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Upwelling di Pantai Selatan Yogyakarta

Wind-Driven Coastal Upwelling in the Southern Coast of Yogyakarta

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Abstrak

Data satelit dapat memberikan informasi sinoptik tentang angin permukaan laut dan bisa digunakan untuk mempelajari variabilitas *upwelling* pantai. Penelitian ini menganalisis data satelit angin permukaan laut, suhu permukaan laut, dan klorofil-a permukaan laut (Chl-a) selama 12 tahun untuk mendeteksi distribusi spasial dan temporal *upwelling* pantai di perairan Yogyakarta. Hasil penelitian menunjukkan bahwa *upwelling* terjadi ketika musim monsun tenggara. Selama musim ini, perairan Yogyakarta dicirikan oleh kecepatan angin yang kuat (~7 m/detik) dan suhu permukaan laut dingin (25°C). Sedangkan selama musim monsun barat laut kecepatan angin rendah (<4 m/s) mendominasi perairan Yogyakarta dan tidak dapat menyebabkan *upwelling*. Terjadinya transportasi Ekman lepas pantai dan upwelling disebabkan karena angin tenggara, sedangkan downwelling disebabkan oleh orientasi garis pantai arah timur barat serta arah angin yang berasal dari barat laut.

Kata kunci: Klorofil-a, perairan Yogyakarta, *upwelling* pantai

Abstract

Satellite measurement provides synoptic view of sea surface wind and can be used to study variability of coastal upwelling. Here we analyzed data of 12 years of satellite-derived sea surface wind, sea surface temperature (SST), and sea surface chlorophyll-a (Chl-a) to examine the spatial and temporal distributions of coastal upwelling off the Yogyakarta waters. Results show that upwelling occurs during the Southeast Monsoon (SEM) season. During this season, the Yogyakarta waters are dominated by strong wind speed (~7 m/s) and SST cooling (25 °C). Whereas during the Northwest Monsoon (NWM) season the low wind speed (<4 m/s) no longer favor upwelling and SST cooling. We suggest that as the Yogyakarta coastline is oriented east-west, northwesterly winds result in downwelling condition at the coast, while southeasterly winds lead to the offshore Ekman transport of surface water and subsequent upwelling.

Keywords: Chlorophyll-a bloom, Yogyakarta waters, coastal upwelling

Introduction

Wind-driven coastal upwelling is a product of the acceleration of winds along a coast that generate an offshore Ekman transport. To compensate for the loss of water mass near the coast, cool and nutrient-rich water is brought towards the sea surface. This upwelled water induces the growth of phytoplankton, enhancing primary productivity and fishery production. Thus, coastal upwelling regions are among the most productive marine regions in the world's oceans and are pivotal for fisheries industry and people living in its coastal regions.

The southern coast of Yogyakarta, including the Trisik Beach, is one of the upwelling regions in Indonesia (Figure 1). The region is located at the center of the Australian Indonesian Monsoon system that blows from the southeast between May and September (Southeast Monsoon season) and from the northwest between November and March (Northwest Monsoon season). Our novel results show that in response to southeasterly winds, coastal upwelling in the Trisik Beach occurs during the Southeast Monsoon (SEM) season. Whereas during the Northwest Monsoon (NWM) season the upwelling vanished. The Trisik Beach is also an important site for sanderling Calidris alba with a number of birds of ~432 (Crossland *et al*., 2010). The beach is located at the Banaran Village, Galur Subdistrict, Kulon Progo District, Yogyakarta and has a coastline of ~2.4 km (Taufiqurrahman *et al*., 2010).

Previous studies have shown that upwelling off the southern coasts of Java is a consistent phenomenon appearing during the SEM (Susanto & Marra, 2005; Iskandar *et al*., 2009; Varela *et al*., 2015). Furthermore, Susanto & Marra (2005) and Iskandar *et al*. (2009) suggest that the intensity of upwelling enhanced significantly during El Niño (1.5 mg m^{-3}) and positive Indian Ocean Dipole (> 4 mg m^{-3}), respectively. Because of its high nutrient during the SEM, the south coasts of Java are a region of high fisheries production (Nurani *et al*., 2010). Although the upwelling of south Java has been well studied by many researchers, however sea surface condition and coastal upwelling off the coasts of Yogyakarta is poorly constrained until today.

In the present study, we describe the spatial and temporal of coastal upwelling in the southern coast of Yogyakarta as well as the Trisik Beach. Specifically, the present study aims to examine the physical mechanism that controls upwelling off the coasts of Yogyakarta by analyzing long-term and high resolution satellite data.

Data and Method

We analyzed satellite data of sea surface wind, SST, and sea surface chlorophyll-a (Chl-a) to provide a synoptic view of the relationship between wind-forcing and phytoplankton response. We employed satellite-derived sea surface wind data obtained from semi daily Quikscat (Ricciardulli & Wentz, 2015) and ASCAT (Figa-Saldana *et al*., 2002) for 2003 to 2009 and 2009 to 2015, respectively. Both data have a spatial resolution of 0.25° × 0.25° and provided by the Remote Sensing Systems (www.remss.com).

We used daily Chl-a and semi daily 11-µm SST Level 3 data from the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard Aqua with spatial resolution of 0.04° × 0.04° (Hu *et al*., 2012) and observation period from 2003 to 2015. The data are provided by the NASA Goddard Distributed Active Archive Center (https://podaac.jpl.nasa.gov).

Monthly climatology analyses were performed to all data to investigate the variability of sea surface wind, Chl-a, and SST. Due to the small size of the Trisik Beach, we analyzed the Yogyakarta waters for generating climatology maps and discussion.

Results and Discussion

Results

Figure 2, 3, and 4 show monthly averaged sea surface wind, SST, and sea surface Chl-a concentration off the Yogyakarta coasts, respectively. These three parameters exhibit marked seasonal variability.

Figure 2 depicts that the region of interest is dominated by weak westerly wind (< 4 m/s) during the NWM season. Whereas during the SEM, the Yogyakarta water is dominated by higher wind speed with the highest speed (~7 m/s) observed in August. Direction of the wind is westward during this season.

The spatial and temporal patterns of SST off the Yogyakarta coasts show high SST (> 28° C) during the NWM season and cool SST (< 27° C) during the SEM season (Figure 3). Throughout the year, SST in the region varies from 26 to 30° C.

Low Chl-a concentration (< 0.2 mg/m^3) dominates open ocean off the Yogyakarta waters during the NWM season (Figure 4). In contrast, higher Chl-a concentration (> 0.6 mg/m^3) is prominent in the study area from June to December.

Discussion

Chl-a is a useful indicator for ocean upwelling and coastal upwelling discussed here is southern hemisphere. Our results clearly demonstrate that Chl-a bloom and sea surface cooling off the Yogyakarta waters occurs consistently with the wind speed maximum, with an exception during September-December. We suggest that the primary driver for this large SST decrease is the SEM wind via the mechanism of coastal upwelling. The coasts of Yogyakarta waters are oriented east-west and subjected to the axis of the SEM wind. Thus, when the southeasterly wind blows, conditions become favorable for the Ekman Transport leading to coastal upwelling that strongly impacts SSTs.

Our results clearly illustrate that the Chl-a bloom is absent during the NWM season. During this season, the wind shows low wind speed and no longer favor SST cooling and coastal upwelling. We suggest that higher SST during the NWM indicates an enhancement in ocean stratification. As a consequence, this condition suppressed vertical mixing of nutrient-rich subsurface waters and reduced Chl-a concentration as well as the intensity of coastal upwelling off the Yogyakarta waters. In the end, this condition may inhibit primary production and cascade through the entire food web in the region.

Unusual higher Chl-a concentrations (1 mg/m^3) are observed in the region from September to December. Interestingly, the wind shows a slowdown during this period, suggesting the deterioration of the SEM season. We postulate that the 2015 El Niño has caused this anomalous Chl-a bloom off the Yogyakarta waters. As a result, it affects the process of averaging data. The effect of 2015 El Niño on sea surface conditions off the Yogyakarta waters will be the focus of our future study.

Conclusion

We have investigated the spatial and temporal evolution of coastal upwelling in the Yogyakarta waters by taking advantage of high resolution satellite observation. The coastal upwelling off the Yogyakarta waters enhanced during the SEM season as a result of the intensification of strong wind speed. In contrast, the region is dominated by low wind speed during the NWM season and upwelling does not present during this season. Anomalous Chl-a concentrations are present from September to December, possibly due to El Niño event. The results presented here are solely based on satellite data. Additional field observation is required to explore the dynamics of upwelling off the Yogyakarta waters.

Acknowledgment

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Figure Captions

Figure 1. Map of Yogyakarta waters and Trisik Beach.

Figure 2. Monthly climatology maps of sea surface wind.

Figure 3. Monthly climatology maps of sea surface temperature.

Figure 4. Monthly climatology maps of sea surface chlorophyll-a concentration.

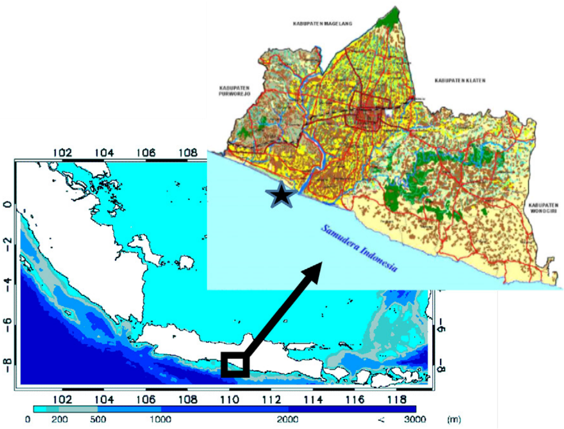

Figure 1. Map of Yogyakarta waters and Trisik Beach (black star).

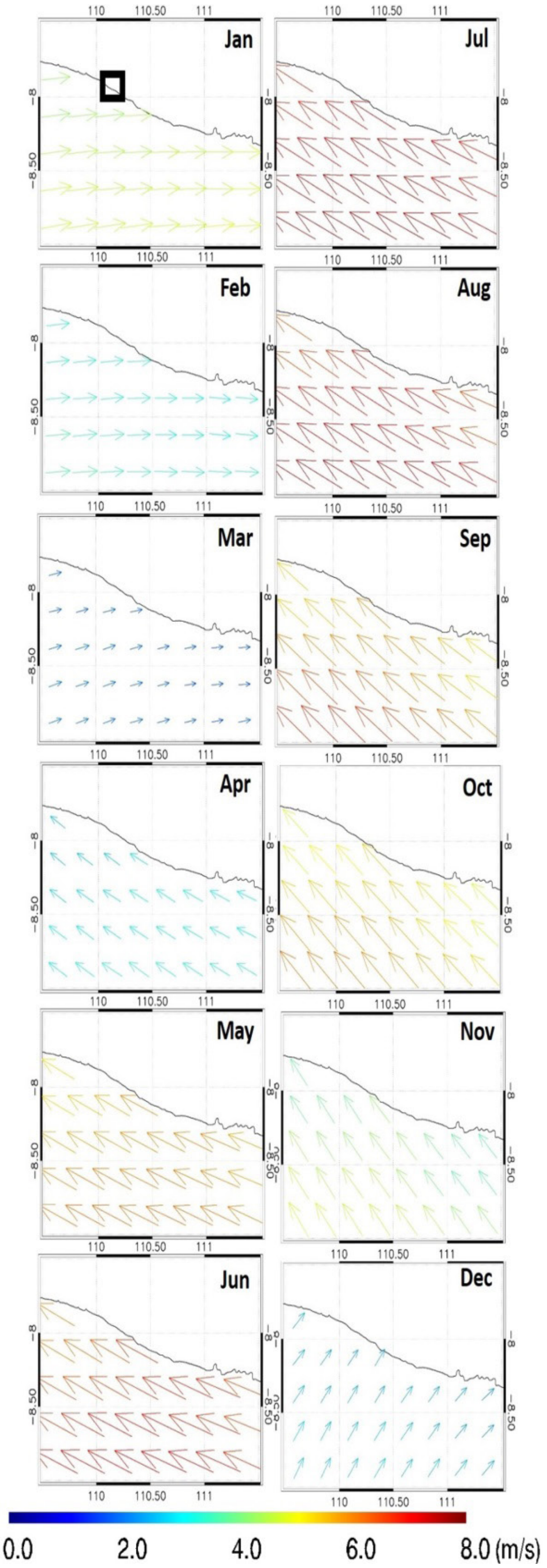

Figure 2. Monthly climatology maps of sea surface wind. Black box denotes the Trisik Beach.

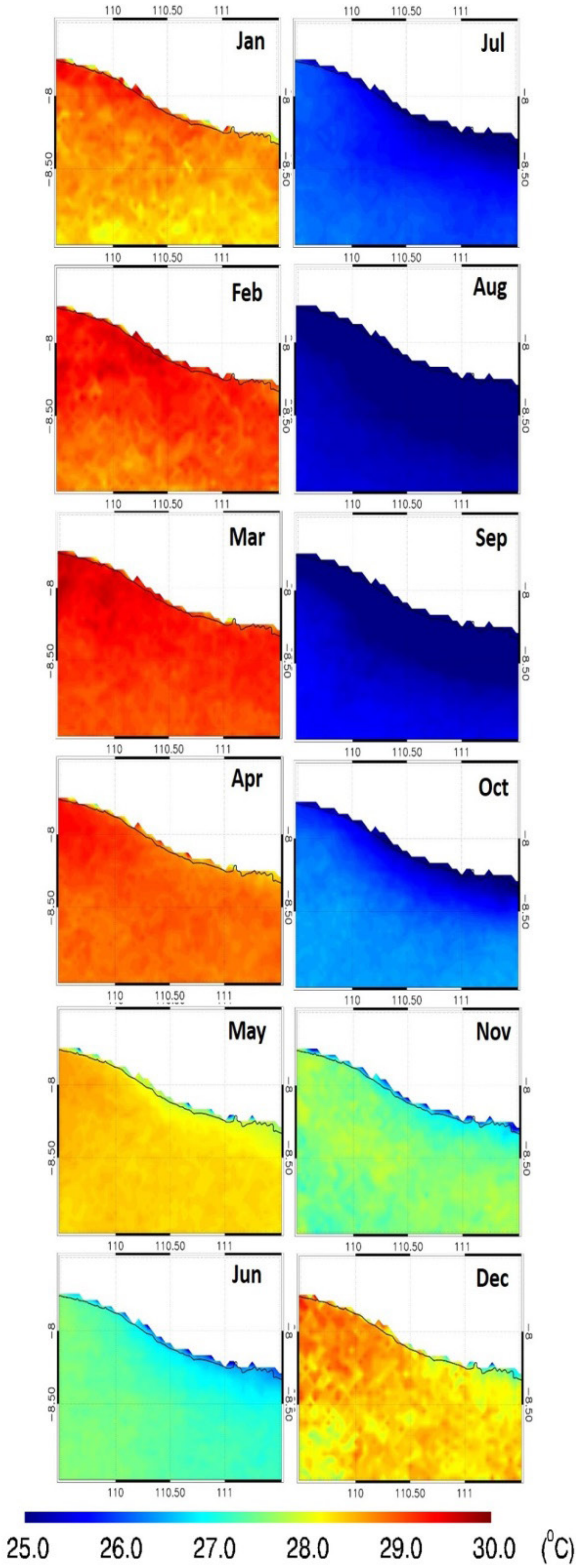

Figure 3. Monthly climatology maps of sea surface temperature.

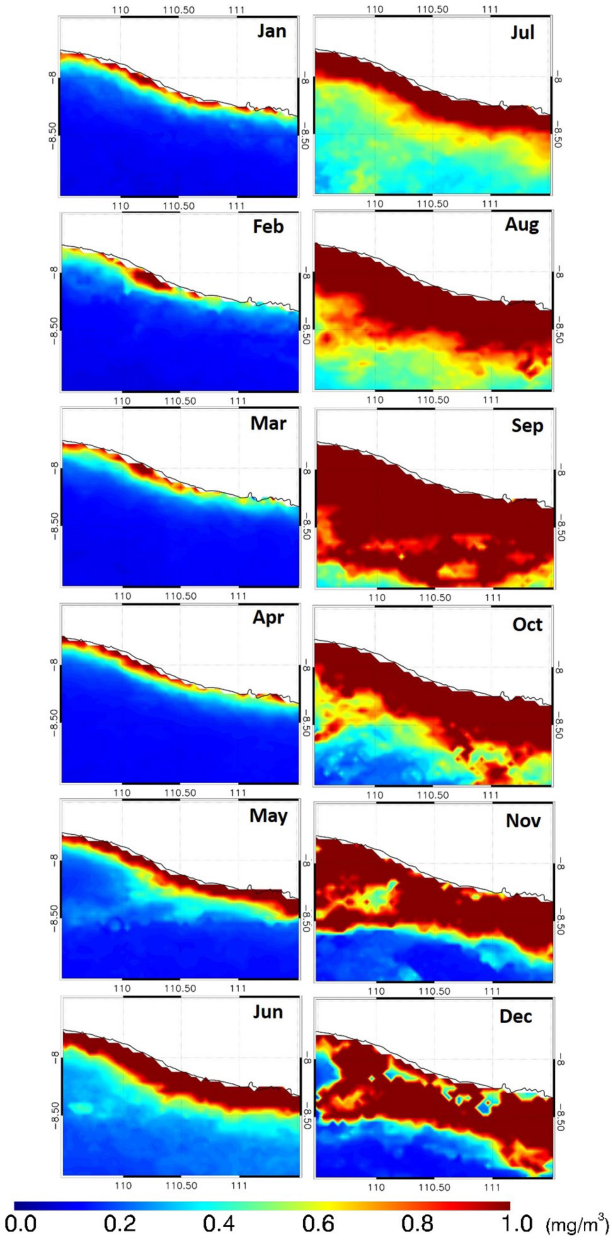

Figure 4. Monthly climatology maps of sea surface chlorophyll-a concentration.