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U.S. NAVAL RESEARCH LABORATORY

High-resolution modeling of local air-sea interaction within the Maritime Continent using COAMPS

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Abstract

The Maritime Continent (MC) is a region of intense deep atmospheric convection that serves as an important source of forcing for the Hadley and Walker circulations. The convective activity in the MC region spans multiple scales from local mesoscales to regional scales, and impacts equatorial wave propagation, coupled air-sea interaction and intra seasonal oscillations. The complex distribution of islands, shallow seas with fairly small heat storage and deep seas with large heat capacity is challenging to model. Diurnal convection over land-sea is part of a land-sea breeze system on a small scale, and is highly influenced by large variations in orography over land and marginal seas. Daytime solar insolation, run-off from the Archipelago and nighttime rainfall tends to stabilize the water column, while mixing by tidal currents and locally forced winds promote vertical mixing. The runoff from land and rivers and high net precipitation result in fresh water lenses that enhance vertical stability in the water column and help maintain high SST. We use the fully coupled atmosphere-ocean-wave version of the Coupled Ocean-Atmosphere Mesoscale Prediction System (COAMPS) developed at NRL with resolution of a few kilometers to investigate the air-sea interaction associated with the land-sea breeze system in the MC under active and inactive phases of the Madden-Julian Oscillation. The high resolution enables simulation of strong SST gradients associated with local upwelling in deeper waters and strong salinity gradients near rivers and from heavy precipitation.

COAMPS – coupled model system

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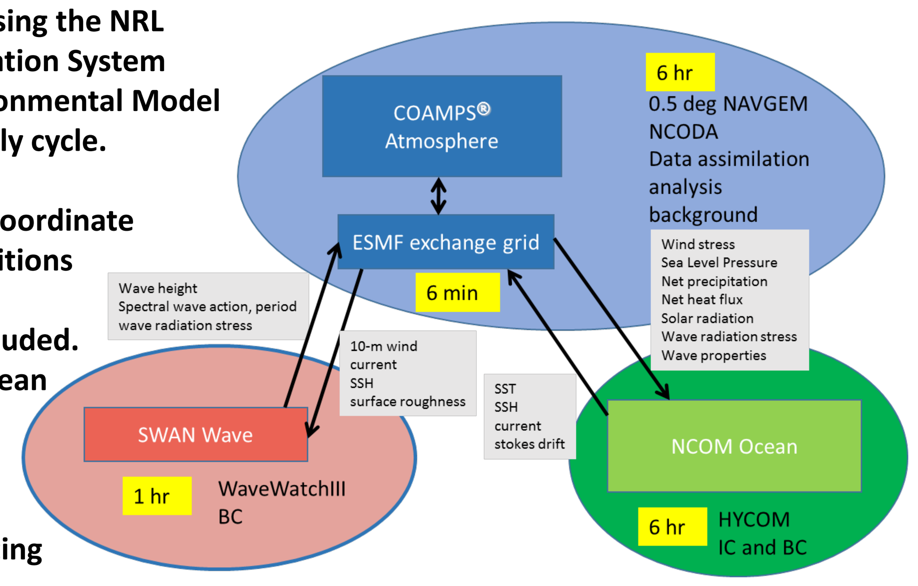
The model atmosphere is initialized using the NRL Atmospheric Variational Data Assimilation System (NAVDAS) and the NAVy Global Environmental Model (NAVGEM) and is updated on a 6 hourly cycle.

The model ocean uses global Hybrid Coordinate Ocean Model(HYCOM) for initial conditions and 6 hourly boundary conditions. Semi-diurnal and diurnal tides are included. Data assimilation is included in the ocean using the Navy Coupled Ocean Data Assimilation (NCODA) 3D-var system.

For surface waves the spectral Simulating WAves Nearshore (SWAN) is used, forced by COAMPS/NCOM winds, currents and sea level. Coupling interval is 6 min between all three model components.



The coupled model is being run daily in a hindcast mode at this time. It will be used for 5-day forecasts in various configurations during the field campaign of the Office of Naval Research (ONR) "Propagation of Intra-Seasonal Tropical Oscillation" (PISTON) research initiative.

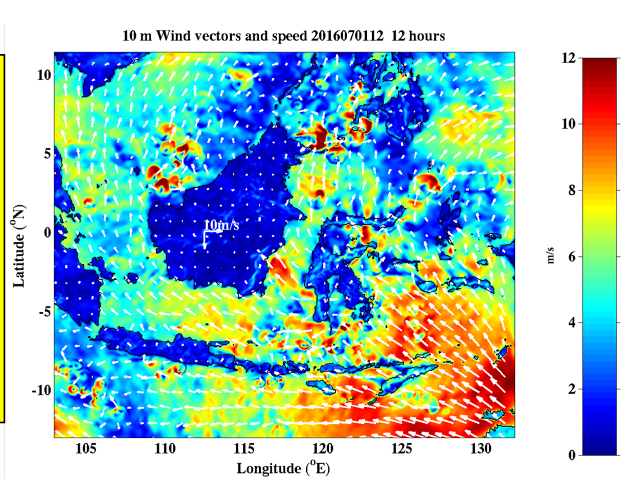
Moderately high resolution

Atmospheric model:
18 km nest
(208 x 168 grid)

6 km nest
(502 x 424 grid)

60 vert. levels

NAVDAS assimilation
NAVGEM BC



Ocean Model and Spectral Wave Model

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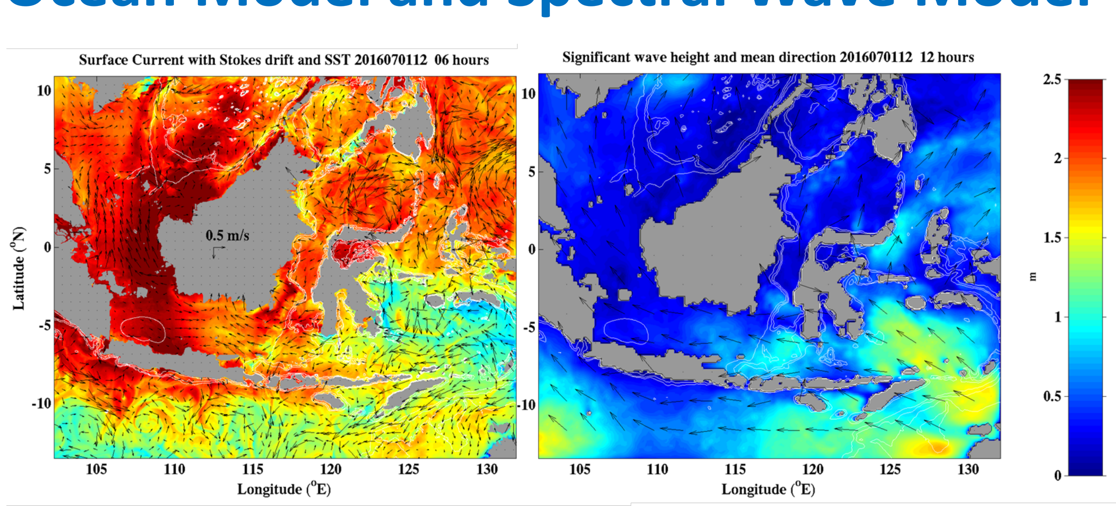


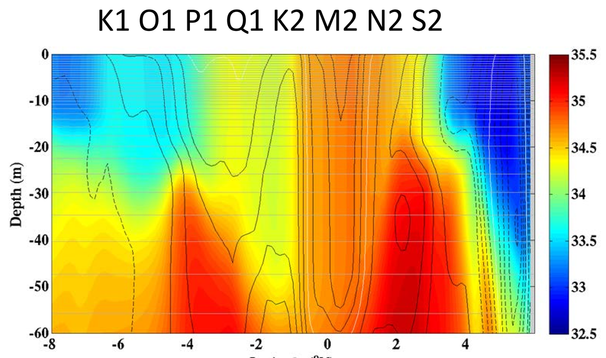
Navy Coastal Ocean Model (NCOM):
1600 x 1320 grid, 1/54° (~ 2 km),
60 vert. levels (0.5 m res. from 0-10 m)
3dvar data assimilation, HYCOM BC

Simulating WAves Nearshore (SWAN)
Wave model: 240 x 200 grid
1/8° spatial resolution
33 spectral freq, 48 dirs
No data assimilation, WW3 BC

Naval Coastal Ocean Model (NCOM)

Hydrostatic Free Surface model on C-grid
3rd order upstream advection with Flux Correction Transport
4th order Coriolis terms
Mellor-Yamada Level 2.5 vertical mixing with wave effects (Kantha and Clayson, 2004)
Flux BC provides TKE from wave breaking
Quadratic bottom drag.
Source term for river and runoff inflows.
Forcing with atmospheric pressure and local tidal potential
Penetrating solar radiation (2-band model for Jerlov types)
Increased bottom drag in shallow water due to wave motions

45 sigma levels + 15 z-levels
Vertical resolution 0.5 m or higher between 0 – 10 m
Tidal forcing with 8 constituents:
K1 O1 P1 Q1 K2 M2 N2 S2



Diurnal Cycle

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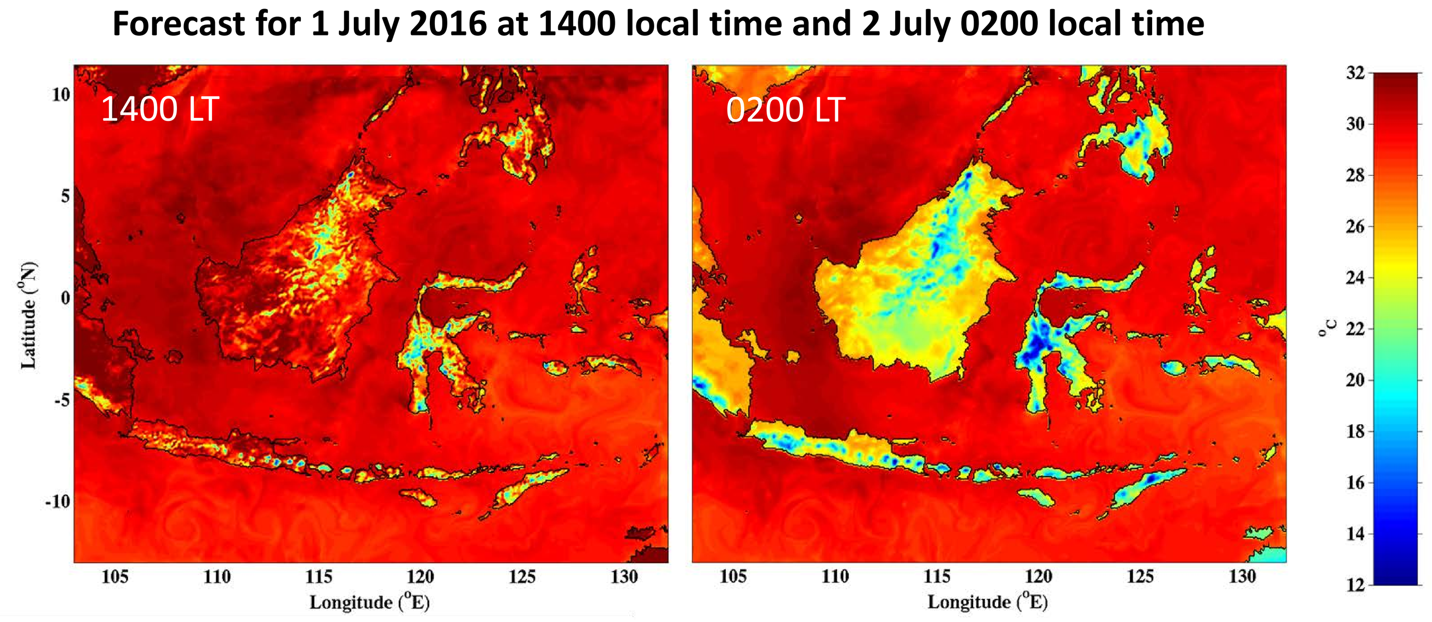
SURFACE TEMPERATURE

The large diurnal cycle in surface temperature over land results in a large land-sea temperature difference, associated with diurnal convective systems that propagate offshore.

Forecast for 1 July 2016 at 1400 local time and 2 July 0200 local time



Heat Flux and Sea Surface Temperature

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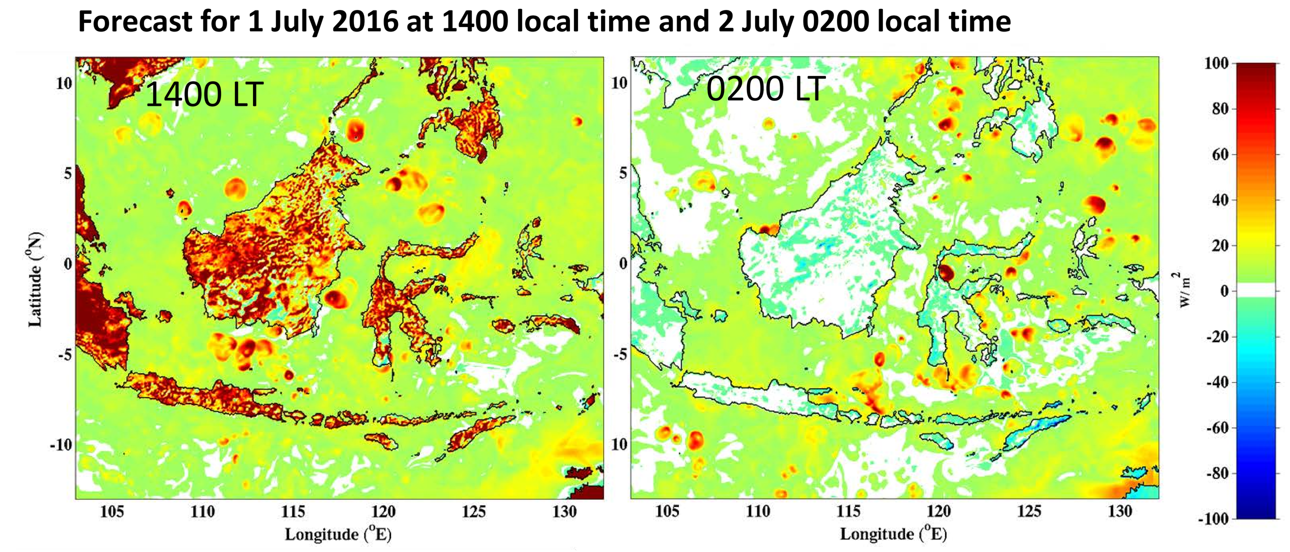
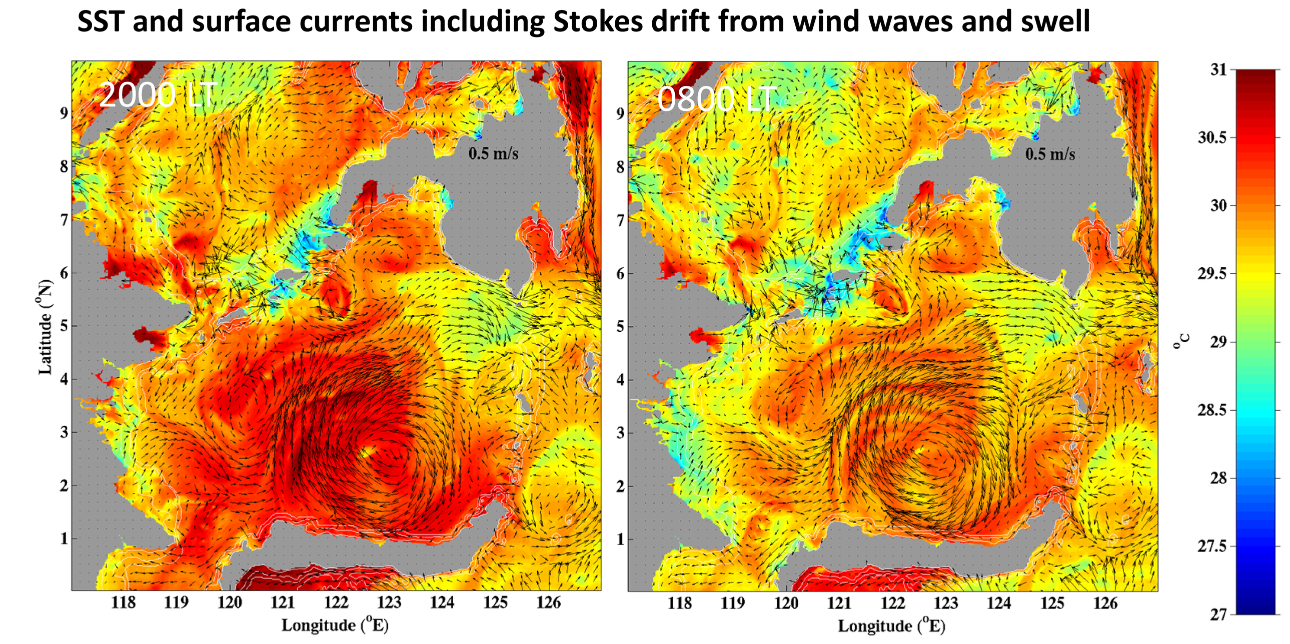
Large diurnal cycle in sensible heat flux over land
Forecast for 1 July 2016 at 1400 local time and 2 July 0200 local time



SST and surface currents including Stokes drift from wind waves and swell



Turbulent heat flux is enhanced by resolved convective cells in the atmosphere model. High vertical resolution help realistic amplitude of the diurnal cycle of SST in the ocean, and high horizontal resolution enables simulation of upwelling induced by flow over complex bottom topography.

Salinity

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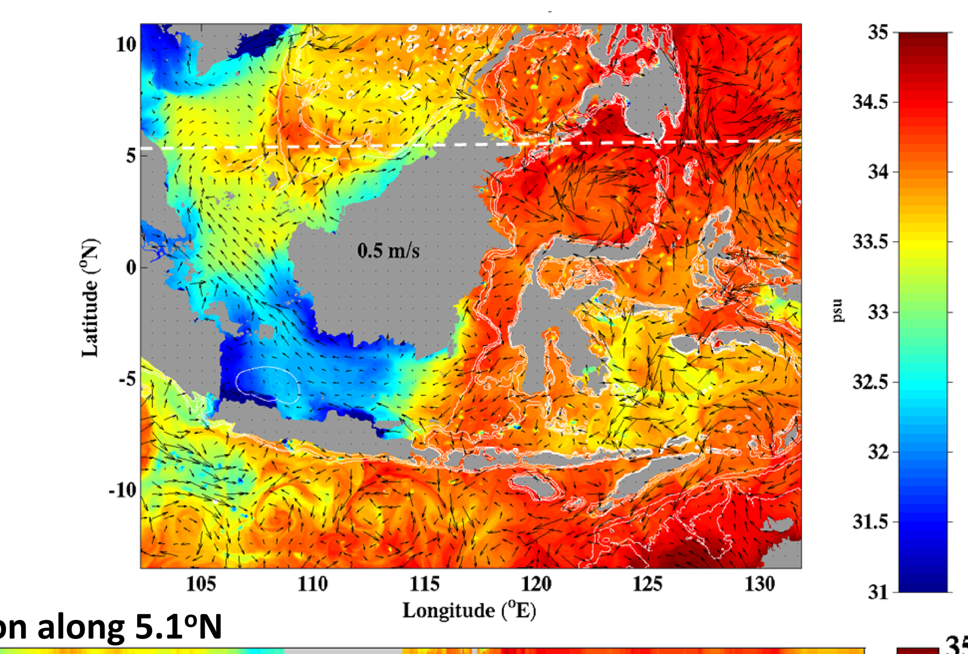
RIVER RUNOFF

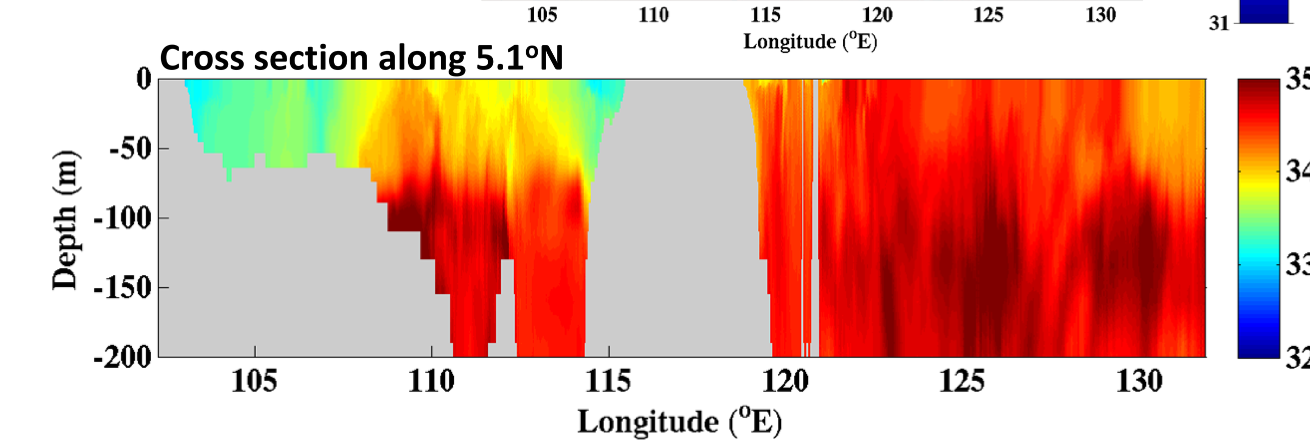
High annual precipitation leads to low surface salinity in the seas of the Maritime Continent.

Precipitation is a prognostic quantity. Monthly climatology is used for river discharges.

Tidal currents are important for vertical mixing in the region

Surface currents and salinity on 2 July, 00 UTC





Sea Surface Elevation

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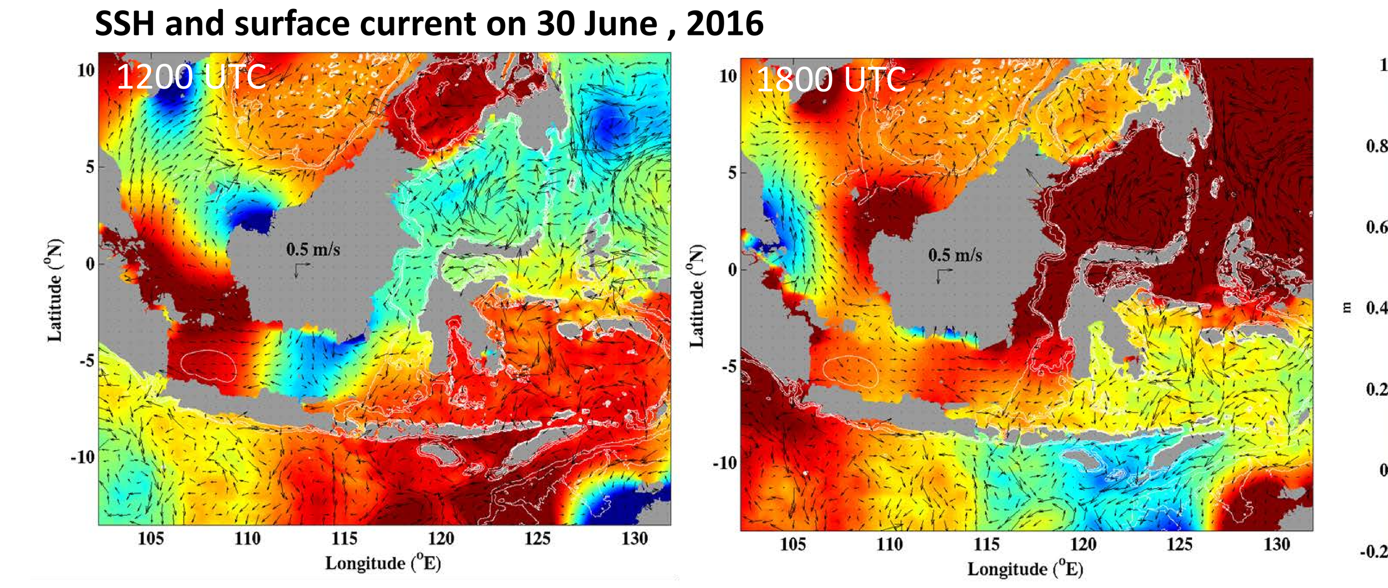
SSH and surface current on 30 June , 2016



Sea Surface Height and surface currents are highly variable due to semi-diurnal tides.

References

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