ICCE 2018
36TH INTERNATIONAL CONFERENCE ON COASTAL ENGINEERING 2018
Baltimore, Maryland | July 30 – August 3, 2018
The State of the Art and Science of Coastal Engineering

Wave Induced Current Monitoring Using UAV-Based Photogrammetry

Bumshick Shin, Assistant professor

CATHOLIC KWANDONG UNIVERSITY

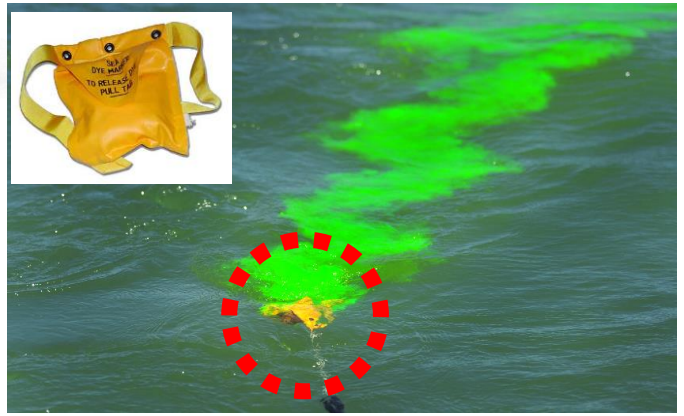
Waterfront and Coastal Research Center & Catholic Kwandong University

Kyu-Han Kim, Professor, Director

Waterfront and Coastal Research Center & Catholic Kwandong University




CONTENTS



- **Background**

Wave-induced current

Sediment transport, water depth change and the spread of such behavior in the near surf zone is often precisely the phenomenon of ***wave-induced current*** in order to solve these environmental problems coast causes serious environmental problems observed in coastal areas

The method to measure the littoral current is classified into two methods including the ***Euler method*** and ***Lagrange method***. (pond and Pockard, 1983)

1) Euler method
Observe a temporal change of current direction and velocity at various ***fixed points*** using a current meter

➔ A large number of current meters are necessary

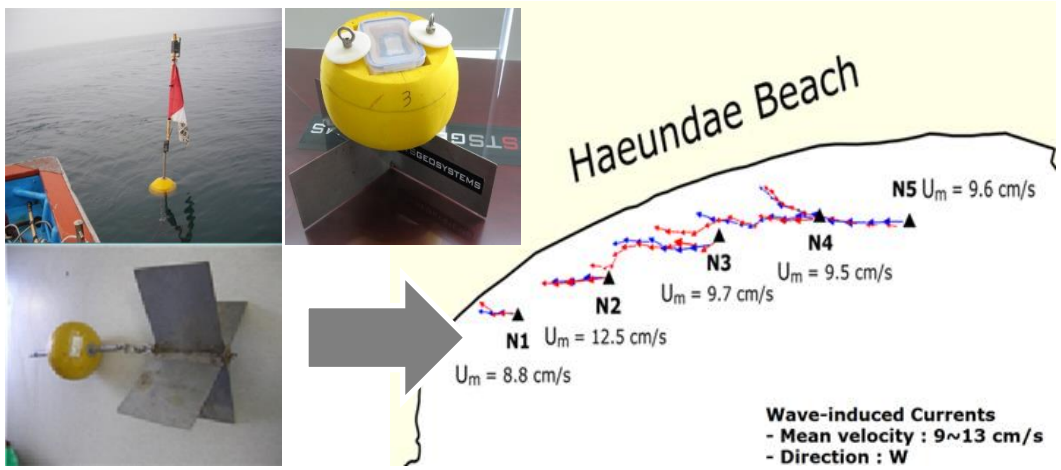
2) Lagrange method
Observe the ***spatial*** current direction and velocity
Use a marker such as a buoy or dye such marker

➔A high observation tower or building for recording require and it is difficult to recognize a coordinate

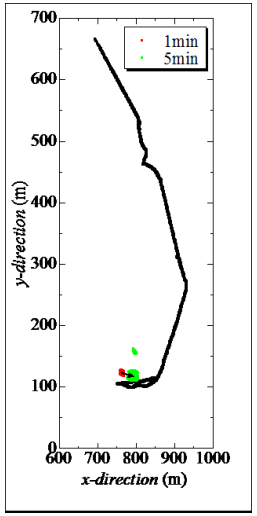
- **Background**

Wave-induced current

1) Euler method : ***fixed points***



2) Lagrange method : the ***spatial data***



Comprehensive Approach for Beach Erosion Mitigation in Korea(Kim et al, ICCE 2008)

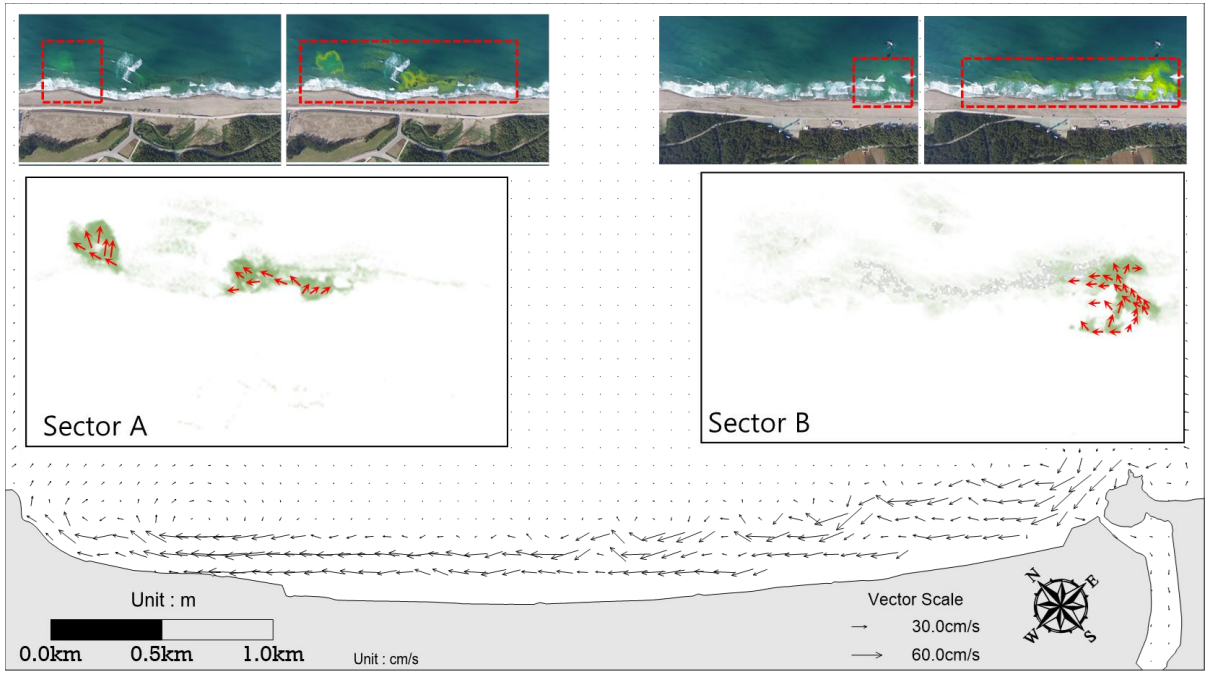
Recently, the observation of shoreline in a wide shore, wave run-up, swash movements and flow information ***using the imagery interpretation techniques*** has become possible due to ***the video hardware and image processing*** However, ***high-resolution image photographing*** from an elevated position is necessary in order to obtain image information for a wide area, but the previous photographing technology had an altitude and resolution limitation. Therefore, the establishment of spatial information ***using UAV(Unmanned Aerial Vehicle)*** systems draws attentions recently and more studies and utilizations of such systems in various fields are being carried out.

1. Introduction

- **Goal**

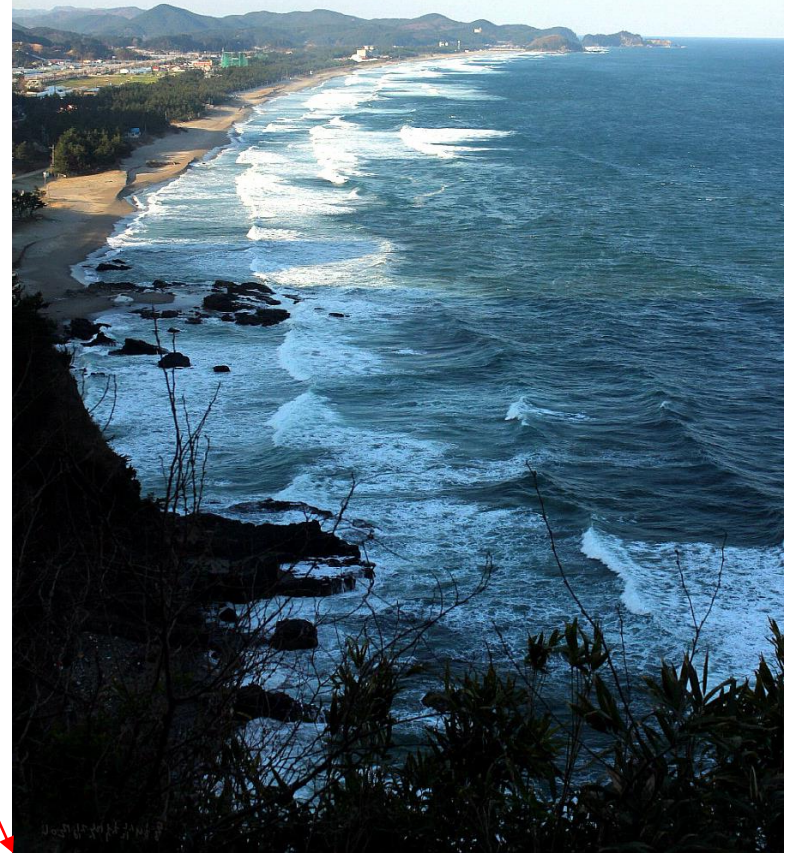
Purposes

- ***Application*** of wave-induced current observation using UAV
- Efficient and scientifically grasped wave-induced current
- Spatial distribution analysis of wave-induced current
- Providing numerical simulation ***validation data*** using spatial characteristics of wave induced current

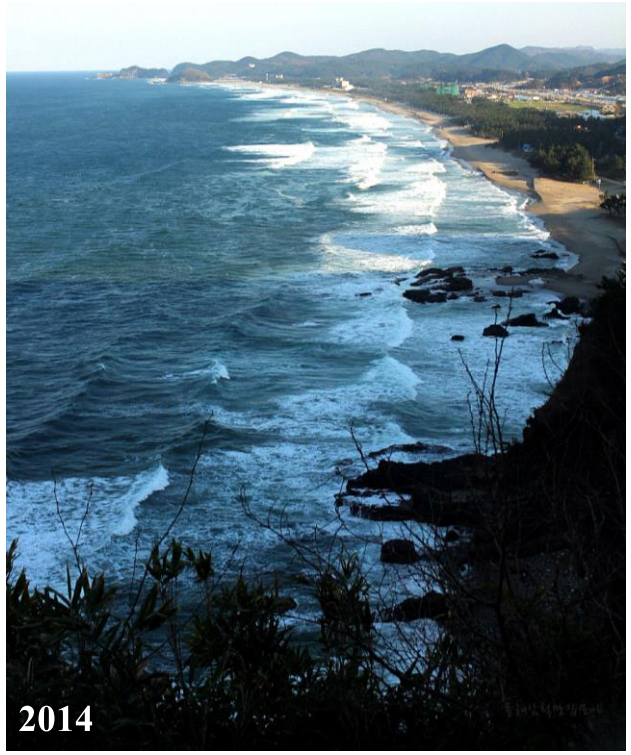


- **Study Area : location**

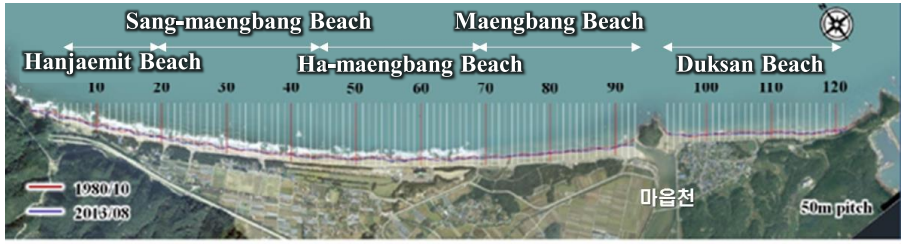
- Located on the eastern coast of Korea
- 4.5 km long shoreline
- During winter, N~E waves due to seasonal wind
- The event of a typhoon during summer, S~SSE

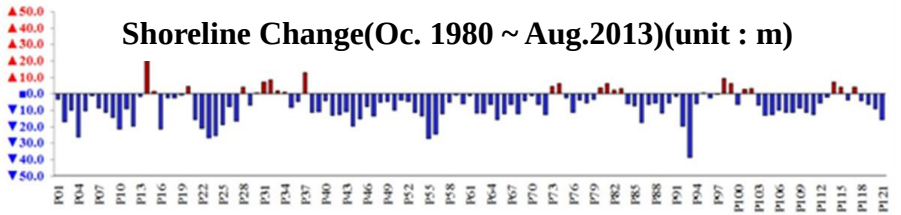


- **Study Area : History and Characteristic of Beach Erosion**



[Coastal Monitoring Project(Gangwon Province, 2013)]





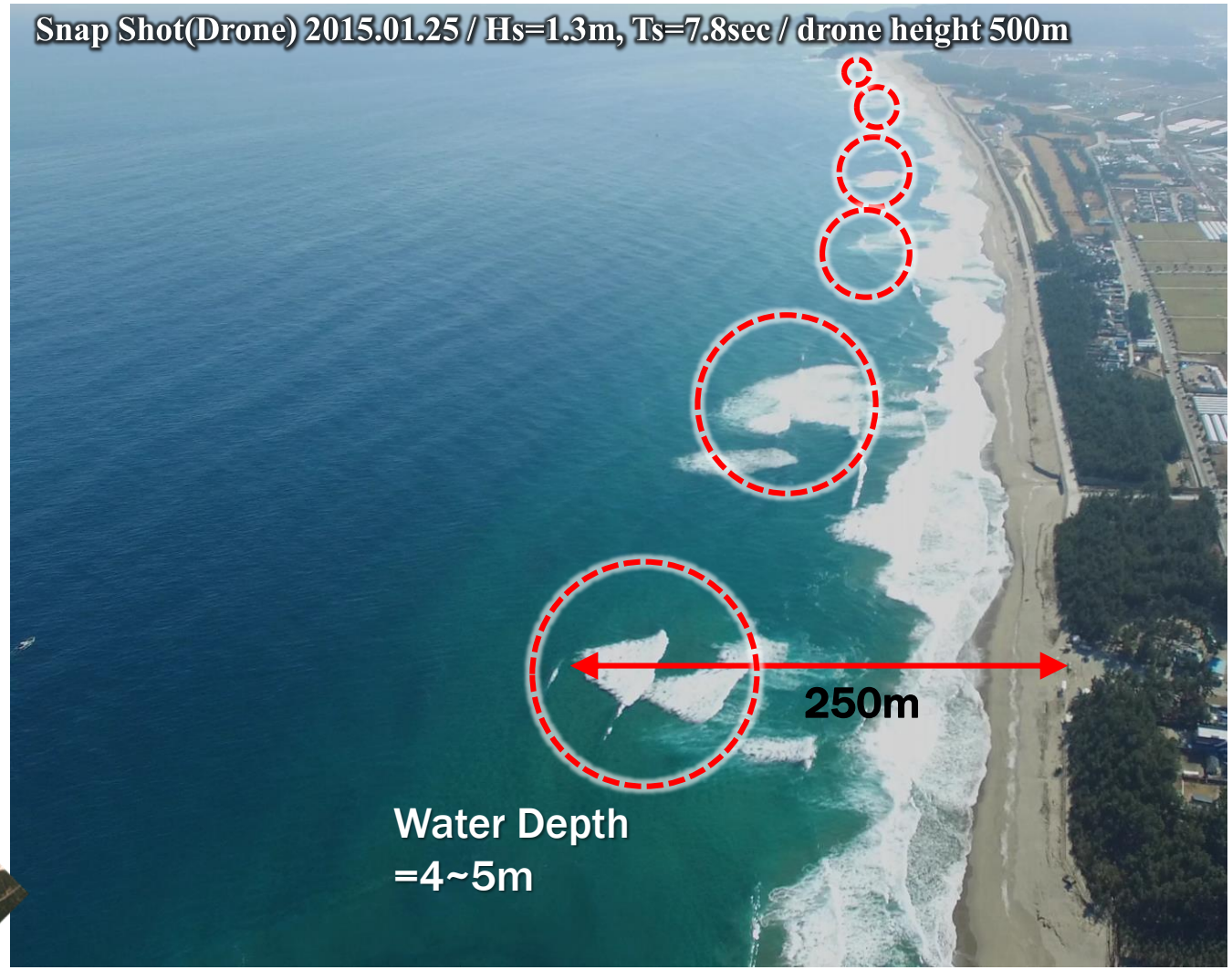
[Erosion Situation]

Continuous erosion is occurring

C·D Level ('11~'14)

Coastal Erosion Management Area
(MOF, 2016)

- **Study Area : Characteristics of Wave Breaking**



Field Investigation Process

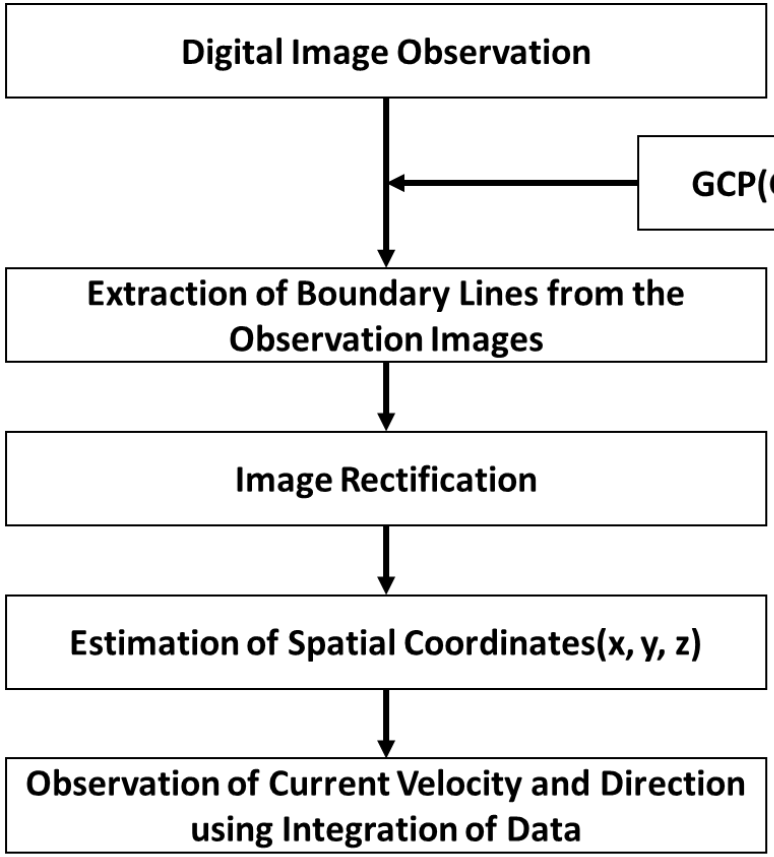
In this study, the current direction of the wave induced-current was able to be confirmed, and the ***sea dye maker*** (Presto dyechem co., Ltd., USA) which was the dye marker for maritime distress harmless to humans was released on the target beach and the diffusion behavior of the dye was photographed using the rotary wing ***UAV(Unmanned Aerial Vehicle)*** in order to observe the hourly moving direction of the dye.

The photographed high-resolution images were produced as 3D orthoimages (error range: ±2cm) and the hourly flow of the wave induced-current was investigated using the diffusion behavior of the dye.

[GCP, Ground Control Point]

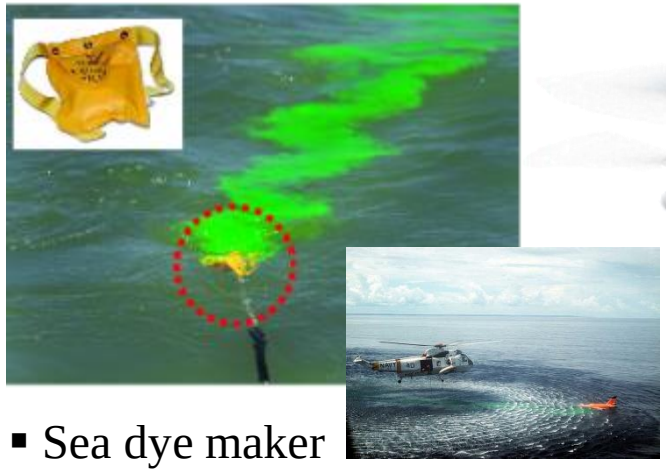
GCP must be easily visible in your aerial imagery.

More than 20 GCPs were set up using fixed structures such as electric poles and roads.



UAV & Sea dye marker

In this study, the current direction of the wave induced-current was able to be confirmed, and the ***sea dye maker*** (Presto dyechem co., Ltd., USA) which was the dye marker for maritime distress harmless to humans was released on the target beach and the diffusion behavior of the dye was photographed using the rotary wing ***UAV(Unmanned Aerial Vehicle)*** in order to observe the hourly moving direction of the dye.
The photographed high-resolution images were produced as 3D orthoimages (error range: ±2cm) and the hourly flow of the wave induced-current was investigated using the diffusion behavior of the dye.

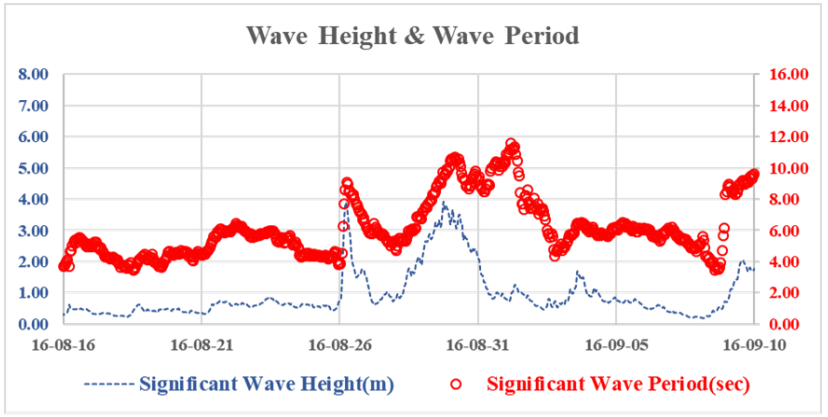


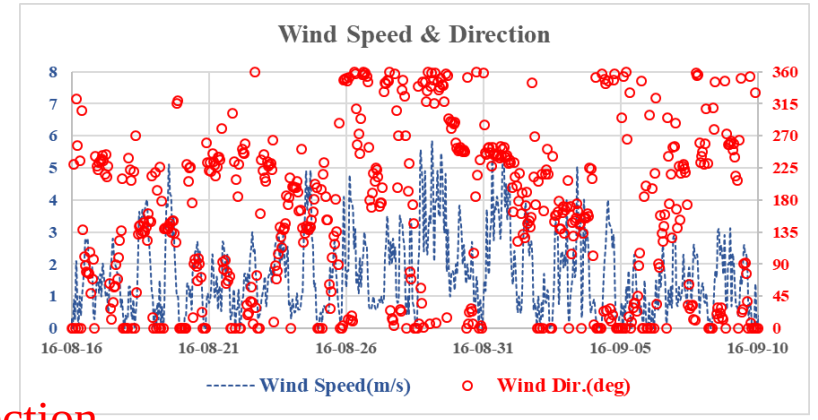
- Sea dye maker
  - lifesaving device used for sea rescue (Presto dyechem co., Ltd., USA)

- Model :Phantom 3 Professional
- Manufacturer : DJI
- Type : Multi-rotary wing UAV
- Battery : Rechargeable lithium ion battery
- GPS, GNSS
- Maximum operating time : 23minute
- Receiving distance : 5km

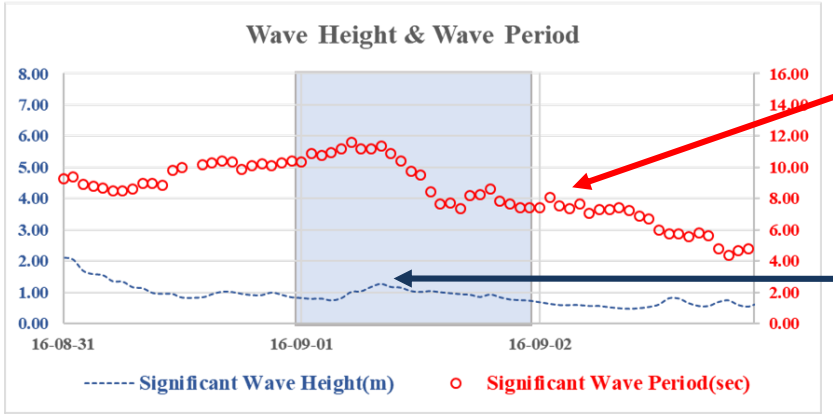
Wave and Wind Conditions

Wave-induced current analysis using Sea dye marker changes according to wave and wind conditions.
Therefore, wave and wind observations performed by KMA (Korea Meteorological Administration) around study area are analyzed as follows.



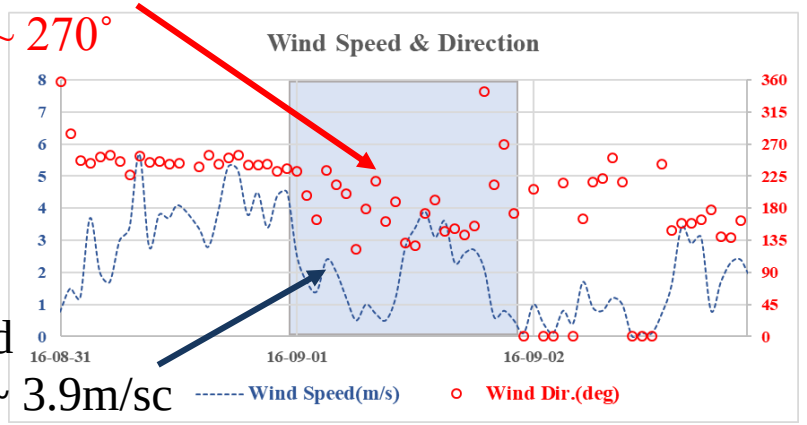


Wind Direction
➔ 122.1˚ ~ 270˚



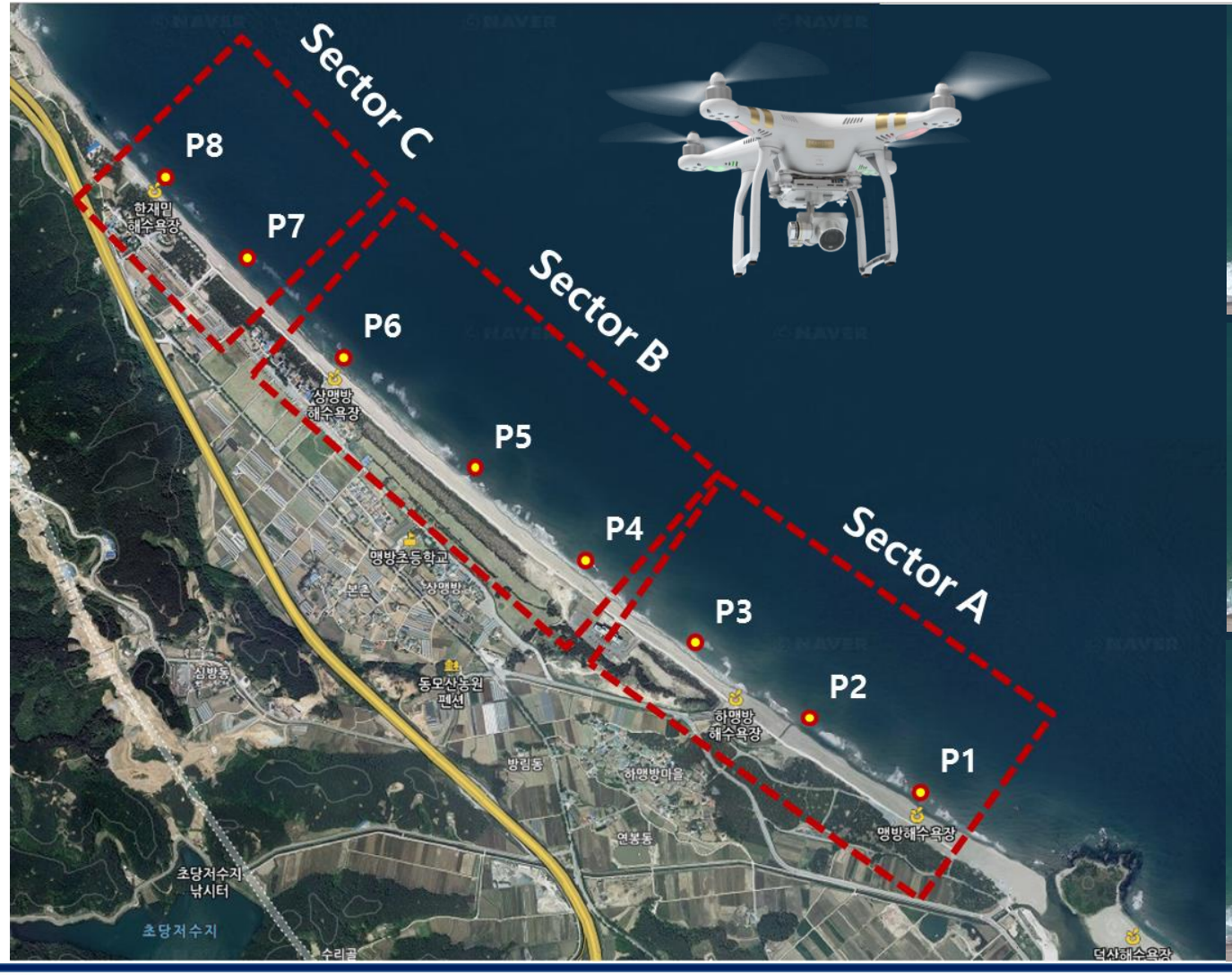
T_s ➔7.4sec~11.6sec

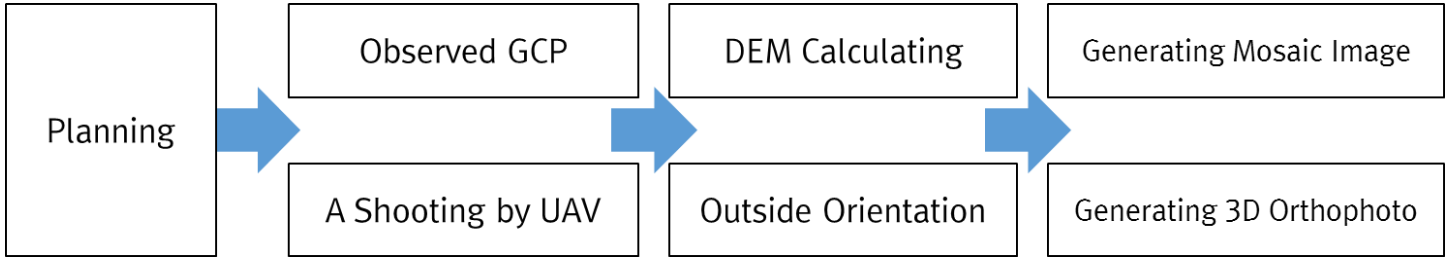
H_s ➔0.7~1.2m



Wind Speed
➔ 0.5m/s ~ 3.9m/sc

UAV operation and shooting





Shooting by UAV

Using the low-altitude high-resolution image data obtained after completion of the flight in order to produce the orthophoto and DSM (Digital Surface Model) can be modeled high-resolution orthophoto and detailed DSM and model body and correction of the picture also built their own it is easy to handle UAV image processing were performed as Figure.

In addition, it was carried unmanned aerial photo image processing operations, and modeling the data acquired. After the shooting order of processing is divided into picture elements using an external expression of the video shoot junction, GCP matching, photo location optimization step of separating the dye diffusion range and interpretation.

Image Analysis

The pattern of wave-induced current was confirmed using

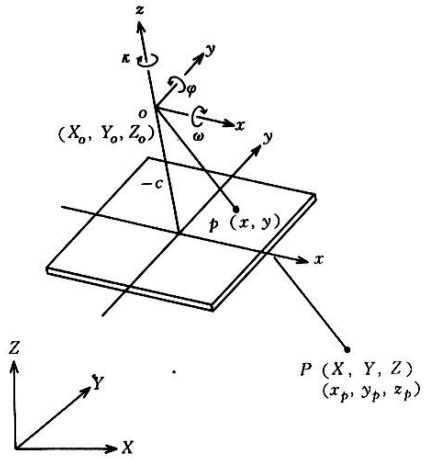
Video Analysis of Sea-marker

1) Spatial distribution of wave induced current
   ➔ Using Projective transformation with
   ➔ Collinearity Equation

PIV Technique

2) ***Time variation*** of wave induced current
   ➔ Vx=dx/dt…

Projective Transformation



$$\begin{pmatrix} x_p \\ y_p \\ z_p \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\omega & -\sin\omega \\ 0 & \sin\omega & \cos\omega \end{pmatrix} \begin{pmatrix} \cos\phi & 0 & \sin\phi \\ 0 & 1 & 0 \\ -\sin\phi & 0 & \cos\phi \end{pmatrix} \begin{pmatrix} \cos\kappa & -\sin\kappa & 0 \\ \sin\kappa & \cos\kappa & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} X - X_0 \\ Y - Y_0 \\ Z - Z_0 \end{pmatrix}$$

$$X = \frac{b_1 x + b_2 y + b_3}{b_7 x + b_8 y + 1} \qquad Y = \frac{b_4 x + b_5 y + b_6}{b_7 x + b_8 y + 1}$$

(where, x, y : Photo Coordinate , X, Y, Z : Ground Coordinate
b1~b8 : unknown coefficients)

Image Analysis

In order to produce an accurate orthophoto and DSM (Digital Surface Model) to install the GCP (Ground control point) identifies itself produced in one place and easy to land and was performed GCP measurement, precise horizontal and vertical position to the ground control points observed a VRS (Virtual Reference Station) was used to calculate the position. Data acquisition and processing flow is the same as that utilized rotorcraft UAV Figure.

The key point for analyzing the captured photographs is the process to calculate the position which changes continuously over time quantitatively, and the ***Collinearity Equation*** showing the relations between each photograph and its position at the site was applied as the basic expression.

$$X - X_L = (Z - Z_L)\frac{m_{11}(x-x_0)+m_{12}(y-y_0)+m_{13}(-f)}{m_{31}(x-x_0)+m_{32}(y-y_0)+m_{33}(-f)}$$

$$Y - Y_L = (Z - Z_L)\frac{m_{21}(x-x_0)+m_{22}(y-y_0)+m_{23}(-f)}{m_{31}(x-x_0)+m_{32}(y-y_0)+m_{33}(-f)}$$

Here, $X, \mathrm{Y}, \mathrm{Z}$ indicate the positions and heights on the coordinate axis measured at the field.
$X_L, Y_L, Z_L, x, \mathrm{y}, x_0, y_0$ and m indicate the location coordinate of camera, that of photos, the error of calibrated value of ***camera***, ***focal length*** and ***each factor*** of the below matrix M respectively.

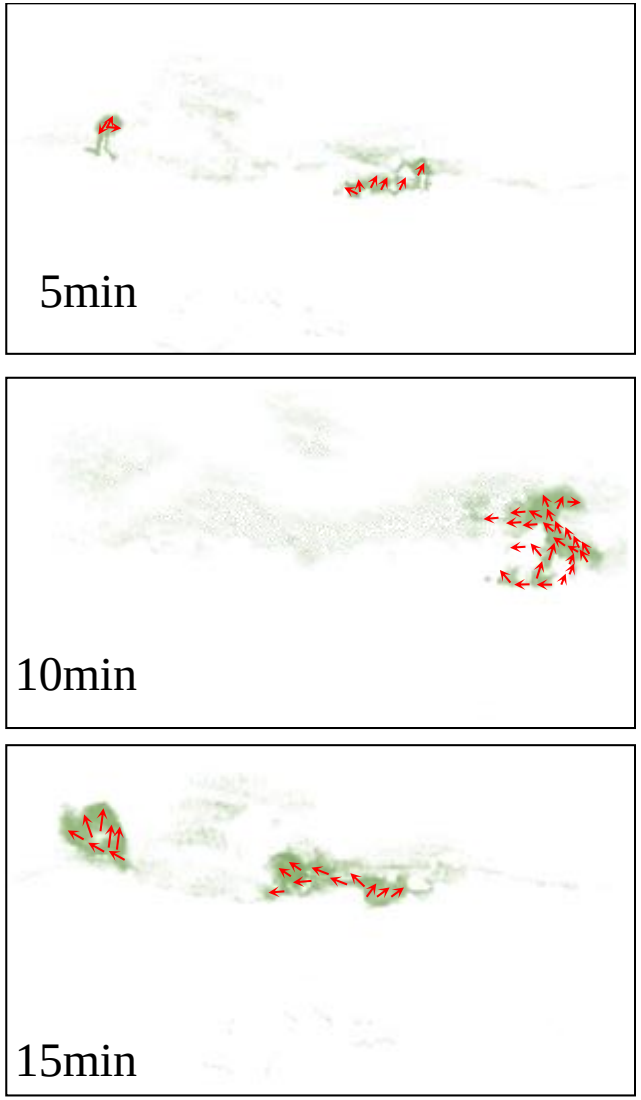
Image Analysis

In order to produce an accurate orthophoto and DSM (Digital Surface Model) to install the GCP (Ground control point) identifies itself produced in one place and easy to land and was performed GCP measurement, precise horizontal position and level to the ground control points observed a VRS (Virtual Reference Station) was used to calculate the position. Data acquisition and processing flow is the same as that utilized rotorcraft UAV Figure.

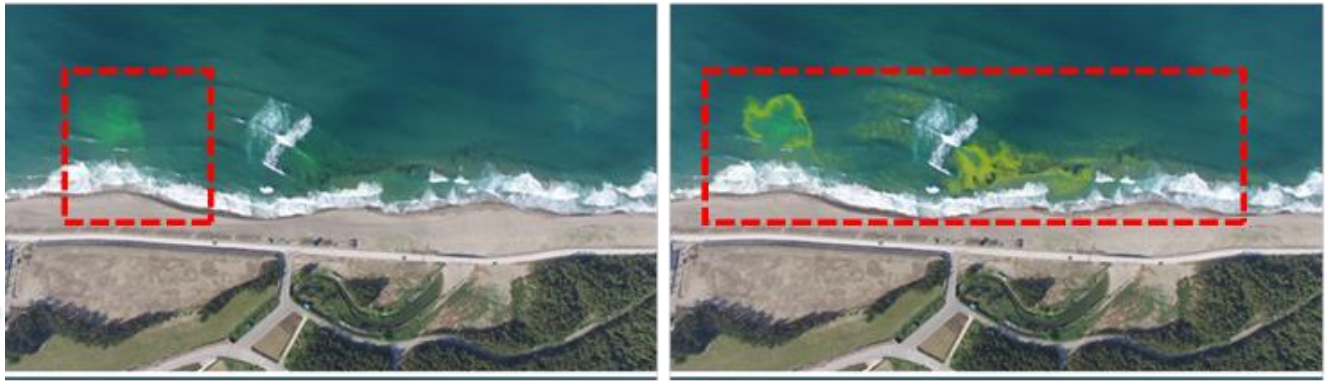
$$M = \begin{bmatrix} \cos\phi \cos k & \cos w \sin k + \sin w \sin\phi \cos k & \sin w \sin k - \cos w \sin\phi \cos k \\ -\cos k \sin k & \cos w \cos k - \sin w \sin\emptyset \sin k & \sin w \cos k + \cos w \sin\emptyset \sin k \\ \sin\phi & -\sin w \cos\phi & \cos w \cos\phi \end{bmatrix}$$

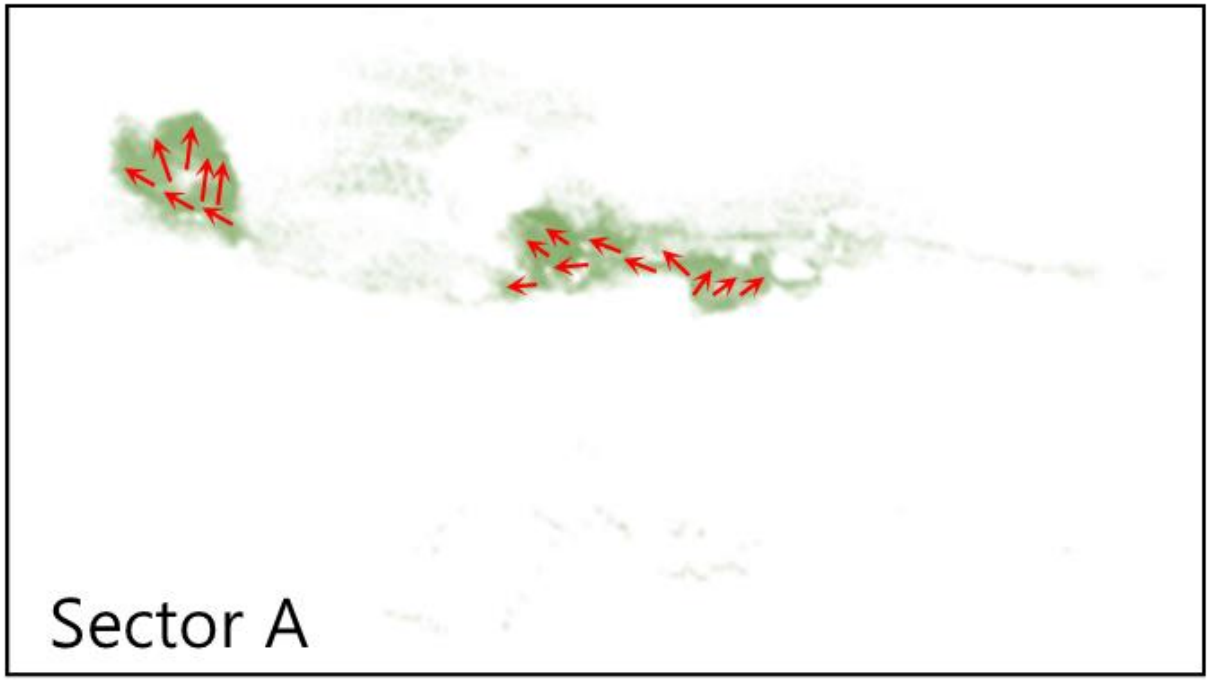
Here are the slope of each camera (tilt, in the upper direction from the horizontal axis), camera rotation (swing or roll angle) and camera angle (azimuth, counterclockwise) respectively. As shown in the equation, when the matrix M and the focal distance f are known through the measurement of ground control point (GCP), the valuables can be known through x and y that are the coordinates of the posion shown on or the photograph and the observation of its height Z, finally the unknown values X, Y, be a two equation can get the full solution.

4. Data Analysis

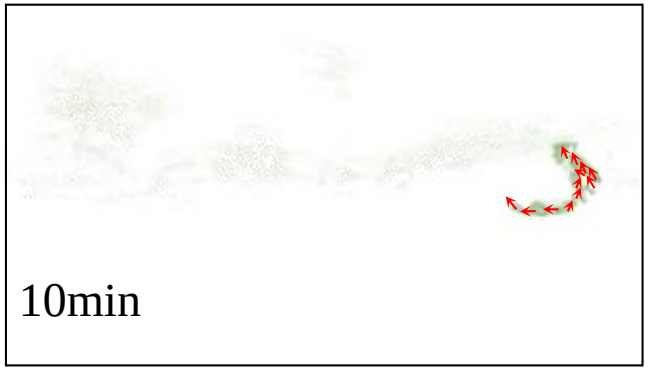


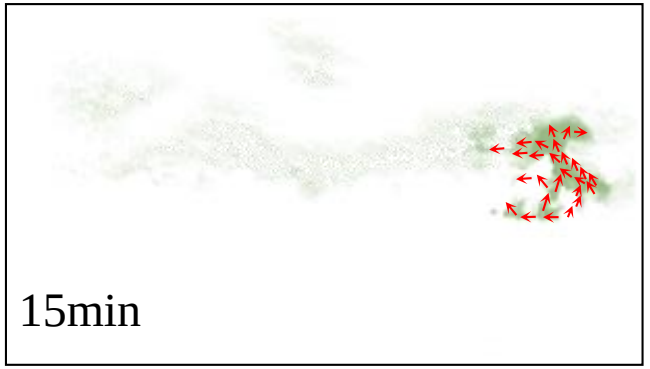
4. Data Analysis



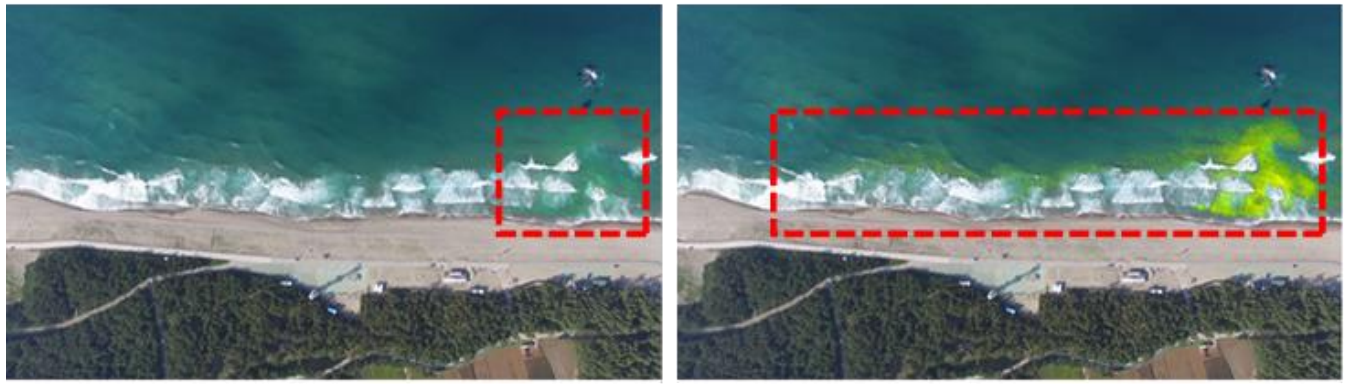


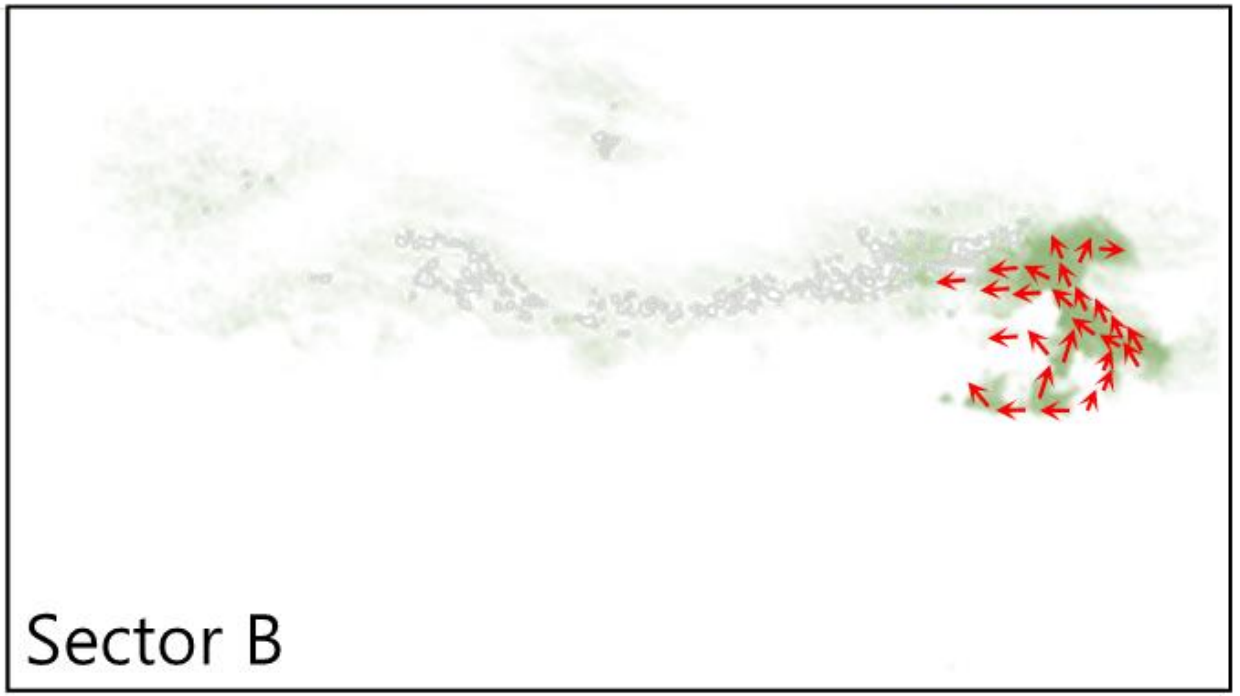
4. Data Analysis





4. Data Analysis





UAV & Sea dye marker

This research investigates the development of wave induced currents using images in East coast of Korea.

- Since rip currents are developed by longshore currents, the observed longshore current variations in space and time can be used to detect rip current generation.
- Rip current recorded by UAV when the significant wave heights was 1,9m and the period was 6.0sec. The average velocity was 25cm/s.
- These remote sensing observations provide a more synoptic picture of the rip current flow field and allow the identification of several rip events that were not captured by the in situ sensors and times of alongshore deflection of the rip flow outside the surf zone.
- The use of UAVs (Unmanned Aerial Vehicles) as a mapping and measurement tool has grown significantly in recent years, such that the potential for coastal engineering applications is beginning to be realized.
- The coastal engineering applications presented highlight the enormous potential of UAV technology to significantly improve and potentially revolutionise the future of coastal zone monitoring.
- In addition, if possible to secure the accuracy of the image analysis method applied current time, the future is expected to be built a system that can monitor the constant monitoring of the risk as well as the engineering field, such as the sediment transport, natural disasters.

Thank you for your attention !




ICCE 2018

36TH INTERNATIONAL CONFERENCE ON COASTAL ENGINEERING 2018

Baltimore, Maryland | July 30 – August 3, 2018