Variability of Sea Surface Features in the Western Indonesian Archipelago: Inferences from the COADS Dataset

CLAUDE ROY
Centre ORSTOM de Brest
B.P. 70 - Plouzané, France

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Abstract

Following a brief review of their key properties (based mainly on K. Wyrtki's Naga Report of 1961), sea surface features of the Western Indonesian archipelago are characterized using time series extracted from the Comprehensive Oceanographic and Atmospheric Dataset (COADS), and covering the period from 1950 to 1990.

Abstrak

Diawali dengan tinjauan singkat sifat-sifat pokok dari laut (terutama berdasarkan pengamatan Naga Report 1961 dari K. Wyrtki), sifat-sifat permukaan laut kepulauan Indonesia bagian barat selanjutnya dianalisis berdasarkan data COADS (Comprehensive Oceanographic and Atmospheric Dataset) tahun 1950-1990.

Introduction

This account of the regional oceanography of Western Indonesia, presented here as background to the surveys documented in this volume, is meant to explain observed patterns of productivity (Fig. 1). This account explicitly builds on the comprehensive review of Wyrtki (1961), from which three sections were adapted, other sources of information on the oceanography of the Southeast Asian region being scarce. The mean spatial structure and the seasonal variability of major surface climatic parameters may be found in the Indian Ocean atlas of Hastenrath and Lamb (1979a, 1979b). Sharp (this vol.) also presented an overview of important, large-scale oceanographical and meteorological patterns.

In the introduction to his report on the physical oceanography of the Southeast Asian Waters, Wyrtki (1961) noted that "a considerable number of local effects and features had to be expected". Indeed, the Southeast Asian region has one of the most complex topographical structures on earth: large and small islands subdivide the region into different seas connected with each other by many passages and channels. The variety of the physical settings also generates complex biological systems where local features are important. Thus, "the region comprises a mosaic of seasonally varying production and system dynamics, all of which interact generate ecological enigma" (Sharp, this vol.). By comparis with other marine ecosystems (see, for example, Parrish et 1983 or Pauly and Tsukayama 1987), any kind of generalizat remains hazardous.

After a review of some important characteristics of atmospheric and marine climate of the area, the seasonal a interannual variability of selected surface parameters in areas, distributed around the Indonesian archipelago, presented.

The Atmospheric Setting: the Monsoon Regime (Modified from Wyrtki 1961)

The monsoon wind regime is a tropical phenomenon: t result of the interaction between a high atmospheric pressu cell centered over the continent in the winter hemisphere a a low atmospheric pressure cell that develops in the summ hemisphere over the continent, as a prolongation of t equatorial low. Because of the relative stationarity of the pressu distribution, the winds are very steady, especially over the se An important characteristic of the area is the biannual signal atmospheric forcing, related to the movement of the sun and the equatorial low, which crosses the equator twice each year

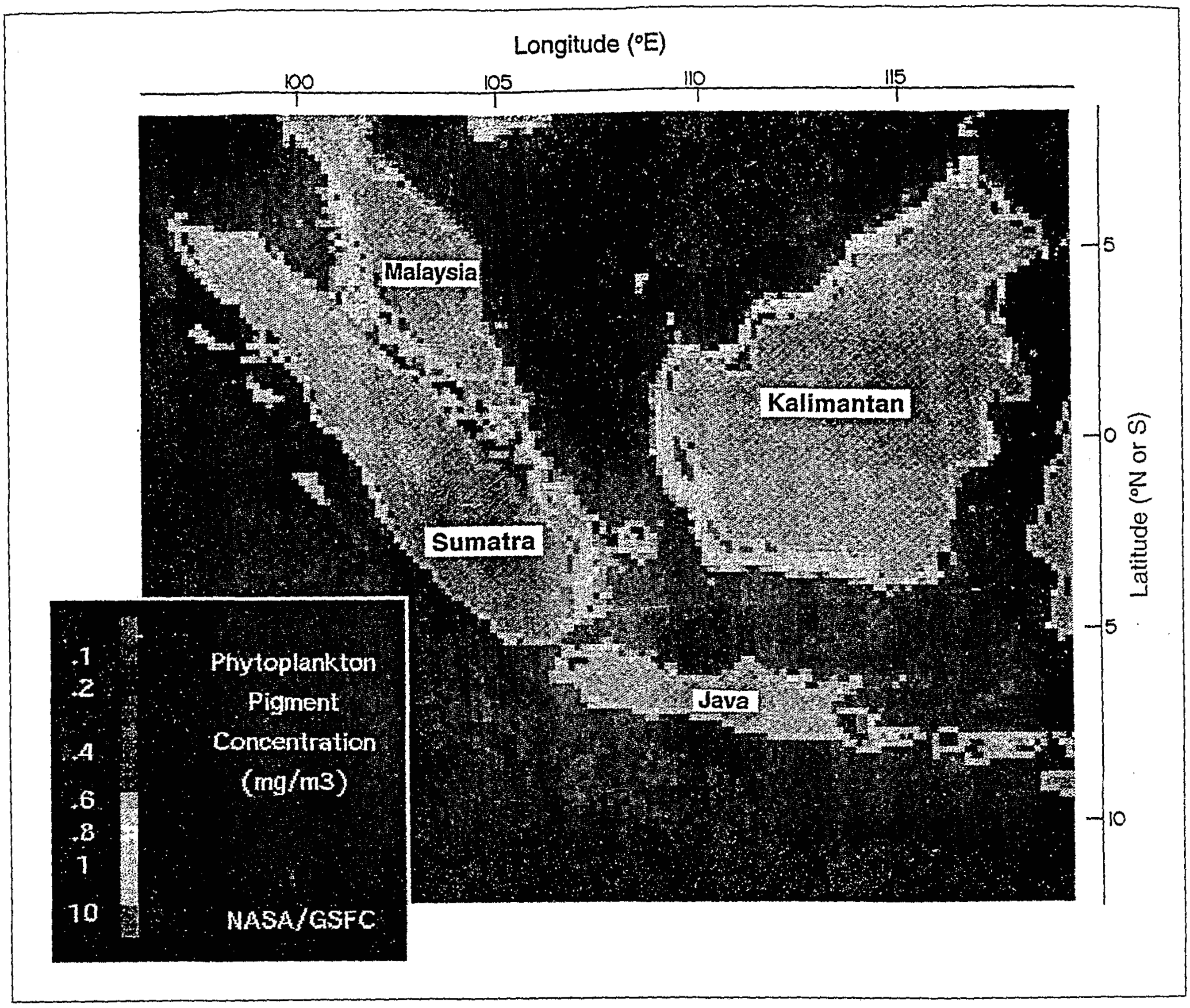

Fig. 1. Composite satellite-derived map of phytoplankton pigment concentrations - indicating primary production levels - for Southeast Asia (courtesy of NASA/GSFC and Dr. F. Chavez, MBARI).
[Gambar 1. Peta komposit konsentrasi phytoplankton berdasarkan beberapa pengamatan melalui satelit yang menunjukkan tingkatan produktivitas primer untuk Asia Tenggara (data NASA/GSFC dan Dr. F. Chavez, MBARI).]

The north monsoon starts in October and is fully developed in January. The monsoon flux passes the equator as a north wind; south of the equator, the wind - due to the Coriolis effect - turns eastward, where it becomes the northwest monsoon. In February, the equatorial low, previously located at 10°S, starts to move northward and comes to lie over Java and the Lesser Sunda Islands. The southeast flux extends to the north. Southwest winds dominate south of the equatorial low, between Java and Australia. North of the equator, the direction of the wind remains unchanged but its strength declines. Little change occurs in April, but a complete reorganization of the atmospheric fluxes is observed in May. The southeast atmospheric flux crosses the equator, then turns eastward. The northeast winds over the China Sea and the Philippines are replaced by the south monsoon, which prevails over the whole of SoutheastAsia. The south monsoon reaches its full development between July and August: the Asian low and the Australian high are fully developed and the north-south pressure gradient and atmospheric circulation are maximum. In September at the end of the boreal summer season, the Asian low starts to weaken and in October the equatorial low starts to move southwards. In the north, northeast winds start to dominate. In November, the equatorial low crosses the equator and the northeast monsoon intensifies. The southward reach of the northeast monsoon follows the migration of the equatorial low which attains its southernmost position in January.

This seasonal variability of the winds cause corresponding changes in surface currents. Following the direction of the monsoon flux, which changes twice a year, the currents also reverse themselves twice a year. This is perhaps the key ecological feature in the area (see e.g., Martosubroto, this vol. and Venema, this vol.).

Some Characteristics of the Surface Circulation in the Southeast Asian Waters (Adapted from Wyrtki 1961)

Some topographical features of Southeast Asia favor the development of a strong surface circulation: the area formed by the South China Sea, the straits between Sumatra and Borneo, the Java Sea, the Flores Sea and the Banda Sea which has its main axis aligned with the wind flux during both monsoons; this, along with the relative constancy of the winds favors the development of surface circulation patterns strongly connected to the wind regime. In other parts of the region, however, it is difficult to extract any large-scale and coherent circulation pattern; local effect and intermittency appear to be dominant. Water exchange with the Pacific Ocean occurs through the Molucca Strait, the Philippines, and the Sulu Sea (Sharp, this vol.). The Makassar Strait has usually a current directed to the south, from the Pacific to the Indian Ocean. However, the water exchange through the Malacca and the Sunda Straits is small, even when the currents are strong. In the Java Sea, the surface water flow is directed to the west from May to September and to the east from November to March (Martosubroto, this vol.). In April and October, when the direction of the flow changes, eddies are generated along with a shear between the eastward current off the coast of Java and the westward current off the coast of Borneo. Through the Malacca Strait and the Sunda Strait, the surface currents are generally directed towards the Indian Ocean and are strongly related to the sea level gradient through the straits. The flow through the Sunda Strait reaches its maximum in August, during the southeast monsoon and there is a second maximum in December/January. In the Malacca Strait, the period of strongest flow is from January to April, during the northeast monsoon.

Properties of the Surface Waters (Modified from Wyrtki 1961)

High sea surface temperature (SST >25°C) and small seasonal amplitude (<3°C) are the dominant characteristics of Southeast Asian waters; moreover, their spatial distribution is quite uniform, with small gradient over the entire region.

The high rainfall, which largely exceeds evaporation, causes an average salinity of less than 34‰. This rainfall, the river runoff it causes and the archipelagic nature of the area are responsible for an extremely variable spatial distribution of the surface salinity. The alternance of the monsoons leads to rainy and dry seasons, and thus to large environmental variations. Rivers runoff, notably into the Java Sea, rather than rainfall is the cause of the low coastal salinities, even far offshore. The largest extent of the low salinity waters occurs in April and May when, with the onset of the southeast monsoon, they are transported from the Java Sea into the southern China Sea. In June, water with a higher salinity (>32‰) enters from the east into the Java Sea and, thence farther north up to the southern China Sea, reaching its maximal westward penetratio in September. With the onset of the northwest monsoon, i October/November, these water masses are pushed bac again towards the Java Sea, while their salinity is reduced b the start of the rain. Salinity in the Java Sea drops below 32‰ reaching its minimum in May, when river runoff from Borneo i maximal.

A steady southeast current flows from the Sunda She through the Malacca Strait into the Indian Ocean. During th northeast monsoon, this current transports relatively hig salinity water from the South China Sea. During the southeas monsoon, the water transported is of low salinity, due to rive runoff from Central Sumatra and direct rainfall. Strong tid currents cause a complete vertical mixing over the wate column.

Inferences from the COADS Dataset

Extraction and presentation of the data extracted fro the Comprehensive Oceanographic and Atmospheric Datase (COADS) dataset (Woodruff et al. 1987), recently publishe as a set of five CD-ROMs through the Climate and Easter Ocean Systems (CEOS) project (Bakun et al. 1992), were use to document the seasonal and interannual variations of SS of scalar wind speed and the north-south and east-wes component of the pseudo wind-stress in six selected area defined on Fig. 2. The COADS database contains the surfac weather observations collected by merchant ships and othe platforms (buoys, weather stations, lightships, etc.) since 1854 The data distribution and density in the area are presented i Fig. 3. Data density was, in the 1950s, low all over the region except along trade lanes such as that passing through th Malacca Strait to Singapore. Later, data density increases alon the eastern part of the China Sea but remains "spotty" over th western part of Southeast Asia.

For the purpose of this study, the Java Sea is separate in two areas, eastern and western (see Fig. 2). Other area defined in Fig. 2 are the southern part of the China Sea, th northern and central parts of the Strait of Malacca, and th Sunda Strait.

For each parameter and each area, a time-series o monthly mean values from 1950 to 1990 was built using th individual observations extracted from the COADS databas A mean annual cycle was derived from the monthly time-serie A time-series of the mean annual value was then calculate and used to characterize the interannual variability from 195 to 1990.

Variability of the Sea Surface Temperature

SSTs are high all year round in the six areas, wit minimum values (27.5°C) observed in January and Februar in the southern part of the China Sea (Fig. 4). Maximum value are comprised between 29.2°C (Sunda Strait) and 29.8°C

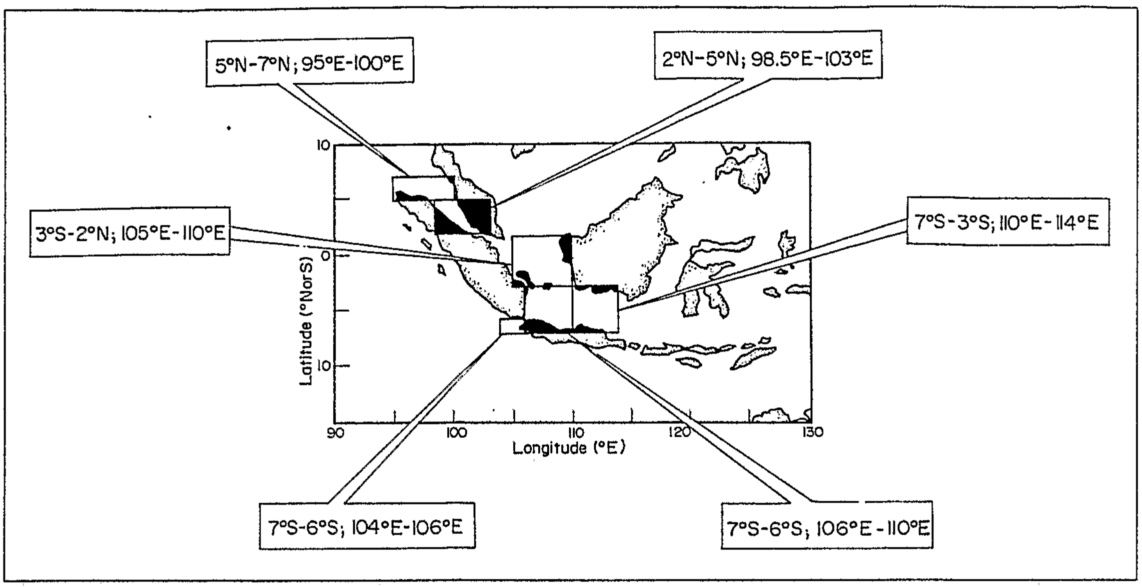

Fig. 2. Definitions of the six areas of Western Indonesia used to structure this contribution (clockwise from the upper left corner): (i) northern Malacca Strait; (ii) central Malacca Strait; (iii) southern South China Sea (including Karimata Strait); (iv) eastern Java Sea; (v) western Java Sea; and (vi) Sunda Strait.
[Gambar 2. Pembagian enam daerah Indonesia bagian barat sebagai dasar penyusunan tulisan ini (searah jarum jam dari pojok kiri atas): (i) Selat Malaka bagian utara; (ii) Selat Malaka bagian tengah; (iii) Laut Cina Selatan bagian selatan (termasuk Selat Karimata); (iv) Laut Jawa bagian timur; (v) Laut Jawa bagian barat; dan (vi) Selat Sunda.]

(Malacca Strait). In some areas located on or south of the equator (Sunda Strait, Java Sea and southern part of the South China Sea), there is a pronounced biannual cycle with a first SST minimum in January-February and a second in August-September.

The amplitude of the SST interannual variability is less than 1.0°C in the Malacca Strait but it increases toward the south (Fig. 5). The greatest amplitude is recorded in the Sunda Strait where it almost reaches 1.5°C. The eastern and western Java Sea, the southern tip of the China Sea and the Sunda Strait all exhibit a similar interannual variability, with mean annual SST values above the average at the end of the 1950s (a feature that may be associated with the 1957-1958 El Niño Southern Oscillation [ENSO] event). SSTs below average appear to have occurred both during the mid-1960s and 1970s. The 1980s, on the other hand, has higher than average SSTs. Major ENSO events (1957-1958; 1972-1973) are associated with a relative peak in SST except for the 1983-1984 event which is nevertheless considered as the most intense of this last century.

Variability of the Wind

The monthly seasonal cycles of the scalar wind speed (i.e., the mean of the two wind

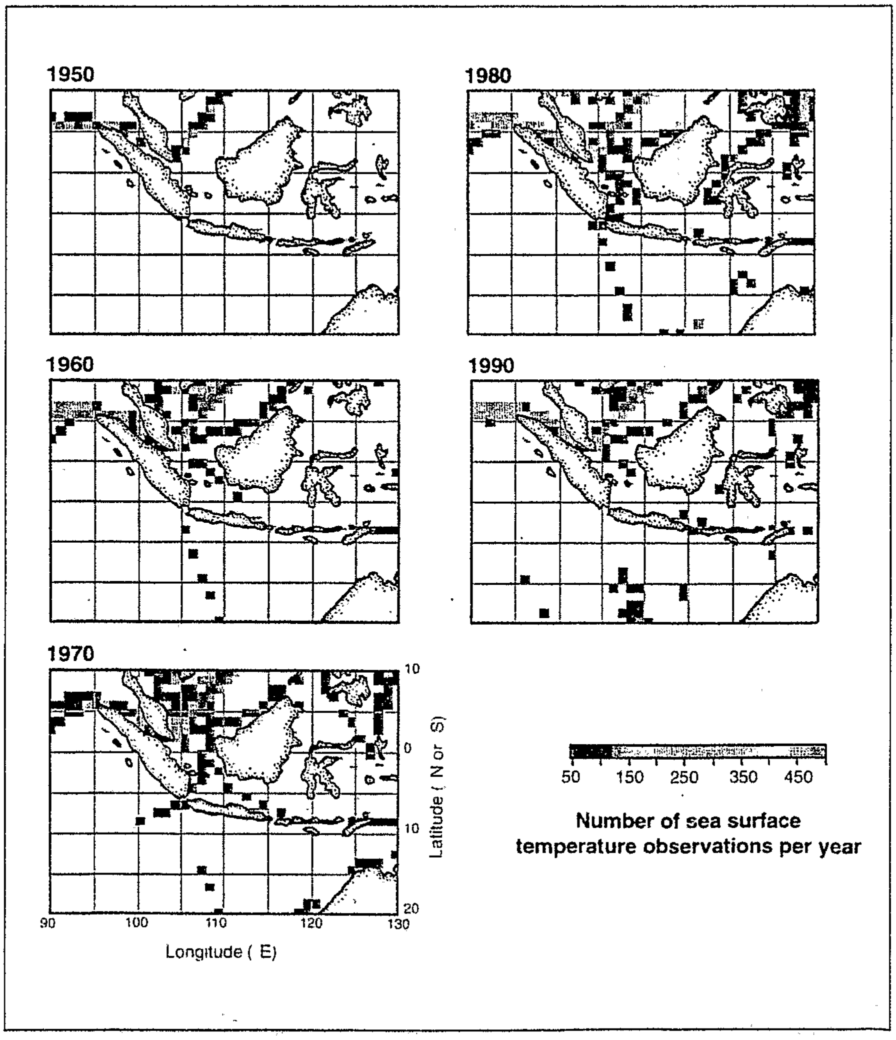

Fig. 3. Data density in the COADS (by selected years: 1950, 1960, 1970, 1980 and 1990). Note that data density is high only along commercial routes and very scarce in the open ocean.
[Gambar 3. Kepadatan data COADS (menurut tahun: 1950, 1960, 1970, 1980 dan 1990). Perlu disimak bahwa kepadatan densitas data tertinggi terdapat di sepanjang daerah pelayaran niaga dan sangat sedikit terdapat di laut bebas.]

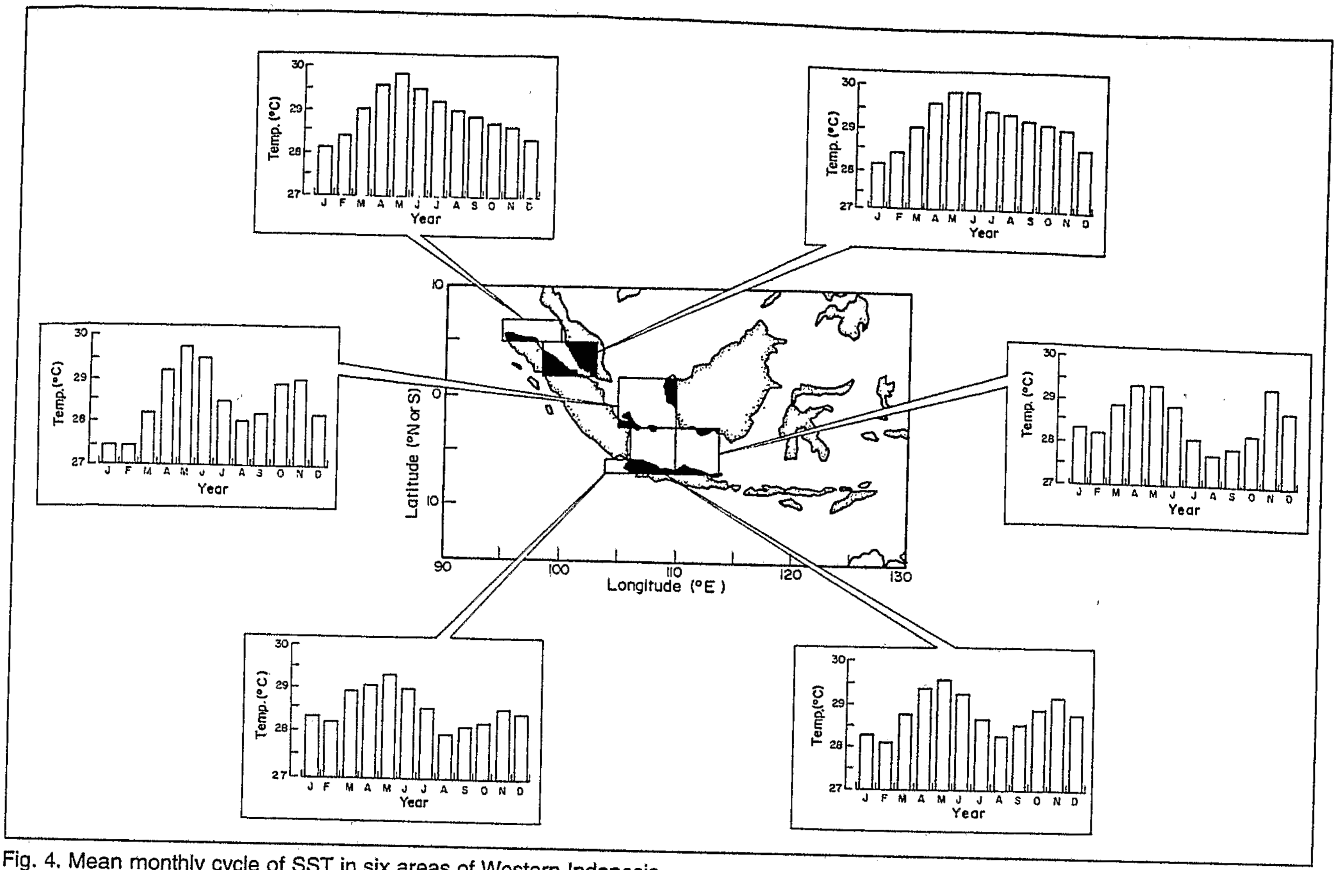

Fig. 4. Mean monthly cycle of SST in six areas of Western Indonesia.
[Gambar 4. Siklus bulanan rata-rata SST di enam daerah perairan Indonesia bagian barat.]

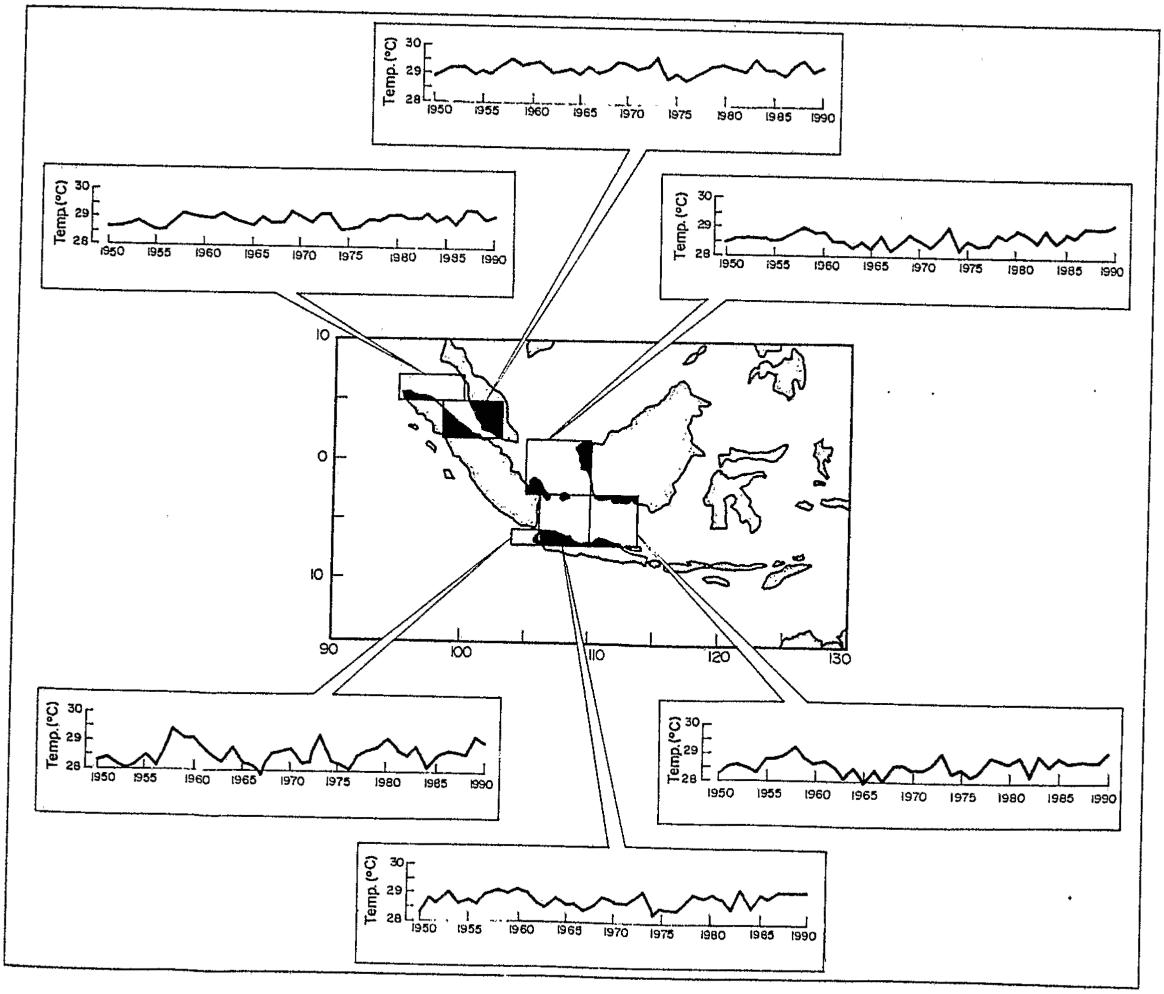

Fig. 5. Mean annual values of SST from 1950 to 1990 in six areas of Western Indonesia (COADS dataset).
[Gambar 5. Rata-rata tahunan SST dari tahun 1950 hingga 1990 di enam daerah perairan Indonesia bagian barat (data COADS).]

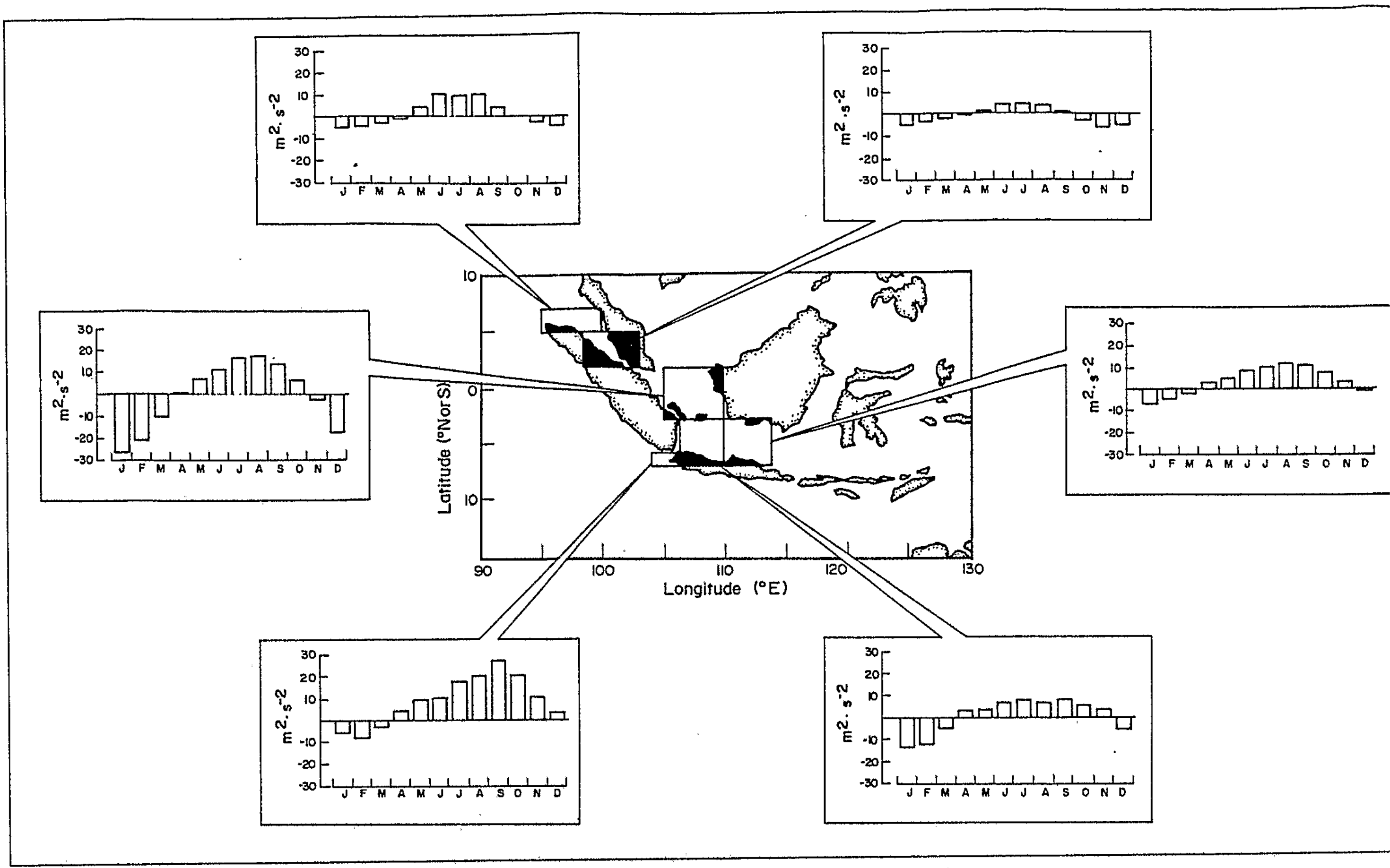

Fig. 6. Mean monthly cycle of the scalar wind speed in six areas of Western Indonesia (COADS dataset).
Gambar 6. Siklus bulanan rata-rata dari kecepatan angin di enam daerah perairan Indonesia bagian barat (data COADS).]

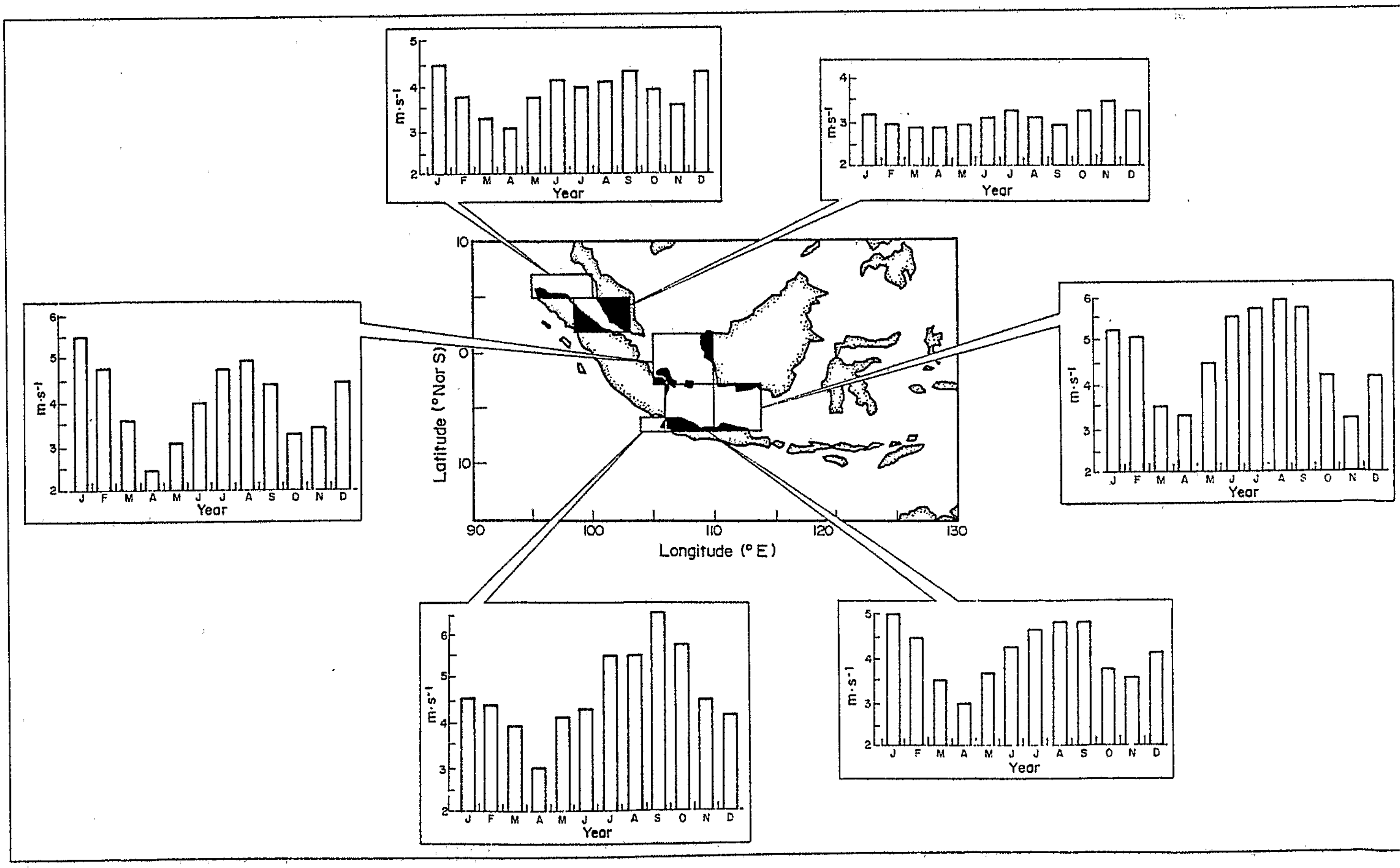

Fig. 7. Mean monthly cycle of the north-south pseudo wind stress component in six areas of Western Indonesia (COADS dataset).
[Gambar 7. Siklus bulanan rata-rata dari komponen pengaruh angin pseudo utara-selatan di enam daerah perairan Indonesia bagian barat (data COADS).]

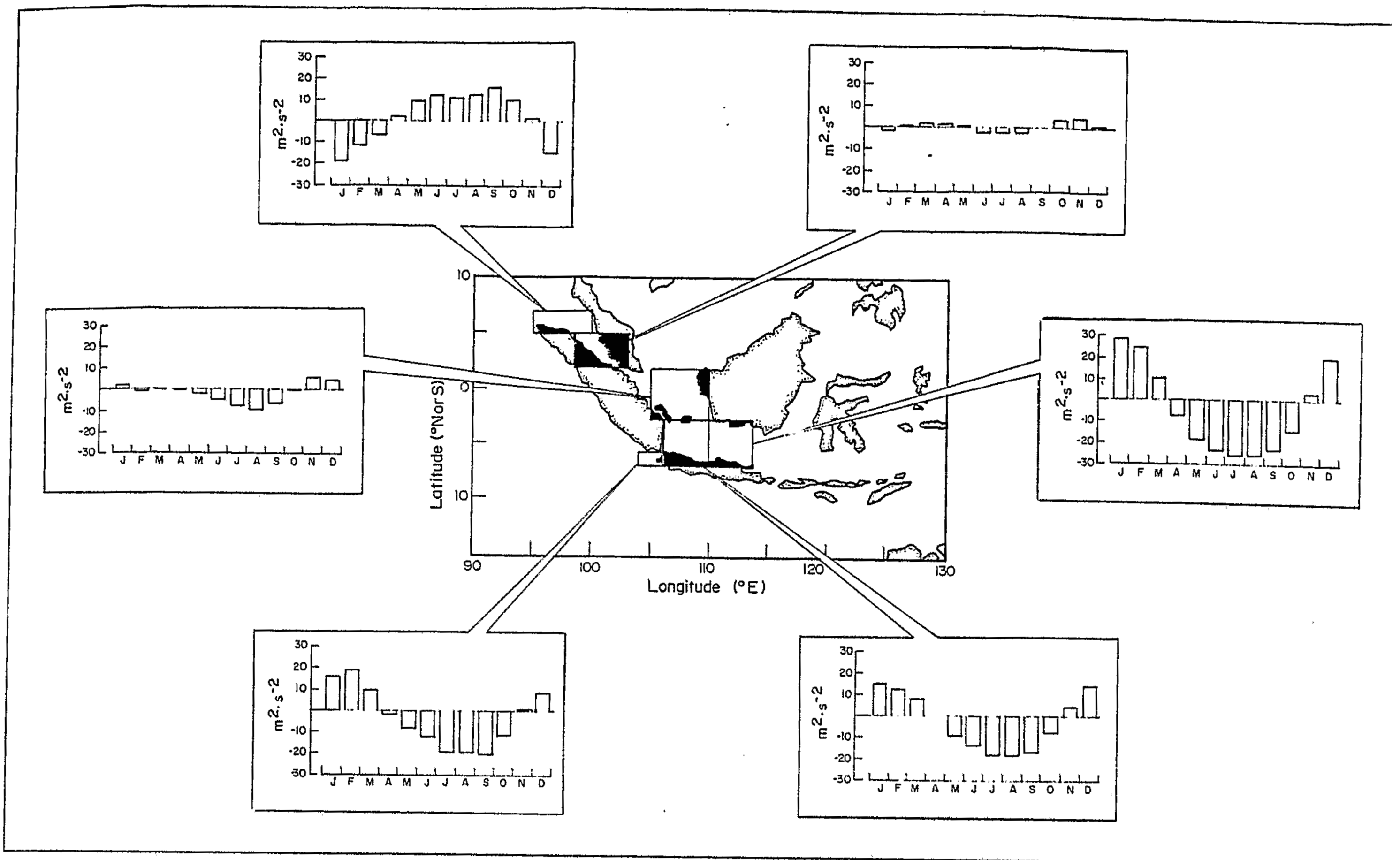

Fig. 8. Mean monthly cycle of the east-west pseudo wind stress component in six areas of Western Indonesia (COADS dataset).
[Gambar 8. Siklus bulanan rata-rata dari komponen pengaruh angin pseudo timur-barat di enam daerah perairan Indonesia bagian barat (data COADS).]

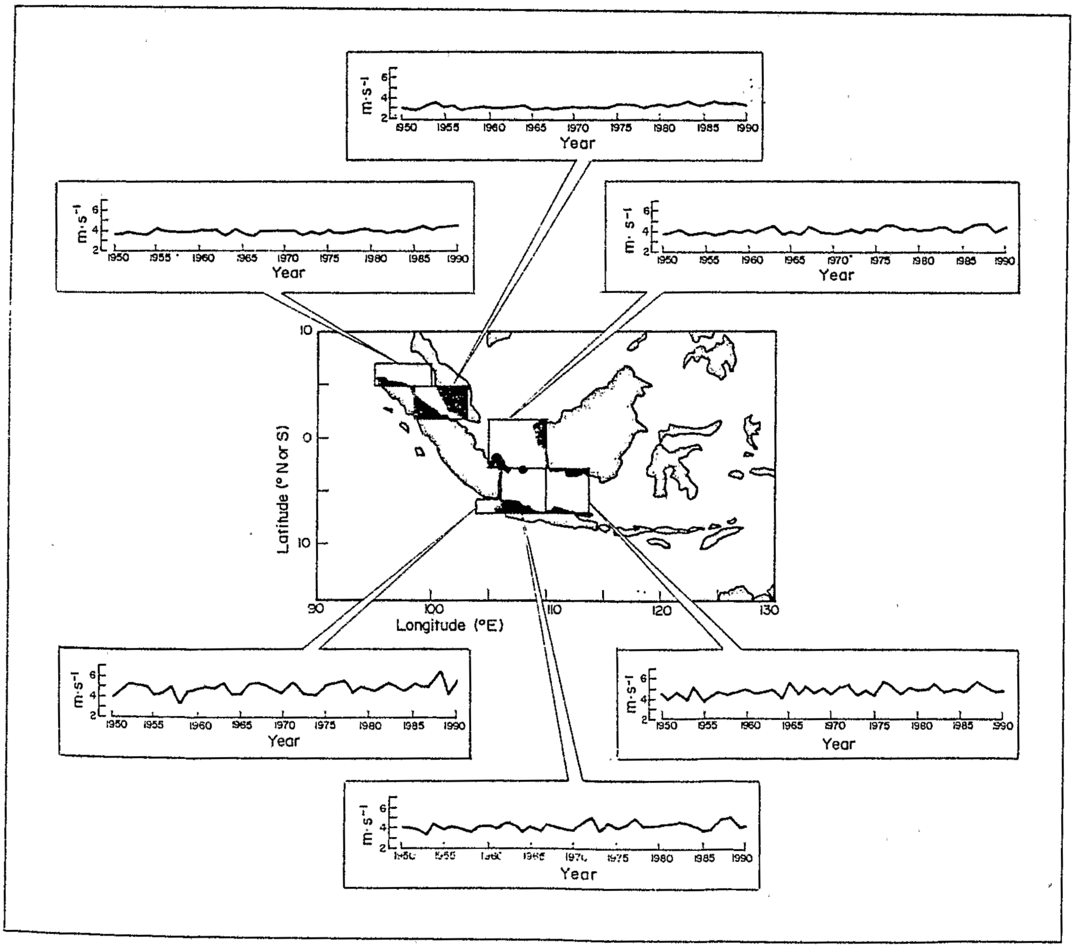

Fig. 9. Mean annual values of the scalar wind speed from 1950 to 1990 in six areas of Western Indonesia (COADS dataset).
[Gambar 9. Nilai rata-rata tahunan kecepatan angin dari tahun 1950 hingga 1990 di enam daerah perairan Indonesia bagian barat (data COADS).]

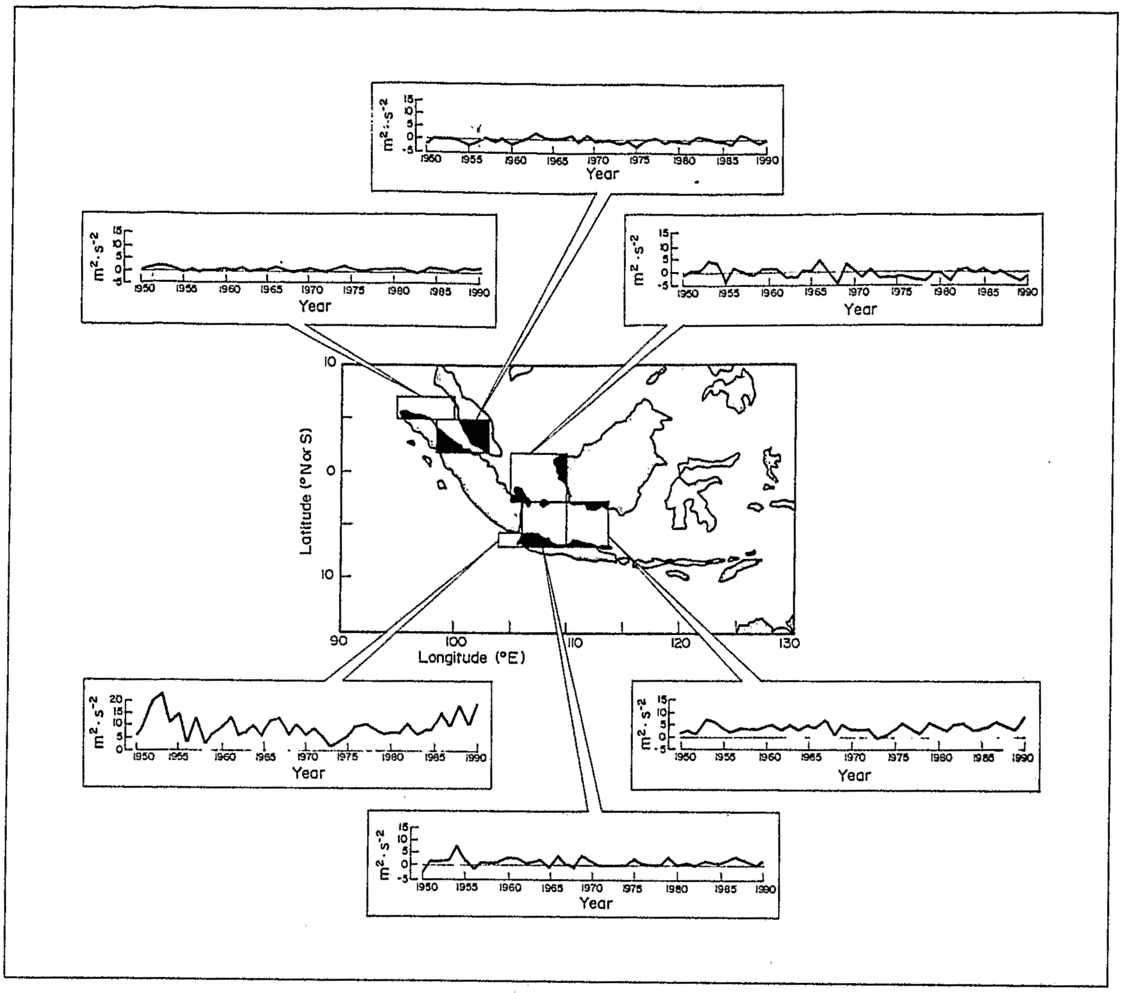

Fig. 10. Mean annual values of the north-south pseudo wind stress component from 1950 to 1990 in six areas of Western Indonesia (COADS dataset).
[Gambar 10. Nilai rata-rata tahunan komponen pengaruh angin pseudo utara-selatan dari tahun 1950 hingga 1990 di enam daerah perairan Indonesia bagian barat (data COADS).]

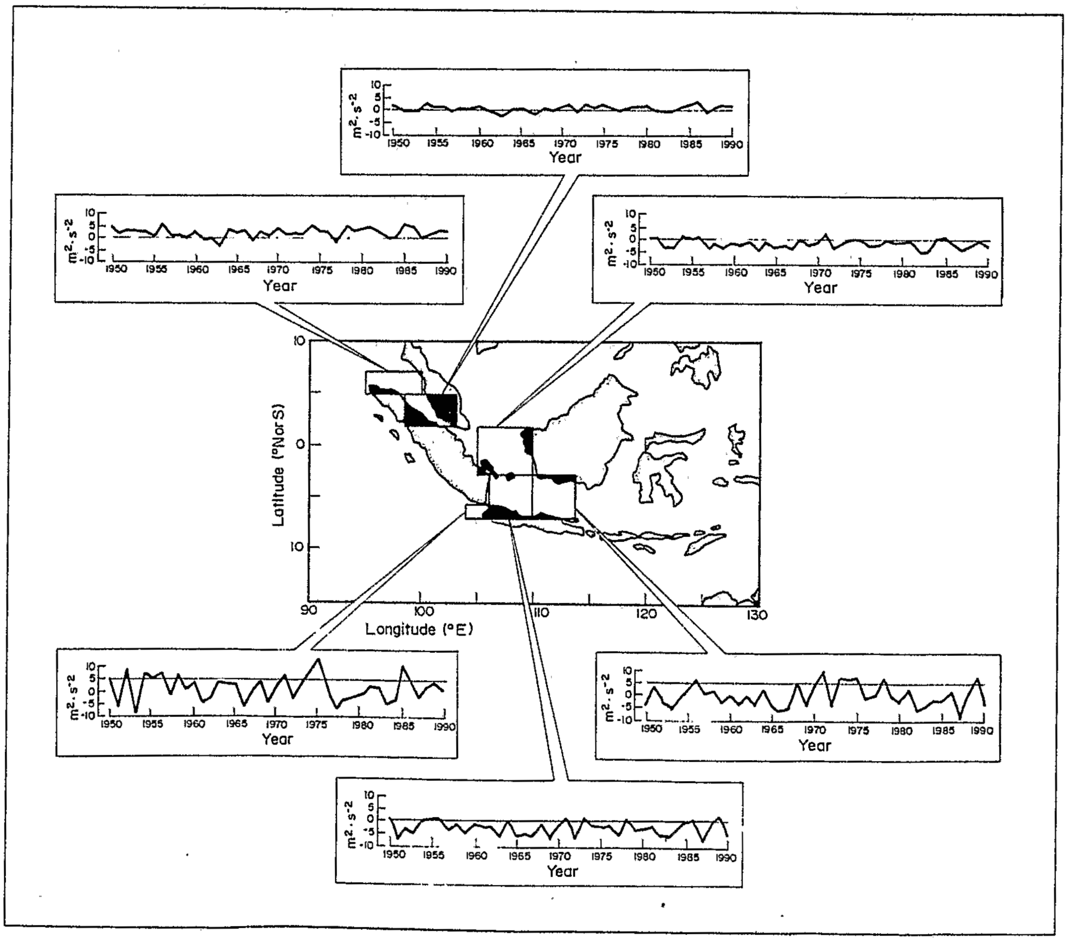

Fig. 11. Mean annual values of the east-west pseudo wind stress component from 1950 to 1990 in six areas of Western Indonesia (COADS dataset).
[Gambar 11. Nilai rata-rata tahunan komponen pengaruh angin pseudo timur-barat dari tahun 1950 hingga 1990 di keenam daerah perairan Indonesia bagian barat (data COADS).]

components) and of the two components of the pseudo wind stress (i.e., squares of the north-south and east-west wind components) are presented in Figs. 6, 7 and 8, respectively. The minimum values are observed in the southern part of the Strait of Malacca (3.5 ms^{-1}); maximum values occur in the Sunda Strait. A marked biannual cycle, due to the monsoon, appears in the southern part of the China Sea, in the Java Sea and in the Sunda Strait areas. Maximum values occur in January and August, while minimum values, in April and November-December. The maximum values stay below 6 ms^{-1} except in the Sunda Strait. This suggests that biological processes may not be dominated by hydrodynamic factors related to the wind (Therriault and Platt 1981; Cury and Roy 1989). The seasonal behaviour of the two wind stress components clearly illustrates the strong alternation (and reversal) of the wind regime due the dynamics of the monsoons (Figs. 7 and 8).

The interannual variability of the wind is rather small in the northern and central Malacca Strait (0.5 ms^{-1}) but increases toward the south (Figs. 9, 10 and 11). The mean annual scalar wind speed exhibits in almost all areas a positive long-term trend. Except for this trend, no clear pattern of variability is readily identifiable: ENSO events do not appear to affect local wind variability. Also, the interannual variability of the two components of the pseudo wind stress exhibits a behavior similar to the variability of the scalar wind.

Conclusion

The previous considerations lead one to conclude that the marine habitats of the adjacent areas to the Indonesian Archipelago are quite unique in the world: the imbrication of land and sea creates complex systems where local processes may prevail over global dynamics. Also, the monsoon regime creates such a strong seasonality of the characteristic of the environment that the alternation of the nor and south winds completely reorganizes the surface circulatio this can be expected to have a strong ecological impac Interannual variability exists, but surprisingly, it appears not t be closely associated with ENSO events - at least, no stron anomalies in either SST or wind appear in the COADS datas that can straightforwardly be linked with ENSO events. Th begs the question whether the complexity of the Southeas Asian environment may have led to some sort of homeostasis

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D. Pauly
and
P. Martosubroto

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DIRECTORATE GENERAL OF FISHERIES
Jakarta, Indonesia

GERMAN AGENCY FOR TECHNICAL COOPERATION
Eschborn, Germany

INTERNATIONAL CENTER FOR LIVING AQUATIC RESOURCES MANAGEMENT
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