Monitoring of Ocean Circulation in Jakarta Bay

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Introduction

Ocean circulation can describe the hydrodynamics of water condition has a great influence to the existence of biota and human activities. A very big changing in hydrodynamics conditions will give a big change into the environment especially to the sensitive biota and marine ecosystem. Current circulation was influenced by many factors such as tides, surface wind, waves, etc. Study about current circulation can be done by analyzing the data which are scattered in many stations in the same time and map it as general circulation. This method is very expensive because needed too many equipment and long period of observation. Another method to understand the physical processes on the ocean circulation is used a numerical modelling. In this study, we wil use an 3 Dimension (3D) ocean modeling to simulate and predict the daily ocean circulation that produce some physical parameters such as sealevel, current vectors, temperature, salinity, etc.

Jakarta bay, as one of the entering gate to the Jakarta City, is one of the important waters in Indonesia. According to this function, Jakarta bay has too many changing in hydrodynamics conditions caused by nature and human activities. The study of current circulation in Jakarta bay was very important. To study the ocean circulation and physical processes in Jakarta Bay, a numerical modeling system based on the Princeton Ocean Model (POM Model, Blumberg and Mellor, 1987) has been implemented in the Jakarta Bay.

A joint collaboation research between Laboratory of Marine Survey Technology (BTSK)-BPPT and Center for Marine and Enviromental Studies (CMES) have been collected the observation data such as sealevel, temperature-salinity and dissolved oxygen (DO) profiling, ocean current observation, nutrient sampling,etc since December 2015- December 2018. These observation data used to perform the above ocean model in Jakarta Bay.

In this study, we only consider the tidal and wind monsoon as principal forcing to generate the physical processes in Jakarta Bay waters.

Aims

The aim of this study are,i.e:
- to understand the current circulation and to predict the physical processes in Jakarta Bay using the POM model.
- to investigate if this model configuration is capable of reproducing the major features of the circulation as known from observations
- to improve what has been made by previous numerical modeling works

Procedures

Numerical Modelling

The Princeton Ocean Model (POM) is a 3-D primitive equations ocean circulation model, which has been described in detail by Blumberg and Mellor (1987) and Mellor (2004). POM is a free surface, sigma coordinate model that uses atime-splitting technique to solve depth-integrated and fully three-dimensional equations with different time steps. The surface elevation, velocity, temperature, and salinity fields are prognosticated assuming the fundamental hypotheses: (i) that the seawater is incompressible, ii) that the pressure in any point of the ocean is equal to the weight of the column of water over it (hydrostatic approximation), and iii) that the density can be expressed in terms of a mean value and a small fluctuation (Boussinesq's approximation). Consequently, in a system of orthogonal Cartesian coordinates, the governing equations are:

$$\frac{\partial U_i}{\partial x_i} = 0 \qquad (1)$$

$$\frac{\partial (U,V)}{\partial t} + \frac{\partial [U_i(U,V)]}{\partial x_i} + f(-V,U) = \rho_0^{-1}\left[\frac{\partial p}{\partial x},\frac{\partial p}{\partial y}\right] + \frac{\partial (K_M \frac{\partial (U,V)}{\partial z})}{\partial z} + (F_{U,}F_V) \qquad (2)$$

$$\frac{\partial p}{\partial z} = -\rho g \qquad (3)$$

$$\frac{\partial \theta}{\partial t} + \frac{\partial (U_i\theta)}{\partial x_i} = \frac{\partial (K_H \frac{\partial \theta}{\partial z})}{\partial z} + F_\theta + \frac{\partial R}{\partial z} \qquad (4)$$

$$\frac{\partial S}{\partial t} + \frac{\partial (U_i S)}{\partial x_i} = \frac{\partial (K_H \frac{\partial S}{\partial z})}{\partial z} + F_S \qquad (5)$$

Which are KM and KH , are computed according to the Mellor-Yamada 2.5 turbulance closure scheme (Mellor and Yamada, 1982). This scheme requires progmostic calculations of (q2) and (q2l), where the turbulent kinetic energy is q2/2 and the turbulent macro scale is (l). The equations that calculate q2 and q2l are similar to those used for temperature and salinity and include production and dissipation source/sink terms. Horizontal diffusion terms (FU,FV , F, and FS) are computed using the Smagorinsky (1963) formulation, implemented into POM according to Mellor and Blumberg (1986). The last term in Eq. (4), is the solar radiation flux that penetrates the sea surface. The UNESCO equation of state, as adapted by Mellor (1991) is used. The in situ density is determined as a function of salinity, potential temperature and pressure; the latter being approximated by the hydrostatic relation and constant density.

Model Configuration

The model domain comprises the Jakarta Bay, Indonesia, from 106º 33' 00"-107º 01' 30"E and from 6 º 12' 00'' – 5º 49' 30"S. The bottom topography used the Shuttle Radar Topography Mission (SRTM) with 30 second grids (https://topex.ucsd.edu/WWW_html/srtm30_plus.html). Grid resolution model constructed from the topogarphy data for 1/400º x 1/400º degree. In this model version (afterward JB model), there are three open lateral boundaries; at 106.555 ºE, at 107.025 ºE and 5.825 ºN. The JB model has been configured with a horizontal resolution of 1/400º in latitude by 1/400º in longitude. In the vertical , the grid has 11 sigma layers with logaritmic distributions at the surface and the bottom and a linear distribution in between. Other significant model parameters are given in Table-1.

Table-1. Model Parameter used in The Jakarta Bay (JB) model.

Parameter	Description	Value
C	Non-dimensional constant used in calculating the horizontal viscosity for momentum	0.2
tprni	Inverse horizontal Prandtl Number	0.2
μM	Background viscosity	0.00002
Zo	Bottom roughness length	0.01
Δt_{ext}	External mode time step	3 sec
Δt_{int}	Internal mode time step	60 sec

Open lateral boundaries conditions which are derived from FES2016 Global Tide Model are modified, e.g. tidal amplitude of FES2016 + 0.008m. Therefore, open lateral boundary of barotropic tidal currents which are derived 2-D tidal model are applied to the 3-D tidal model. Surface boundary applied in this model are only the wind data collected from Meteorological Maritime Station at Tanjung Priok Port, Jakarta (106° 52' 49.7"E, 06° 06' 28.3" S). Time simulation period for the model is started from June 1, 2015 untill December 31, 2016 (1.5 years).

Results

In the following paragraph, the harmonic analyses for four constituents (M2,S2, K1 and O1) from model results compare to the tide observations as reported by Koropitan and Ikeda (2008) on a tidal station at in Jakarta Port (106.89083^{o}E, 6.10667^{o}S). Table-2 show the model is very close to the observation. Some small differences of phase is considered as mixing process of water masses in the Jakarta Bay.

After the wind forcing considered in the JB's 3D-Tide model, we did the monthly-mean of surface horizontal distributions of sea level and current velocity fields from the daily model results. The analysis started from August 2015 to December 2016 due to neglect the spin-up time period (~about 2 months).

In August-September 2015 the vector fields flows from the east to west side of Jakarta Bay. Vector field on September 2015 tends to increase due to the moonsoon winds change from east to east-west transition monsoon winds. Sea surface tends to increase on western side of Jakarta Bay on August-September 2015. But, starting in October-December 2015 the increasing of sea surface propagates to the center and eastern side of Jakarta Bay (**Figure-1**).

Table-2. Comparison of observed and modelled M2,S2,K1 & O1 tidal elevations at the coastal tide-gauge station at Jakarta (106° 52' 49.7"E, 06° 06' 28.3" S).

Constituents Amplitude (cm) Phase (oG)	Observed*	Model
M2	5.41	5.45
	140.85	134.06
S2	5.04	5.08
	78.08	73.69
K1	25.17	24.92
	34.73	32.69
O1	13.75	13.70
	25.32	22.84

**Koropitan and Ikeda,2008*

Again, the surface currents tends to flow from west to east side Jakarta Bay during December 2015 to February 2016. But in this period, there are three positions of high sealevel in Jakarta Bay, i.e. east side (December 2015), west side (January 2016) and east side (February 2016). It means the model results shows the anomaly sea surface in January 2016.

From March-May 2016 the surface velocity fields shows changing from southward to westward. This conditioo is similar to the propagation of high sea surfaces (the transition monsoon period). The easterly monsoon wind looks dominant in period May to August 2016. In this period the surface current propagate from east to west side of Jakarta Bay (westward currents). This situation confirmed to the existence of high sea surface in west side of Jakarta Bay.

The westward surface current fields increase from September to December 2016. This situation is also coincide to the presence of high sea surface in east side of Jakarta Bay.

Perspective in the future

To complete the JB mode become the realistic ocean model, in future, we will consider the density-driven currents induced by the river discharges, heatflux and temperature-salinity fields from the observations. Finally, this model coupled by the ecosystem model with initial observation data in Jakarta Bay such as dissolved oxygen (DO), nutrients, pH, etc. Then, we will made the simulation of physical-ecosystem model in Jakarta Bay from October 2015 to December 2018.

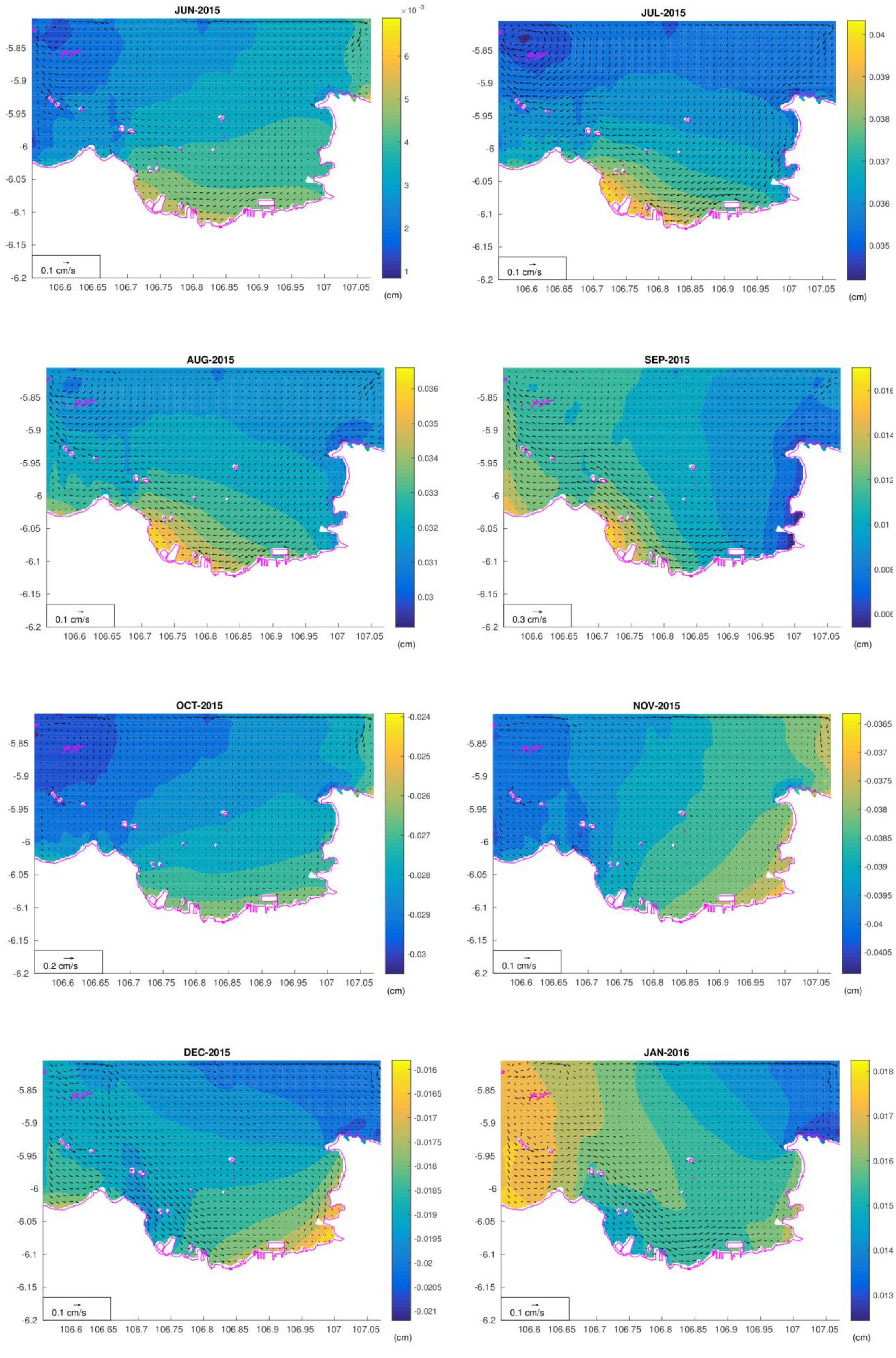
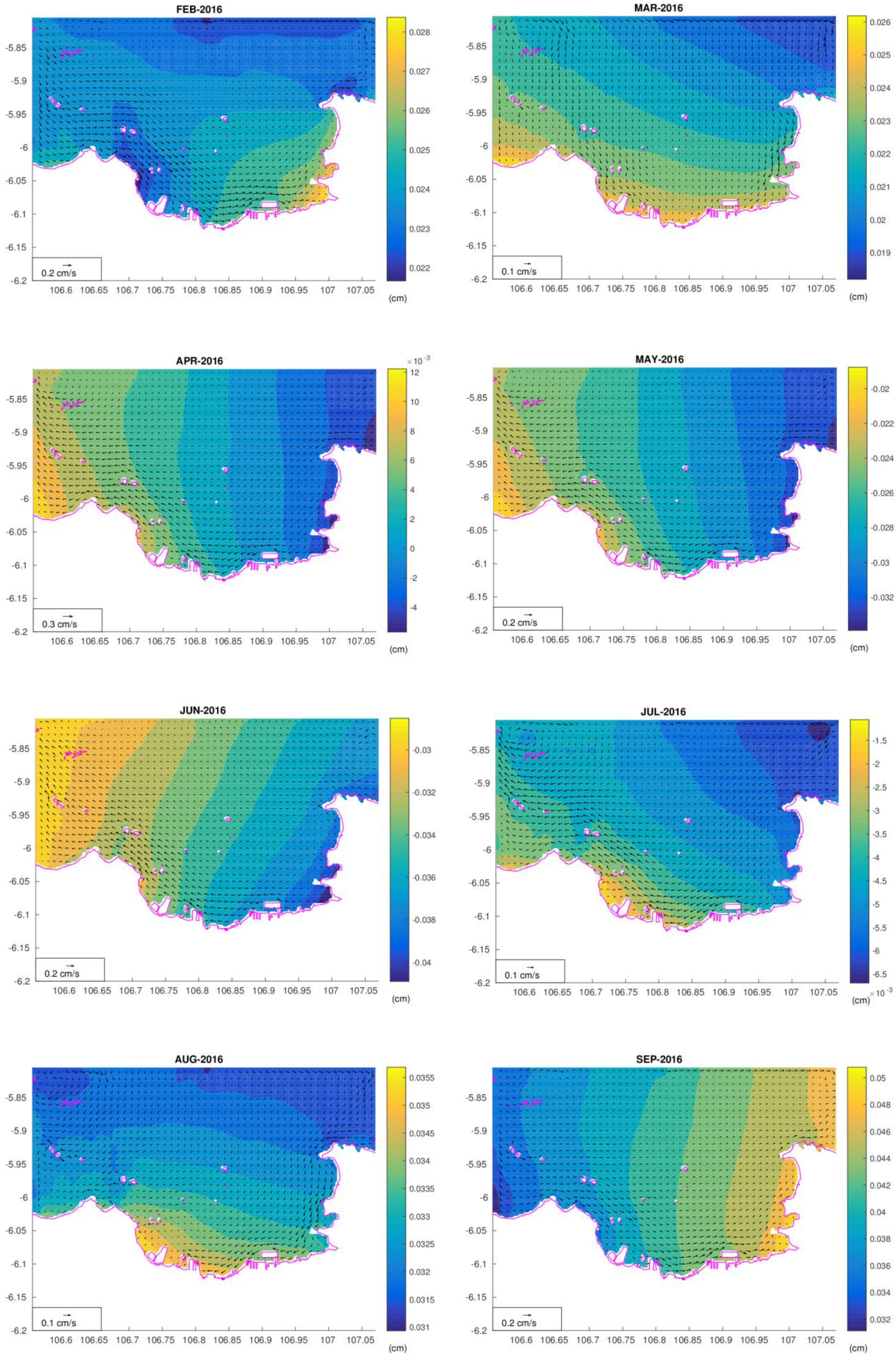


Figure-1. Monthly mean of Surface Current and Sealevel from June 2015 to December 2016

(to be continued)



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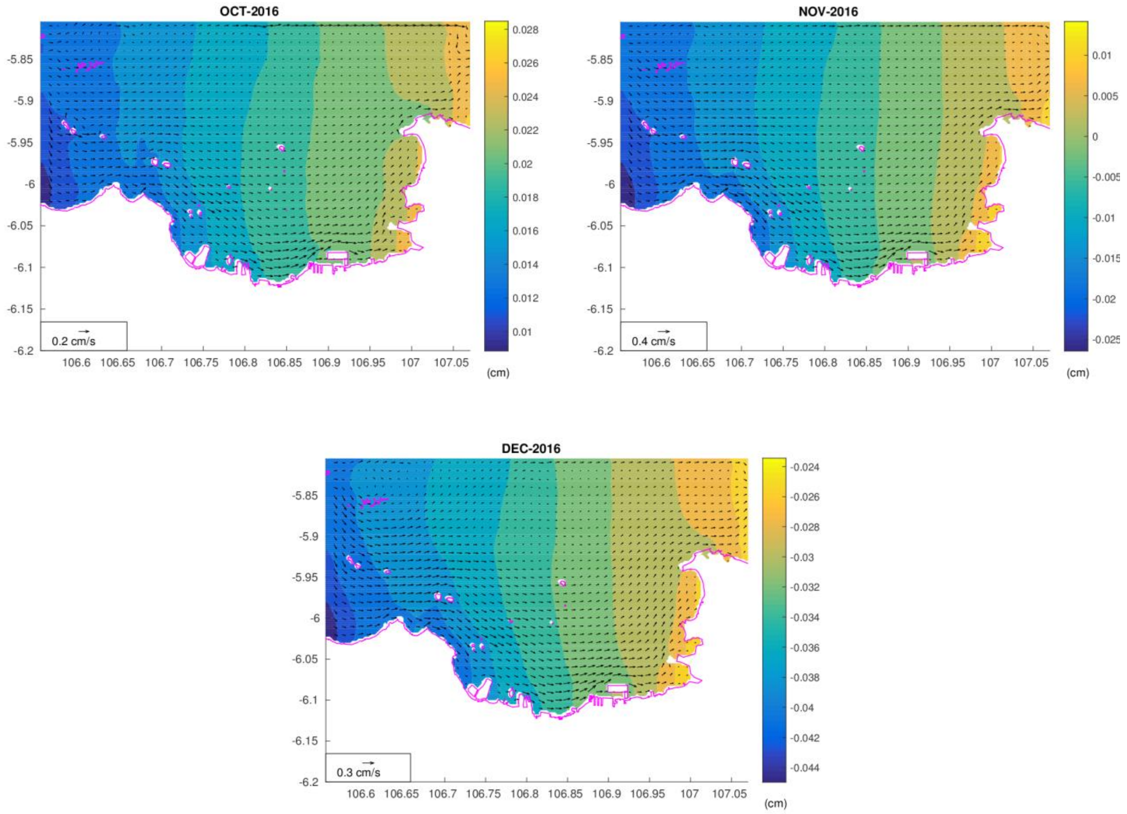

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