Interannual Variation of Ocean Heat Content and Sea Surface Height of Outer Indonesian Water Related to Global Ocean Warming

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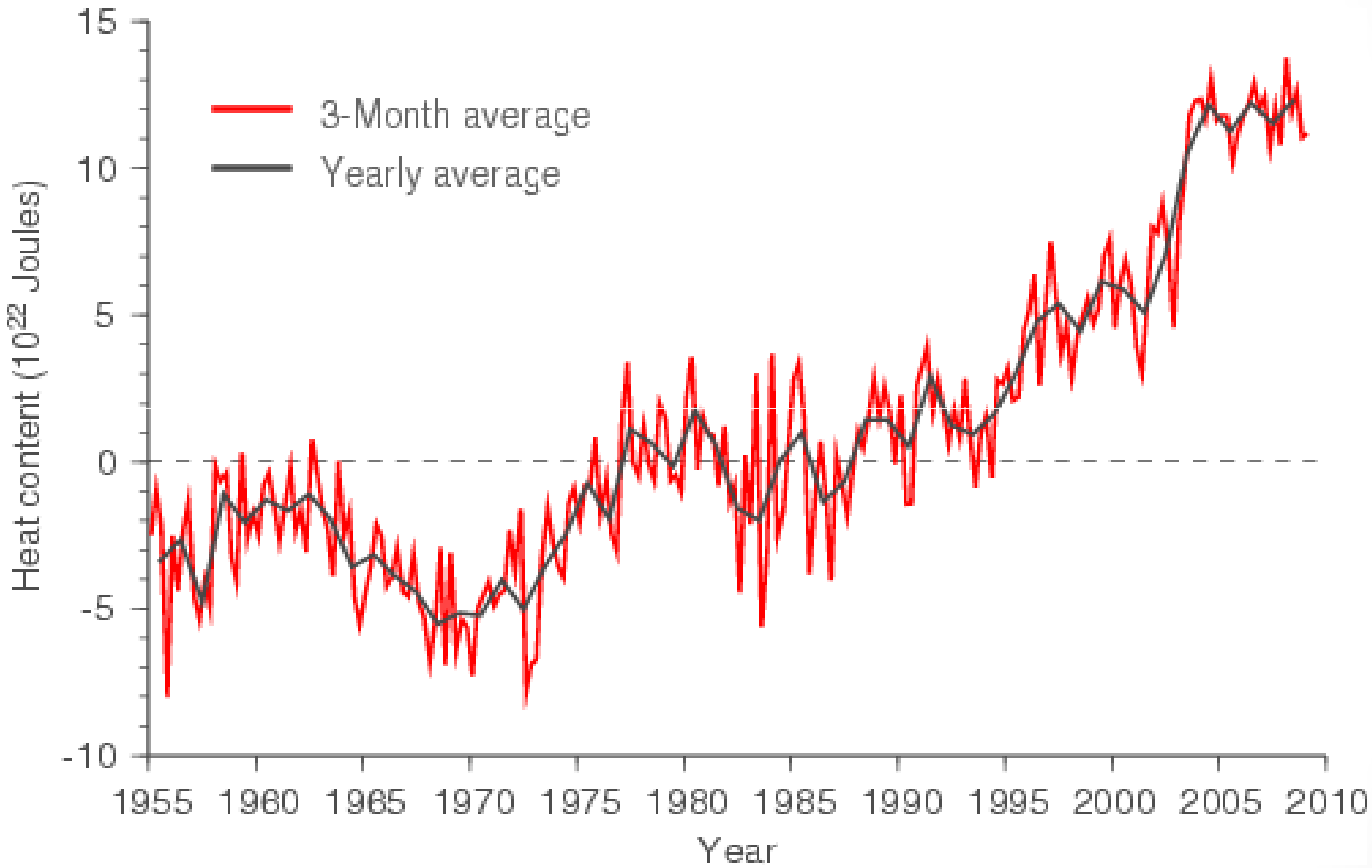
Background

- About 80 to 90% of global warming involves heating of the seawater.
- Estimating the amount of heat stored in the ocean (mentioned as Ocean Heat Content) is important to better understand how heat trapped by greenhouse gases and to identify where heat enters the ocean and where it re-emerges to interact with the atmosphere, and to identify changes in thermohaline circulation and monitor for indications of possible abrupt climate change (NOAA)
- Decreasing of the Ocean Heat Content (refer to as OHC) within the recent years, but the sea level had increased half an inch in the last four years. →??
- This triggers a debate, since increase of OHC should cause increase of sea level as well

Earth's Ocean Heat Content Trend, 1955 - 2010, Upper 700 Meters of Ocean



After: NOAA

Objectives

- The proposed research is intended to observe at inter annual variations of OHC in associated with sea level (hereinafter referred to as SSH- Sea Surface Height) to global sea surface warming at outer of Indonesian Waters.

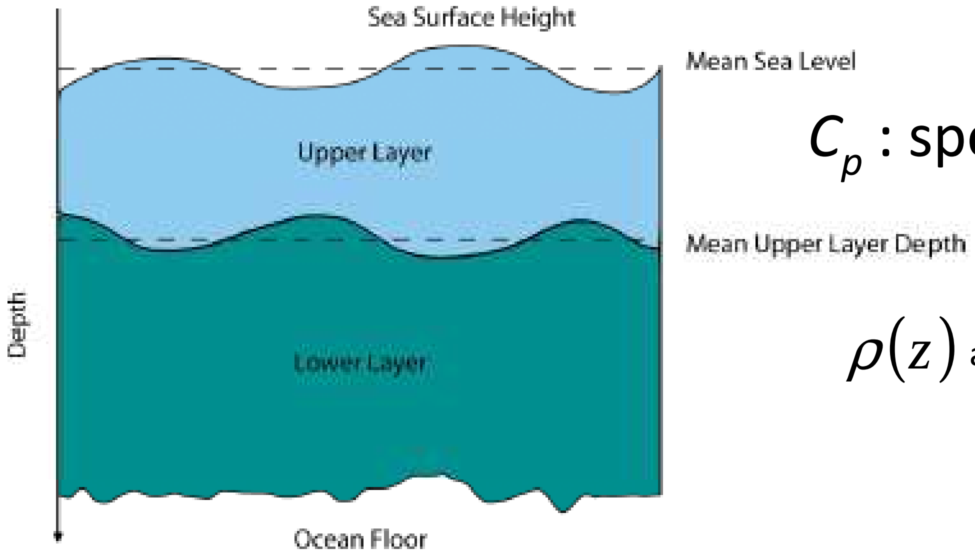
Merits

- SSH was chosen in order to see more detailed heating-and consequently the expansion / rise of sea-level. Previous studies had used tidal data to determine the sea level, and the use of OHC itself can be claimed as **the first to be calculated** for EEZ waters of Indonesia.

Calculation of OHC

following Young et al, 2009.

$$Q = c_p \int_0^{d_{28}} \rho(z)[T(z) - T_0]dz \qquad (1)$$



C_p : specific constant of ocean water

$\rho(z)$ and $T(z)$: density and temperature functions at depth z

Calculation of OHC

- Because low latitude sea surface temperature (SST) waters near Indonesia is no less than 28 ° C, this study will only use temperatures above 28 ° C.
- Derived from the surface (0) to 28 ° C isotherm depth(d28), and T0 is equivalent to 28 ° C.

  Because the temperature and density profiles are known (from the Argo data), the integral in equation (1) can be calculated by the trapezoid rules

Then OHC

$$Q \cong C_p \sum_{k=1}^{M} \rho_k (T_k - T_0)(z_k - z_{k-1}) = Q_{cont} \qquad (2)$$

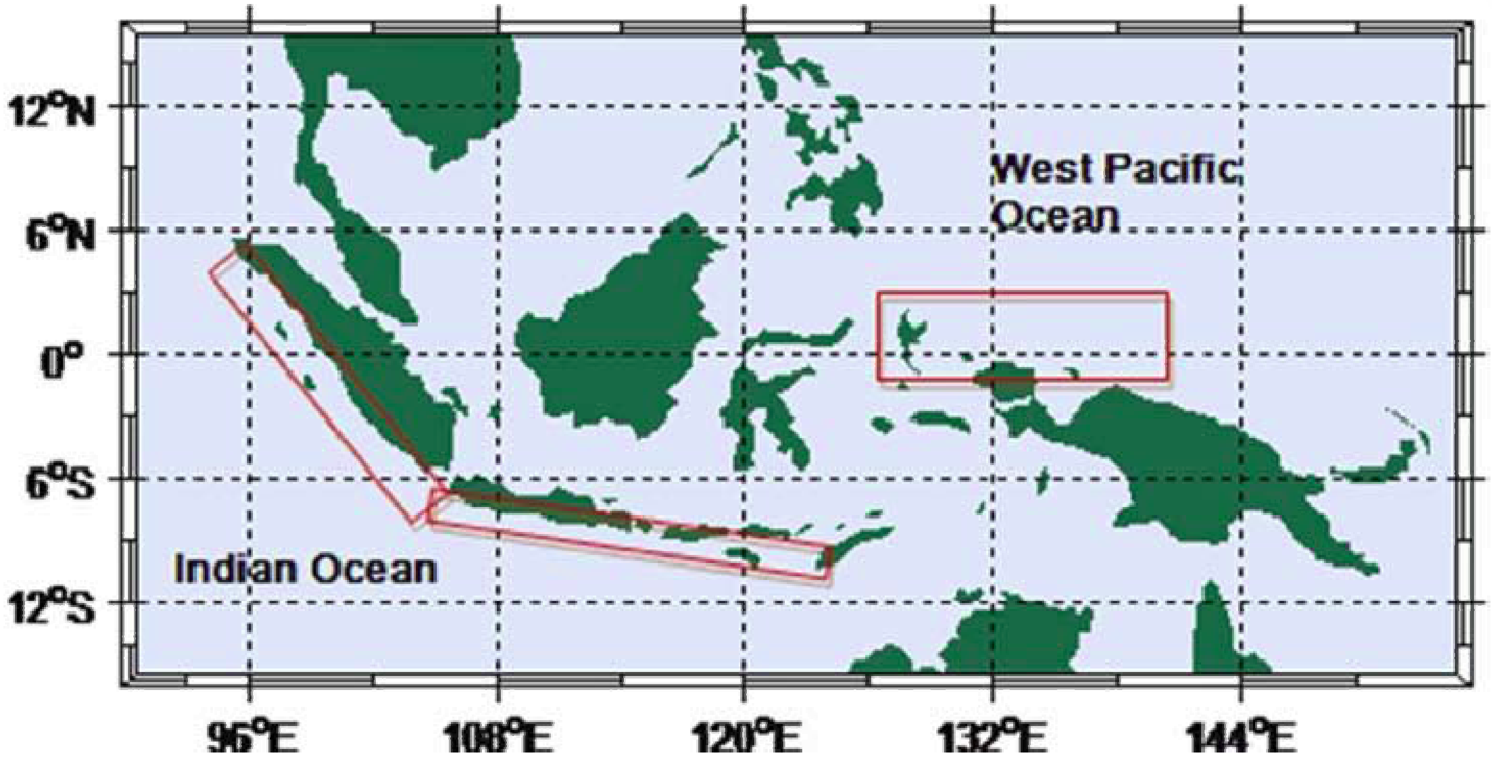
ρ_k density at depth z_k

T_k temperature at depth z_k

z_0 at depth 0.

Estimation in equation (2) is defined as the continuous-profile heat content of the upper layer, *Qcont*. The calculation in this equation will also be done by writing a program in Matlab computing language.

LOCATION AREA



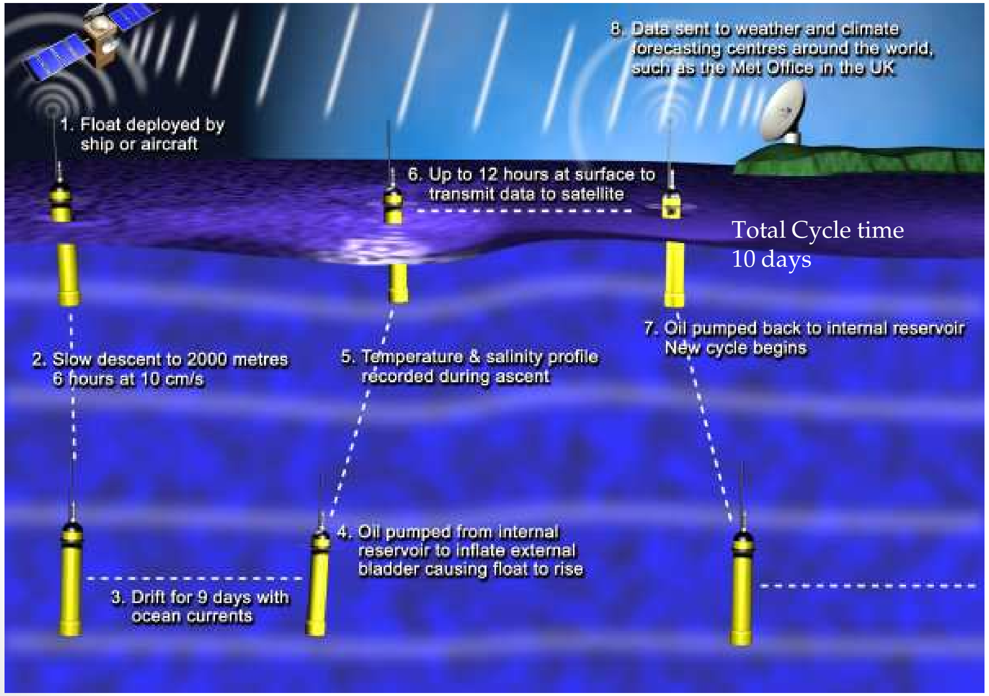
This research will be an input to adaptation and mitigation strategic to cope with global warming, mostly for the coastal areas exposed to the West Pacific and Indian Oceans.

Data (1)

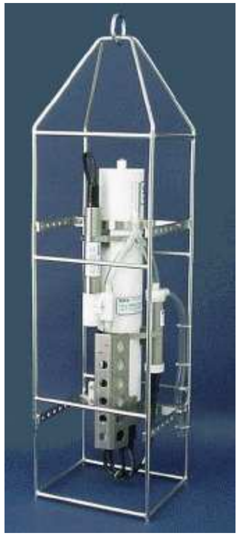
Data

2000 – 2012

- **Argo Float** — www.coriolis.eu.org.
- **CTD** — www.godac.jamstec.go.jp
- **XCTD** — www.godac.jamstec.go.jp



Sistem Kerja Argo Float



CTD

XCTD

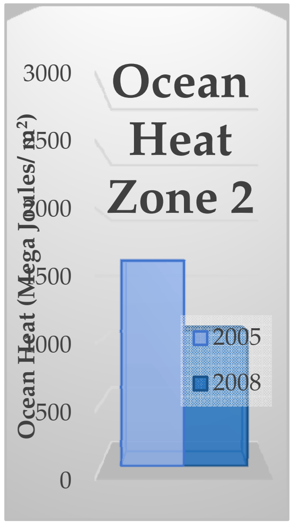
Data (2)

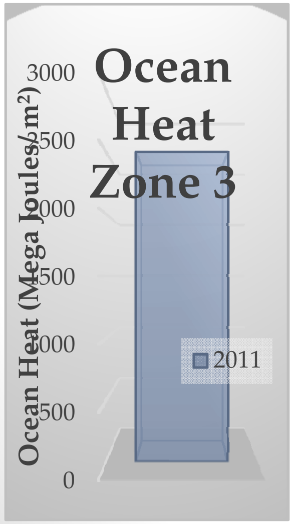
- SSHA was collected from the Topex/Poseidon and Jason Satellite (altimeter data)
- Surface Heat Flux from ECCO :Estimating Circulation and Climate of the Ocean

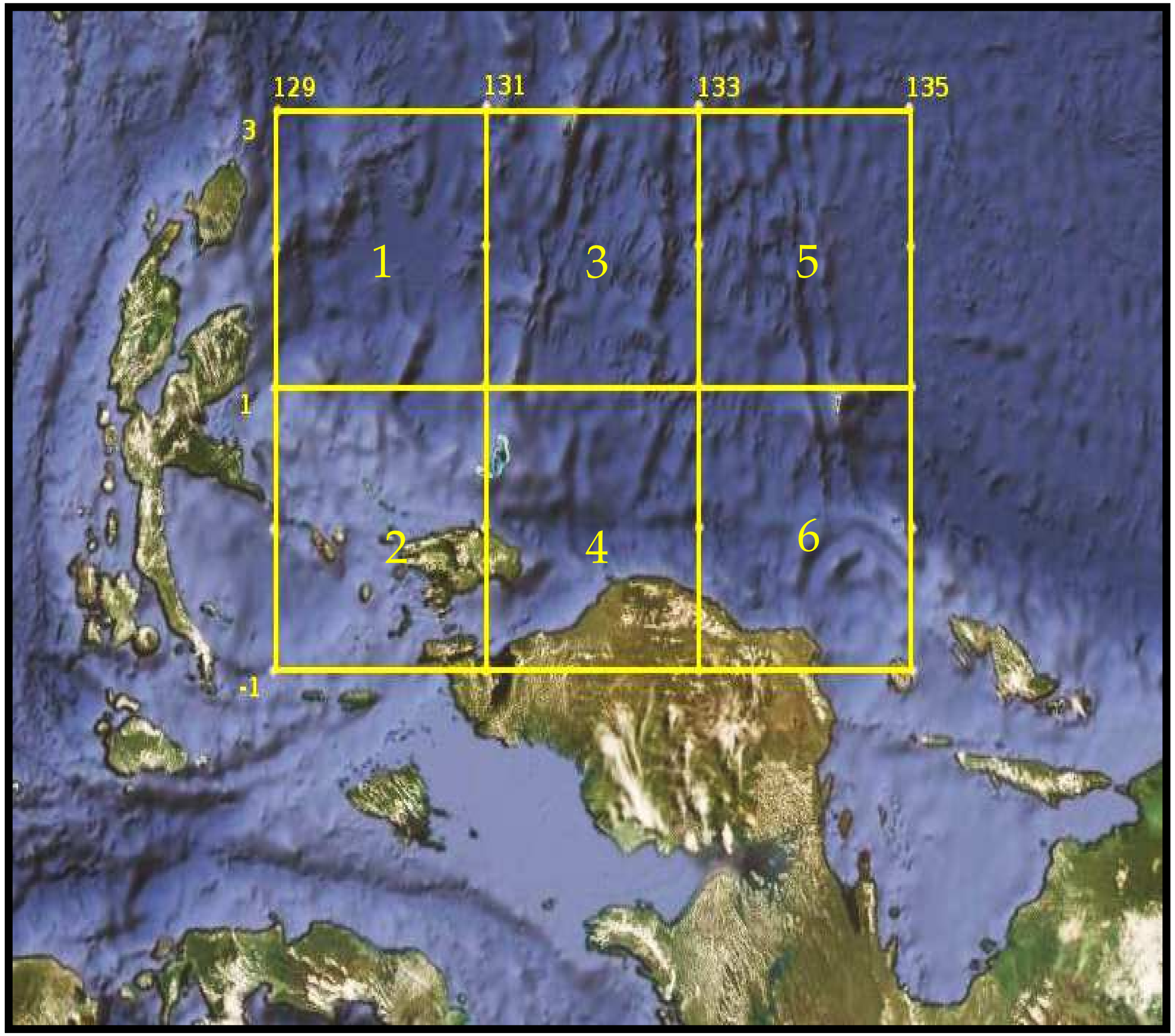
  http://www.ecco-group.org/

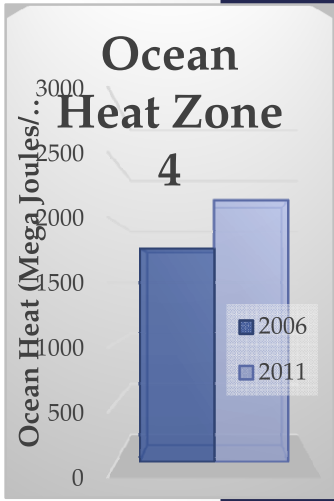
RESULTS

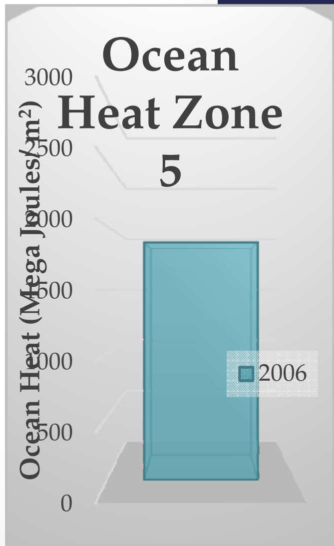
Data Result for Ocean Heat Content on January in North Papua



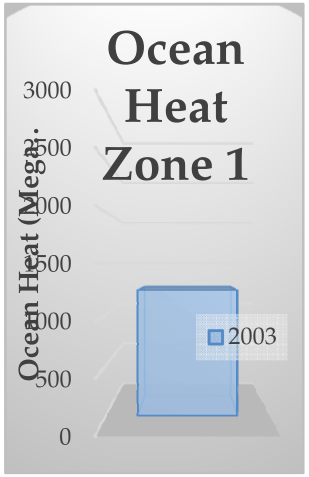


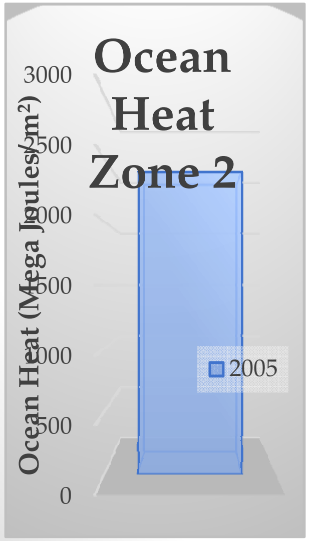


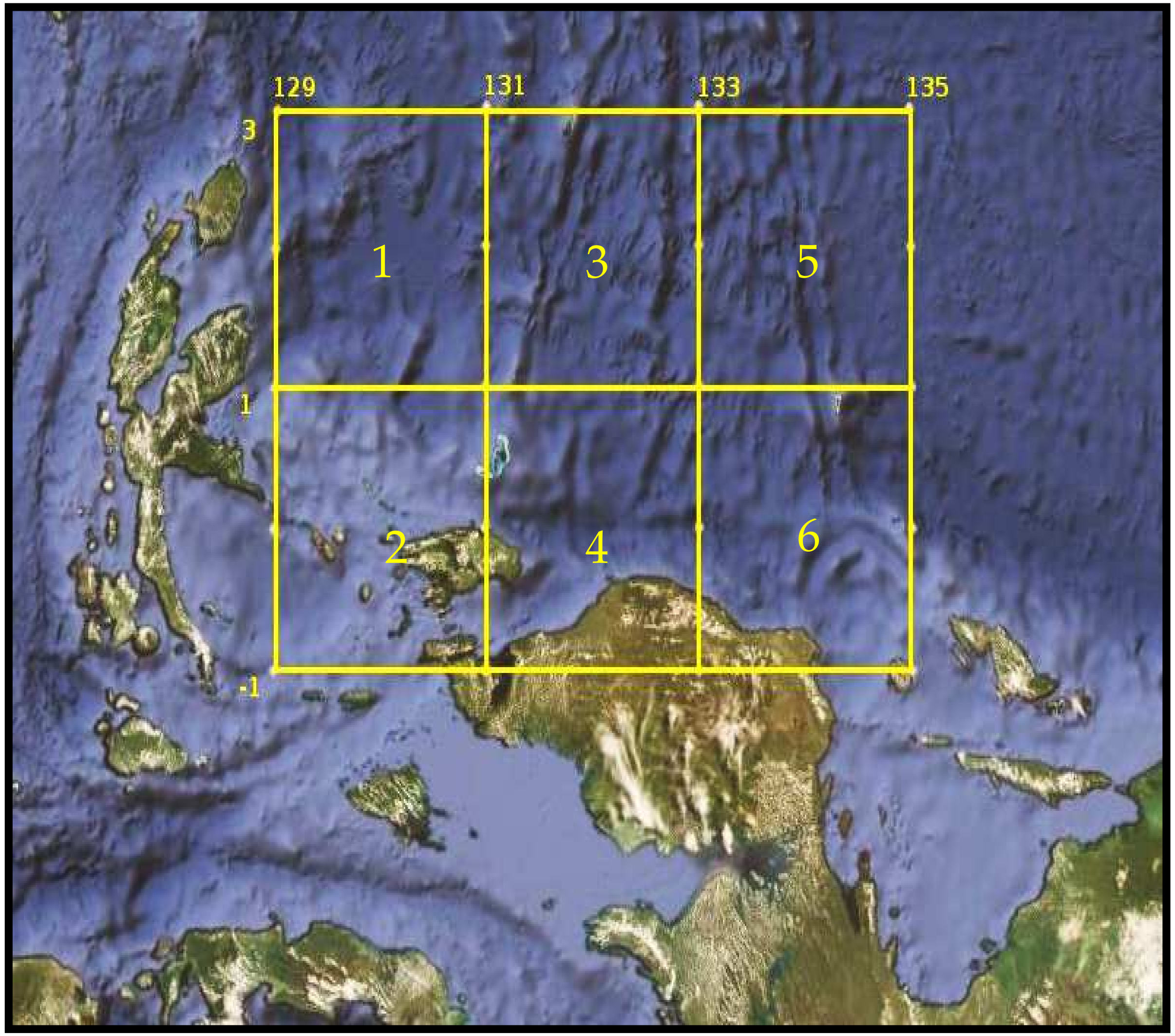


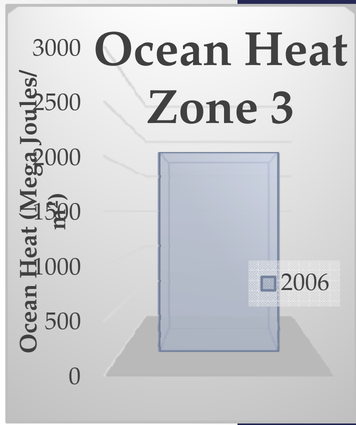


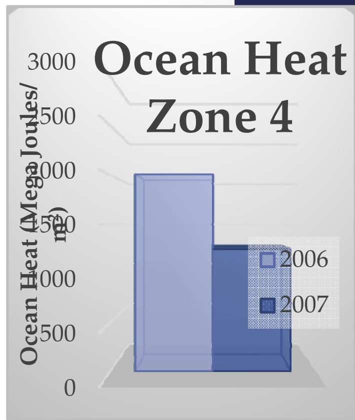
Data Result for Ocean Heat Content on May in North Papua

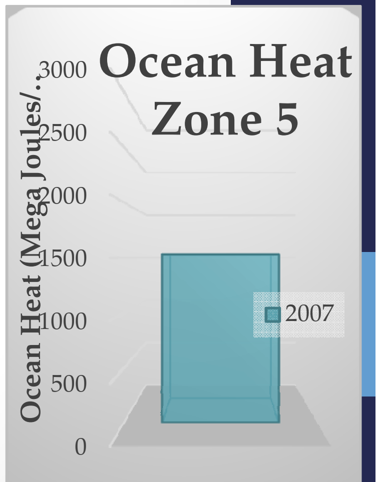




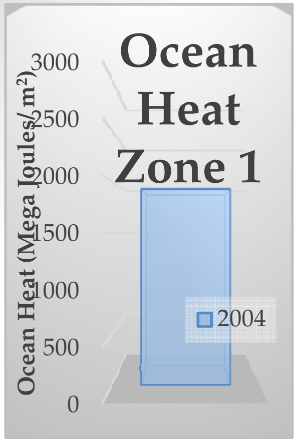


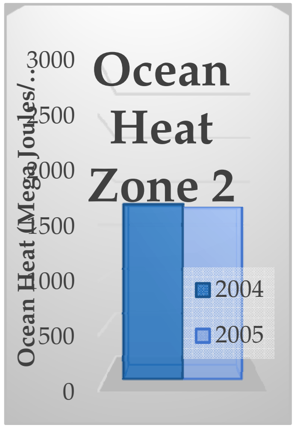


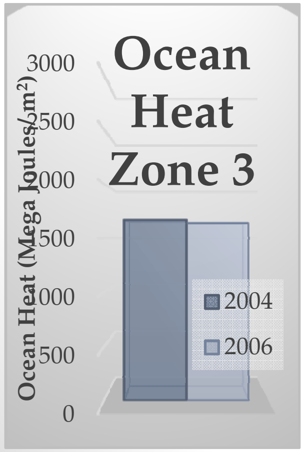


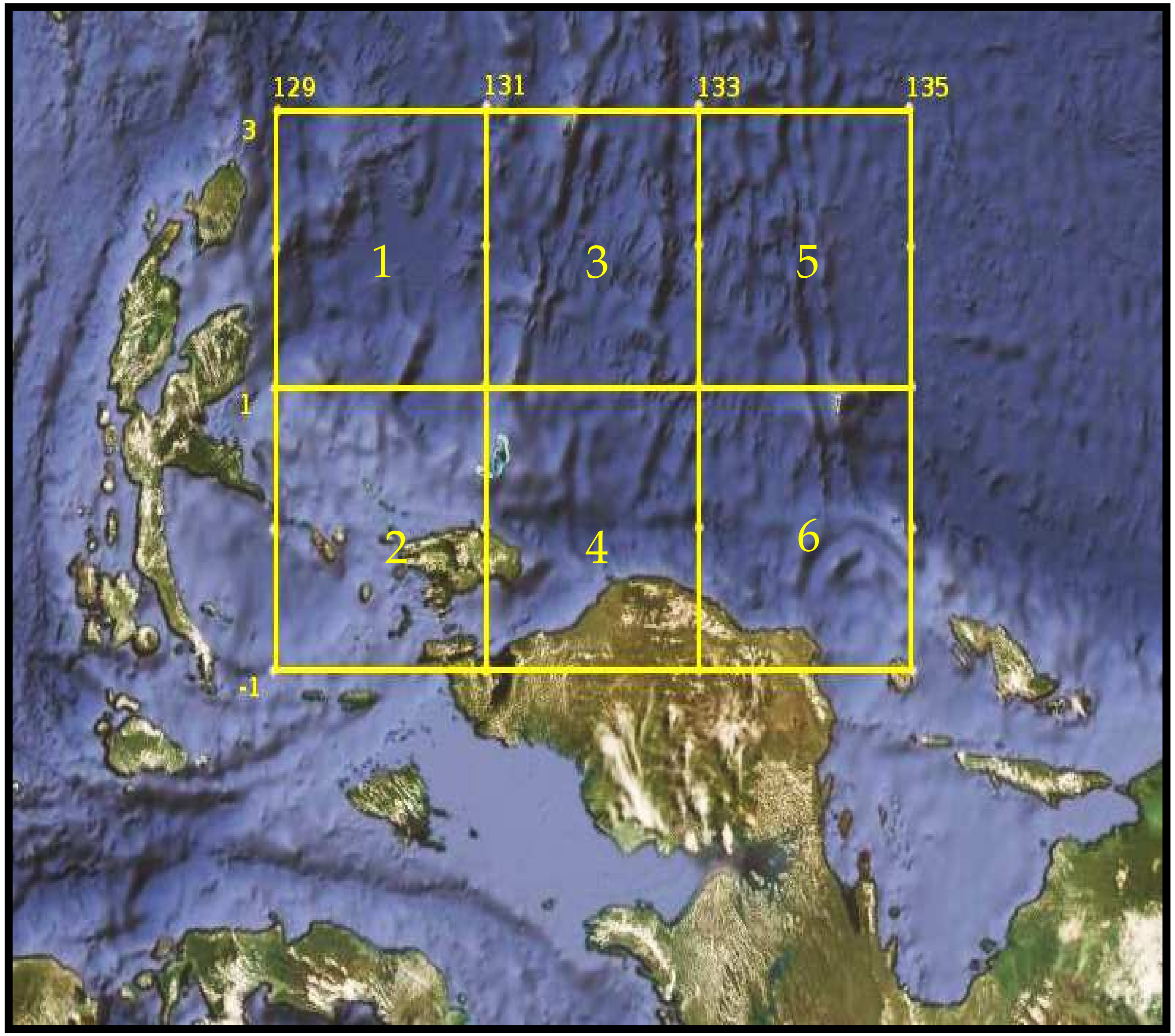


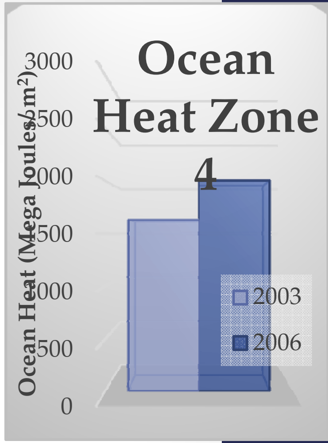
Data Result for Ocean Heat Content on August in North Papua

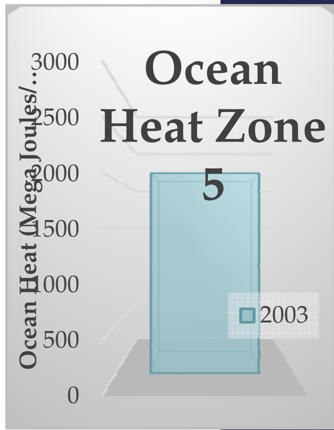


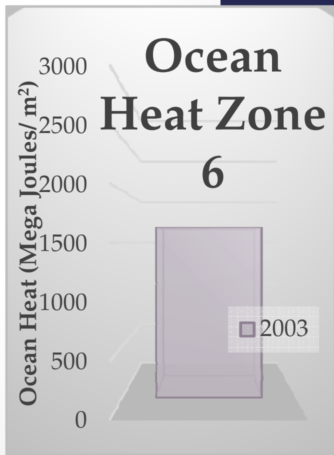




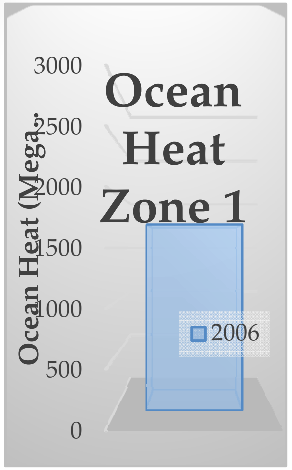


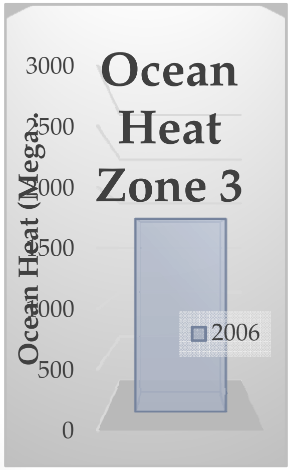


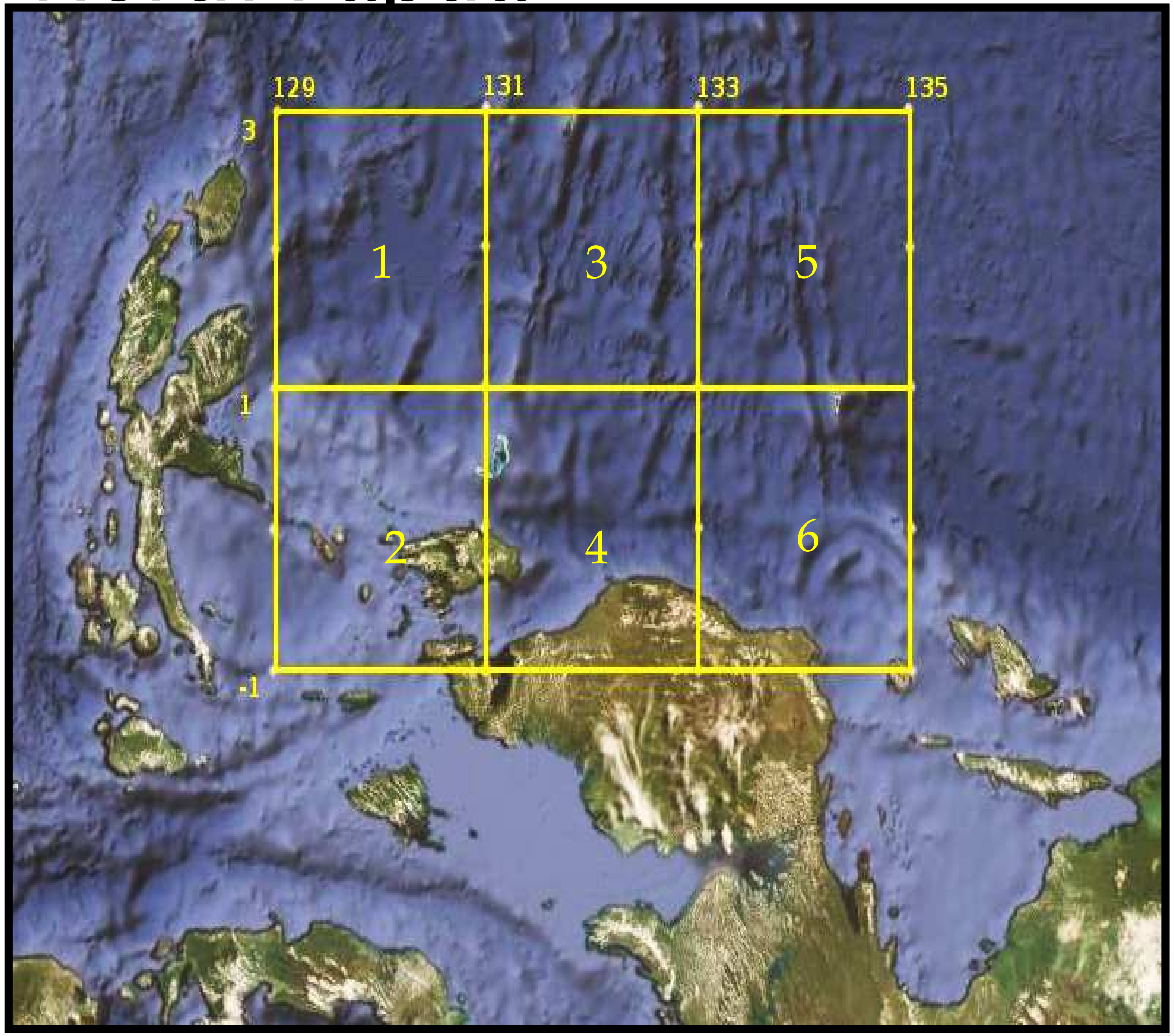


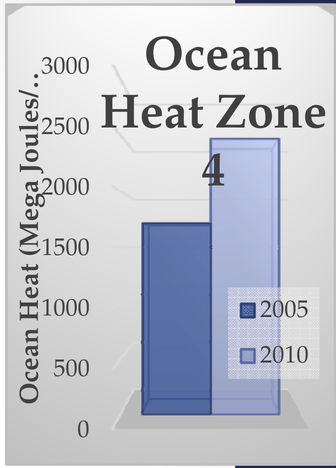


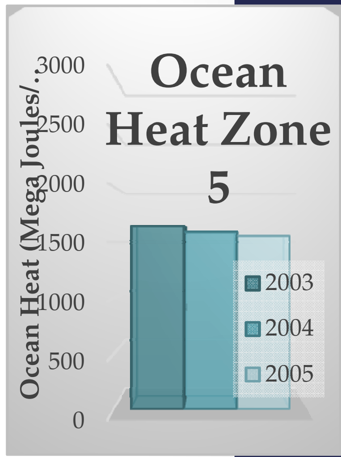
Data Result for Ocean Heat Content on October in North Papua

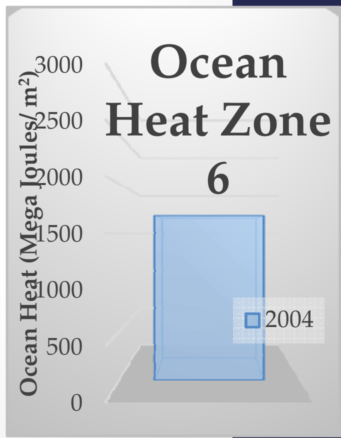




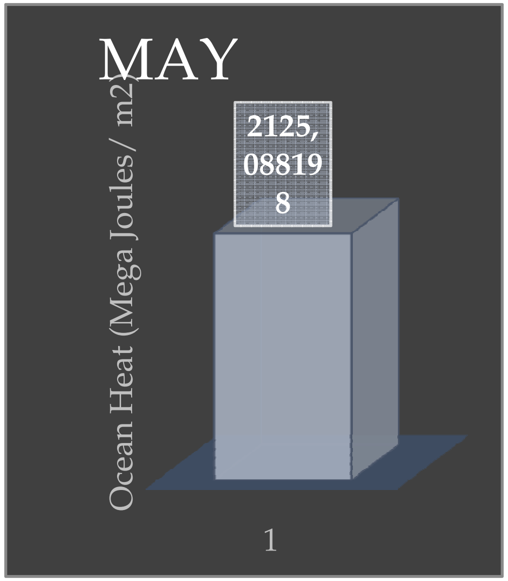


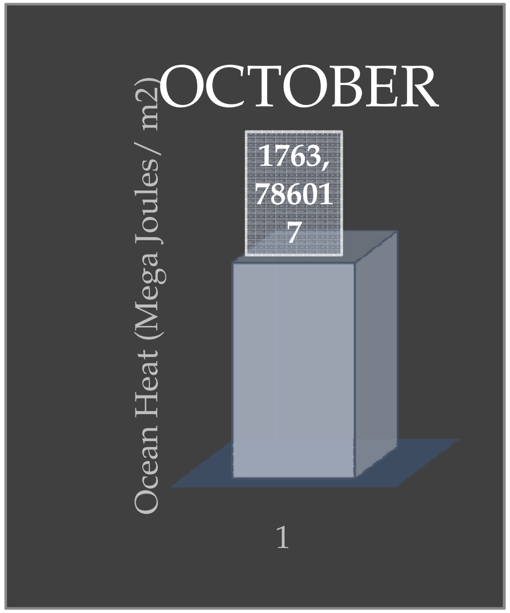


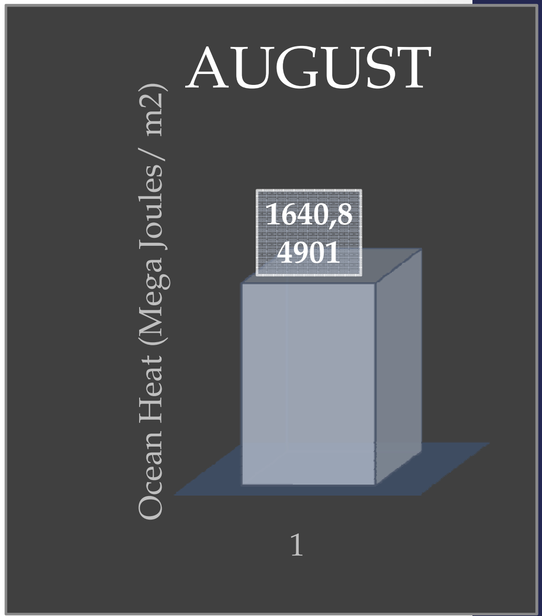


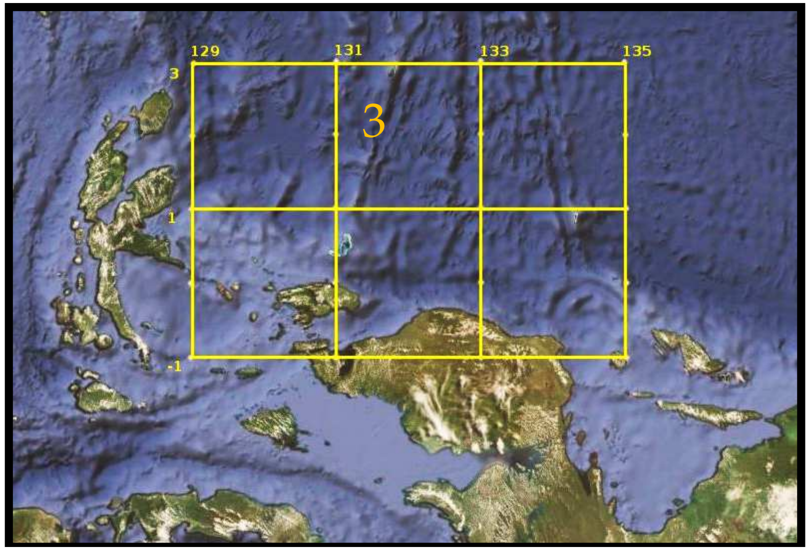


Ocean Heat Content on 2006 in Zone 3

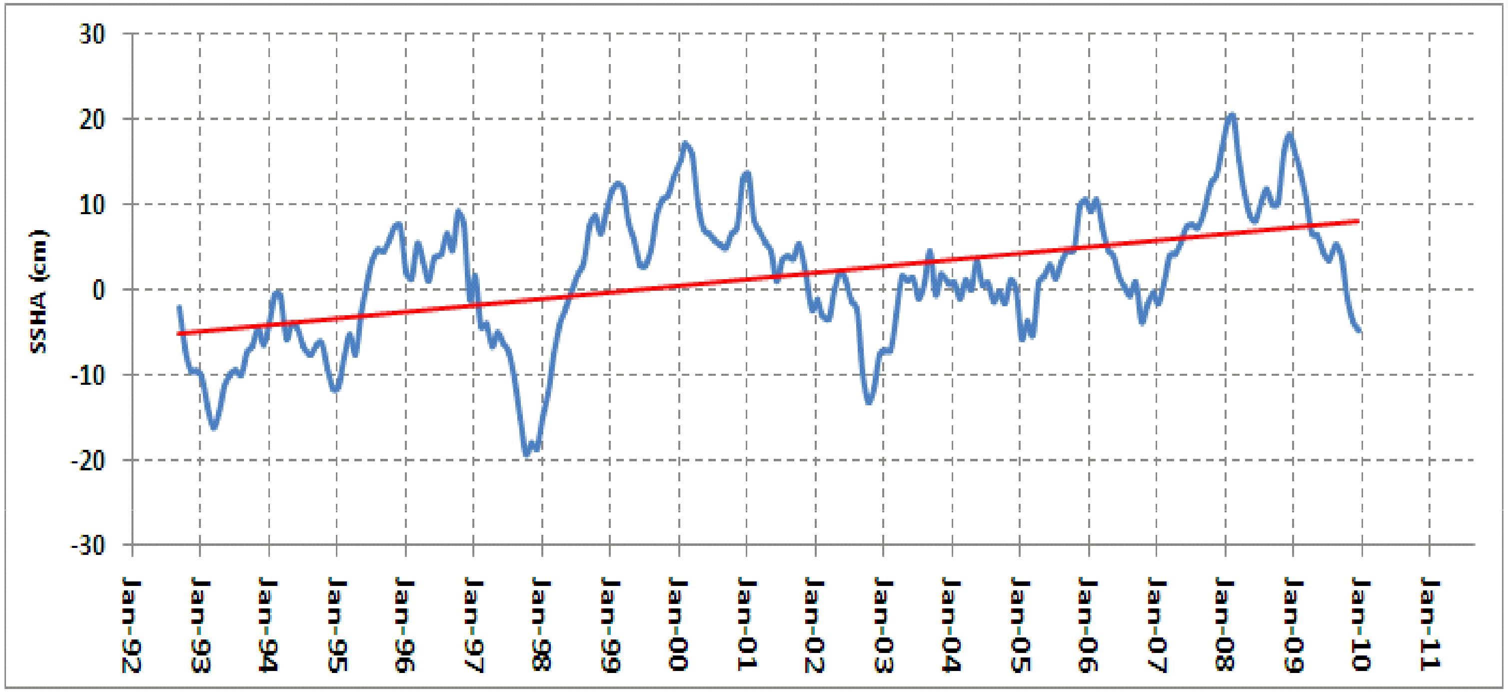






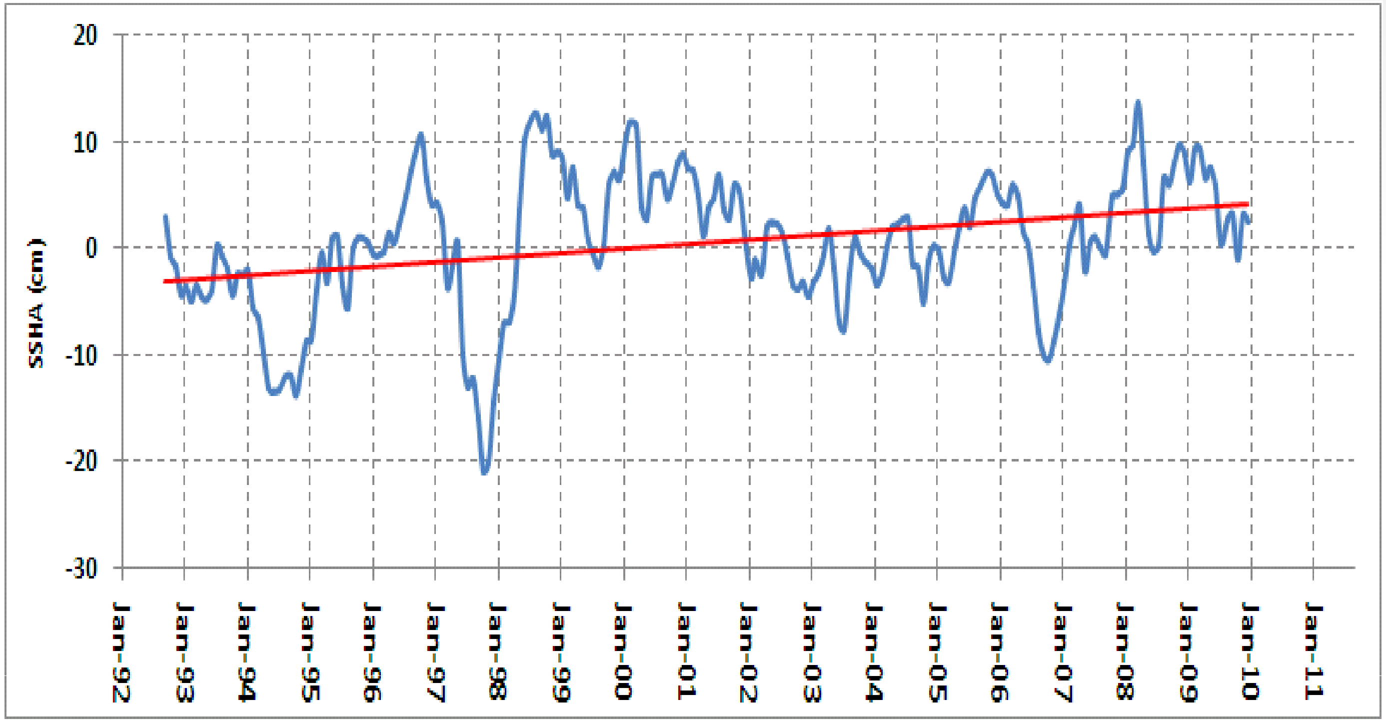


October 1992 – January 2010 in North Papua Region



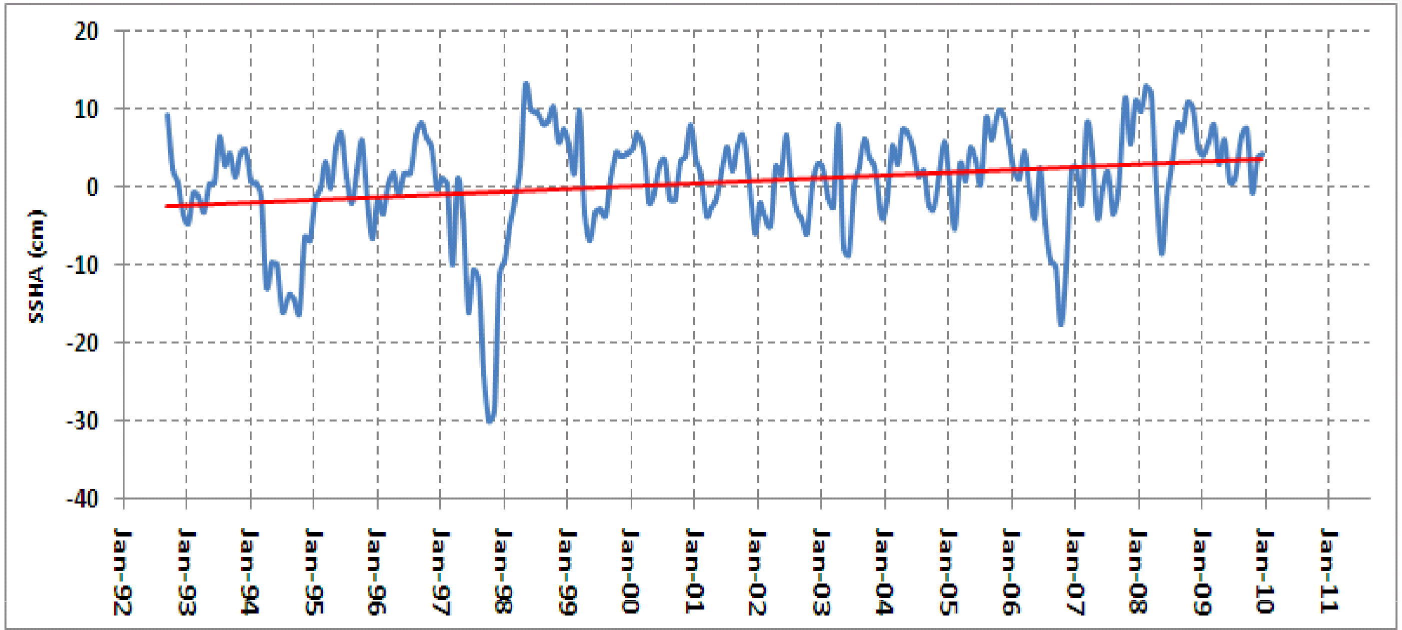
Variation and trend of SSHA in North of Papua Water (Okt 1992 – Jan 2010)

Time series data of SSHA , trend of increasing is 12.6 cm over 208 months, equivalent to 0.73 cm per year.



Variation and trend of SSHA in the Southern Java water (Okt 1992 – Jan 2010)

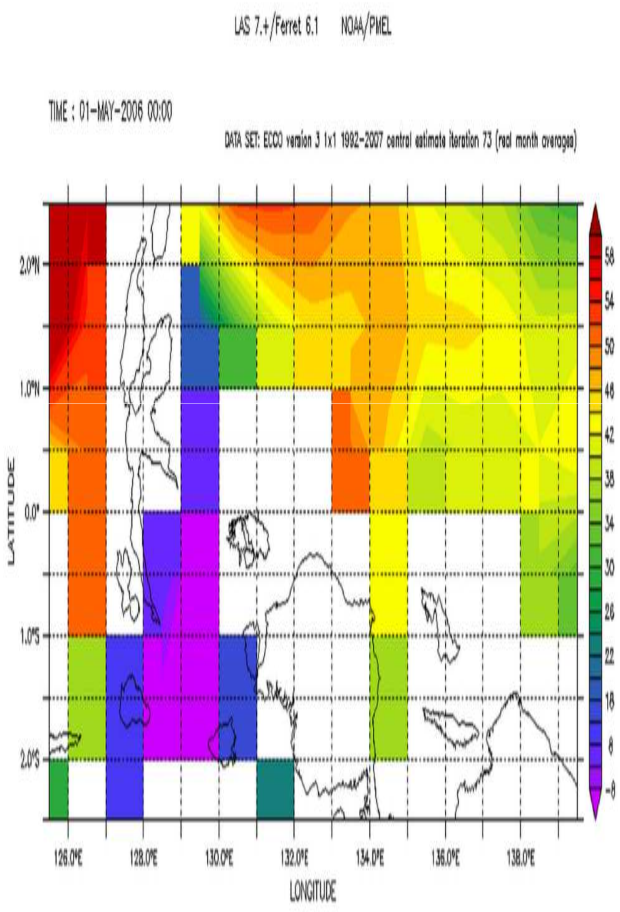
6.5 cm over 208 months or 0.375 cm per year.



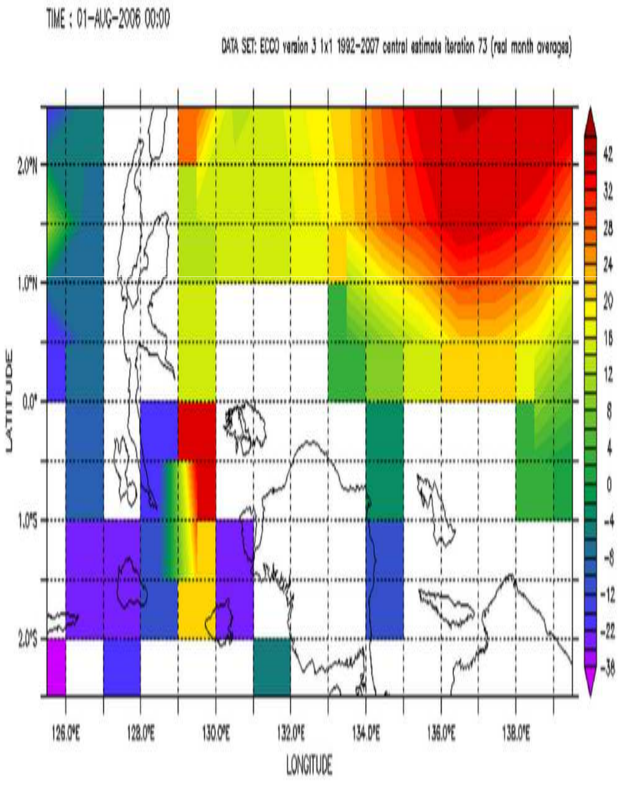
Trend and variation of SSHA at western part of Sumatra (Oct 1992-Jan 2010).

The increasing trend of SSHA in west of Sumatra is 6.5cm over 208 months, or 0.375 cm per year (October 1992 – January 2010)..

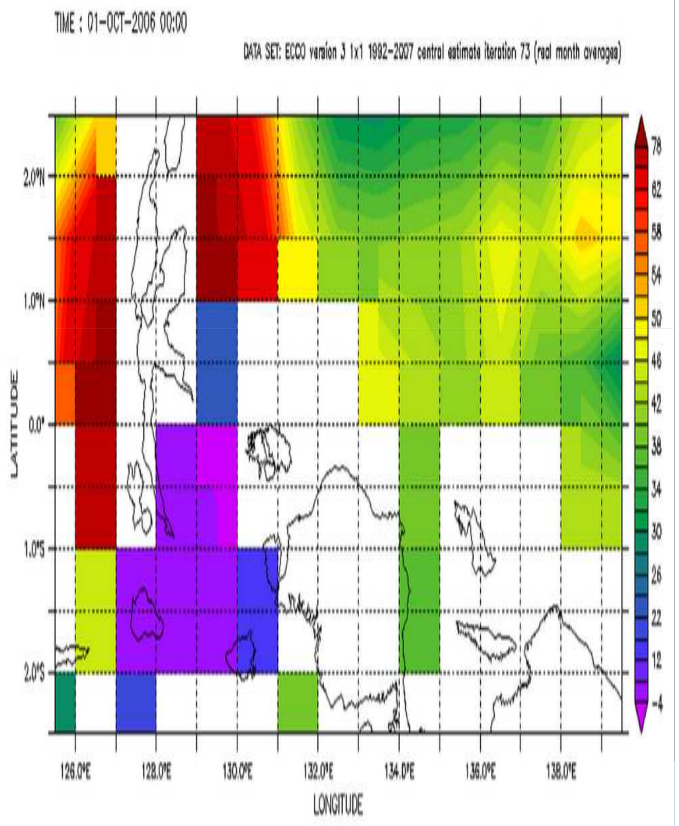
Surface Heat Flux on 2006 (ECCO)



net surface heat flux, >0 increases theta (W/m^2)

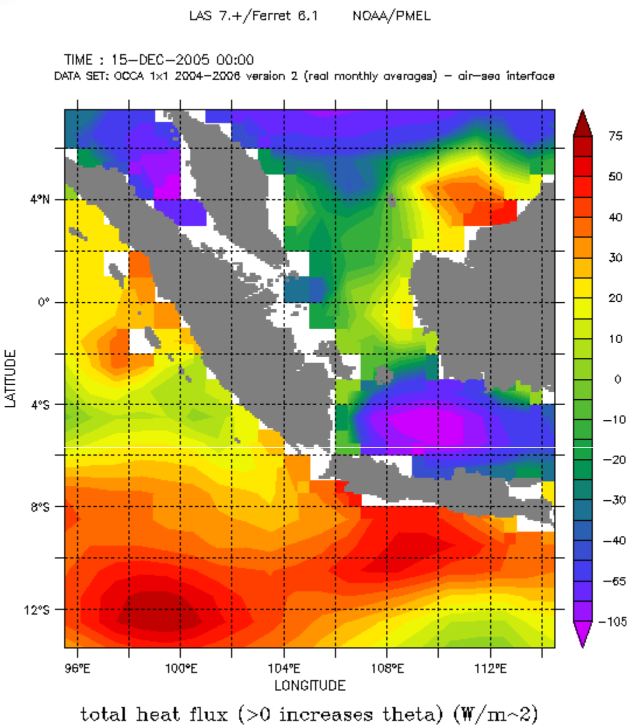


net surface heat flux, >0 increases theta (W/m^2)

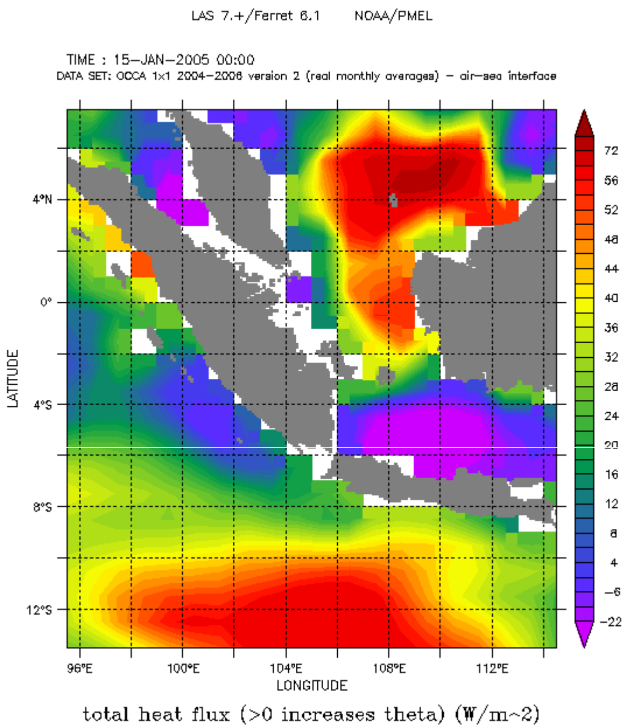


net surface heat flux, >0 increases theta (W/m^2)

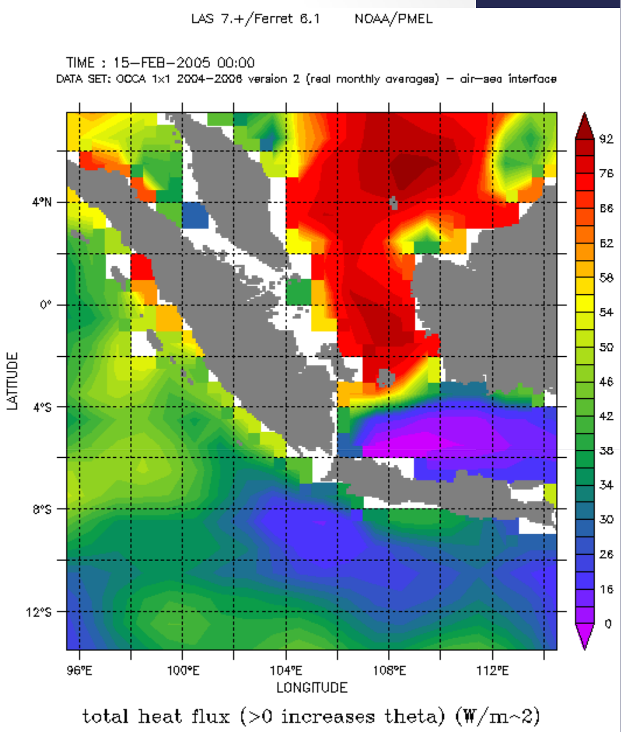
Total Heat Flux Bulan Desember (A), Januari (B), Februari (C)



A



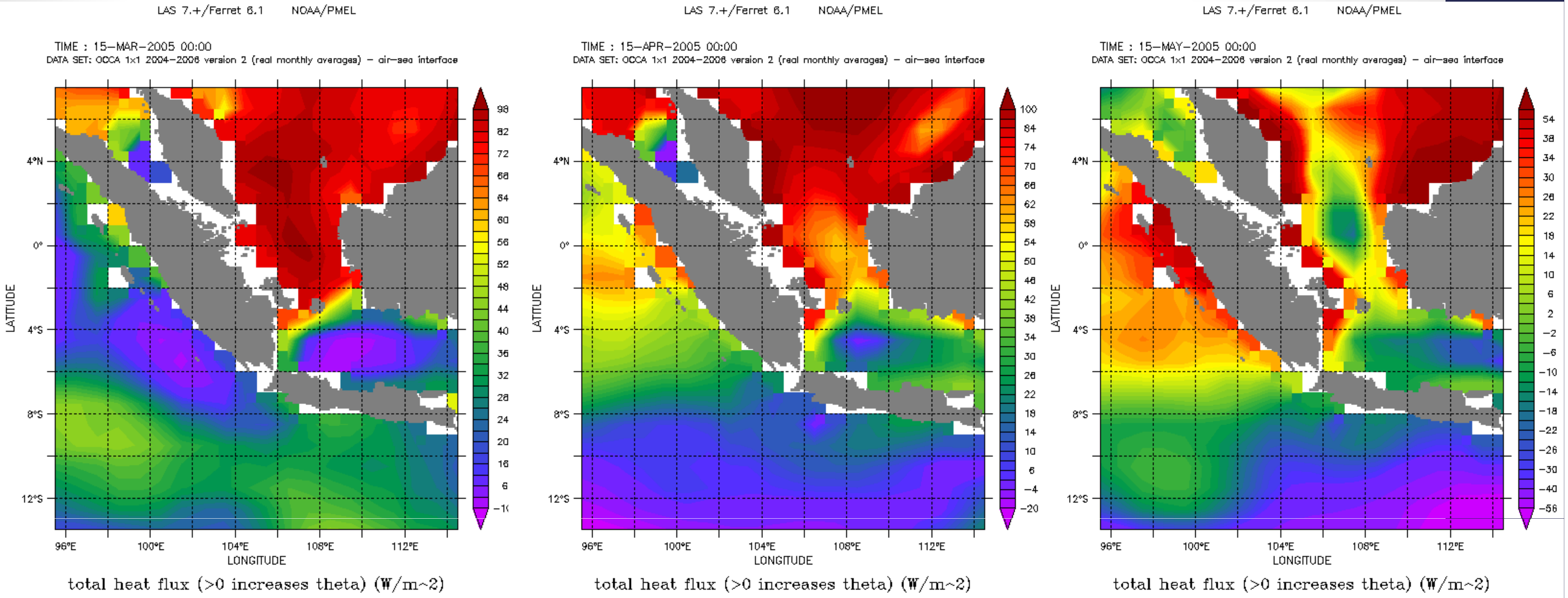
B



C

The image above shows the total heat flux that occurred in December (A) January (B) and February (C) called West Season. In December (A), the sun is in the southern hemisphere (23.5^0 S) that heating the Indian Ocean as indicated by the red area in Figure A. South China Sea, Java Sea, and the Strait Karimata average flux has a negative value due to lack of sunlight. This makes the sea water releases heat into the air. In January (Figure B) and February (Figure C), the position of the sun begin to move to the equator. This causes the heat flux in all waters started toward the positive. Intense heating makes water absorb heat and store.

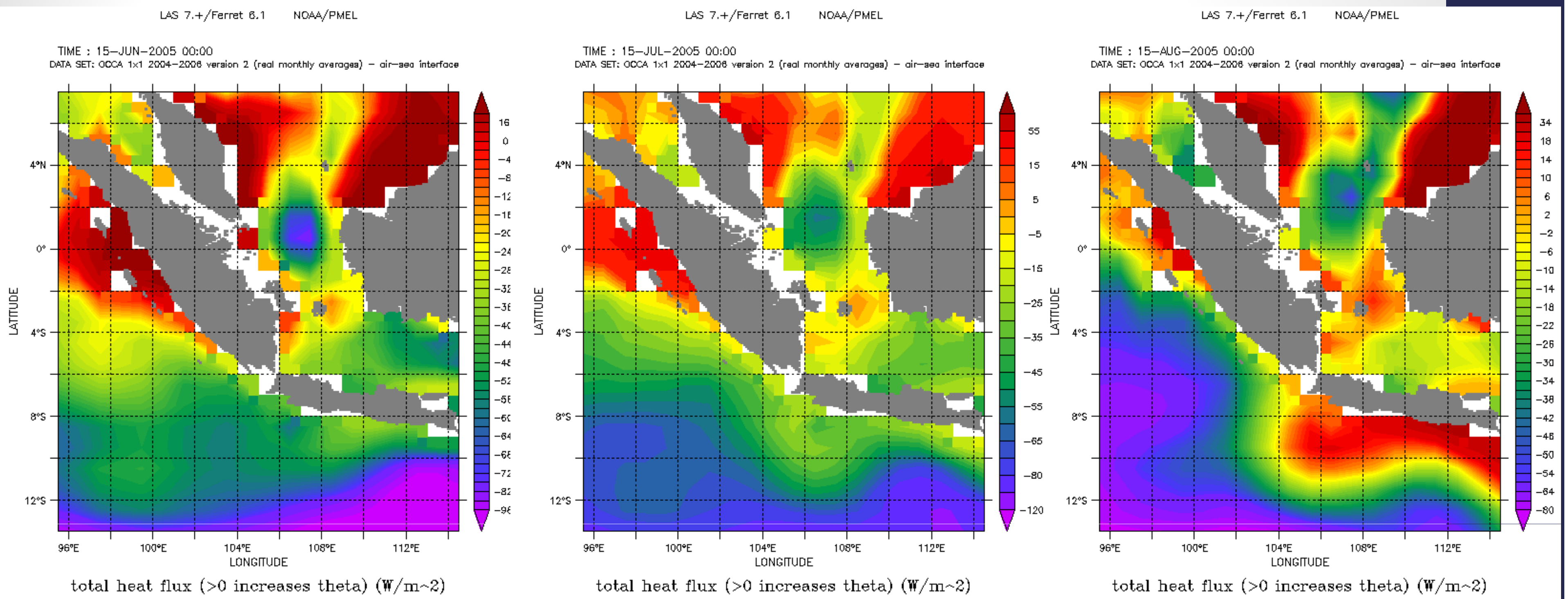
Total Heat Flux Bulan Maret (A), April (B), Mei (C)



A B C

The image above shows the total heat flux that occurs in March (A), April (B) and May (C) that called Peralihan 1 Season. In March (A), the position of the sun is at the Equator, so Karimata Strait, the South China Sea will experience intense heating. This causes the heat flux value to be positive in the northern waters. The value of Total Heat Flux in Indian Ocean is begin negative. It caused by the position of the sun is far enough so that the waters will begin to release heat to the air. In April (B) and May (C), the sun is moving further to the north. It cause the value of total heat in Indian Ocean increasingly negative. Value of total flux in the South China Sea waters, Karimata Strait, and Java Sea also showed a tendency toward negative values like the Indian

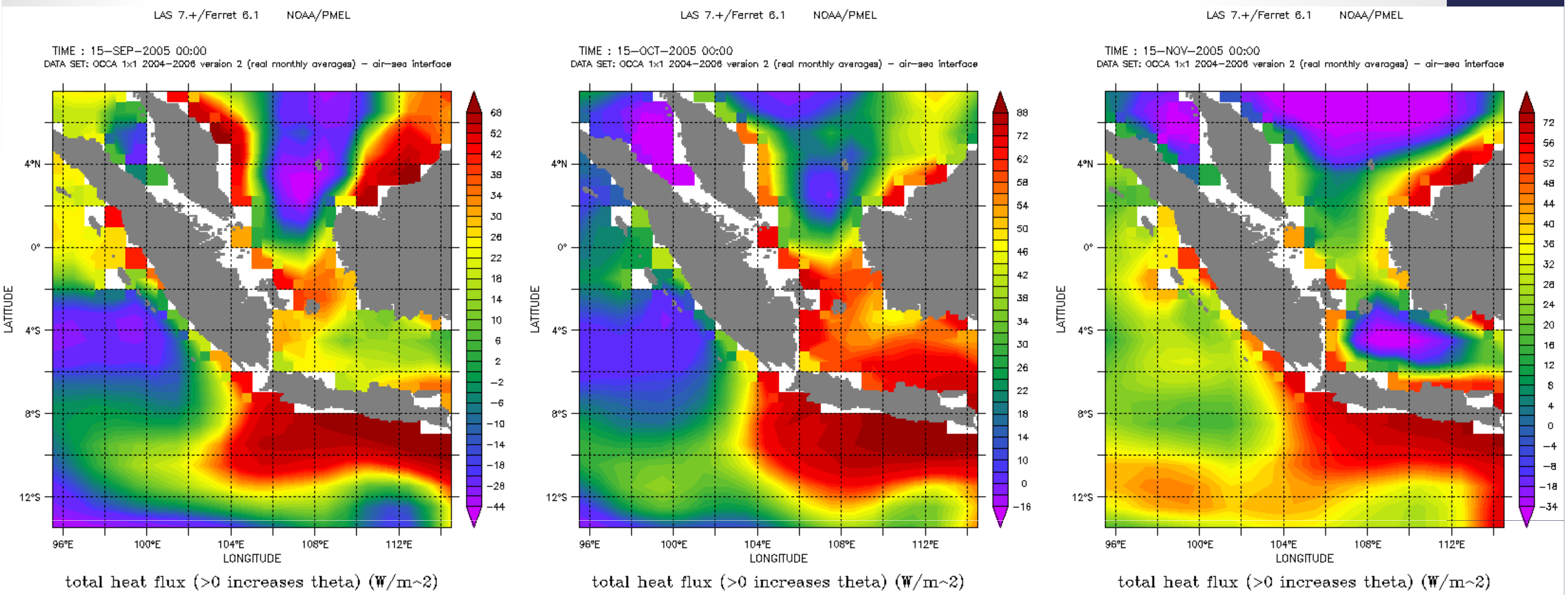
Total Heat Flux Bulan Juni (A), Juli (B), Agustus (C)



A B C

The image above shows the total heat flux occurs in June (A), July (B) and August (C) that called East season. In June (A), the position of the sun is at 23.5^0 N. This causes South China Sea, Karimata Strait, Java Sea and the Indian Ocean lose much heat because of the position of the sun. Almost all waters showed the total value of negative flux. In July (B) and August (C), the Sun begins to move back toward the equator. This causes the equatorial waters begin to warm up so that the total flux in the waters started toward the positive.

Total Heat Flux Bulan September (A), Oktober (B), November (C)



A B C

The image above shows the total heat flux occurs in September (A), October (B) and November (C) called Peralihan 2 Season. In September (A), the position of the sun is at Equator. This causes the waters of the South China Sea, Karimata Strait, Java Sea and the Indian Ocean back to get the hot sunshine as indicated by the positive flux values. In October (B) and November (C), the Sun begins to move towards the south. This causes the waters of the Indian Ocean is experiencing intense warming so that the total flux in the waters to be positive. The reverse occurs in the waters of the North where the total flux toward negative values due to reduced heating by the sun.

CONCLUSION REMARKS

- Trend of increasing SSHA in
- North Papua water is 12.6 cm over 208 months, equivalent to 0.73 cm per year.
- South Java water is 6.5 cm over 208 monthsor 0.375 cm per year.
- west of Sumatra water is 6.5cm over 208 months, or 0.375 cm per year.
- The Ocean Heat Content in outer Indonesia waters varies spatial by month, seasonal and year as well as the total surface heat flux.
- The Ocean Heat Content is around 500-2500 MJoule/m2 for the case of north Papua water.

Acknowledgment

- We would like to thank to Asahi Glass Foundation for supporting this research.

Thank you for your attention