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Appearance of solar activity signals in Indian Ocean Dipole (IOD) phenomena and monsoon climate pattern over Indonesia

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Abstract. From previous studies, it is known that interaction between ocean-atmosphere causes climate variability in the tropical Indian Ocean region as well as in Indonesia. It has also been proposed that solar activity affects Earth's climate globally and regionally. In this study, we report association between Indian Ocean Dipole (IOD) phenomena and cloud cover over western Indonesia. The statistical correlation coefficient (r) is found to be 0.64, for the period April 1976 to January 1996. By using wavelet analysis, we also find that solar signal appears strongly on IOD during December-February.

Keywords : methods : data analysis – Sun : activity

1. Introduction

Indonesia is an important source of global atmospheric convection because of its location close to the equator, as well between two continents and two oceans. As a result, effects of atmospheric phenomena such as the IOD phenomena and El Nino Southern Oscillation (ENSO) in Pacific Ocean causes severe floods and drought in this region. They give rise to different effects over different regions in Indonesia. Hence three climate patterns (based on rainfall) are usually used to analyze climate variability in Indonesia; monsoon, equatorial and local pattern. In general, monsoon pattern has monthly rainfall distribution with maximum rainfall in December-February (called wet season). Most of the regions in Indonesia, particularly in western Indonesia, Java Island, some parts of Sumatra and Sulawesi Island belong to this category. On the contrary, local patterns have rainfall

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characteristic opposite to the monsoon pattern. Only small parts of Indonesia have local patterns: one of them is Ambon at Maluku in eastern Indonesia. Equator pattern characterizes climate variability over Padang city in Sumatra island and Pontianak city at Kalimantan island.

According to Saji et al. (1999), ENSO explains about 30% of the total variation of anomalous Indian ocean sea surface temperature. The IOD phenomena explains about 12%. This implies that there should be another factor which influences climate's variability in Indonesia, in addition to the above two. ENSO phenomena in Pacific makes the dry season in Indonesia longer (especially in eastern Indonesia) causing severe drought. The IOD is believed to cause severe drought in western Indonesia.

From previous studies (Djamaluddin 2003; Sinambela et al. 2005) it is known that there is a regional-global factor caused by ENSO signal with periodicity about 3-6 years, on cloud cover over Indonesia. Additionally there is also a signal with 11 years periodicity, indicating the solar cause. This solar signal does not appear on all regions with different climate patterns or seasonal time ranges. The stronger solar signal appears over regions with monsoon patterns and during dry seasons, when local or regional effects are the least.

Here we report the correlation between cloud cover over Indonesia, based on climate patterns and IOD phenomena and also indication of solar signal in IOD, to understand the factors that may contribute to the climate in Indonesia.

2. Data

The global monthly Sea Surface Temperature (SST) data from April 1978 to January 1994 is obtained from *www.hadobs.org*. We have identified the IOD phenomena by a simple index time series which describes the difference in SST anomaly between the tropical western Indian Ocean (50°E-70°E, 10°S-10°N) and tropical south eastern Indian Ocean (90°E-110°E, 10°S- equator). The total cloud amount data is obtained from Japanese GMS published by Meteorological Satellite Centre (1978-1996). We get the monthly data by averaging five day mean of this data. We classified Indonesian region based on their climate patterns, i.e. monsoon (5°-10°S, 101°-117°E), equatorial (5°N-3°S, 109°-117°E) + (5°N-3°S, 92°-108°E), and local patterns (1°-7°S, 121°-133°E). The wavelet spectral analysis was done by using a computer program namely WWZ (Weighted Wavelet Z-transform) developed by the American Association of Variable Star Observers (Foster 1996).

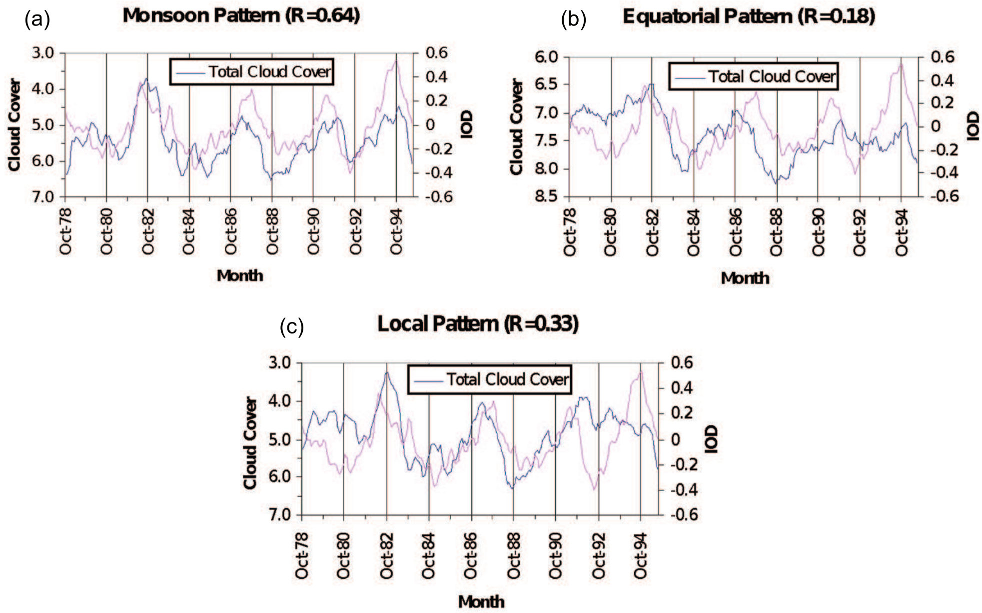

Figure 1. (**a**) Correlation between total cloud cover over Indonesia with monsoon pattern (5°-10°S, 101°-117°E) and IOD from April 1978 up to January 1996. (**b**) and (**c**) are the same plots for equatorial (5°N-3°S, 109°-117°E) + (5°N-3°S, 92°-108°E) and local pattern (1°-7°S, 121°-133°E). The correlation coefficients are 0.64, 0.18 and 0.33 respectively. Running average 13 months to eliminate seasonal factor is applied to these data.

3. Results

Here, we show the correlations between IOD and the monthly cloud cover over Indonesia for three different climate patterns. From Fig.1a we find good correlation between IOD and monthly total cloud cover over Indonesia from April 1976 until January 1996, especially for regions with monsoon pattern. The correlation coefficient (r) is about 0.64. For equatorial and local patterns, shown in Fig. 1b & 1c, the correlations are relatively weak with $r = 0.18$ and 0.33 respectively. The results imply that IOD mainly affects western Indonesia with monsoon climate patterns. When IOD moves to positive value the total cloud cover (including the convective cloud) decreases and the sky is bright. So no precipitation occurs. If IOD value is relatively high, in long term, it can cause severe drought in some regions. It should be noted that the correlation between total cloud cover for equatorial pattern is also weak when compared to Southern Oscillation Index (SOI) as ENSO indicator. It is suggested that Sun's direct radiation is intense for regions near the equator and hence the global effects of ENSO and IOD become weaker.

From previous reports, it has been shown that by using clustering method, the west

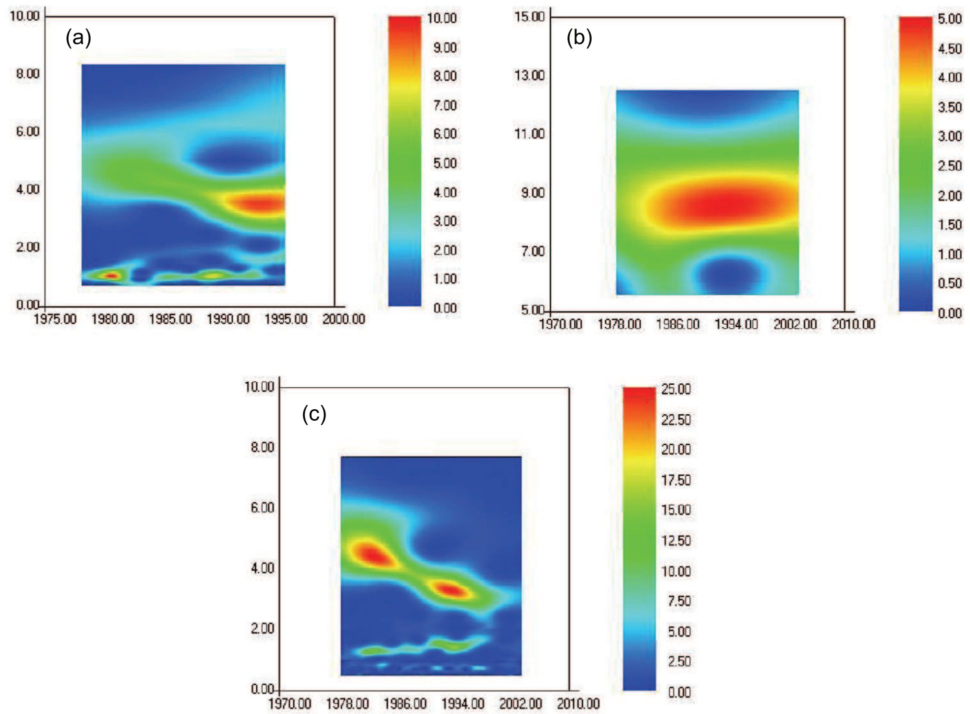

Figure 2. (**a**) Spectral analysis of IOD monthly data from April 1978 up to January 1996. Periodicity is about 6 down to 3 years and annual signal. (**b**) Showing of 11 years periodicity indicating the solar signal of selected IOD data for wet season in monsoon pattern (December-February period). Axis (x) and ordinate (y) represent year of data and periodicity in year, respectively. (**c**) Showing the 6 down to 2 years periodicity indicating the climatic signal of selected IOD data for dry season in monsoon pattern (June-August period). In this case the solar signal did not appear and is covered by other stronger signals.

Indonesian regions are mainly influenced by IOD cycle, and the east Indonesian regions by ENSO cycle. The middle regions are mainly influenced by sunspot numbers cycle (The Houw Liong 2006). This solar signal does not appear on regions with different climate patterns or seasonal time ranges. The stronger solar signal appears when local or regional effects are least.

Although there are some empirical evidences about solar effects on climate, actually the physical mechanism is not yet well known. Cosmic rays mechanism is a possibility. The cosmic rays interact in the upper atmosphere and produce secondary particles. When the neutrons or the muons interact with the air molecules or water molecules, they become charged and act as condensation nuclei for the formation of clouds. During the sunspot minimum, the intensity of the cosmic ray becomes maximum which in turn increases the coverage of clouds. This implies that solar radiation reaching Earth will be minimized. Conversely, during sunspot maximum, the intensity of cosmic ray reaching lower levels of the atmosphere reduces and the cloud cover decreases. Furthermore, extra energy is received on the Earth from eruptive events like flares on the solar atmosphere. Therefore, Indonesia through which the equator crosses, a number of large clouds will form and can influence the heat source distribution.

From spectral analysis (using WWZ) of IOD monthly data from April 1978 up to January 1996, we found periodicity around 3-6 years, suggesting climatic signal. Annual periodicity, known as seasonal signal, is also there (Fig. 2a). Further, if we select IOD data only for December-February (or wet season in Indonesian monsoon), we find solar signal with about 11 years periodicity (Fig. 2b). If we select data only for June-August (dry season in Indonesian monsoon) the solar signal was relatively weak and didn't appear in spectral contour (Fig. 2c). Here we only see signal with 6 down to 2 years indicating climatic effects. This implies that solar signal does not appear on all regions with different climate patterns or seasonal time ranges. The stronger solar signal appears when local or regional effects are least (Djamaluddin 2003; Nugroho & Djamaluddin 2005).

It is clear that solar activity plays a role in the climatic changes in Indonesia. Unfortunately, the physical mechanism that could explain this interaction has not yet been understood. This is a challenge in understanding of Sun-Earth interaction mechanism.

4. Conclusions

IOD phenomena influence on Indonesian climate, mainly over western Indonesia with monsoon climatic patterns, was evaluated from the correlation with cloud cover. Spectral analysis indicates the presence of a periodicity of about 11 years, indicating the solar effects on IOD. The effects appear during dry seasons (June - August), especially over the area with monsoon climate pattern. It is found that solar signal does not appear on all regions with different climate patterns or seasonal time ranges. The stronger solar signal appears over regions with monsoon patterns and during dry seasons, when local effects are less. The ENSO signal with the period of about 4 - 6 years seem to be related with solar activity.

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