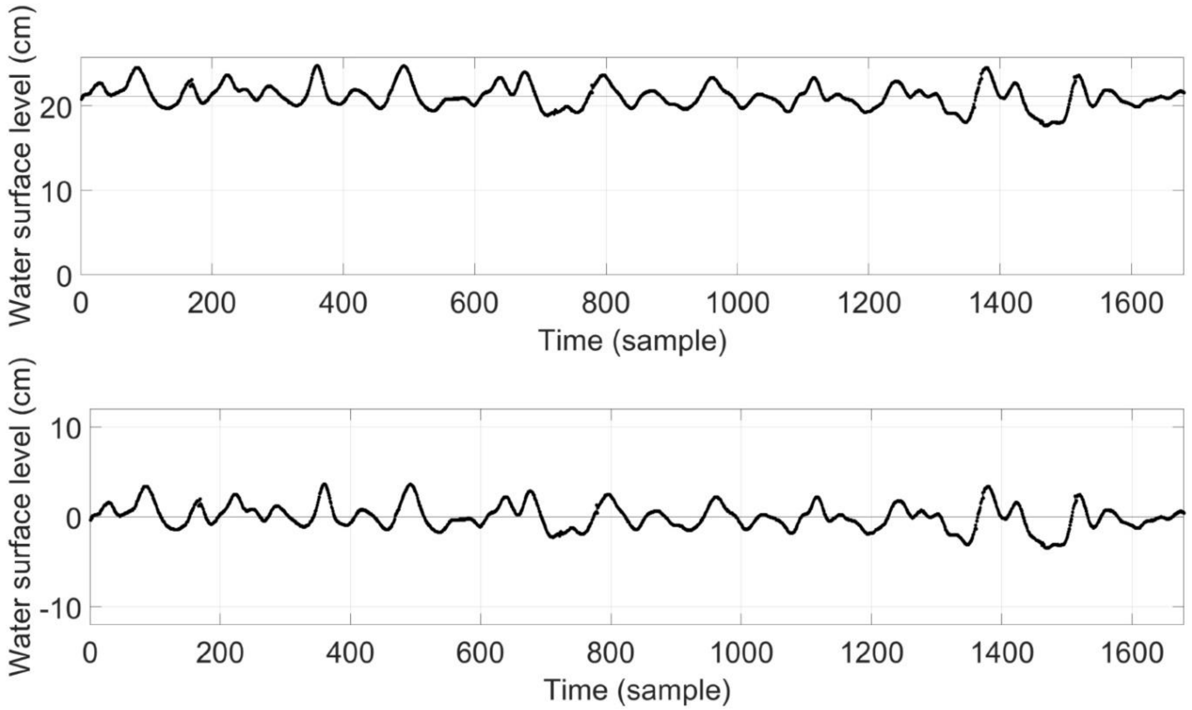


Experimental Setup

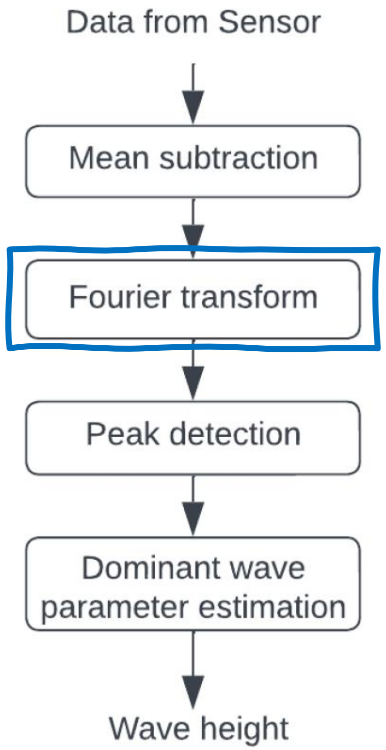


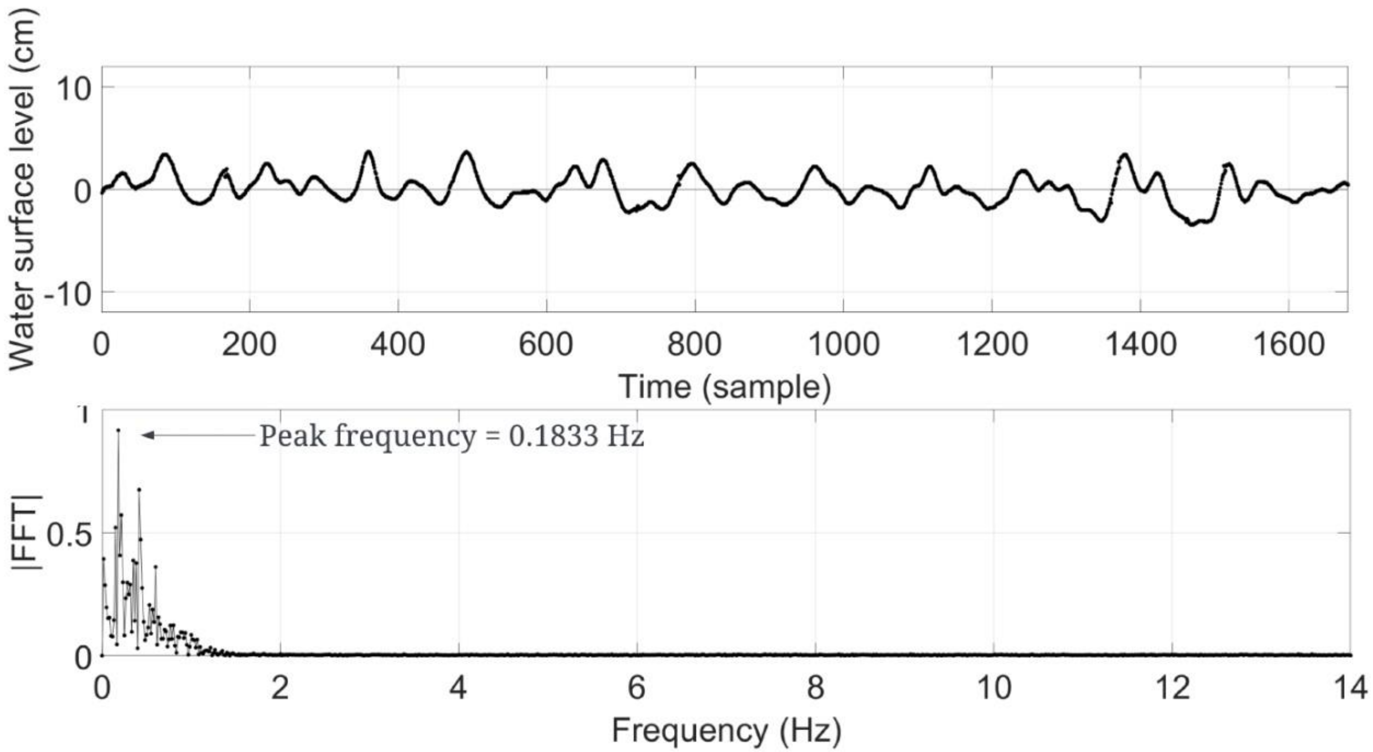
Proposed Method



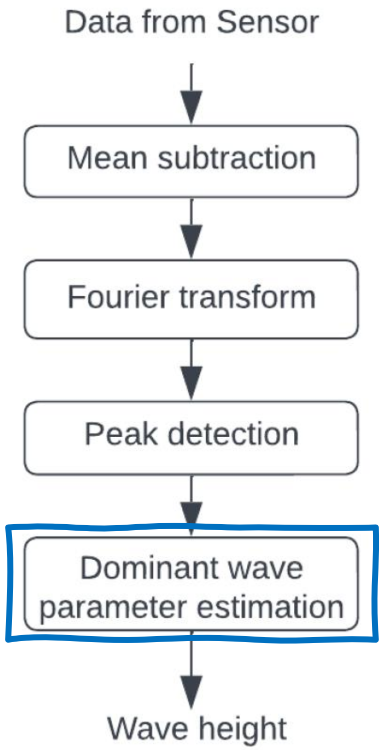


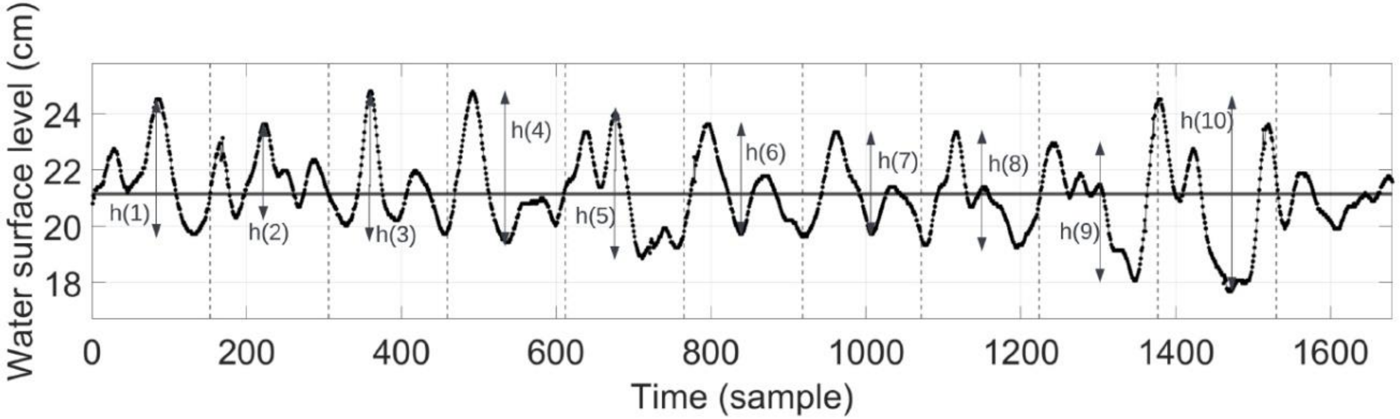
Proposed Method (cont'd)



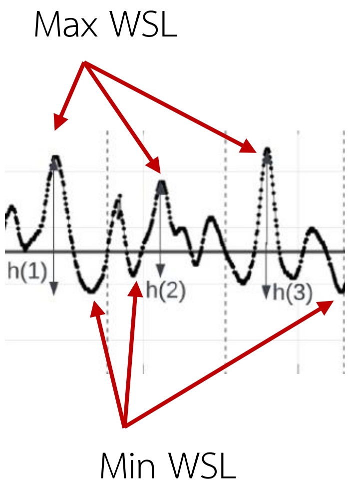


Proposed Method (cont'd)

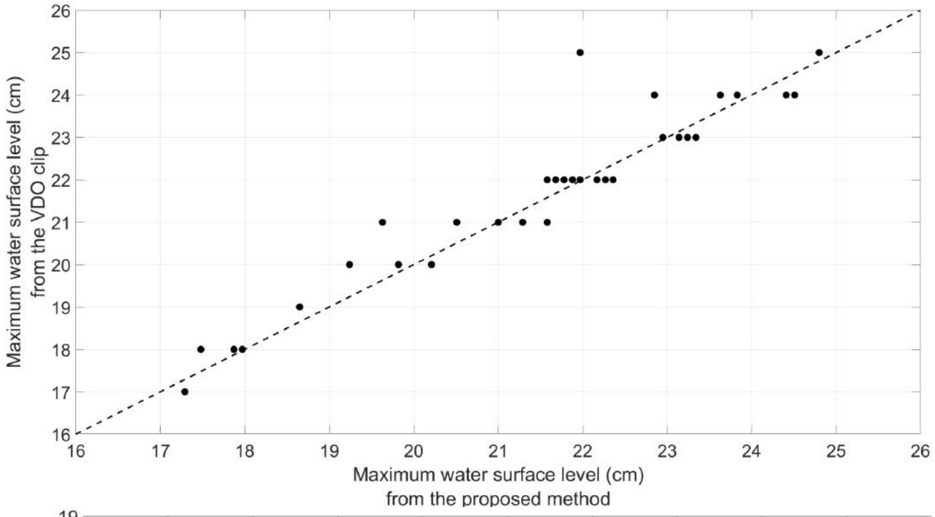


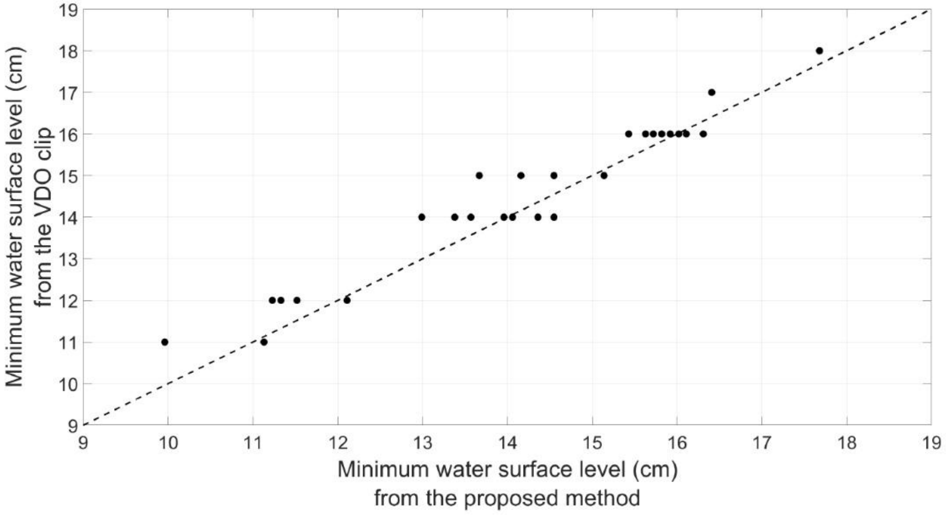


Experimental Results



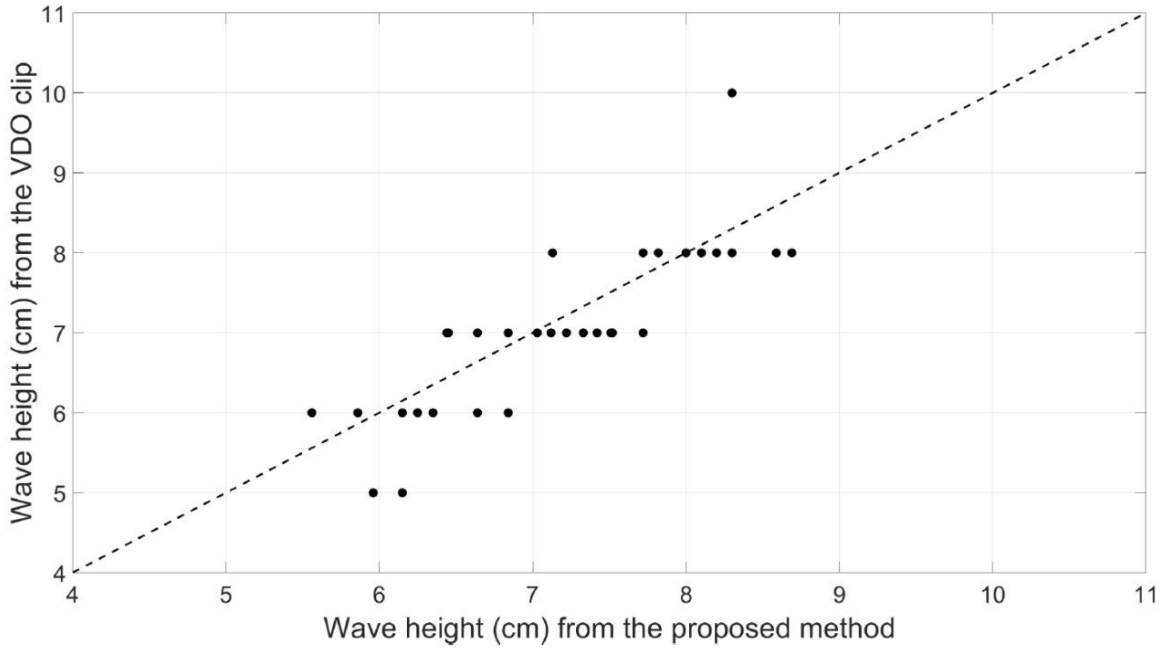
Time series	Video Clip				Proposed Method					
	L_{max} (cm)	L_{min} (cm)	H_p (cm)	N	L_{max} (cm)	L_{min} (cm)	H_{max} (cm)	H_{av} (cm)	H_p (cm)	N
1	25.00	18.00	7.00	10	24.80	17.68	6.83	4.87	7.12	10
2	24.00	16.00	8.00	7	24.51	15.82	6.54	3.33	8.69	24
3	24.00	16.00	8.00	12	24.41	15.82	7.72	5.80	8.59	12
4	23.00	16.00	7.00	6	23.24	16.02	7.22	3.93	7.22	24
5	24.00	16.00	8.00	8	24.41	16.31	8.10	4.96	8.10	12
6	23.00	16.00	7.00	9	23.14	15.63	7.12	5.29	7.51	14
7	23.00	16.00	7.00	5	23.34	15.92	6.84	3.32	7.42	24
8	22.00	16.00	6.00	8	21.58	16.02	5.56	3.07	5.56	28
9	22.00	14.00	8.00	8	22.36	14.36	7.42	5.44	8.00	14
10	22.00	14.00	8.00	7	21.88	14.06	6.45	4.45	7.82	14
11	20.00	14.00	6.00	7	19.82	13.96	5.86	3.84	5.86	12
12	20.00	14.00	6.00	5	20.21	13.57	6.05	3.38	6.64	24
13	21.00	14.00	7.00	5	20.51	14.06	5.67	3.78	6.45	15
14	21.00	14.00	7.00	6	21.00	14.55	4.59	3.13	6.45	25
15	22.00	16.00	6.00	5	21.78	15.63	5.86	3.46	6.15	21
16	23.00	16.00	7.00	8	22.95	15.92	6.15	3.70	7.03	28
17	24.00	16.00	8.00	9	23.63	15.43	7.42	4.14	8.20	12
18	22.00	16.00	6.00	9	22.27	15.92	6.15	3.82	6.35	15
19	21.00	16.00	5.00	7	21.58	15.43	5.08	2.92	6.15	30
20	21.00	15.00	6.00	9	21.00	14.16	5.47	3.98	6.84	10
21	21.00	14.00	7.00	7	21.29	13.57	7.23	3.87	7.72	17
22	22.00	14.00	8.00	11	21.68	13.38	8.30	5.05	8.30	14
23	22.00	15.00	7.00	9	21.88	14.55	6.84	4.36	7.33	16
24	22.00	16.00	6.00	12	21.97	15.72	5.17	4.03	6.25	10
25	22.00	15.00	7.00	7	22.17	15.14	7.03	3.52	7.03	16
26	24.00	16.00	8.00	8	23.83	16.11	7.52	3.51	7.72	25
27	24.00	17.00	7.00	8	22.85	16.41	5.56	3.36	6.44	24
28	25.00	15.00	10.00	9	21.97	13.67	8.30	3.60	8.30	26
29	21.00	14.00	7.00	13	19.63	12.99	6.45	4.14	6.64	14
30	20.00	12.00	8.00	8	19.24	12.11	6.54	4.90	7.13	12
31	19.00	12.00	7.00	9	18.65	11.23	7.42	4.69	7.42	12
32	18.00	11.00	7.00	9	17.97	11.13	6.55	3.66	6.84	30
33	18.00	11.00	7.00	9	17.48	9.96	6.74	4.55	7.52	14
34	18.00	12.00	6.00	10	17.87	11.52	6.25	3.36	6.35	28
35	17.00	12.00	5.00	7	17.29	11.33	5.57	4.06	5.96	12





Experimental Results (cont'd)

- MAE
  - 0.41 cm (maximum water surface level)
  - 0.39 cm (minimum water surface level)
  - 0.45 cm (dominant wave height)
- Correlation coefficient
  - 0.95 (maximum water surface level)
  - 0.97 (minimum water surface level)
  - 0.83 (dominant wave height)

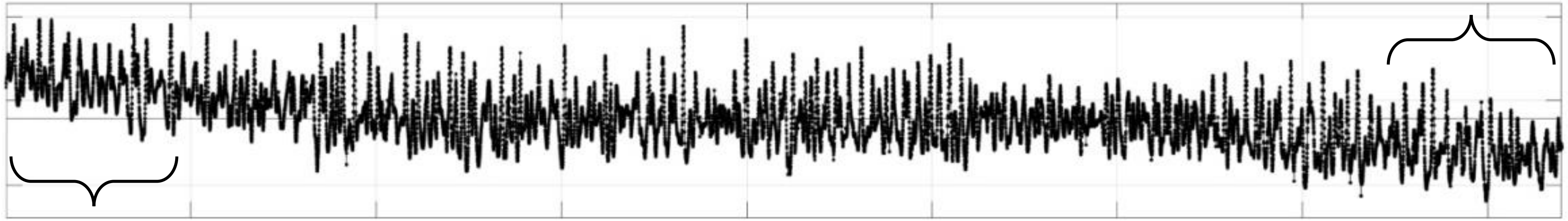


Discussion

- ❑ **Sampling rate** (Can it be reduced?)
- ❑ **Analysis period** (frequency resolution **vs** tidal effect)

$\overline{\boldsymbol{L}}_{\mathrm{T,r}}$

r samples



r samples

$\overline{\boldsymbol{L}}_{\mathrm{H,r}}$

$$\Delta_{\boldsymbol{r}} = |\overline{\boldsymbol{L}}_{\mathrm{H,r}} - \overline{\boldsymbol{L}}_{\mathrm{T,r}}|$$

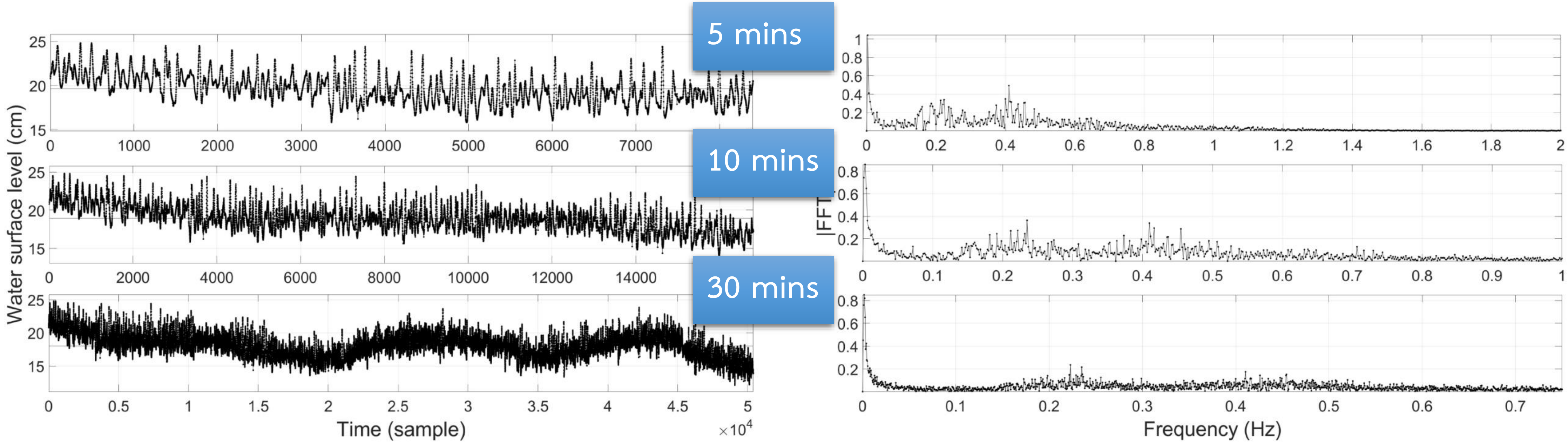
$$\Delta_{\mathbf{140,1-min}} = \mathbf{0.93}\ \mathrm{cm}$$

$$\Delta_{\mathbf{140,5-min}} = \mathbf{2.78}\ \mathrm{cm}$$

$$\Delta_{\mathbf{140,10-min}} = \mathbf{4.91}\ \mathrm{cm}$$

$$\Delta_{\mathbf{140,30-min}} = \mathbf{7.02}\ \mathrm{cm}$$

Discussion (cont'd)



Summary

- **Issue**: Coastal erosion, breakwater's efficacy (wave transmission coefficient)
- **Aim**: Real-time (or near-real-time) method for estimating dominant wave height from time-series data obtained from a pressure sensor
- **Method**: Spectral analysis (Fourier transform)
- **Data**: 29 June 2023, Prachuapkhirikhan Province, 35-min time series, 28 Hz sampling
- **Result**: MAE = 0.45, ρ = 0.83 (comparing between the estimator and VDO record)

THANK YOU FOR LISTENING

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