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PREDICTION NINO3.5 SST ANOMALY

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Abstract

The impact of global climate disturbance like El Nino-La Nina on human life and its environment tends to increase from year to year in the last 2 decades and may be one of the most serious problems of the next millenium. To mitigate the impact we should make an improvement on the numerical model prediction ability which have only 3 months accurateness. Using Fourier theorem, we elucidated NINO3.5 SST anomaly time series by applied Fast Fourier Transformation (FFT) and obtain 6 main periods. By trial and error, we generated harmonic model to predict NINO3.5 SST anomaly but the result is not sufficient because the periodicity of model. By applied Phase Dispersion Minimization (PDM) method, we found another period i.e. 68.50 months/cycle and put it as 4th harmonic. By added this period in the harmonic model, the periodicity is disappear.

To increase the prediction accurateness we have applied the artificial neural network and trained the model. After running for 30 epoch we could improved the correlation between model and data from 0.506 to 0.812.

Analysis on the harmonics showed that for El Nino event since 1950 are dominated by 3 first harmonics meanwhile for the La Nina event by the last 4 harmonics. Comparison the El Nino 82/83 to El Nino 97/98, showed that the El Nino 82/83 dominated very strong by the 1st, 2nd and 6th harmonics and moderate by 3rd and 5th harmonics, meanwhile El Nino 97/98 dominated very strong by 3rd, 4th, 5th, and 6th harmonics and strong by 1st and 4th harmonics. These condition may could explain why El Nino 82/83 slightly stronger then El Nino 97/98

From all of harmonics, we known only about 2 of them, i.e. 4th and 6th as half of sunspot and QBO period and we supposed that way to understood El Nino/La Nina is to understand these 7 harmonics.

1. INTRODUCTION

Many studies showed that El Nino-La Nina are significantly related to Indonesia rainfall (Bayong et al., 1996; Quinn et al., 1978) particularly in eastern part of Indonesia like southeast Kalimantan, Sulawesi and center part of Irian Jaya (Dupe, 1999). Based on drought experiences in the last 40 years, not all of drought occurrences are associated with El Nino event, but for region with rainfall type A (Borema, 1928) the influences of El Nino are significant. It was found that sea surface temperature (SST) anomaly at Nino 3(5^0 N – 5^0 S, 90^0-150^0 W) and Nino 3.4 (5^0 N – 5^0 S, 120^0-170^0 W) was significant correlated to Indonesia regional rainfall (Quinn et al., 1978). In the La Nina case the oscillation and the existence of warm pool center ($T \geq 30\ ^0C$) shown good correlation to rainfall in western and eastern part of Indonesia. When the center lay north of equator, wetter than normal condition develop in western part of Indonesia. If the center move to the south over the equator, the ITCZ over eastern part of Indonesia became very intensive and wetter than normal condition reign over this area and in the meanwhile dryer then normal condition develop in western part of Indonesia, particularly Sumatra and western part of Java. When the center disappear, then the monsoon reign over Indonesia season (Dupe, 1999).

In the last 2 decades, the ENSO impacts on socio-economics life trend to increase and it showed by Indonesia's losses at El Nino 82/83 and El Nino 97/98. Although El Nino 82/83 is slightly stronger then 97/98 event (Walter et al., 1998) but the latest impacts over Indonesia is more then twice from the first one (Dupe et al., 1999). The study of ENSO influence on Bandung Area (West Java – Indonesia) rainfall and its correlation to the NINO3.5 SST anomaly showed that the ENSO started to show its influence on Bandung rainfall if the anomaly is greater than $|0.75\ ^{0}C|$ (Dupe, 1999). To mitigate the impact of next ENSO, the government and people should be warned 1 to 2 years ahead so they could have enough time to prepare themselves so that the offers could be hold down to a minimum level.

2. NINO3.5 SST ANOMALY PREDICTION

Fourier theorem says that the function on real line R = (-∞, ∞) as (continuous) superposition of the basic oscillatory function $e^{i\xi x}$ ($\xi \in R$) (Folland, 1992: Wirjosoedirdjo, 1994). Starting from that idea, we have supposed that the now days ENSO prediction model could be improving using simple harmonic model when the basic function of ENSO could be found. In the way to find the ENSO basic function we have made 3 stages of work i.e.:

- Analysis of ENSO behavior
- Analysis of ENSO basic period
- Reconstruction and refine the model

a) Analysis of ENSO behavior

In this stage, we try to understood the behavior of ENSO and using it as a concept of model and for test the model. An analysis of ENSO behavior using NINO3.5 SST anomaly and SOI time series we found 3 principal point, that is:

1. The entire sequence of the event lasts about 10 to 12 months.
2. The events are separated by 24 to 84 months, in irregular pattern and
3. There are no similarities in each ENSO event.

b) Analysis of ENSO basic periods

Utilizing FFT and filtered with 2nd behavior of ENSO, 6 simple harmonics of NINO3.5 SST anomaly are elucidated (see Table 1). After try for more then 500 simple model using all these harmonics, we found there are permanent error on the model, i.e. periodicity. That mean the model showed same signal after runing for 600 months. In this sense that model could not pass our test using the 3rd ENSO behavior. So we try to reanalyze the time series using PDM (Wijaya, 1996) and found the 4th harmonic, that is 68.50 months/cycle (Table 1).

Table 1. Simple Harmonic Period of NINO3.5 SST anomaly (Dupe, 1999)

No	Period (months/cycle)	Power of Spectrum	Legend
1	58.60	2.0065	FFT
2	41.86	1.5366	FFT
3	29.30	0.8933	FFT
4	68.50	0.8500	PDM (Half of Sunspot period)
5	34.47	0.8297	FFT (quarter of Sunspot period)
6	25.48	0.6640	FFT (QBO)
7	83.71	0.3008	FFT

c) Reconstruction and refined the model

As we have mention before, by trial and error adjustment we have got:

$$f(t) = f_1(t) + f_2(t) + f_3(t) + f_4(t) + f_5(t) + f_6(t) + f_7(t)$$

where

$f_1(t) = 0.5 * 2.0065 \sin((2\pi / T_1)t + 0.975\pi)$
$f_2(t) = 0.5 * 1.5366 \sin((2\pi / T_2)t + 1.550\pi)$
$f_3(t) = 0.5 * 0.8933 \sin((2\pi / T_3)t + 1.250\pi)$
$f_4(t) = 0.5 * 0.8500 \sin((2\pi / T_4)t + 1.575\pi)$
$f_5(t) = 0.8 * 0.8297 \sin((2\pi / T_5)t + 1.250\pi)$
$f_6(t) = 0.8 * 0.6640 \sin((2\pi / T_6)t + 1.450\pi)$
$f_7(t) = 0.8 * 0.3008 \sin((2\pi / T_7)t + 1.350\pi)$
(Dupe, 1999)

The model was assessed in the way that we made ENSO prediction for 256 months (January 1977 to December 1997) and compared it with actual NINO3.5 SST anomaly. Figure 1 showed the comparison between them and the correlation coefficient is 0.506. The model in its present form has been run since December 1997 until January 2004 so the validation of the forecasts is appropriate since that date (see figure 2).

To improve the forecasting, we have applied artificial neural system (Demuth et al., 1994) to the model, in the way, we have used simple harmonic model output as an input for the artificial neural network and trained it with actual NINO3.5 SST anomaly. After trained for 30 epoch with 266 neuron it shown significant improvement as indicated by figure 3. The correlation of model to data stepped up from 0.506 to 0.812.

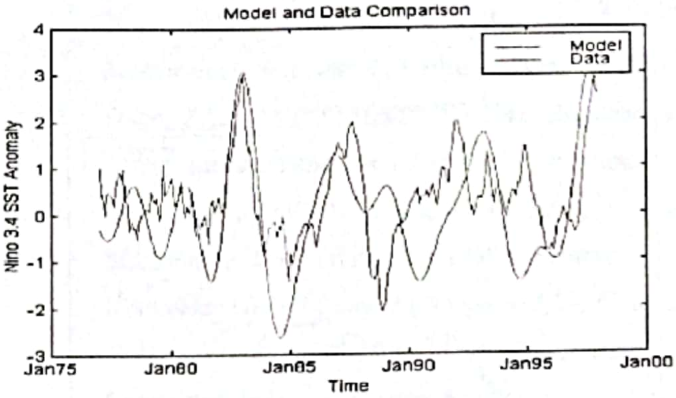

Figure 1. Comparison between model and data actual

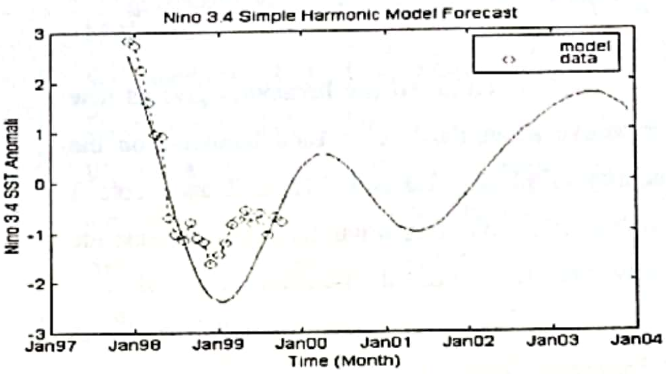

Figure 2. NINO3.5 Forecasting using a simple harmonic model

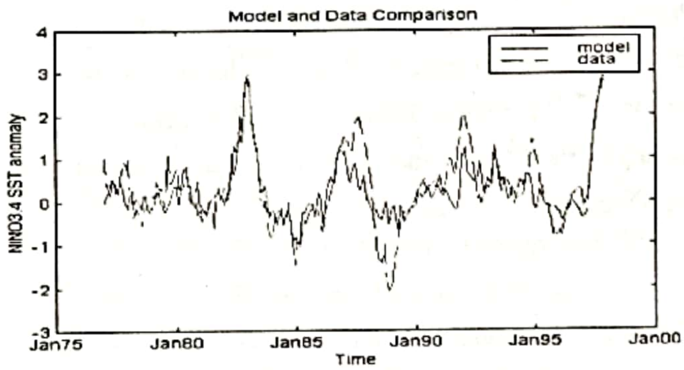

Figure 3. Comparison between model and data after using artificial neural network

3. ENSO FORECASTING AND DISCUSSION

3.1. ENSO Forecasting

The display in figure 4 is 6 years forecasting using the combination model (harmonic and artificial neural network), starting from January 1998 to December 2004. The forecast shows that the present weak cold conditions are expected to continue until the end of the year 1999, follow by weak El Nino until the end year 2000. Starting from early 2001 until the beginning of year 2002, the SST anomaly oscillated on normal line. Beginning at middle of year 2002, the anomaly starting to has positive value and expected to develop to be moderate El Nino.

3.2. Discussion

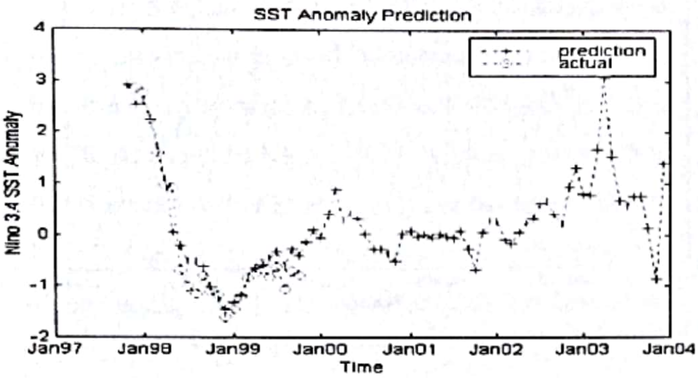

Figure 4. NINO3.5 SST anomaly forecasting

Analysis on all simple harmonics give us new perspective about the role of each harmonic on the intensity of El Nino/La Nina. Table 2 and Table 3 shows contribution of each harmonic to determine the intensity of strongest El Nino/La Nina since 1950.

El Nino 57/58 influenced strong by the 1^{st} and 4^{th} harmonics, moderate by 2^{nd}, 5^{th}, and 6^{th} harmonics. El Nino 65/66 dominated very strong by 6^{th} harmonic, strong by 2^{nd} harmonic, and moderate by 3^{rd} and 5^{th} harmonics. El Nino 72/73 dominated strong by 1^{st} and 2^{nd} harmonics, moderate by 3^{rd} and 6^{th} harmonics and weak by 5^{th} harmonic. El Nino 82/83 dominated very strong by the 1^{st}, 2^{nd} and 6^{th} harmonics and moderate by 3^{rd} and 5^{th} harmonics. El

Table 2. Contribution of each Single Harmonic on El Nino classification

Harmonic \ El Nino	57/58	65/66	72/73	82/83	86/87	91/92	97/98
1	***		***	****	**	*	***
2	**	***	***	****	**		*
3		**	**	**	*		****
4	***				**	**	***
5	**	**	*	**		****	****
6	**	****	**	****	****		****
7				*			

Note: **** = very strong *** = strong ** = mode-rate
* = weak

Table 3. Contribution of each Single Harmonic on La Nina classification

Harmonic \ La Nina	54/55	64/65	70/71	73/74	75/76	88/89	98/99
1	**	*	***		**		**
2		*	***	**		***	**
3	***	***				**	****
4	****					*	*
5	*	****	*	*	*		****
6		****	***	*	*	*	****
7	*	**	****				****

Note: **** = very strong *** = strong ** = mode-rate
* = weak

Nino 86/87 influenced very strong by 6^{th} harmonic, moderated by 1^{st}, 2^{nd}, and 4^{th} harmonics, and weak by 3^{rd} harmonic. El Nino 91/92 dominated very strong by 5^{th} harmonic, moderated by 4^{th} harmonic and weak by 1^{st} harmonic. El Nino 97/98 dominated very strong by 3^{rd}, 4^{th}, 5^{th}, and 6^{th} harmonics and strong by 1^{st} and 4^{th} harmonics.

La Nina 54/55 influenced very strong by 4^{th} harmonic, strong by 3^{rd} harmonic, moderated by 1^{st} harmonic, and weak by 5^{th} and 7^{th} harmonics. La Nina 64/65 dominated very strong by 5^{th} and 6^{th} harmonics, strong by 3^{rd} harmonic, moderate by 7^{th} harmonic and weak by 1^{st} and 2^{nd} harmonics. La Nina 70/71 dominated moderated by 2^{nd} harmonic and weak by 5^{th} and 6^{th} harmonics. La Nina 75/76 influenced moderate by 1^{st} harmonic and weak by 5^{th} and 6^{th} harmonics. La Nina 88/89 dominated strong by 2^{nd} harmonic, moderate by 3^{rd} harmonic and weak by 4^{th} and 6^{th} harmonics. La Nina 98/99 influenced very strong by 3^{rd}, 5^{th}, 6^{th}, and 7^{th} harmonics, moderate by 1^{st} and 2^{nd} harmonics and weak by 4^{th} harmonic.

4. CONCLUSION

Discussion showed that the 3 first harmonics dominated the El Nino event except El Nino 97/98 and the 4 last dominated the La Nina event. We supposed that these condition playing significant role in the way to determine the intensity of El Nino and La Nina. Maybe it could clearly why the intensity of La Nina less then El Nino (Dupe, 1999).

Because of El Nino influence on socio-economic life, we should spend our interests in these 3 harmonics and make a cross checking and analysis for the other main component of ENSO, like SOI, equatorial SOI, Trade wind anomaly, and SST anomaly at the other ENSO key area and its correlation to other weather and climate phenomenon.

Beside them it should make an analysis on the 4th and 6th harmonics (wavelet analysis) and checking the correlation between El Nino/La Nina and sunspot and QBO.

Comparison between this combination model with other model like low order coupled ocean-atmosphere model (Syu et al., 1999) , hybrid coupled model (Kleeman, 1999) , and numerical model (Gordon, 1999) show that this model is reasonably good. In order to create a useful technique in meteorology and climate prediction branch, it is necessary to further develop.

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