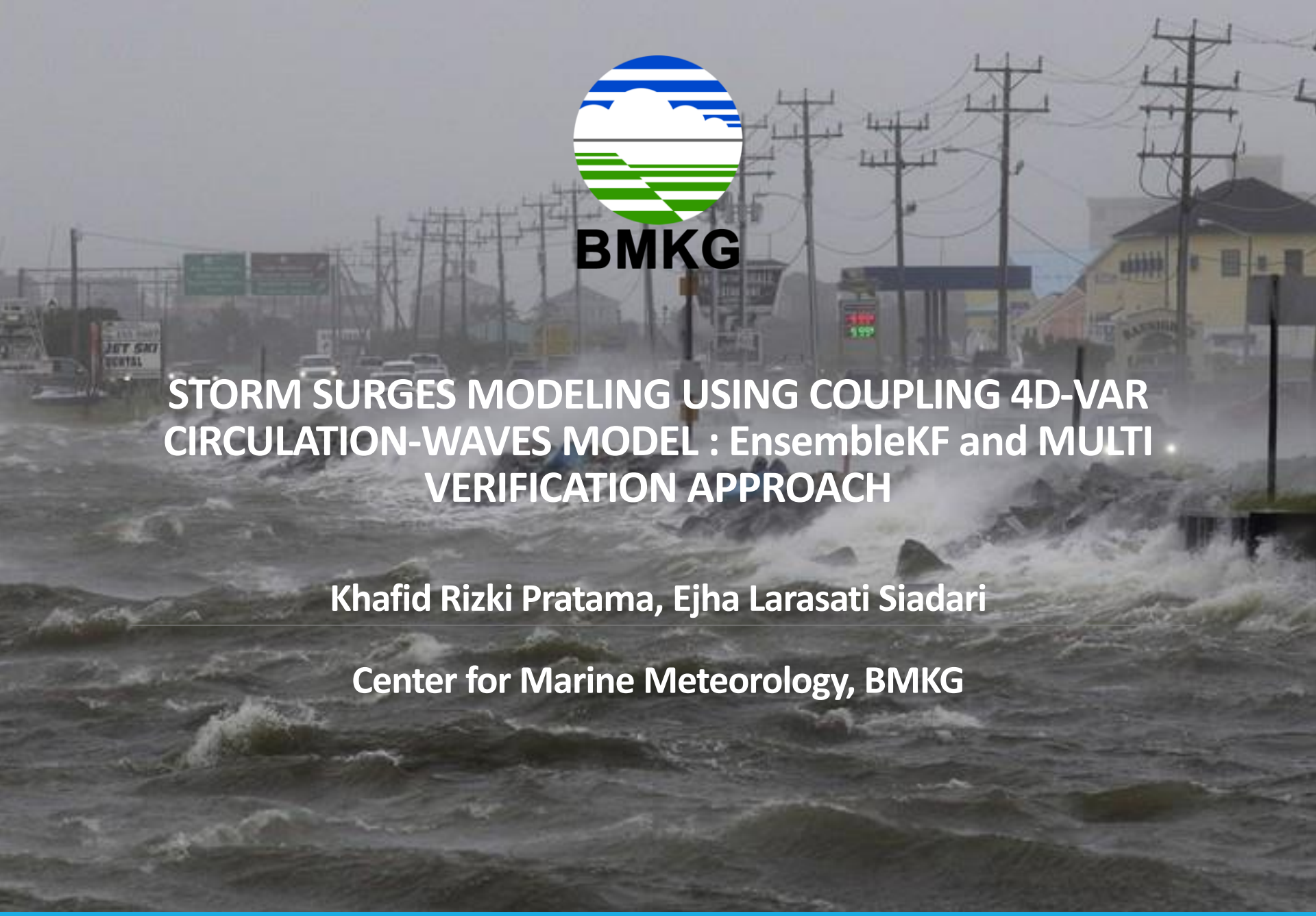

STORM SURGES MODELING USING COUPLING 4D-VAR CIRCULATION-WAVES MODEL : EnsembleKF and MULTI VERIFICATION APPROACH

Khafid Rizki Pratama, Ejha Larasati Siadari

Center for Marine Meteorology, BMKG

Indonesia Agency for Meteorology Climatology and Geophysics

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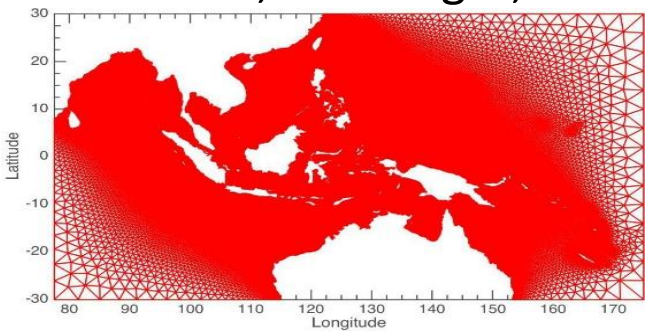
Introduction

Purpose of Research

INTRODUCTION

a. Indonesia as an archipelago country consists of more than 17.000 islands with a coastline of approximately 80,791 km (Tjasyono, 2006). Many aspects of people's lives are closely related to the marine sector especially transportation, fisheries, tourism, oil and gas, defense, and security etc.



a. The air-sea interaction in Indonesia sea results on some phenomena such as Tropical Cyclone and Deep Convection.
b. Need better research for Inundation Forecasting Technique to improve Disaster Risk Reduction Effort especially for areas along the coastlines. How to do that?

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Introduction

Purpose of Research

a. Improving initial model data using Real-Time Observation and In-Situ Observation
b. Multi Verification or EnsembleKF to know the best output model for research purpose

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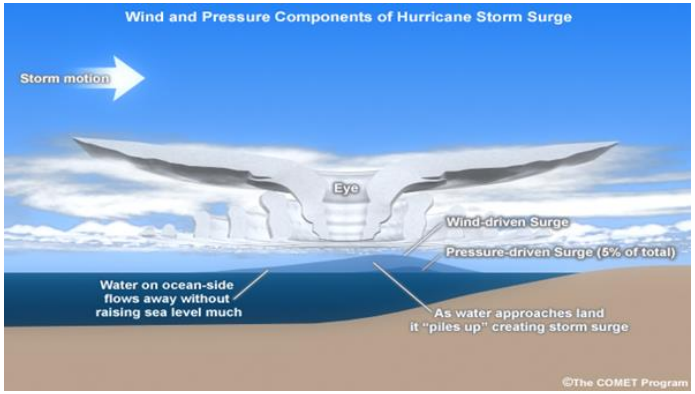
Introduction

Role of Research

THEORY

Storm Surge

- Rising sea level rises associated with intense cyclones.
- Water strength increases, especially in shallow / coastal waters depending on the development of the cyclone **(Ali, 1996; Dube dkk, 1997; De Scally, 2008)**
- Caused by atmospheric stability **(Ali, 1996; Holland, 1997; Gray, 1998)**



Storm Tide

- *The level of water produced by the combined action of storm surges and astronomical tides*
- *Wind stress and strong tide* **(Harris, 1963)**

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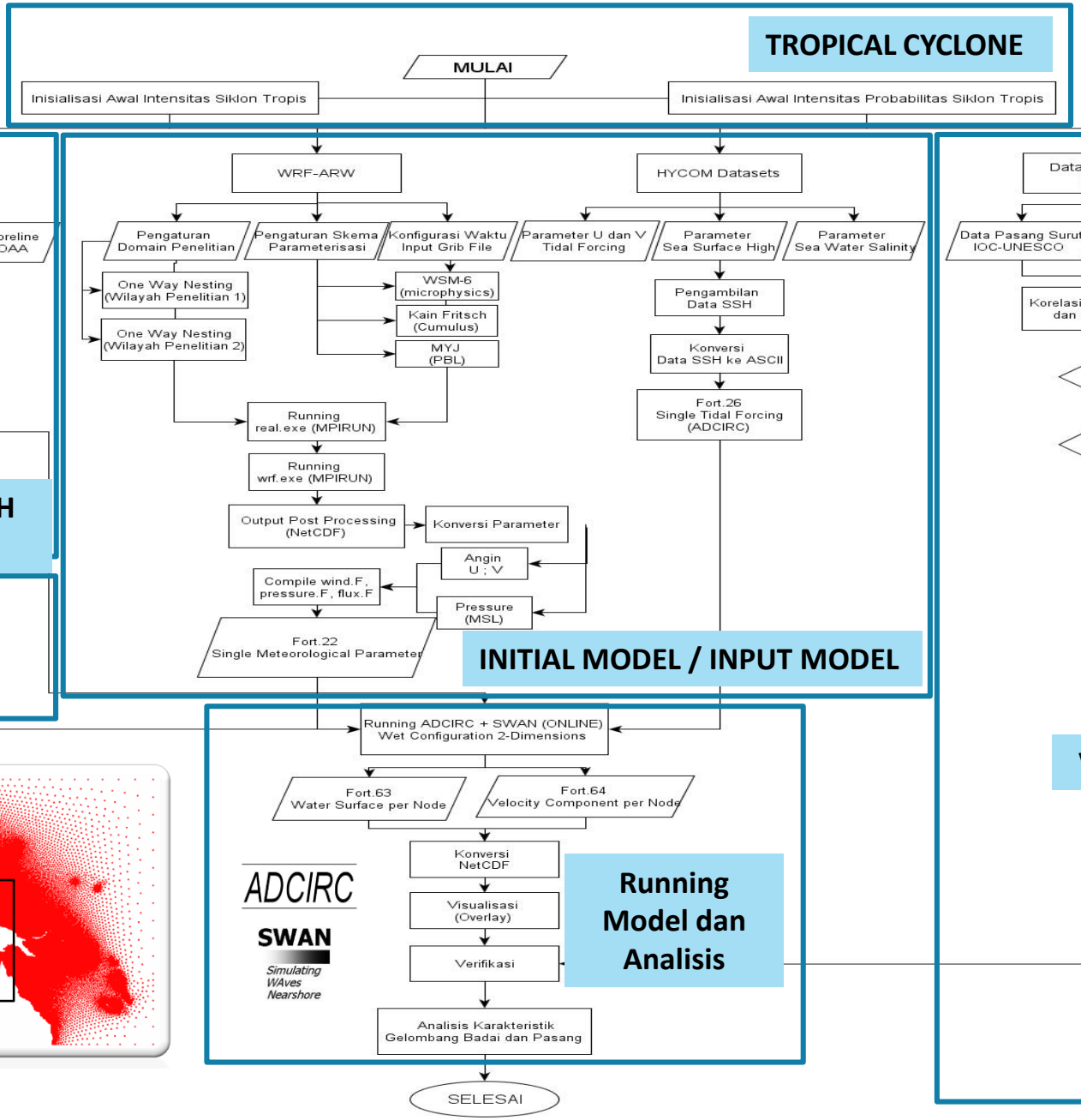
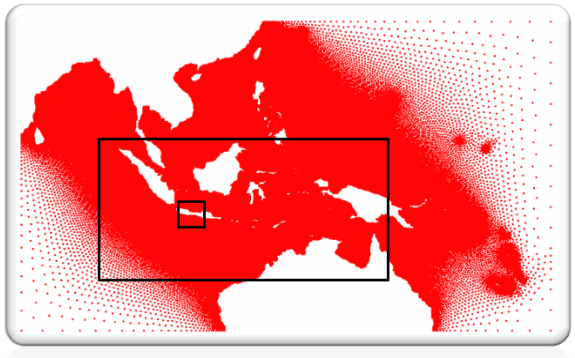
TROPICAL CYCLONE





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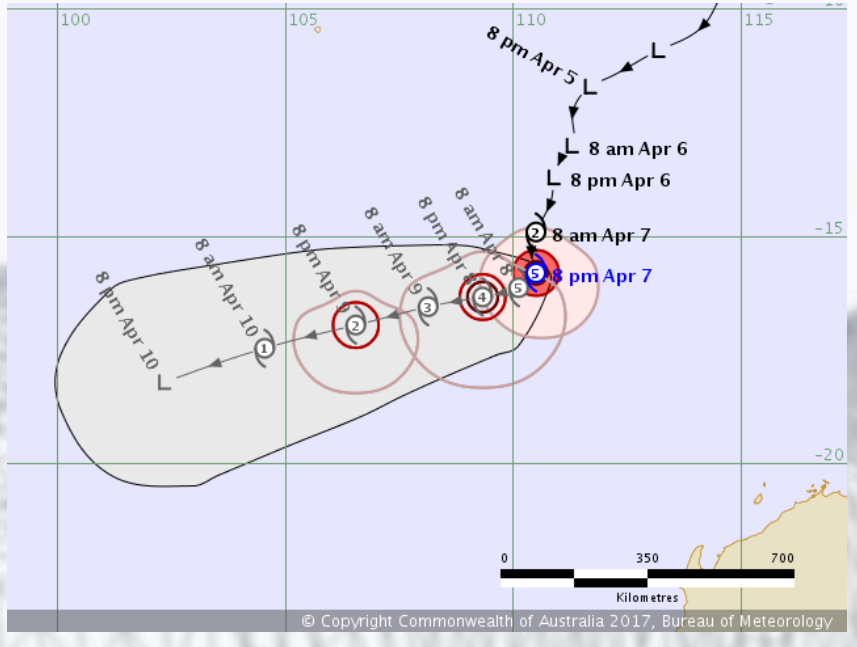
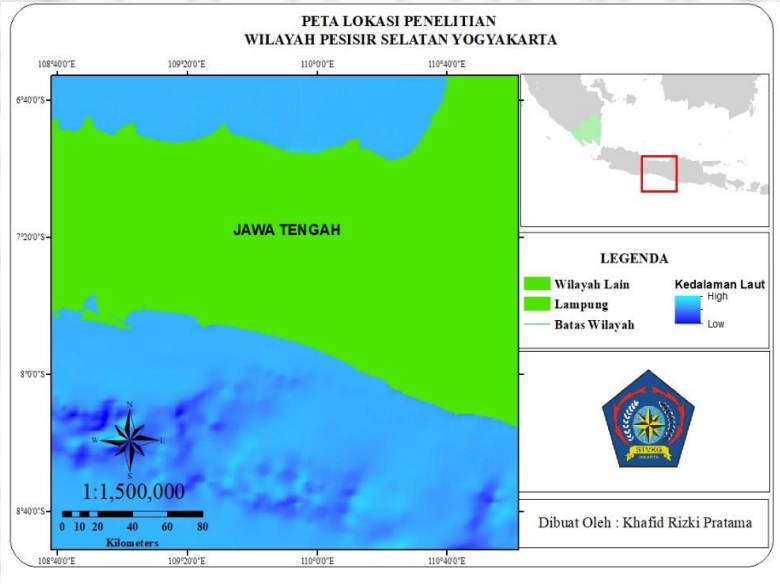
Location :

- Tropical Cyclone Ernie (06 – 10 April 2017) ***(PDC-BMKG, BOM)***





Data

- Bathymetri 30 S GEBCO
- Coastline - GHHSS
- GFS NCEP
- HYCOM
- Tide gauge from BIG Indonesia and Synoptic Data from Automatic Weather Station (AWS)
- InaWaves WaveWatch 3 1/16 Resolution

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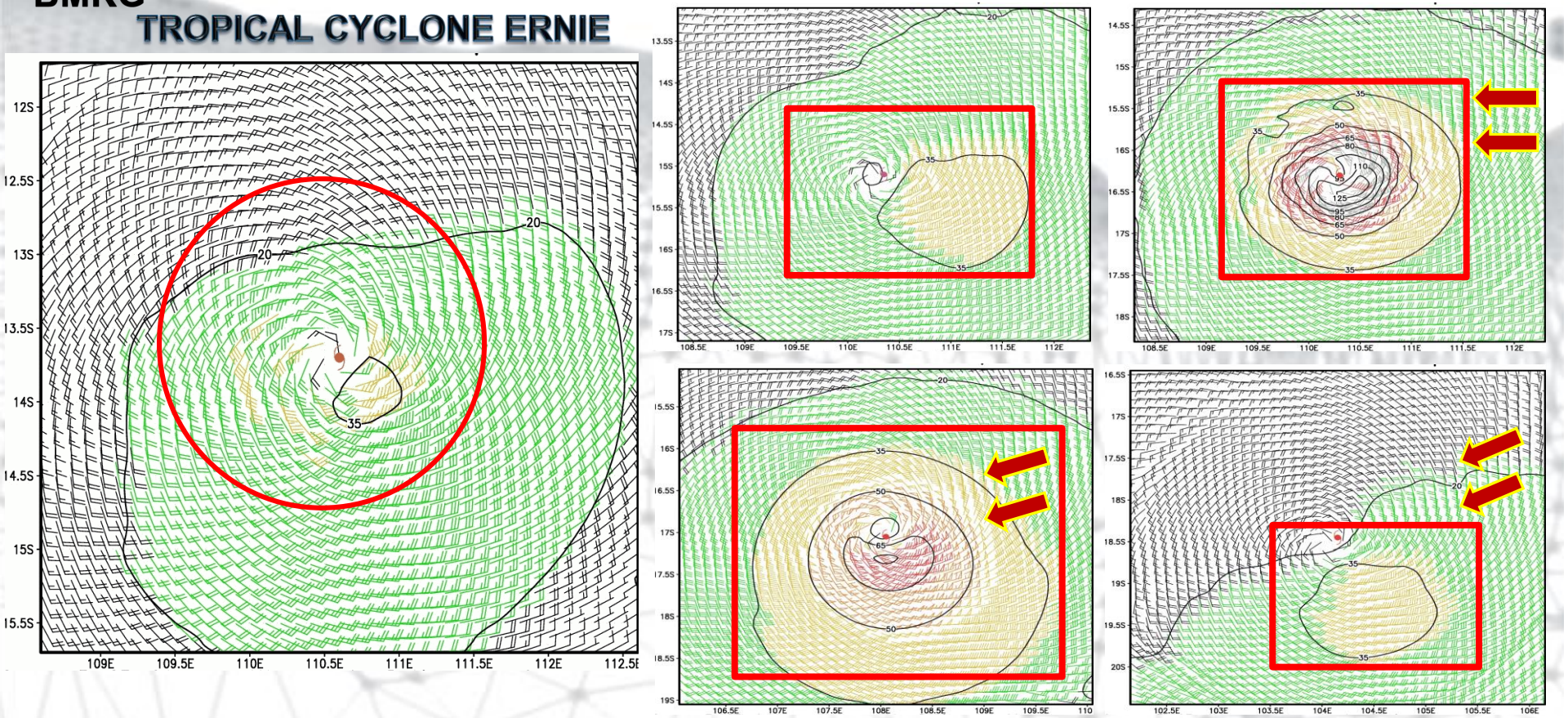
Effect of strong winds from tropical cyclone causing Storm Surge or Inundation



The intensity based on the strengthened condition on April 8, 2017 and weakened condition on April 10, 2017. Based on the Wind Track Intensity (STI), the condition for increasing the peak of maximum wind intensity results on the rise of the upwelling system in the center of the cyclone and an increase in the storm surge response system.

TROPICAL CYCLONE ERNIE : EVOLUTION

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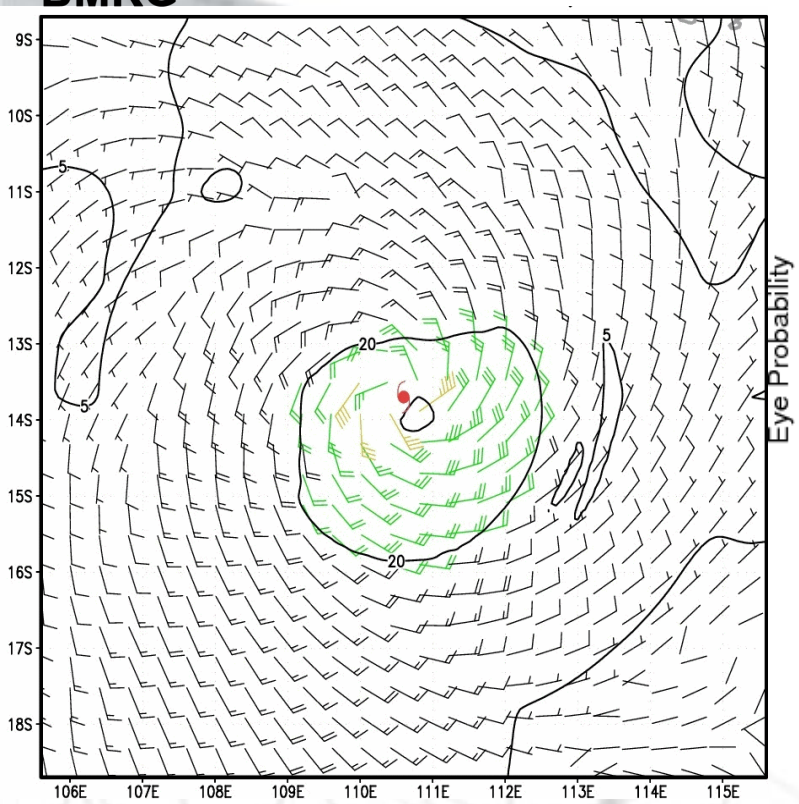
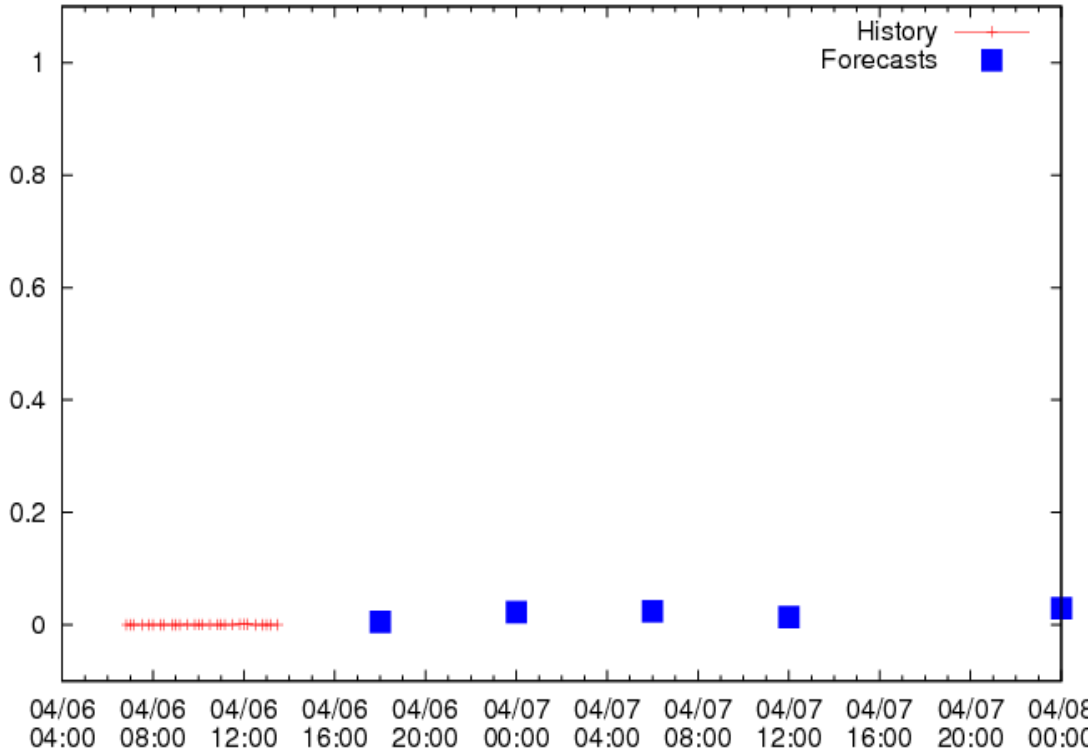
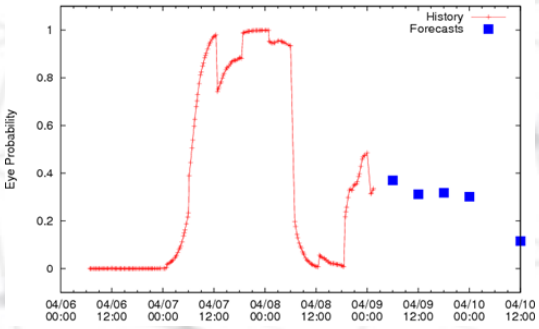
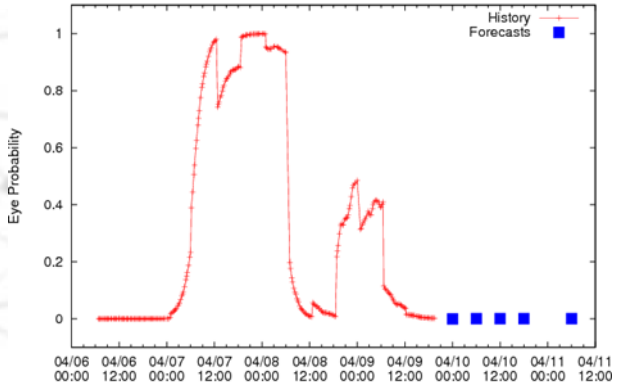




The intensity of eye probability is 0.0 to 1.0 and for the wind is 35 - 95 knots





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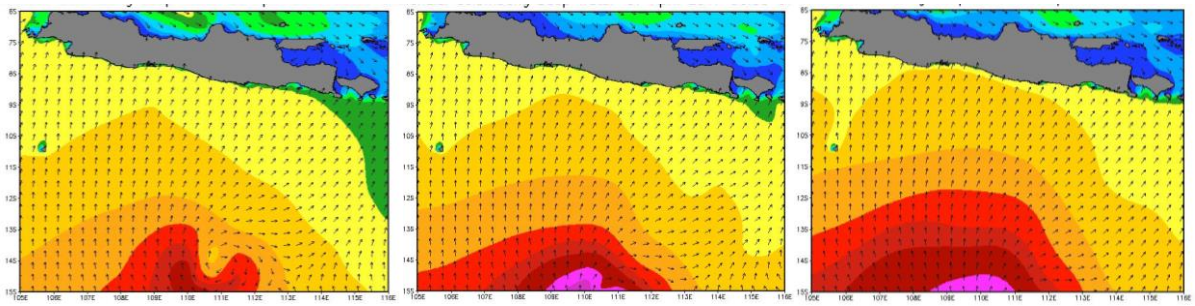
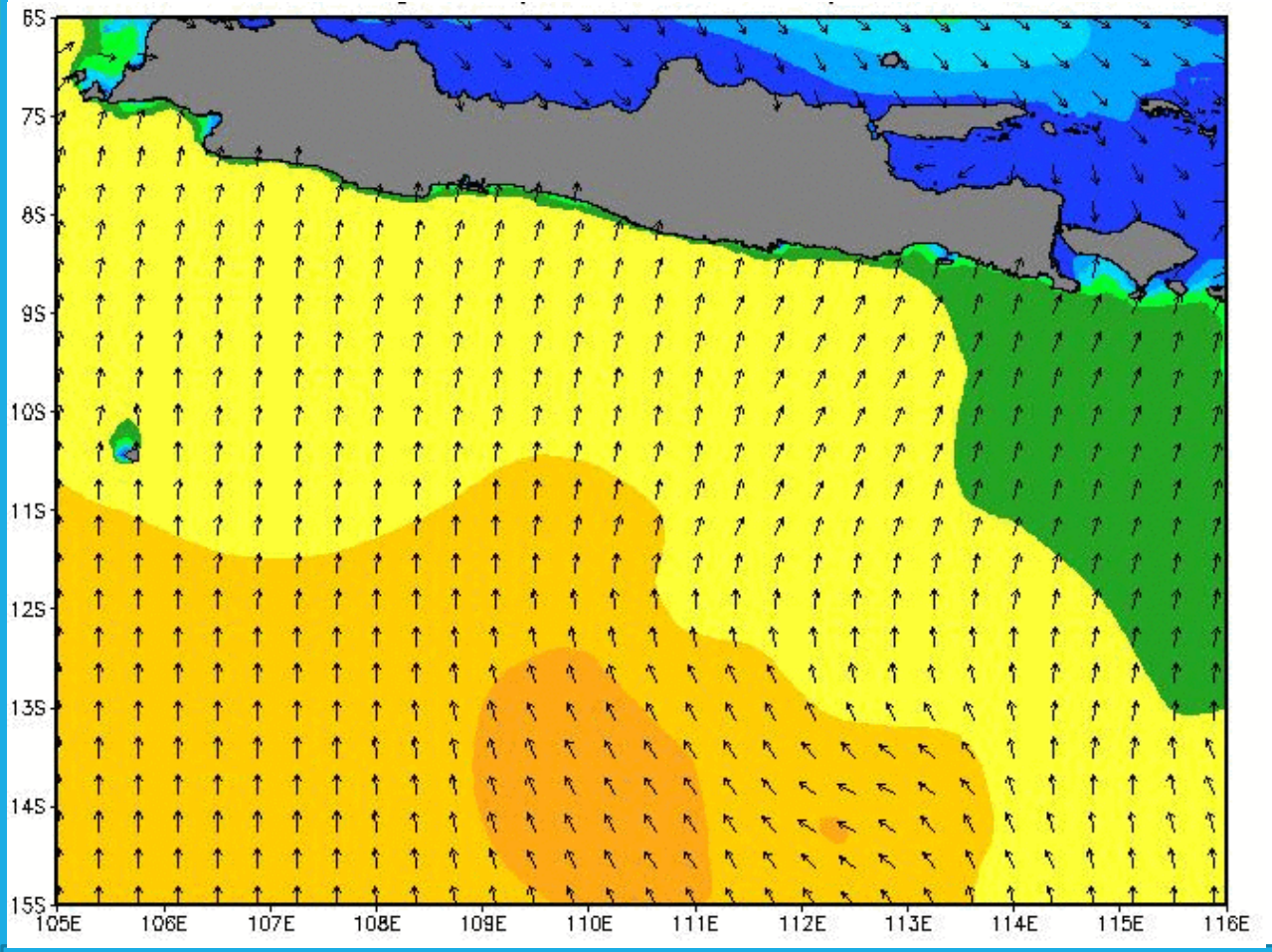
WAVES

Waves Height

Swell



Waves Height on 06-10 April 2017



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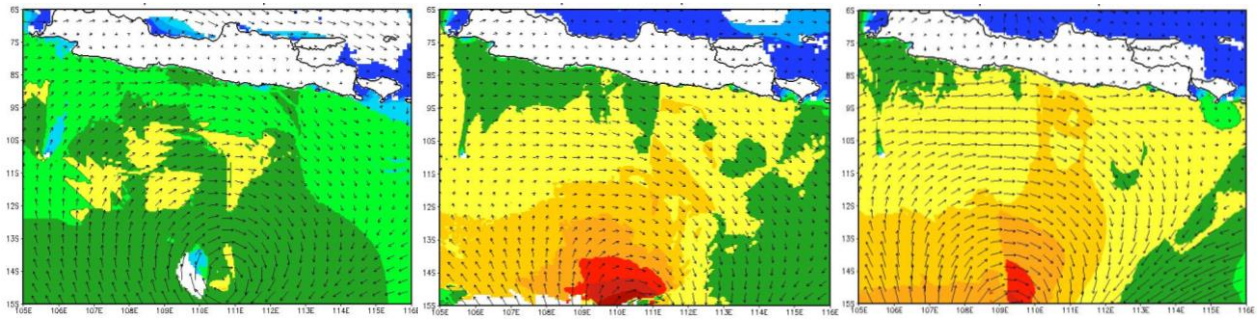
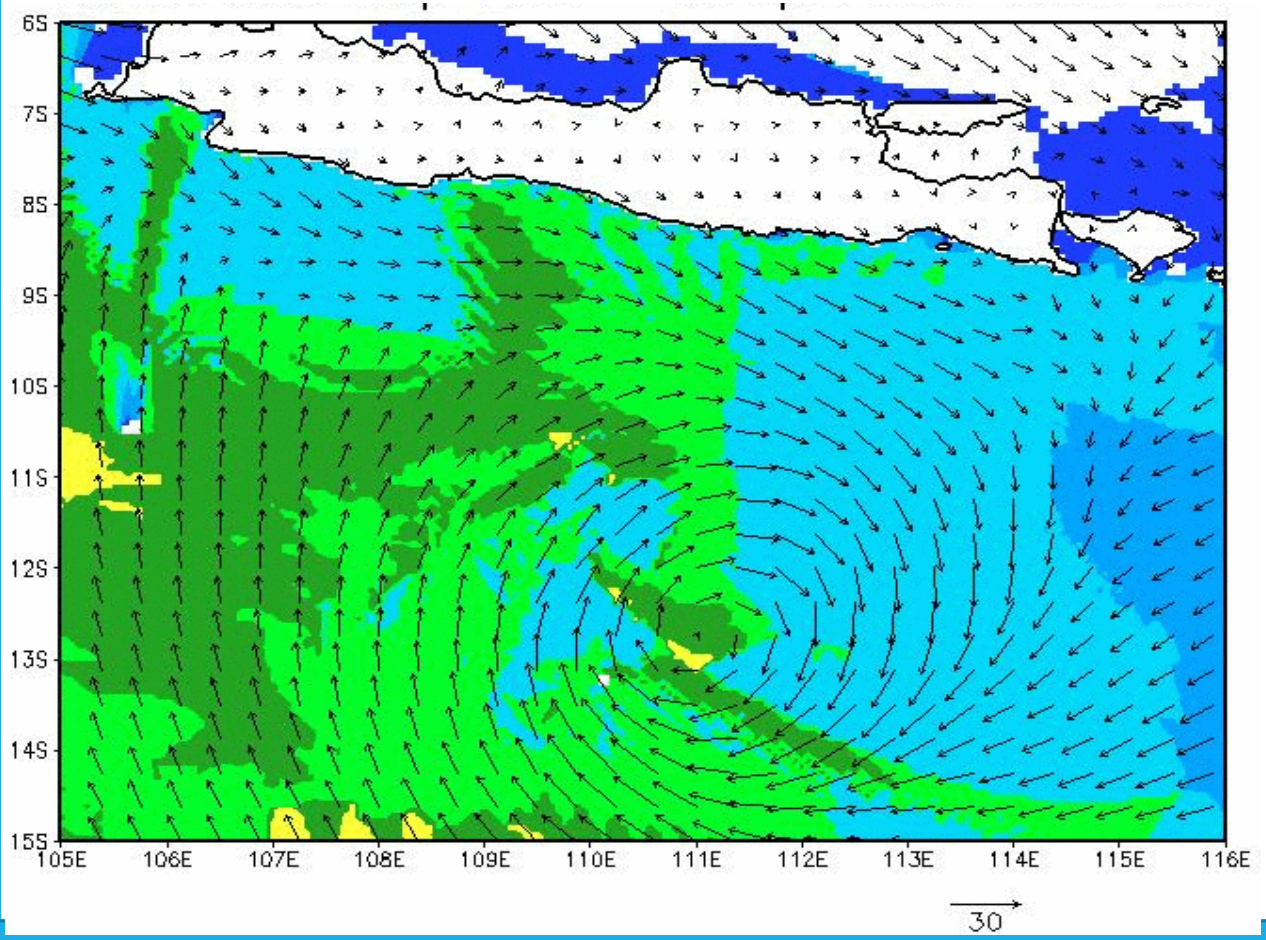
Swell

Waves Height

Swell



Swell on 06-10 April 2017



IMPROVE INITIAL MODEL : OBS AND IN SITU OBS

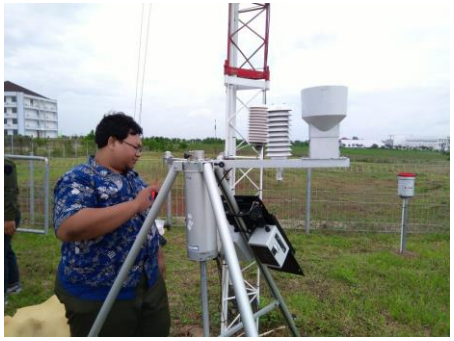
$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}-fv=-\frac{1}{\rho_0}\frac{\partial P}{\partial x}+\frac{1}{\rho_0}\frac{\partial \tau_x}{\partial z}$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}+fu=-\frac{1}{\rho_0}\frac{\partial P}{\partial y}+\frac{1}{\rho_0}\frac{\partial \tau_{yx}}{\partial z}$$

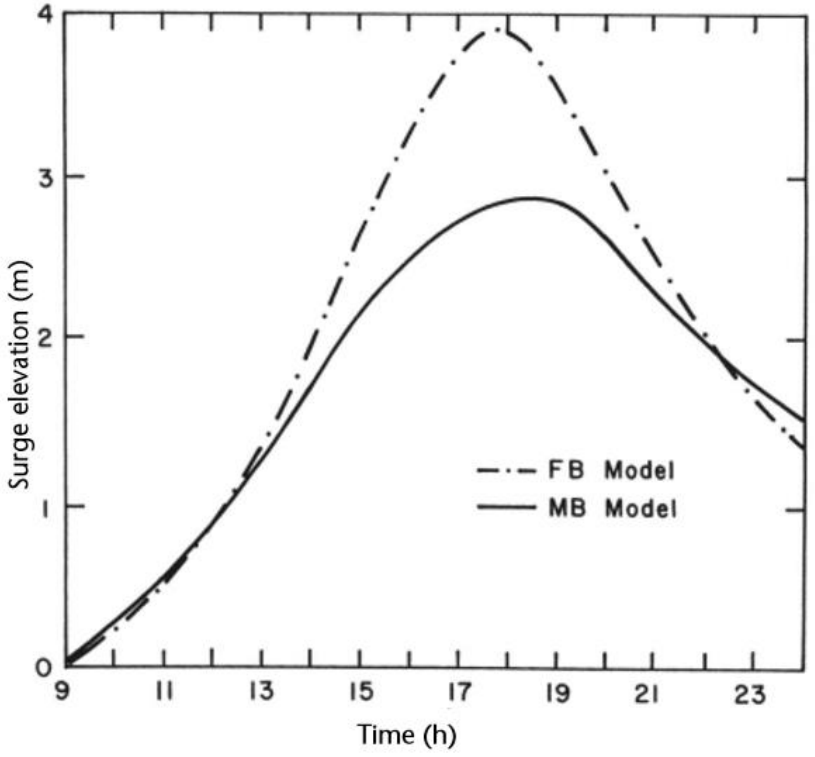
$$\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}=-\frac{1}{\rho_0}\frac{\partial P}{\partial z}-g$$

Tide Gauge

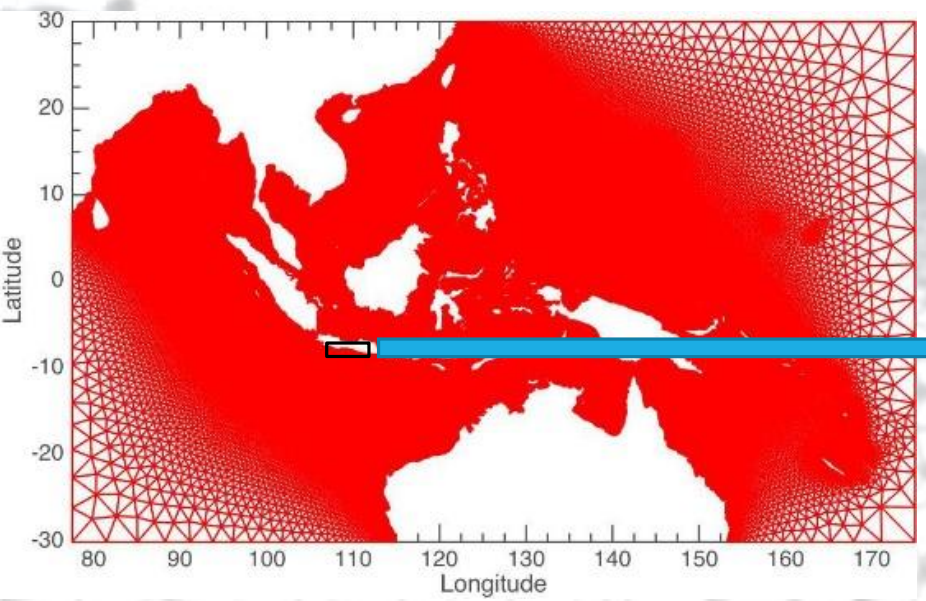
$$\frac{v^2}{r}+fv=-\frac{1}{\rho}\frac{dp}{dr}$$

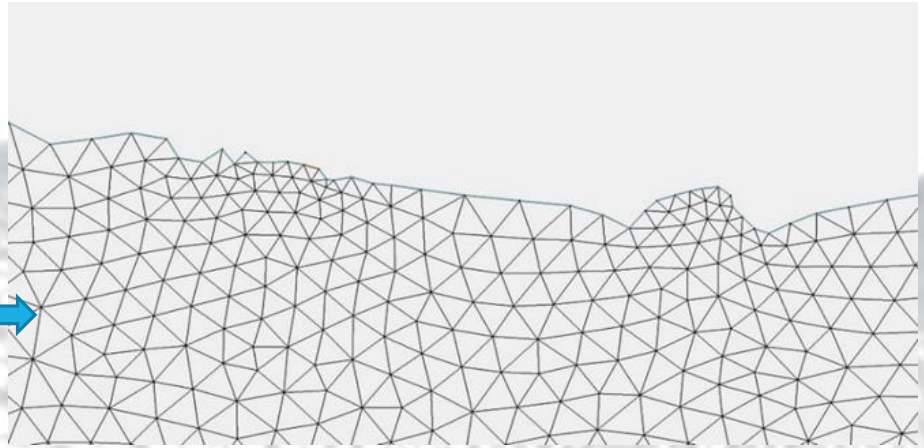


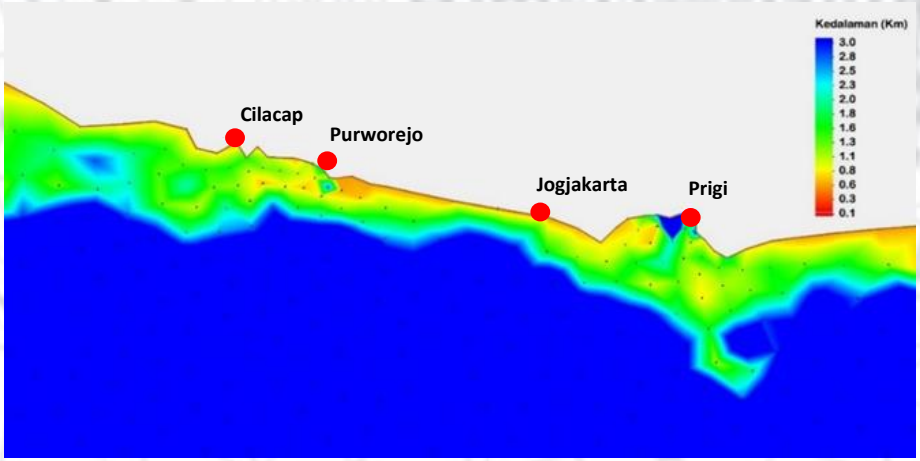
AWS

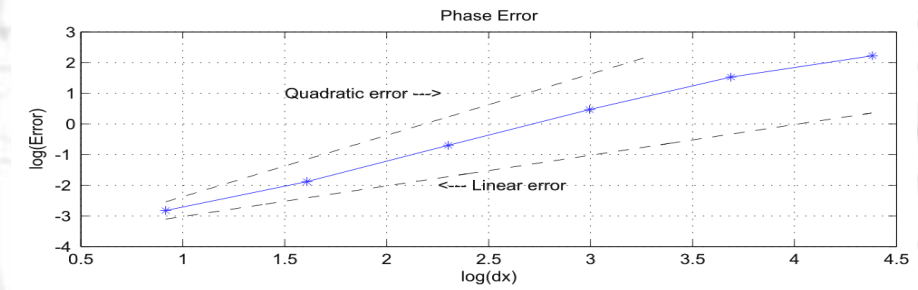


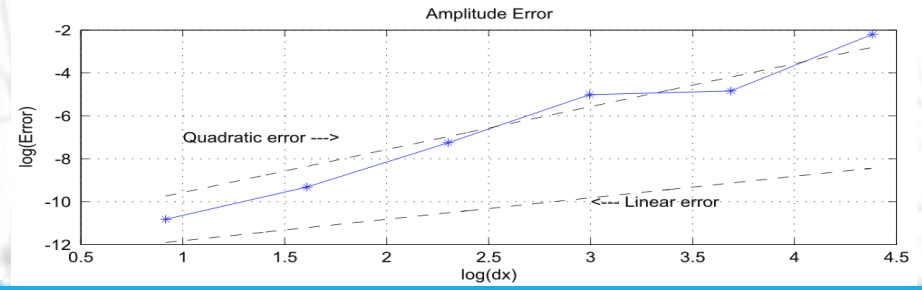
UNSTRUCTURED MESH GRID (TRIANGULAR NETWORK)





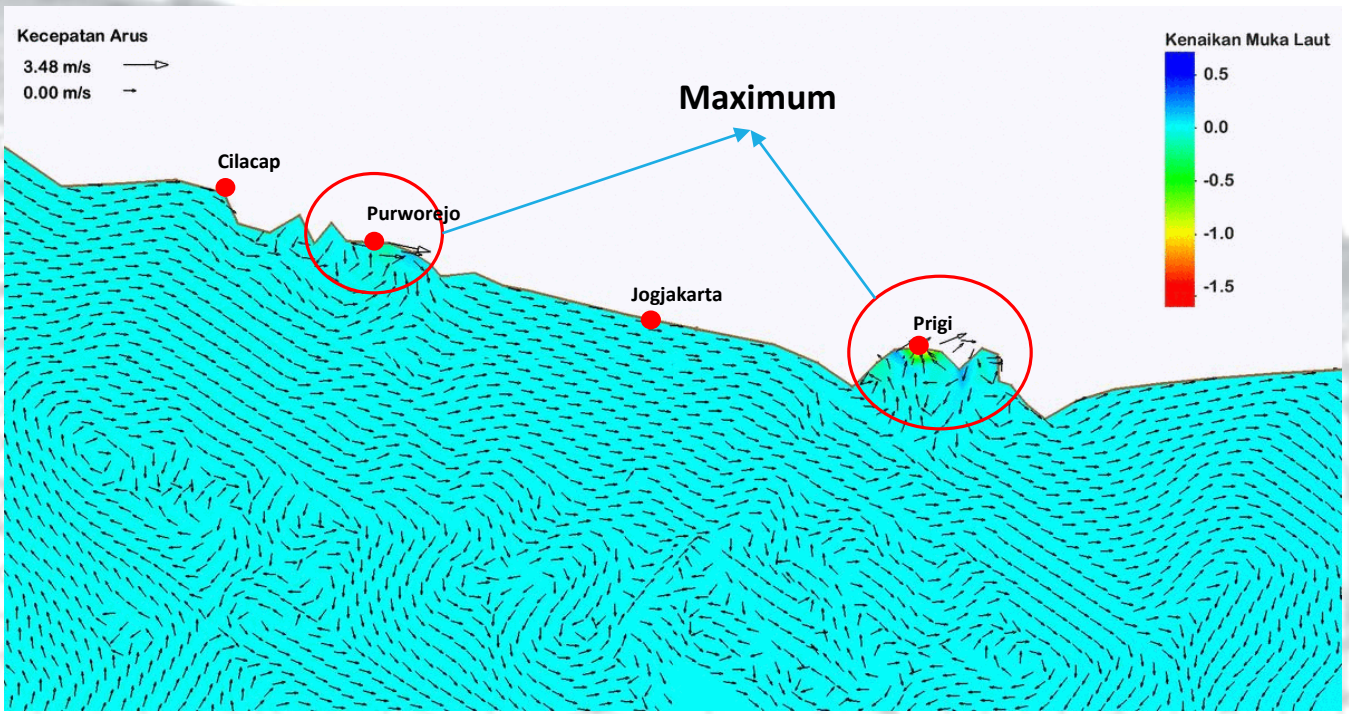






Unstructured Mesh Grid (Triangular Network) : due to the contour of South Java coast which is representative for shallow water leads directly to the slope of the ocean depth with a contour of at least 2000 meters.

Water Level Elevation Non EnsembleKF

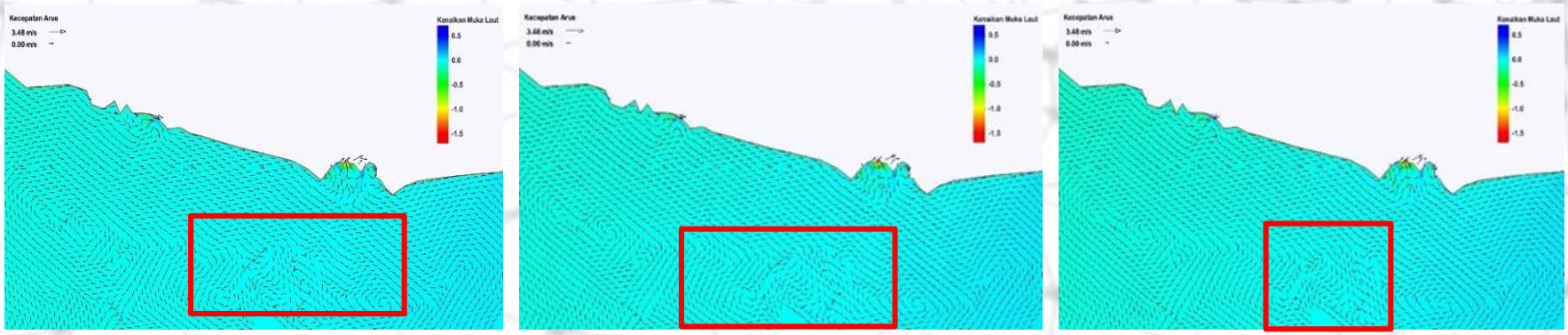


Wind + Surface Current

The condition at 06.00 UTC dominated by the propagation of waves which are more visible than the condition of currents approaching the coast, where the southern region of Java experienced a sea level rise of 0.2 meter or 20 cm.

The condition at 09.00 UTC indicate that sea level rise is 0.2 meters or 20 cm.

At 18:00 UTC, sea level rise is 0.3 meter or 30 centimeters.



Breaking Waves

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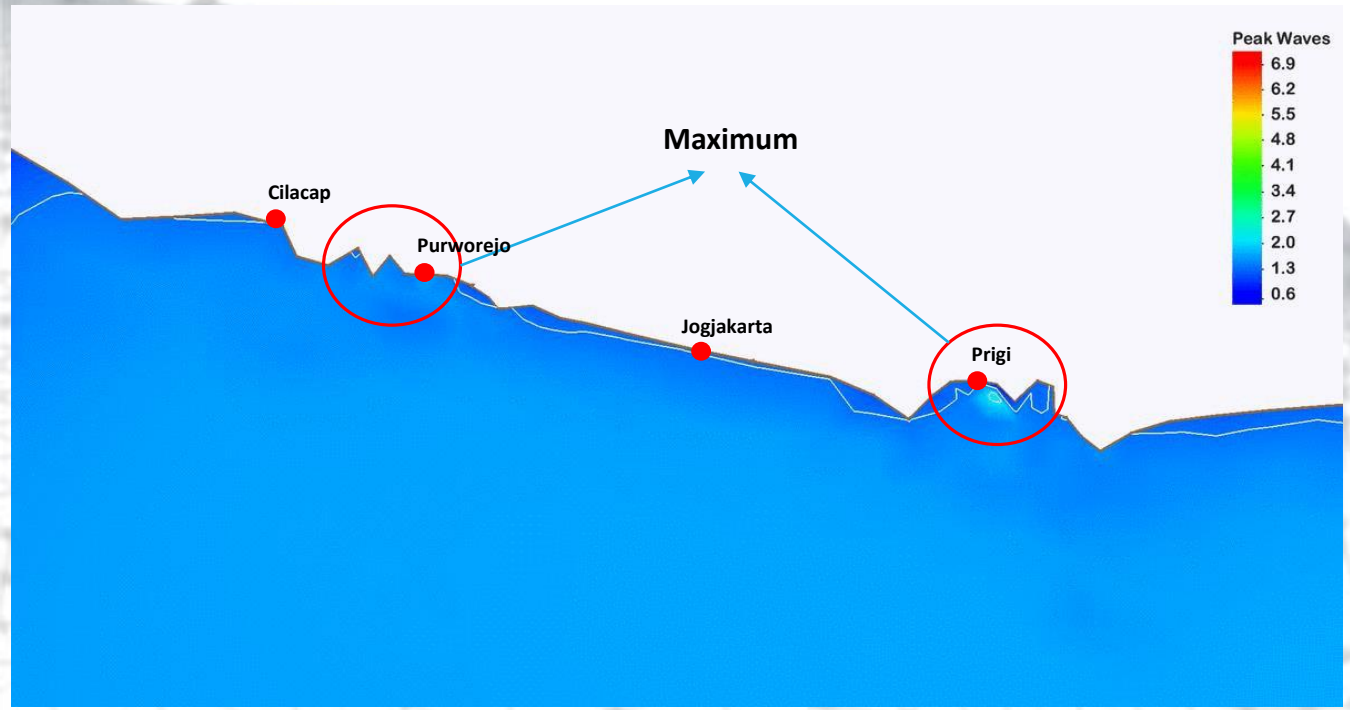
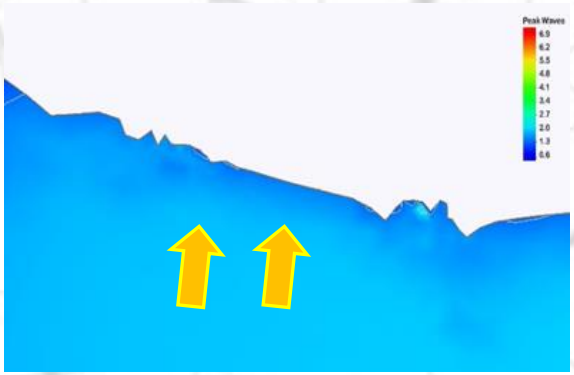
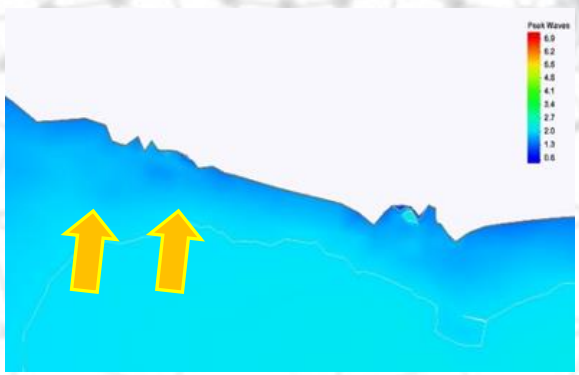
PEAK SURGE
Non EnsembleKF



Wind
+
Tides

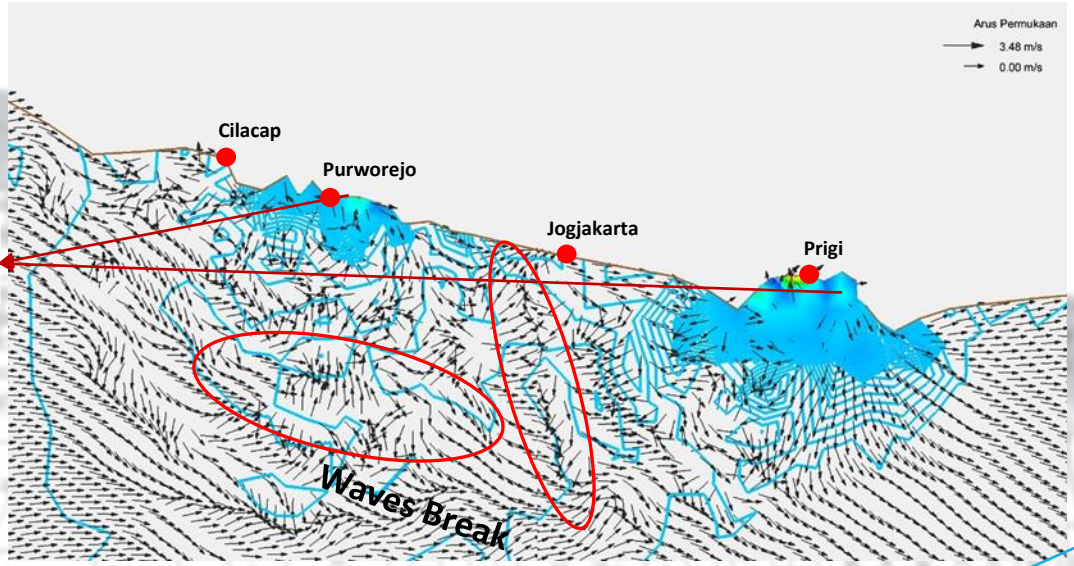




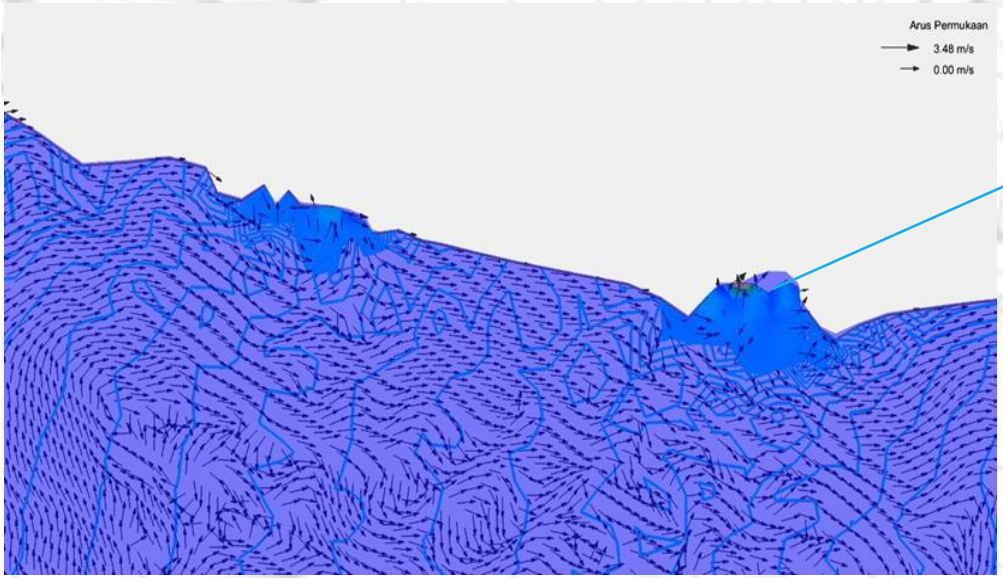
INUNDATION : Non ENSEMBLEKF

BMKG

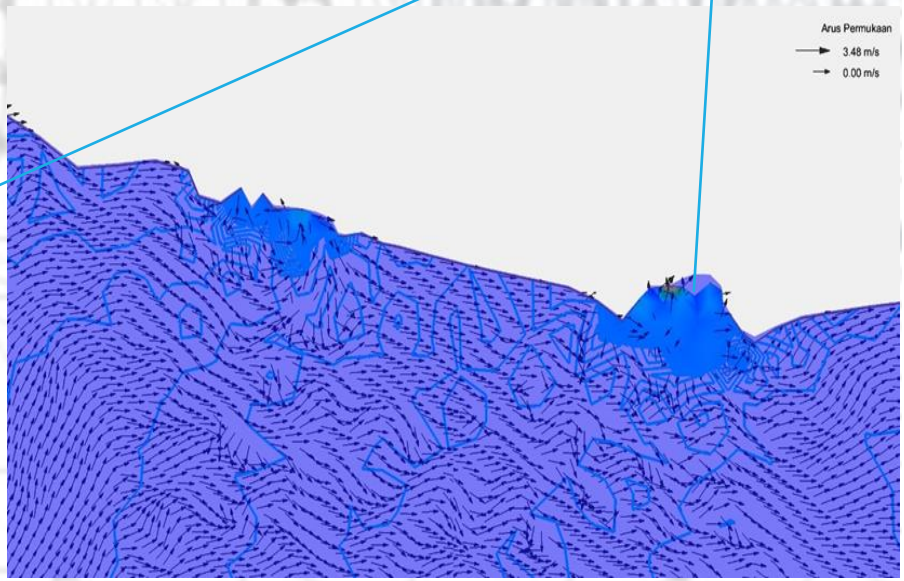
Peak Surge + Tides



Inundation

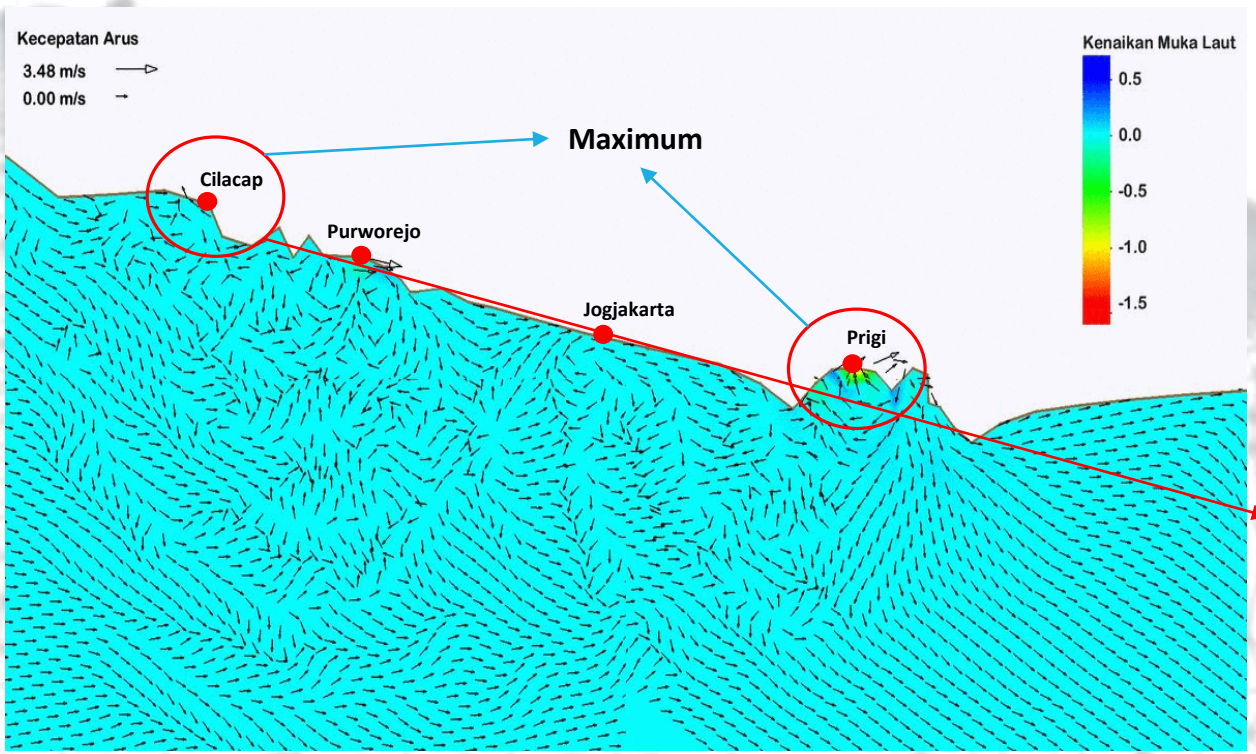


Within TC Ernie



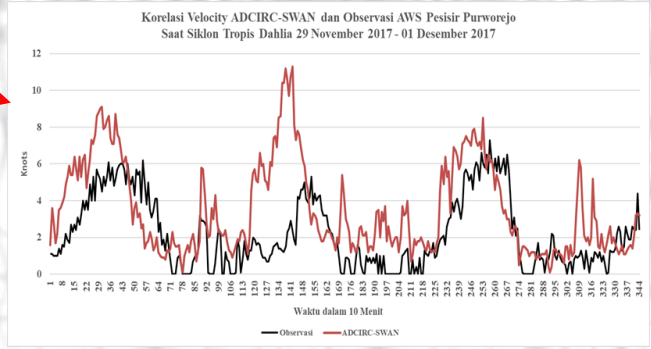
After TC Ernie

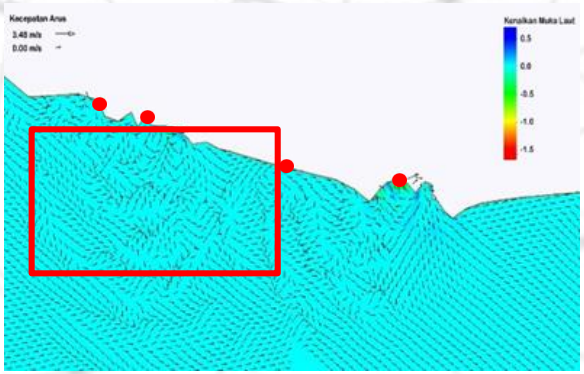
Water Level Elevation EnsembleKF

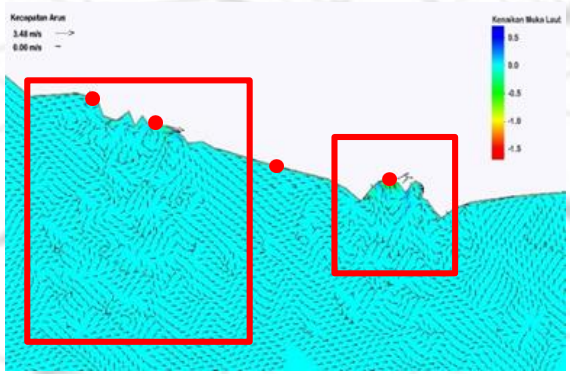


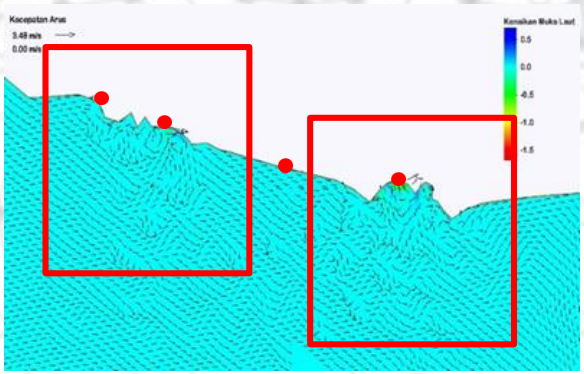
Wind + Surface Current

Maximum Water Level 0.3 meter





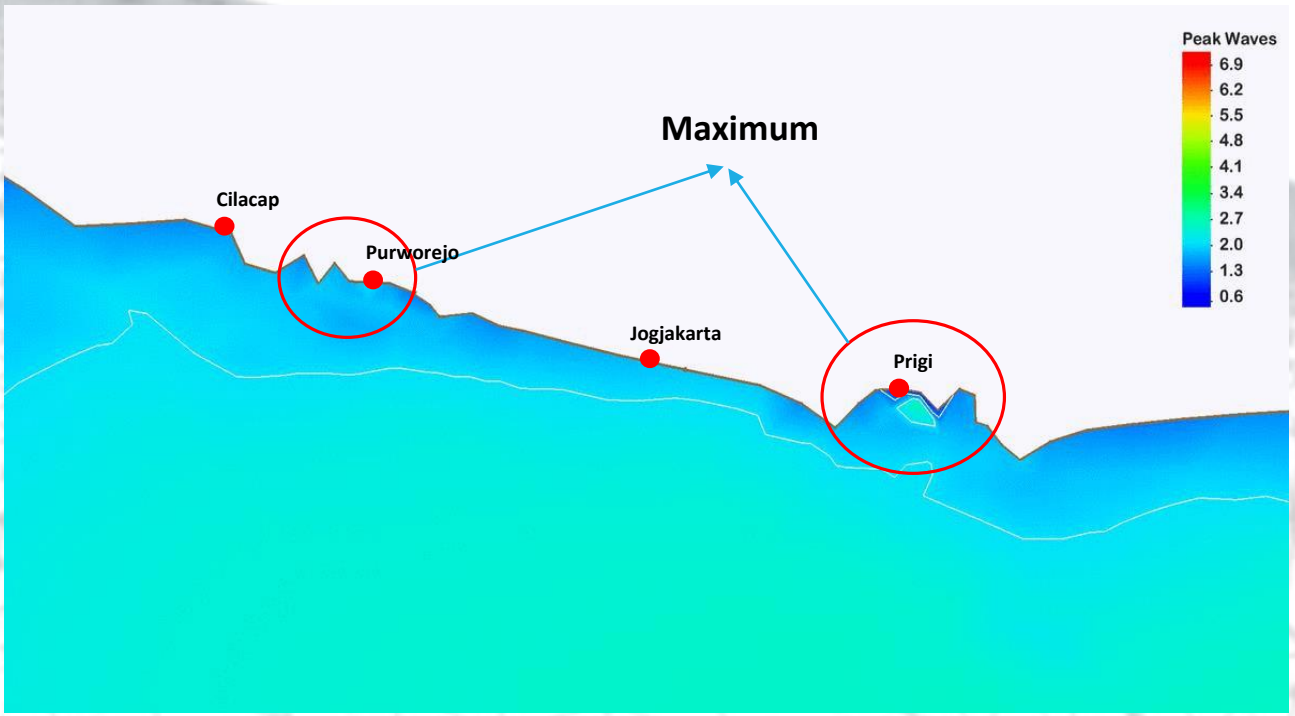


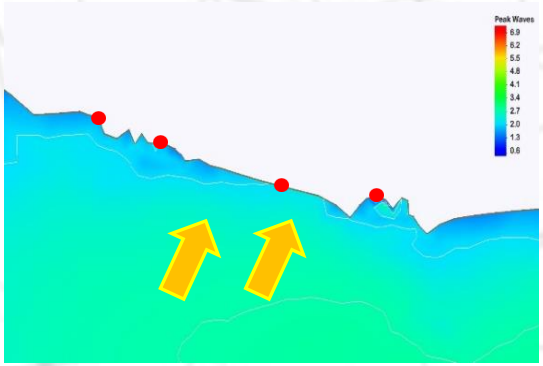


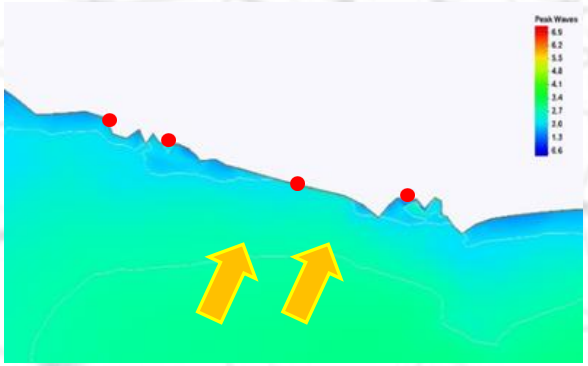
Breaking Waves

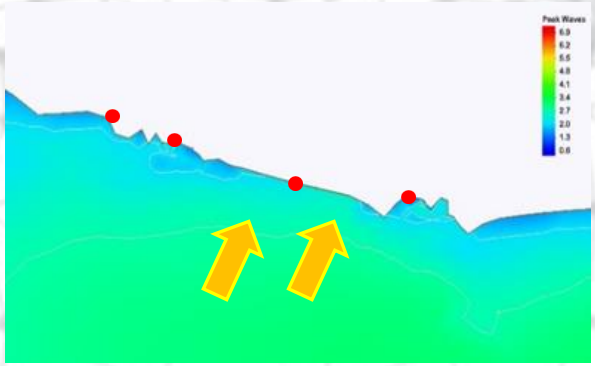
PEAK SURGE
EnsembleKF

Wind + Tides



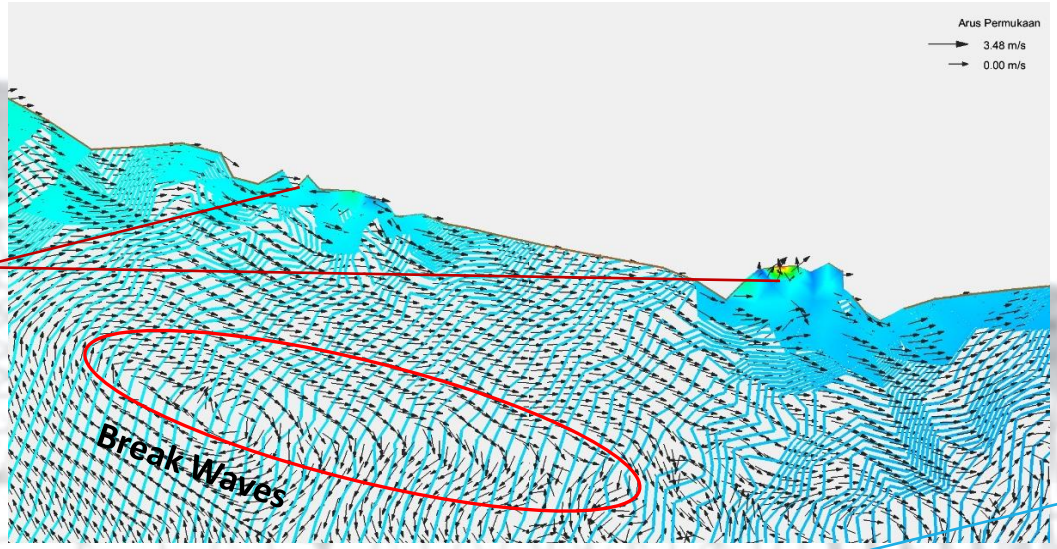






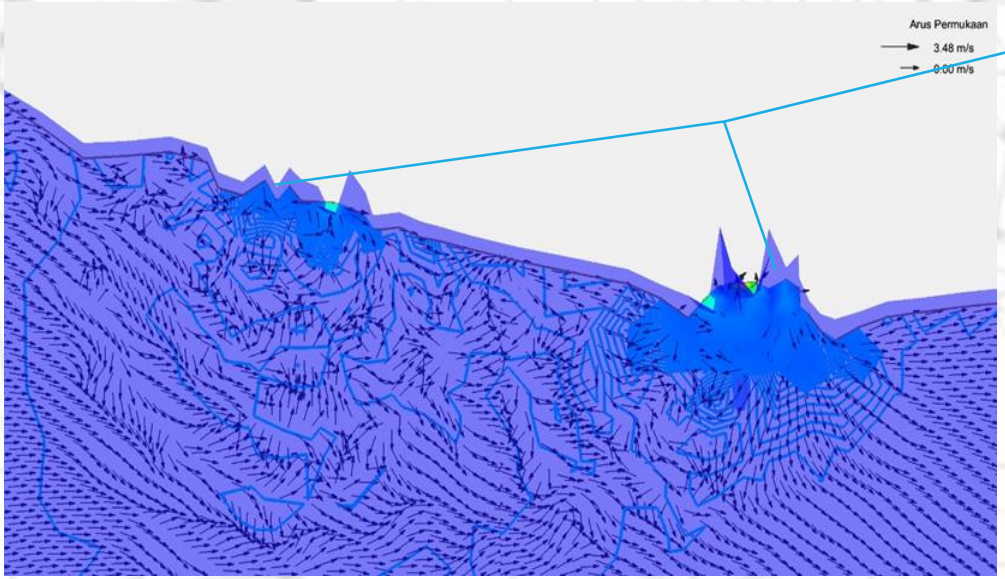
Tide Surge

INUNDATION : EnsembleKF

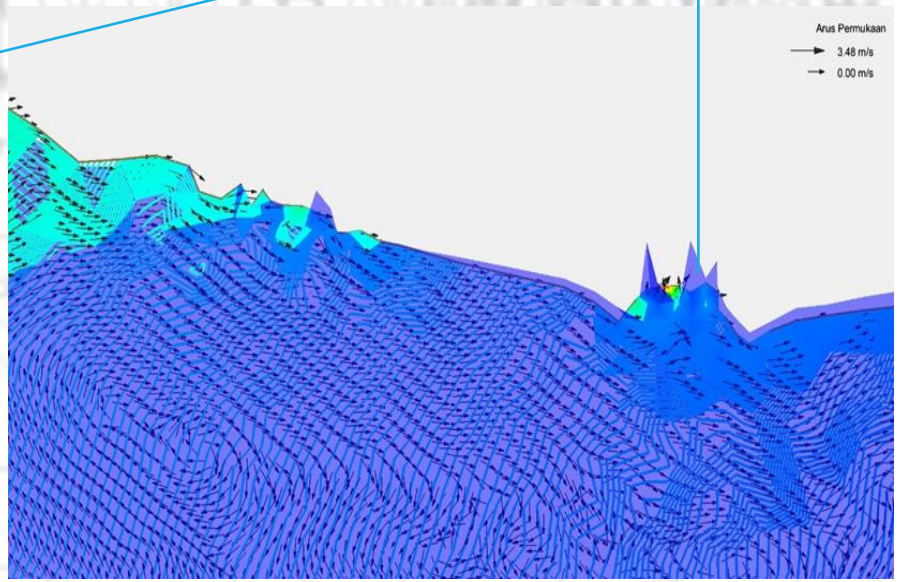


Peak Surge + Tides

Inundation



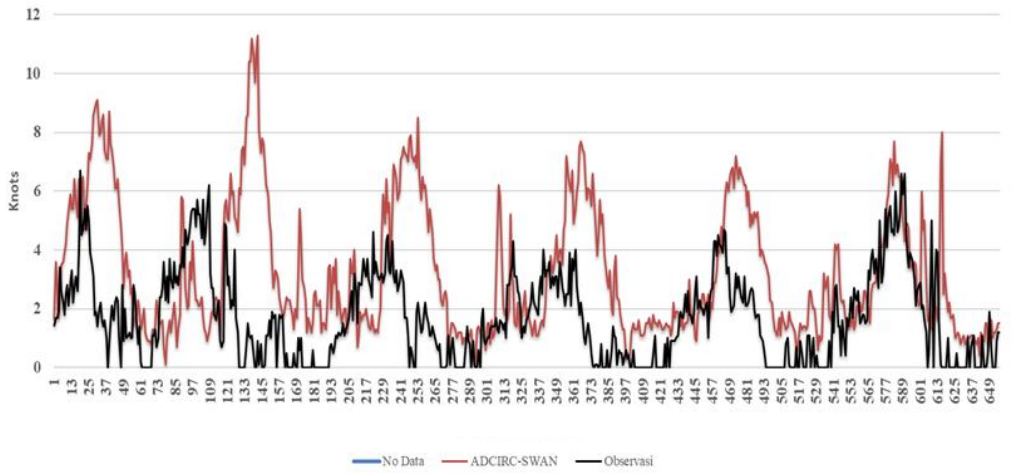
Within TC Ernie



After TC Ernie

VELOCITY
(MULTI-VERIFICATION)

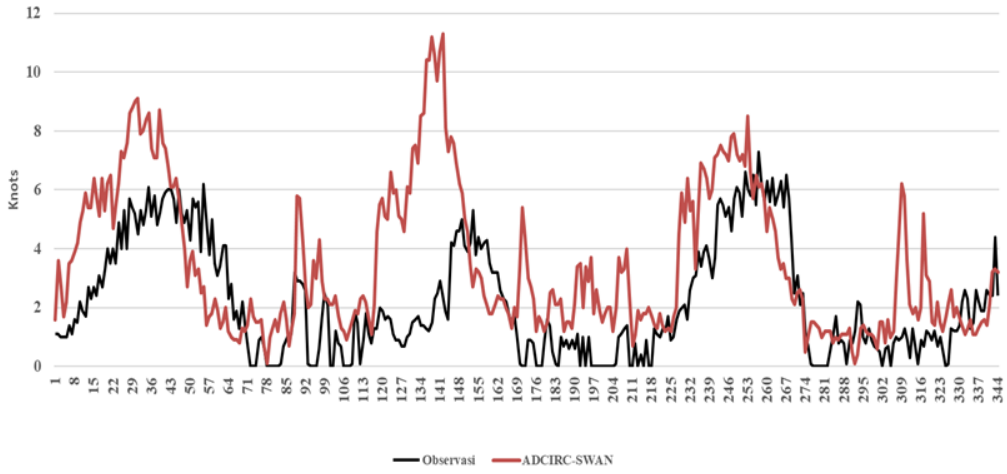
PRIGI



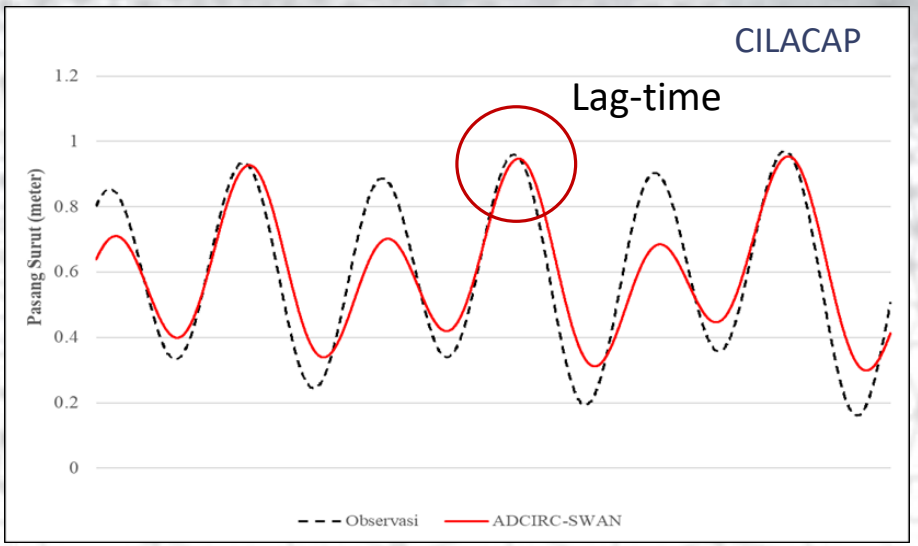
BMKG

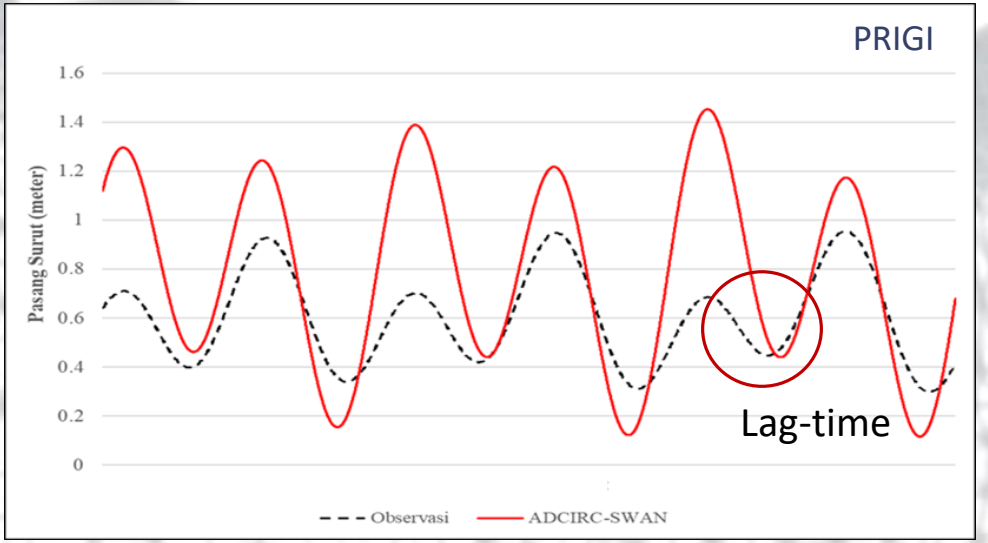
Station	Correlation	RMSE
Prigi	0.67	4 – 7 knots
Cilacap	0.65	5 – 7 knots

CILACAP



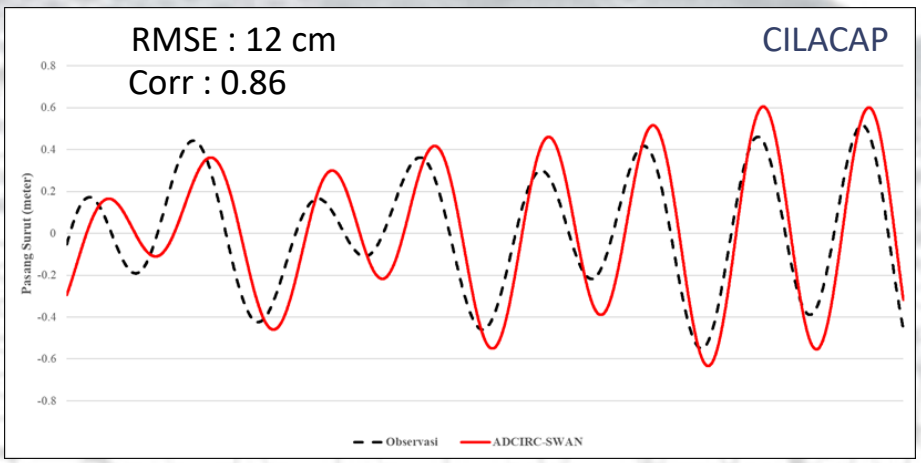
Non ENSEMBLE

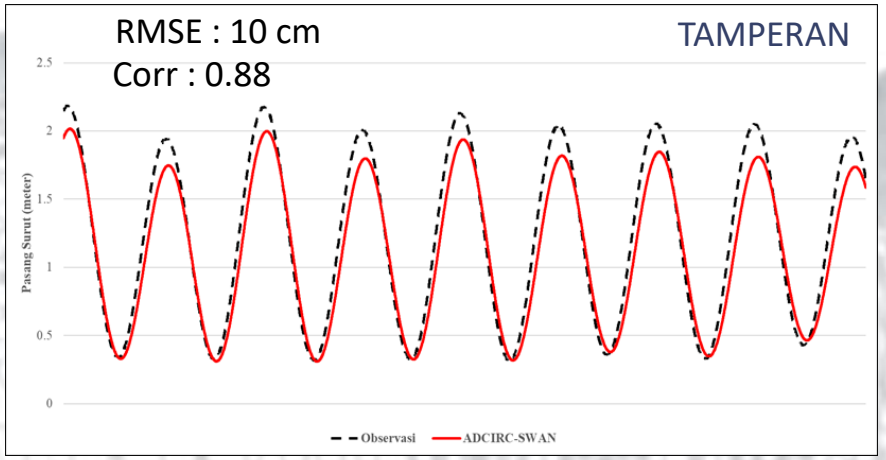


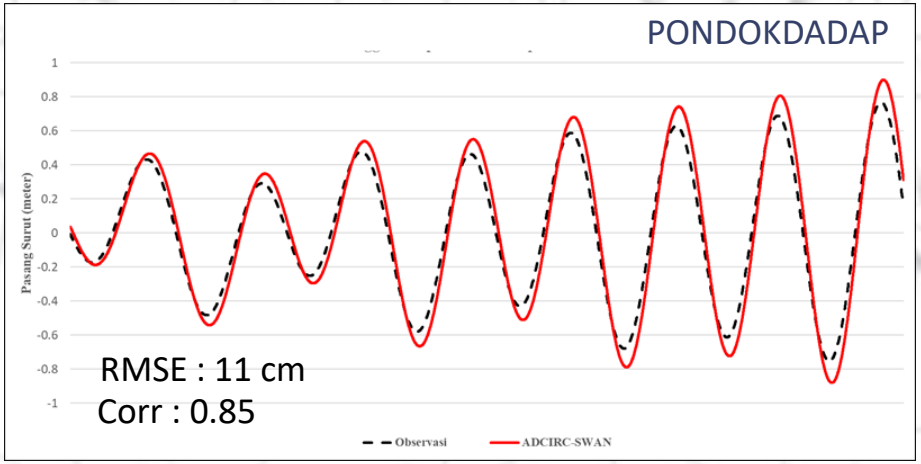


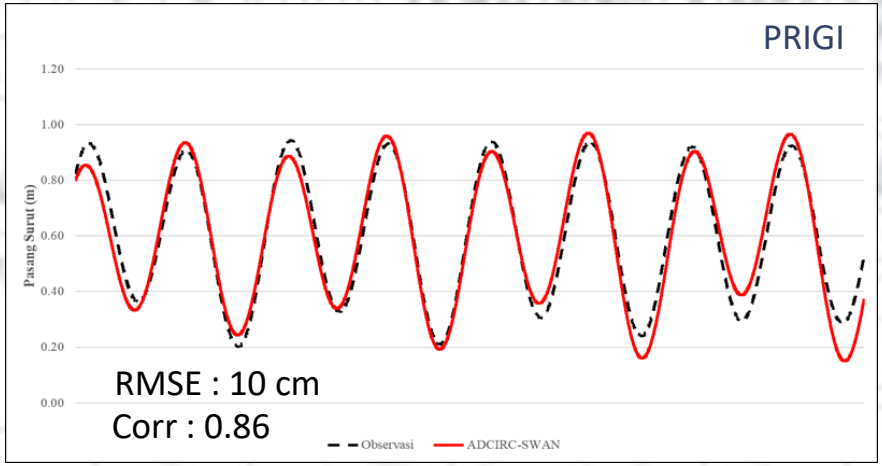
Station	Correlation	RMSE
Cilacap	0.70	20 cm
Prigi	0.63	21 cm

EnsembleKF


RMSE : 12 cm
Corr : 0.86
CILACAP
Pasang Surut (meter)
Observasi
ADCIRC-SWAN


RMSE : 10 cm
Corr : 0.88
TAMPERAN
Pasang Surut (meter)
Observasi
ADCIRC-SWAN


PONDOKDADAP
Pasang Surut (meter)
RMSE : 11 cm
Corr : 0.85
Observasi
ADCIRC-SWAN


PRIGI
Pasang Surut (m)
RMSE : 10 cm
Corr : 0.86
Observasi
ADCIRC-SWAN

BMKG

CONCLUSION

1. The wind produced by Ernie Tropical Cyclone is 95-110 knot at the center of the cyclone and 25 - 35 knot at the tail of the cyclone.

2. The verifications for ADCIRC-SWAN model output produce good correlation, normal RMSE, and are not too distorted with observational data.

3. Further research for the bottom friction coefficient (bottom friction) in the coastal areas of Java is needed.

BMKG

Thanks to :

Marine Meteorological Center, BMKG
Meteorology Department

TERIMA KASIH