EMPIRICAL ORTHOGONAL FUNCTIONS (EOF) ANALYSIS OF SST VARIABILITY IN INDONESIAN WATER CONCERNING WITH ENSO AND IOD

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ABSTRACT:

The observation of El Nino Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) impact on Sea Surface Temperature (SST) reveals some influence on Indonesian water . The data used is SST of NOAA-Pathfinder satellite dataset. Data of ENSO represent by Multivariat ENSO Index, while data of IOD represent by IOD Index. Influence of ENSO and IOD on SST variability in Indonesia is calculating by using empirical orthogonal functions (EOF) analysis. The result show SST in Indonesian water such as Arafura sea, Banda sea, Maluku sea, Java sea, Natuna sea and Makasar strait is mostly correlated to ENSO and IOD phenomenon.

1. INTRODUCTION

El Nino is an oscillation of the ocean-atmosphere system in the tropical Pacific, having important influence to the global weather. Normally, the sea surface height in Indonesia is about 0.5 meter higher rather than in Ecuador. While, the sea surface temperature is averagely 8° C higher in the west, with cool temperatures off South America, due to an upwelling of cold water from deeper levels, (NOAA-a,2009).

NOAA CIRES Climate Diagnostics Center, Boulder CO, developed a Multivariate ENSO Index (MEI) based on six observed variables over the tropical Pacific: sea-level pressure, zonal wind, meridional wind, sea surface temperature, surface air temperature and total cloudiness, (Wolter, 2009).

During the period of El Niño or La Niña, the changes of Pacific Ocean temperatures, influence the patterns of tropical rainfall from Indonesia to the west coast of South America, a distance covering approximately one-half way around the world. These changes in tropical rainfall correlate to weather patterns throughout the world, (NOAA-b, 2009).

During El Nino observation, SST is a main indicator, measured by time series satellite dataset. El Nino, a unique surface phenomenon of Pacific Ocean, give direct influence on Indonesian water characteristic, including SST, (Sukresno, 2008)

The Indian Ocean Dipole (IOD) is a coupled ocean-atmosphere phenomenon in the Indian Ocean. It is normally characterized by anomalous cooling of SST in the south eastern equatorial Indian Ocean and anomalous warming of SST in the western equatorial Indian Ocean. Associated with these changes the normal convection situated over the eastern Indian Ocean warm pool shifts to the west and brings heavy rainfall over the east Africa and severe droughts / forest fires over the Indonesian region. (JAMSTEC, 2009)

The Indian Ocean Dipole (IOD) has profound socioeconomic impacts on not only the countries surrounding the Indian Ocean but also various parts of the world. A forecast system is developed based on a relatively high-resolution coupled ocean–atmosphere GCM with only sea surface temperature (SST) information assimilated. (Luo, *et. Al*, 2007)

Behera (2008), observed the positive Indian Ocean Dipole (IOD) of 2007, which is evolved together with a La Niña in the Pacific and consecutive to a positive IOD event of 2006. It was an extremely rare blend of climate anomalies in those two basins. The evolution of a negative IOD, which normally follows a positive IOD, was reversed during boreal summer of 2007. This was associated with a pattern of sea surface temperature (SST) anomalies in which the colder seas of the Maritime Continent were flanked by the warmer central Pacific and Indian Oceans. The associated subsidence over the Maritime Continent caused divergent easterly wind anomalies in the eastern equatorial Indian Ocean to trigger a successive positive IOD event through ocean dynamics.

During the southeast monsoon (April to October), southeasterly wind from Australia generates upwelling, bringing cooler waters and increased nutrients to the surface along the southern coasts of Java and Sumatra. Conditions are reversed during the northwest

This observation is aimed to measure the influence of ENSO and IOD on variability of SST in Indonesian water by using EOF analysis.

2. METHOD

This study is performed in Indonesian water by using satellite dataset as follows :

- SST derived from NOAA-Pathfinder satellite dataset
- ENSO represented by Multivariat ENSO Index
- IOD represented by IOD Index
- Influence of ENSO and IOD calculated by applying EOF analysis

The SST data is calculated from NOAA pathfinder satellite data, by applying *Miami Pathfinder SST* algorithm as follow :

$$SST = c_1 + c_2 * T_{31} + c_3 * T_{3132} + c_4 * (\sec(\theta) - 1) * T_{3132} \quad (1)$$

where T_{31} = *brightness temperature (BT)* band 31

T_{3132} = *BT difference* (band 32 – band 31)

θ = *satellite zenith angle*

COEFISIENT		
	T30 - T31 <= 0.7	T30 - T31 > 0.7
C_1	1.228552	1.692521
C_2	0.9576555	0.9558419
C_3	0.1182196	0.0873754
C_4	1.774631	1.199584

The MEI is based on surface marine data (COADS), filtered through spatial cluster analysis and based on six different observational fields: sea level pressure (P), zonal and meridional wind component (U, V), sea surface temperatures (S), near-surface air temperatures (A), and total cloudiness (C). The MEI is the first Principal Component (EOF) of all six observational variables analyzed jointly for the tropical Pacific basin (normalized variance for each field).

The Dipole Mode Index (DMI) is defined as the SST anomaly difference between the eastern and the western tropical Indian Ocean between western equatorial Indian Ocean (50°E-70°E and 10°S-10°N) and the south eastern equatorial Indian Ocean (90°E-110°E and 10°S-0°N).

EOF analysis can be define as follow , Once the anomaly data matrix is determined, the covariance matrix is then defined by :

$$\Sigma = \frac{1}{n-1} X'^T X', \qquad (2)$$

which contains the covariance between any pair of grid points. The aim of EOF is to find the linear combination of all the variables, i.e. grid points, that explains maximum variance. That is to find a direction **a** = (a1, . . . , ap)^T such that **X'a** has maximum variability. Now the variance of the (centered) time series **X'a** is

$$\text{var}\ (X'\mathrm{a}) = \frac{1}{n-1}\|X'\mathrm{a}\|^2 = \frac{1}{n-1}(X'\mathrm{a})^T (X'\mathrm{a}) = \mathrm{a}^T \Sigma \mathrm{a} \qquad (3)$$

To make the problem bounded we normally require the vector a to be unitary. Hence the problem readily yields:

$$\max_{\mathbf{a}} (\mathbf{a}^T \Sigma \mathbf{a}), \quad \text{s.t. } \mathbf{a}^T \mathbf{a} = 1 \qquad (4)$$

The solution is a simple eigenvalue problem (EVP) :

$$\Sigma \mathbf{a} = \lambda \mathbf{a}. \qquad (5)$$

By definition the covariance matrix ∑ is symmetrical and therefore diagonalisable. The **k**'th EOF is simply the **k**'th eigenvector **a**$_k$ of ∑ after the eigenvalues, and the corresponding eigenvectors, have been sorted in decreasing order. The covariance matrix is also semidefinite, hence all its eigenvalues are positive. The eigenvalue λ_k corresponding to the **k**'th EOF gives a measure of the explained variance by **a**$_k$, k = 1, . . . p. It is usual to write the explained variance in percentage as :

$$\frac{100\lambda_k}{\sum_{k=1}^{p} \lambda_k}\% \qquad (6)$$

The projection of the anomaly field X ' onto the **k**'th EOF a$_k$, i.e. c$_k$ = X'**a**$_k$ is the **k**'th principal component (PC)

$$\frac{100\lambda_k}{\sum_{k=1}^{p}\lambda_k}\% \qquad (7)$$

3. RESULT AND DISCUSSION

Variability of SST in Indonesian water can be seen in NOAA Pathfinder satellite data in figure 1 . Northwest monsoon SST is represented by satellite dataset in February, while southeast monsoon SST is represented by satellite dataset in August .

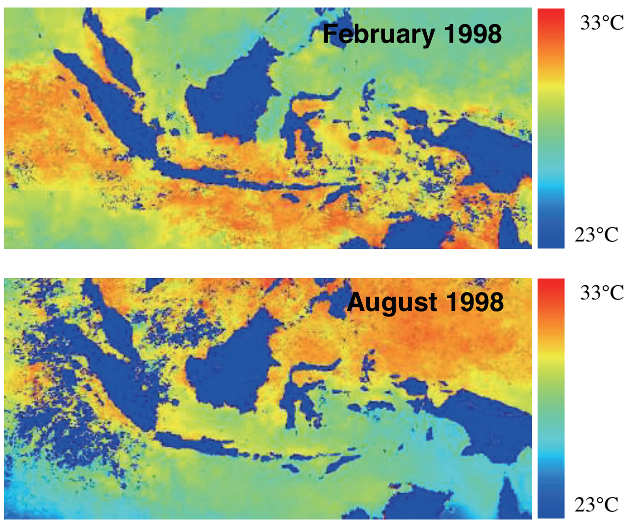


Figure 1. Monthly Average SST in Indonesia

Usually SST in Indonesia during Northwest monsoon is tend to warmer than SST during southeast monsoon as shown in figure 1.

EOF distribution of SST in Indonesia is displayed in figure 2.

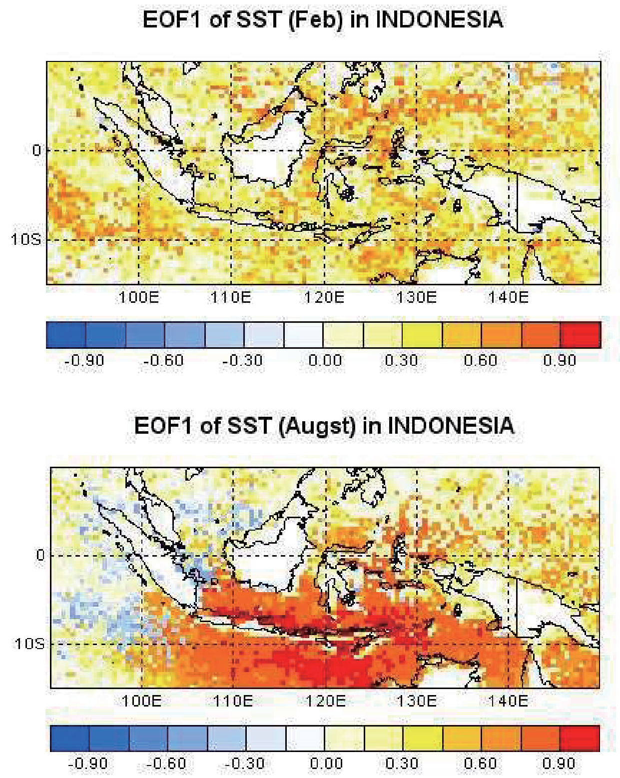
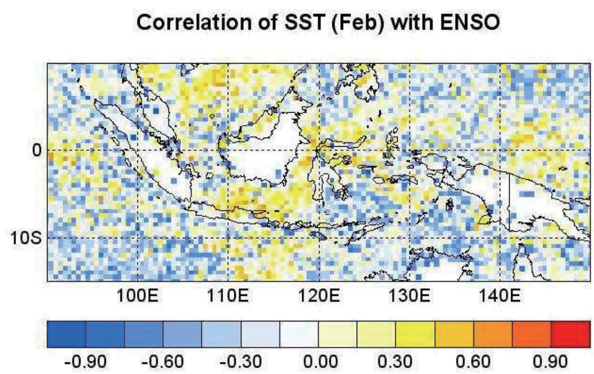


Figure 2. EOF distribution of SST in Indonesia

Figure 2 revealed that high variability of SST in Indonesia is occured in August especially in central and south of Indonesian region.

Influence of ENSO on SST variability in Indonesia can be expalined in figure 3.



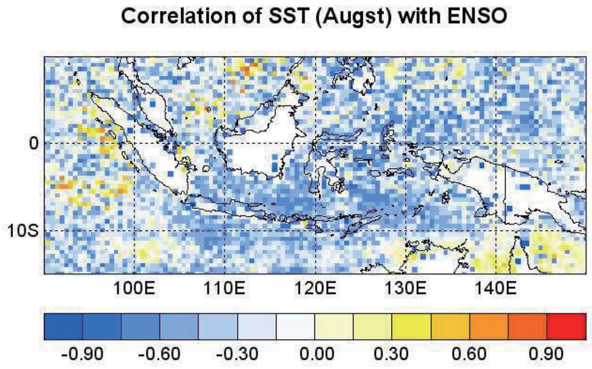


Figure 3. Correlation of ENSO with SST

Correlation of ENSO with SST displayed in figure 3. along with the EOF distribution, influence of ENSO clearly revealed in August. Influence of ENSO on SST variability in Indonesia is relatively high, such as in the central and south of Indonesian region .

In Februari correlation of ENSO with SST in some of indonesian water is high such as Java sea, Maluku sea and Sulawesi sea. On the other hand Banda sea and Arafura sea has high correlation of ENSO with SST in opposite condition. During ENSO period, SST in Banda sea and Arafura sea is decrease.

Correllation of SST and ENSO is more clearly shown in august, where almost whole region of Indonesian water have high index. During ENSO period, SST in Indonesia is decrease.

Correlation coeffitien of SST and ENSO reach maximum index in the time lag 6 months after El nino peaks. This condition is along with Cai (2005) that reveal about influence of ENSO to SST variability using coupled climate model. In the model, the ENSO discharge Rossby waves arrive at the Sumatra–Java coast some 6 to 9 months after an El Niño peaks.

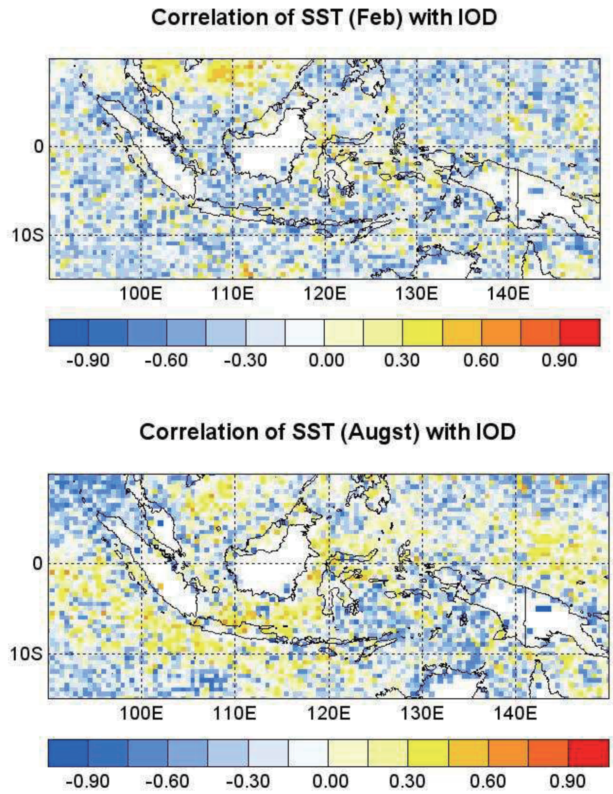


Figure 4. Correlation of IOD with SST

IOD influences variability of SST in most of Indonesian region. in February, the index of correlation seem high, blue color indicates almost all Indonesian waters has decreased. In August there are several areas that have a positive correlation as represented by yellow color such as Makasar strait, Java sea and Indian Ocean.

Cai (2005) fond that In the positive dipole phase, cold SST anomaly produces local upwelling, the easterlies raise the thermocline to the east via upwelling Kelvin waves and deepen the off-equatorial thermocline to the west via off-equatorial downwelling Rossby waves.

4. CONCLUSIONS

- ENSO influences variability of SST in most of Indonesian region with highest corellation occurs in Maluku sea.
- Variability of SST in most of Indonesian region also influenced by IOD with highest corellation occurs in Java sea.

5. REFERENCES

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