The Steady State Response of Indonesian Sea to a Steady Wind Field

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ABSTRACT

A barotropic fluid model based on the vertically integrated equations of motion was used for studying the steady-state response of Indonesian sea to a steady wind field. Using climatological wind field in Indonesia, the model results yield reasonable direction of water transport due to wind. It was also found that direction of water transport vary according to the direction of the wind.

1. Introduction.

Information about sea water transport in Indonesia is important. Sea water transport may be caused by wind, tidal forces, fresh water discharges, etc.

This study aims to determine the steady state response of Indonesian sea to steady wind field. For this purpose, Indonesian sea was assumed to be barotropic.

2. Theoretical background.

The circulation of a confined body of water is governed by a set of hydrodynamic equations derived from Newton's Law of motion and the mass conservation principle. The basic hydrodynamic equations are presented in their primitive form. Using the right-handed rectangular coordinate system in which x is eastward, y is northward, and z is the vertical coordinate positive upward, and the term definitions display in Table 1, the equations are :

$$u_t + uu_x + vu_y + wu_z - fv = \rho^{-1} (-p_x + \tau^x{}_z) \qquad (1)$$

$$v_t + uv_x + vv_y + wv_z - fu = \rho^{-1} (-p_y + \tau^y{}_z) \qquad (2)$$

$$w_t + uw_x + vw_y + ww_z = -\rho^{-1} p_z - g \qquad (3)$$

$$u_x + v_y + w_z = 0 \qquad (4)$$

where, for example, u_x is $\partial u/\partial x$.

Invoking the barotropic assumption, it is possible to define horizontal component of water transport,

$$U = \int^{\xi}_{-h} u\, dz \qquad \text{and} \qquad V = \int^{\xi}_{-h} v\, dz \qquad (5)$$

If the Coriolis force is negligible, Jorge De Las Alas and Marzan (1982), simplified the equation, and the steady-state solution for horizontal component are :

$$gh\, \xi_x = \rho^{-1} (\tau^x{}_w - \tau^x{}_b) \qquad (6)$$

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$$gh\,\xi_y = \rho^{-1}\,(\tau^y{}_w - \tau^y{}_b) \qquad (7)$$

$$u_x + v_y = 0 \qquad (8)$$

with,

$$\tau^x{}_w = \rho_a\, C_d\, |u_a|\, u_a \quad \text{,and} \quad \tau^y{}_w = \rho_a\, C_d\, |v_a|\, v_a \qquad (9)$$

$$\rho^{-1}\,\tau^x{}_b = DU \quad \text{,and} \quad \rho^{-1}\,\tau^y{}_b = DV \qquad (10)$$

Using (9) and (10), equation (6) and (7) become :

$$gh\,\xi_x = \rho_a\, C_d\, |u_a|\, u_a - DU \qquad (11)$$

$$gh\,\xi_y = \rho_a\, C_d\, |v_a|\, v_a - DV \qquad (12)$$

From equation (8) assumed

$$U = -\,\psi_y \quad \text{,and} \quad V = -\,\psi_x \qquad (13)$$

and equations (6) and (7) can be simplified as:

$$\Delta\psi - h^{-1}\, h_x\, \psi_x - h^{-1}\, h_y\, \psi_y = G(x,y) \qquad (14)$$

with

$$G(x,y) = \rho_a \rho^{-1}\, C_d\, D^{-1}\, [\, (|v_a|\, v_a)_x - (|u_a|\, u_a)_y - h^{-1}(|u_a|\, u_a\, h_x - |v_a|\, v_a\, h_y)\,]$$

----

x = eastward coordinate axis
y = northward coordinate axis
z = vertical coordinate axis
u = fluid velocity component along x axis
v = fluid velocity component along y axis
w = fluid velocity component along z axis
f = coriolis parameter ($2\omega \sin\phi$)
ω = angular velocity of the earth
ϕ = latitude
ρ = density of fluid
ρ_a = density of air
p = hydrostatic pressure
$\tau^x{}_b$, $\tau^y{}_b$ = stress components along x and y axis
u_a = wind velocity component along x axis
v_a = wind velocity component along y axis
ξ = height of the free water surface above undisturbed level
h = undisturb depth of water
$\tau^x{}_w$, $\tau^y{}_w$ = stress components due to the wind
C_d = drag coefficient
U = water transport along x component
V = water transport along y component
Δ = Laplacian operator

Table 1. Definition of terms used in the paper.

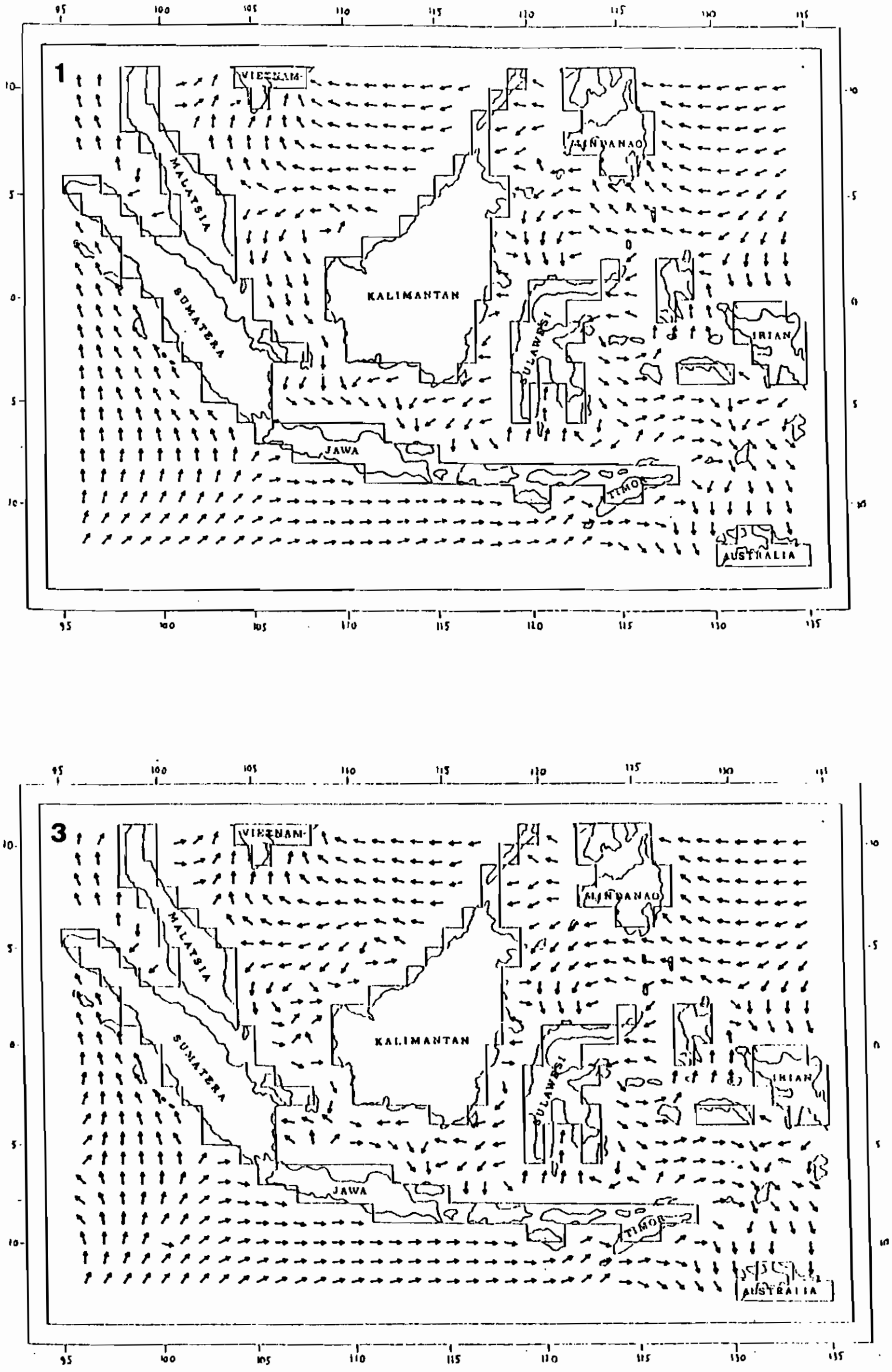

FIG.1. Direction of water transport (#1 is January, #3 is March, *etc*...)

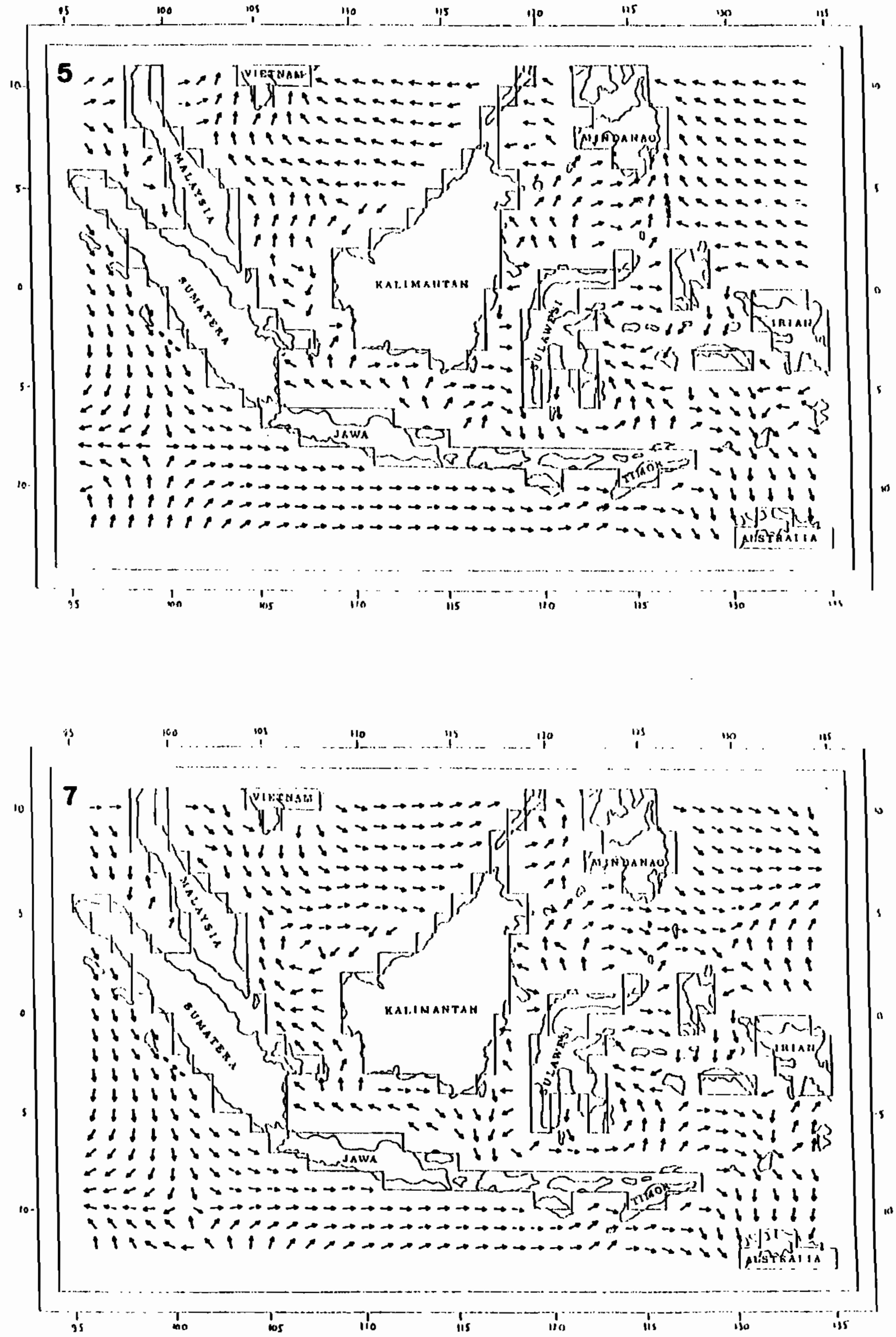

FIG.1. (Continue)

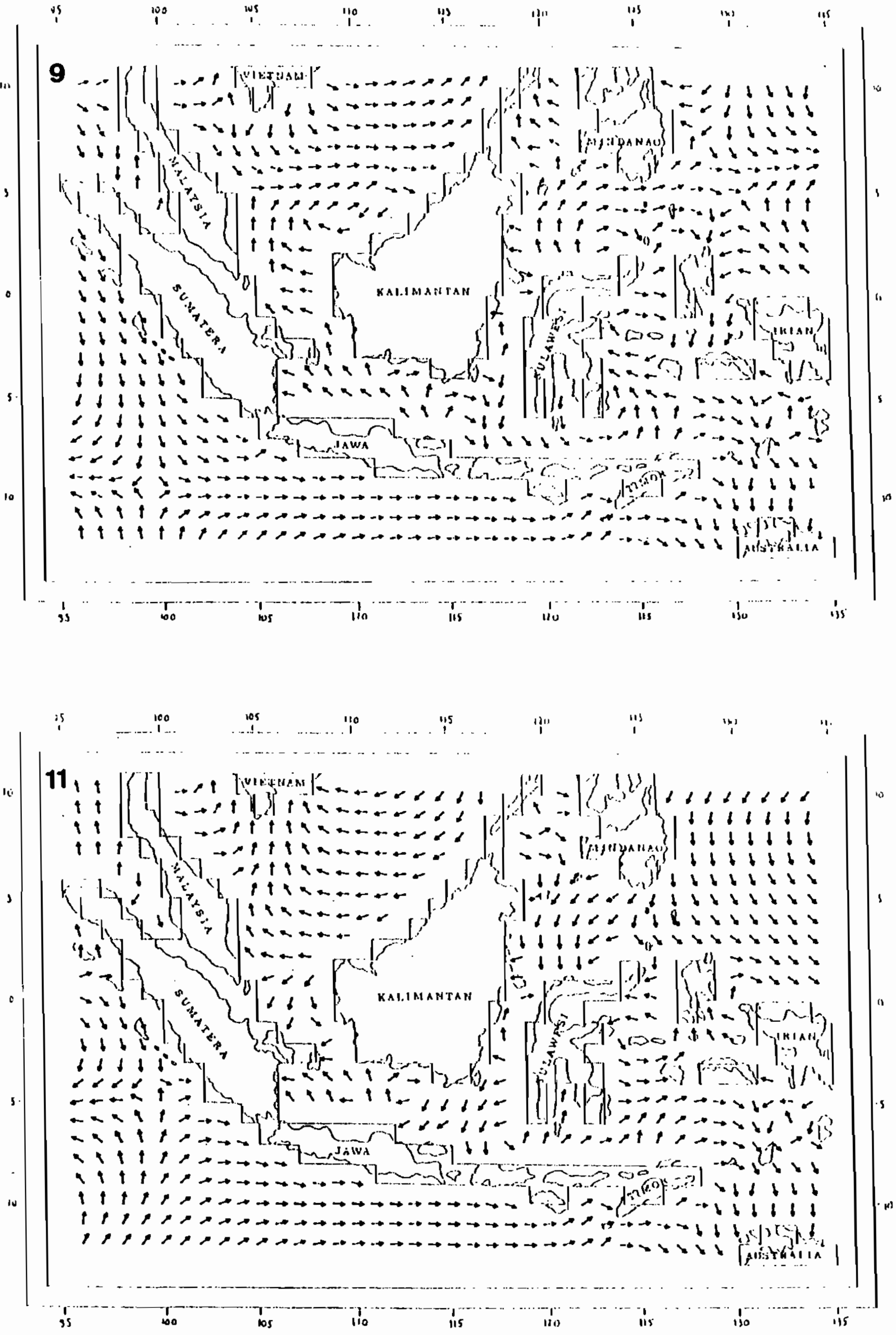

FIG.1. (Continue)

2. Numerical solution.

Equation (14) is Poisson type partial differential equation which can be solved by relaxation method. For lateral boundary condition, ψ along the coast line was set to zero. A grid network consist of square grid elements which are 1°latitude by 1°longitude.

3. Results.

Using monthly wind field in Indonesia, the direction of sea water transport due to wind are presented in Fig. 1. The results clearly evidence water movement from Pacific Ocean to Indian Ocean and vice versa. The direction of water transports of Indonesian sea vary according to the direction of the wind.

From the barotropic assumption, it is possible to define the vertically averaged horizontal velocity component of the current. The results of the model yield reasonable current speed.

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WESTERN PACIFIC INTERNATIONAL MEETING AND WORKSHOP ON TOGA COARE

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PROCEEDINGS

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