Reply to comment by L. Giglio et al. on "Seasonal, intraseasonal, and interannual variability of global land fires and their effects on atmospheric aerosol distribution"

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[1] We thank *Giglio et al.* [2003] (hereinafter referred to as G03) for their comments in response to our recent paper [*Ji and Stocker*, 2002] (hereinafter referred to as JS02), which provide an opportunity for us to clarify several issues that were not fully explained by JS02. The major objection raised by G03 to the statistical results presented by JS02 is that the intraseasonal oscillations found by JS02 from the Tropical Rainfall Measuring Mission (TRMM) Visible and Infrared Spectrometer (VIRS) observations are likely artifacts caused by severe aliasing of the diurnal burning cycle. G03 used a satellite-derived diurnal cycle from Borneo to model the global fire variability. G03 concluded that the 5-day averaging interval used by JS02 is 5–10 times too short to average out the signature of the diurnal burning cycle.

[2] The local overpass time of the TRMM satellite does drift each day, completing a daily cycle in 46 days. However, the twice-daily observations in the lower tropics from descending and ascending TRMM orbits are usually more than several hours apart. For example, this time interval is about 10–12 hours in Southeast Asia. The 5-day time averaging and $\sim 10^\circ$–20° spatial averaging in the longitude direction contribute an additional 3 hours to the averaging window. Further, on the basis of the TRMM overflight model, the $\sim 10^\circ$–20° averaging in the latitude direction may add ~ 2 hours to the moving window. Therefore the 5-day averaging of TRMM data for a $10^\circ \times 10^\circ$ box in Southeast Asia gives a moving average of ~ 15 hours. As a result, the effect of the aliasing of the diurnal burning cycle indicated by G03 may have certain effects in determining the intraseasonal variability from the TRMM/VIRS product.

[3] First of all, the diurnal burning cycle presented by G03 may not be representative for global fires. This diurnal burning cycle shows maximum fire occurrence between noon and 1500 local time (LT) and indicates almost no fires at nighttime. While a complete study of global diurnal burning cycles is out of the scope of this paper, Table 1 shows that the diurnal burning cycle used by G03 does not exist during fire seasons in all the major fire regions. The data used in Table 1 excluded the nonfire season observations; during these seasons a large number of false fire pixels may occur in the daytime because of errors in the land type screening. As shown in Table 1, in Southeast Asia, South America, and Africa, the numbers of fire pixels in the daytime and at nighttime do not differ substantially. The ratios are ~ 1–1.5. In Indonesia the nighttime fire pixels outnumber the daytime fires pixels. We speculate that the diurnal burning cycle presented by G03 may be clouded by the false fire pixels in their data in the nonfire season. We examined the number of day/night hot spots in nonfire seasons for various regions; the data do show significant contrast between day and night. A typical example is that in Southeast Asia during June–July–August 1998, the number of daytime hot spot pixels is 558 while the number of nighttime hot spots is only 9. However, in observation, fire occurrences in this summer monsoon season are rare. In the January–February–March season in South America the ratio of day/night pixels is also above 10; while in the June–July–August season, this ratio is only ~ 1–1.5. Using an extreme diurnal cycle from G03 to model the global intraseasonal variability would substantially exaggerate the effect of satellite aliasing.

[4] In order to verify the conclusion from the findings of JS02, a simplified model is developed to transform the TRMM fire data such that the effect of TRMM satellite aliasing can be eliminated as much as possible. Only nighttime results are presented in this paper to avoid discussions of issues such as false fire and day/night screening although the methods can be used for daytime too. In the prototype the nighttime period is divided into four particular time windows (Table 2), and the model assumes one overpass for each window for all pentads. Multioverpasses are normalized before processing. The

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Table 1. Comparison of Day/Night Fire Observations

Region	Longitude	Latitude	Time Period	Day Count	Night Count
Indonesia	110°–120°E	10°S to 0°	1 March to 30 April 1998	152	157
Southeast Asia	90°–110°E	5°–25°N	1 Feb. to 31 March 1999	717	612
Southeast Asia	90°–110°E	5°–25°N	1 Feb. to 31 March 1999	744	640
South America	70°–50°W	25°–5°S	1 July to 31 Aug. 1998	2136	1450
South America	70°–50°W	25°–5°S	1 July to 31 Aug. 1999	2149	2078
South America	70°–50°W	25°–5°S	1 July to 31 Aug. 2000	658	592
South America	70°–50°W	25°–5°S	1 July to 31 Aug. 2001	790	630
Africa	25°–35°E	0° to 10°N	1 Jan. to 31 March 1998	709	559
Africa	25°–35°E	0° to 10°N	1 Jan. to 31 March 1999	850	540

model then calculates the average fire count per overpass within each window using TRMM observations during major fire seasons. As an example, the ratios for each window and each fire season in Southeast Asia (90°–110°E, 5°–25°N) are listed in Table 2. Since each pentad of this region has observations that cover about 2/3 of the daily cycle, TRMM overpasses for at least one of the four windows in all pentads are guaranteed. Available observations within certain windows and precalculated ratio look-up tables are then used to extrapolate fire counts for windows with no observed overpasses.

[5] Time series of the TRMM observed fire count (count/d) and the transformed fire count (count/d) in Southeast Asia are displayed in Figure 1. In the observed time series the effect of satellite aliasing can be seen from some of the dips during certain fire episodes. Such dips are largely eliminated in the transformed time series. The fire time series in Southeast Asia are also compared with the Global Precipitation Climatology Project (GPCP) [*Janowiak and Arkin*, 1991] rainfall over land. The results (Figure 1) indicate that the fire intraseasonal variability is indeed closely related to the rainfall variations in the premonsoon season rather than an artifact caused by the TRMM overflight patterns as claimed by G03. The intraseasonal fire variability is dominated by fire episodes relative to the rainfall variability rather than a few dips relative to the aliasing. The transformation does not substantially change the pattern of time series. The comparison also indicates that the onset and duration of the fire season are also related to the intraseasonal variability of rainfall. The 15–30-day and 30–60-day intraseasonal oscillations of tropical rainfall have been well defined [e.g., *Madden and Julian*, 1994].

[6] The singular spectrum analysis (SSA) from the TRMM transformed nighttime fire count for Southeast Asia during 1998–2002 (Figure 2) clearly shows the dominant modes of 30–60-day oscillations. These oscillations may be related to the Rossby wave and Madden-Julian Oscillation [*Madden and Julian*, 1994] in the tropics. Notice that these modes are similar to those found by JS02 using observed fire counts and that in the transformed fire counts the effects of aliasing are eliminated. The time series of these modes are shown in Figure 3. The amplitudes are much smaller as compared to the JS02 results because the number of samples is significantly reduced. However, the trends during fire seasons are similar to those presented by JS02. In the study by JS02 the fire seasons are in general longer than that displayed in Figure 3 because of the inclusion of daytime fire counts.

[7] The previously examined examples demonstrate that the analysis of G03 exaggerated the effect of the diurnal burning cycle on the JS02 findings. However, the effect of the diurnal burning cycle combined with the overflight patterns suggested by G03 is important and interesting. A complete model that contains effects from satellite overflight design, spatial and temporal averaging, and the ground-observed diurnal cycle for the concerned region is needed to realistically estimate the effect of diurnal cycle on the intraseasonal variability. Such a model is also important and useful in analyzing the TRMM rainfall time series.

[8] The other points raised by G03 are the nonuniform latitudinal sampling frequency of TRMM/VIRS and the data quality of the TOMS aerosol index after mid-2000. The latitudinal sampling frequency of TRMM/VIRS is quite uniform between 25°S and 25°N. Sustained fires occur mainly within this region. The major patterns of fire empirical orthogonal functions (EOF) from JS02 are also well within this area, and therefore the principal components are not affected significantly. Although the number of overpasses peak around 32°N and 32°S, the average number of overpasses within the 30°–40°N and 30°–40°S latitudes are similar to the other zones because of the significant drop beyond 35°N and 35°S. The results of EOF analyses using data between 30°S and 30°N (Figure 4) show very similar patterns to those presented by JS02. However, we agree that for consequent TRMM studies the regions beyond 35°S and 35°N are better avoided.

[9] The degradation of TOMS aerosol index data after mid-2000 does have an effect on the EOF and SSA analyses. Such an effect can be seen in the principal components presented by JS02. However, as shown by both

Table 2. Count per Overpass for Time Windows in Southeast Asia

Year (Time of Year)	Count per Overpass			
	1800–2100 LT	2100–2400 LT	2400–0300 LT	0300–0600 LT
1998 (1 Jan. to 20 May)	5.10	1.64	1.09	1.11
1999 (1 Jan. to 5 April)	6.59	1.92	1.42	0.94
2000 (1 Jan. to 10 April)	2.52	0.26	0.35	0.13
2001 (1 Jan. to 15 April)	2.35	0.82	0.22	0.10

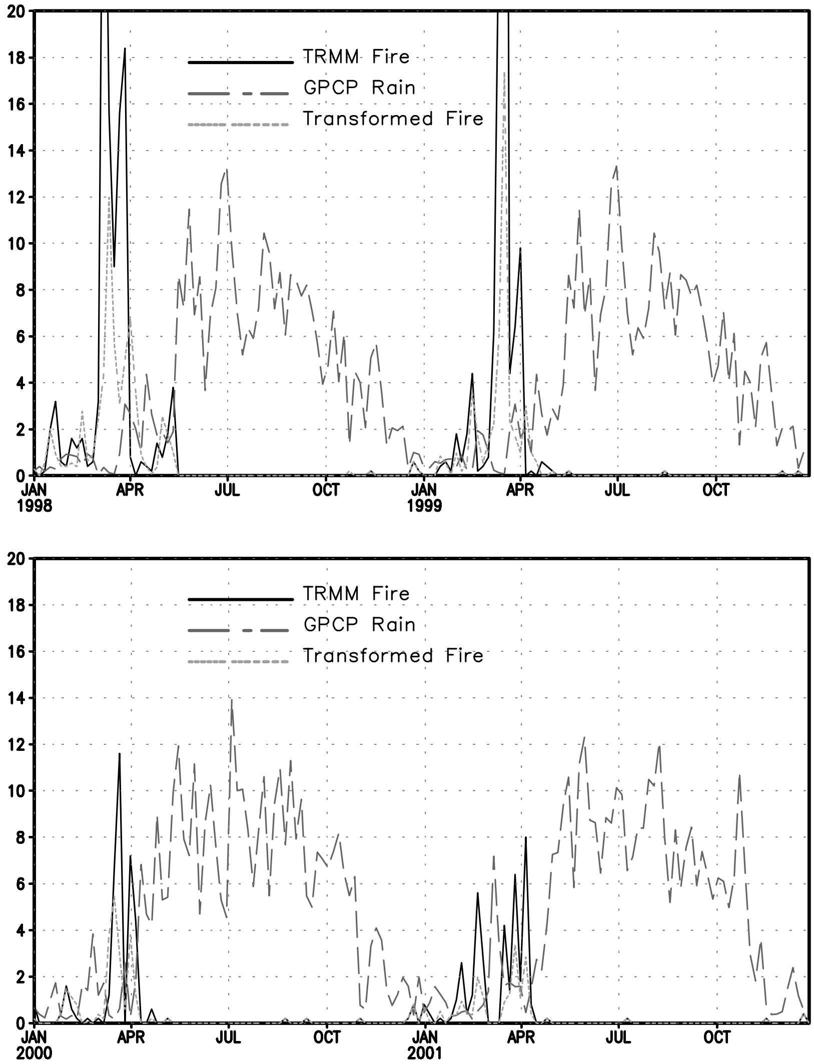

Figure 1. Time series of TRMM fire count (count/d, solid line), TRMM transformed fire count (count/d, short-dashed line), and GPCP rainfall (mm/d, long-dashed line) in Southeast Asia (90°–110°E, 5°–25°N).

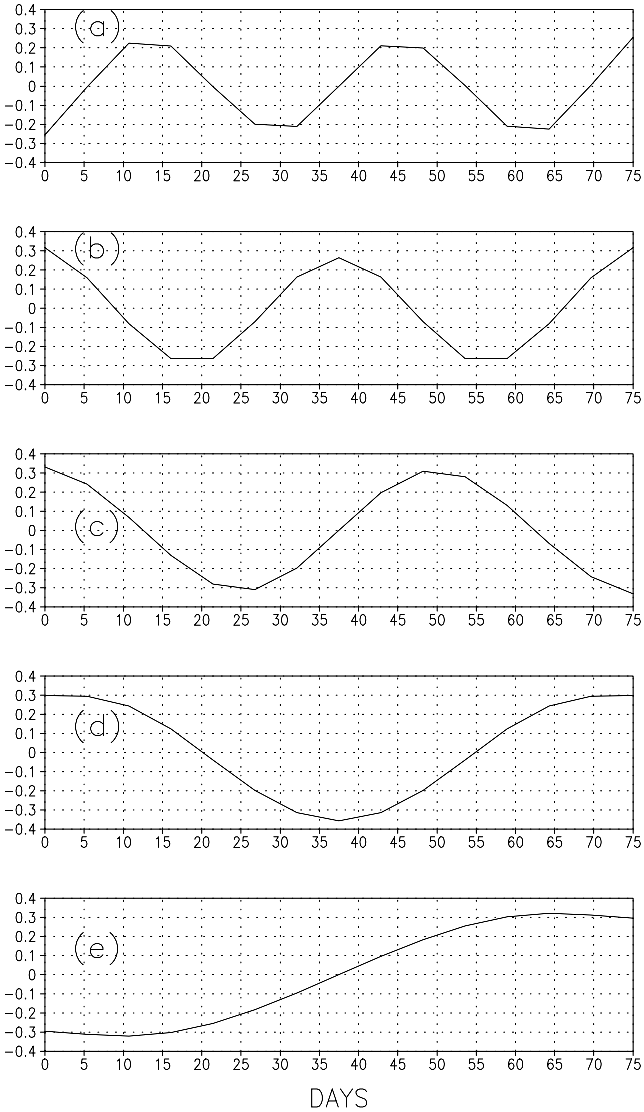

Figure 2. (a–e) First five leading eigenvectors of SSA analyses from nighttime TRMM fire data in Southeast Asia.

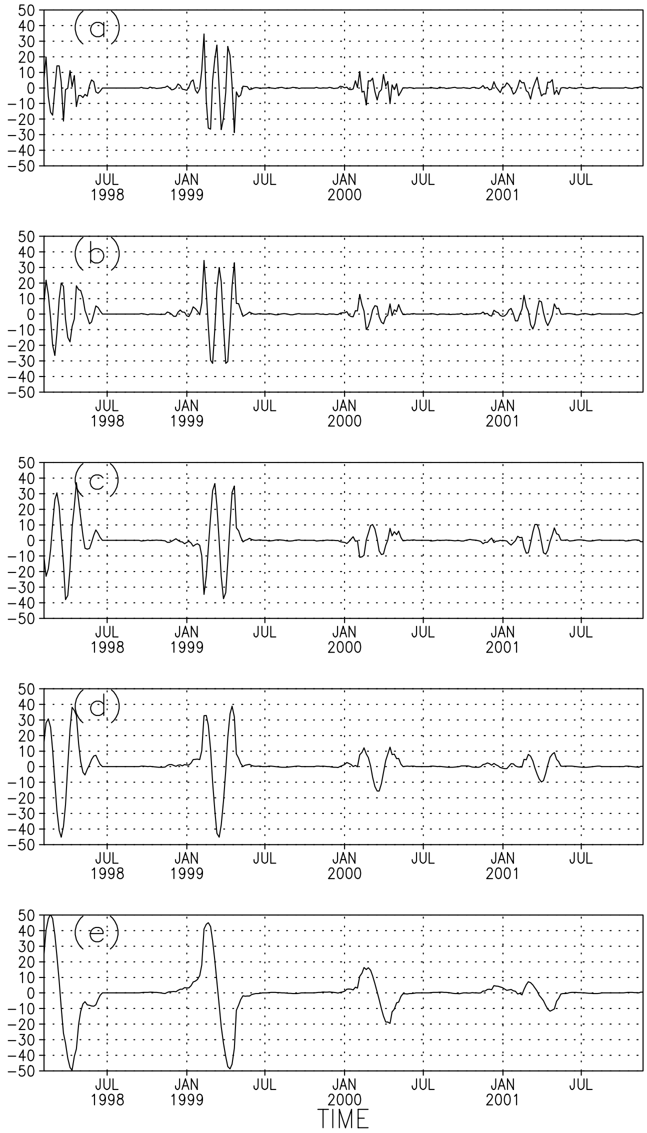

Figure 3. (a–e) Principal components of the five leading eigenvectors of fire SSA in Southeast Asia derived from TRMM nighttime data.

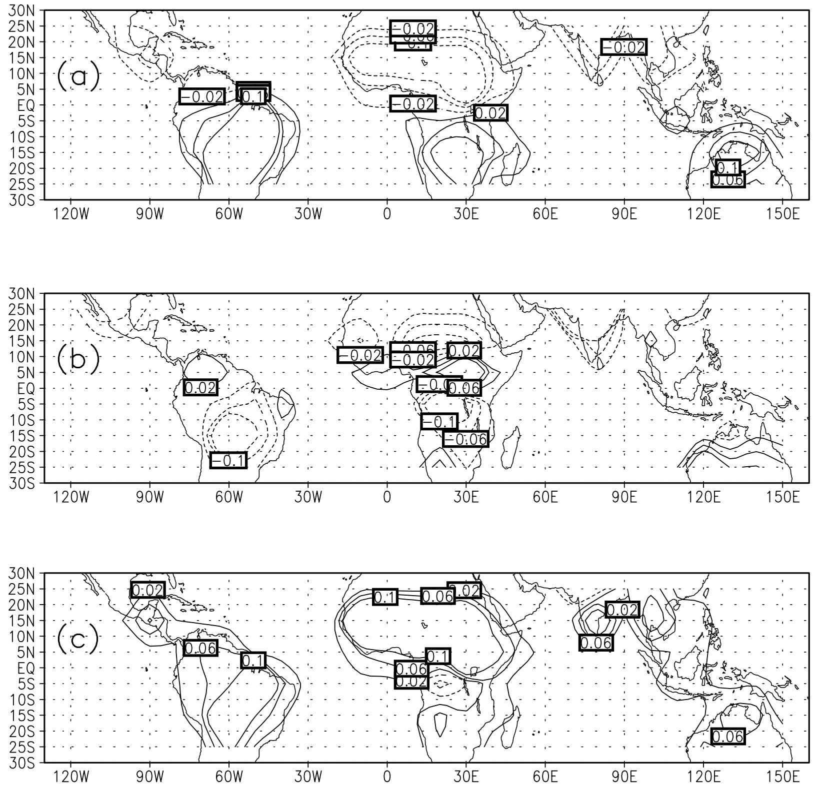

Figure 4. (a–c) First three leading eigenvectors of EOF analyses derived from TRMM global fire data between 30°S and 30°N.

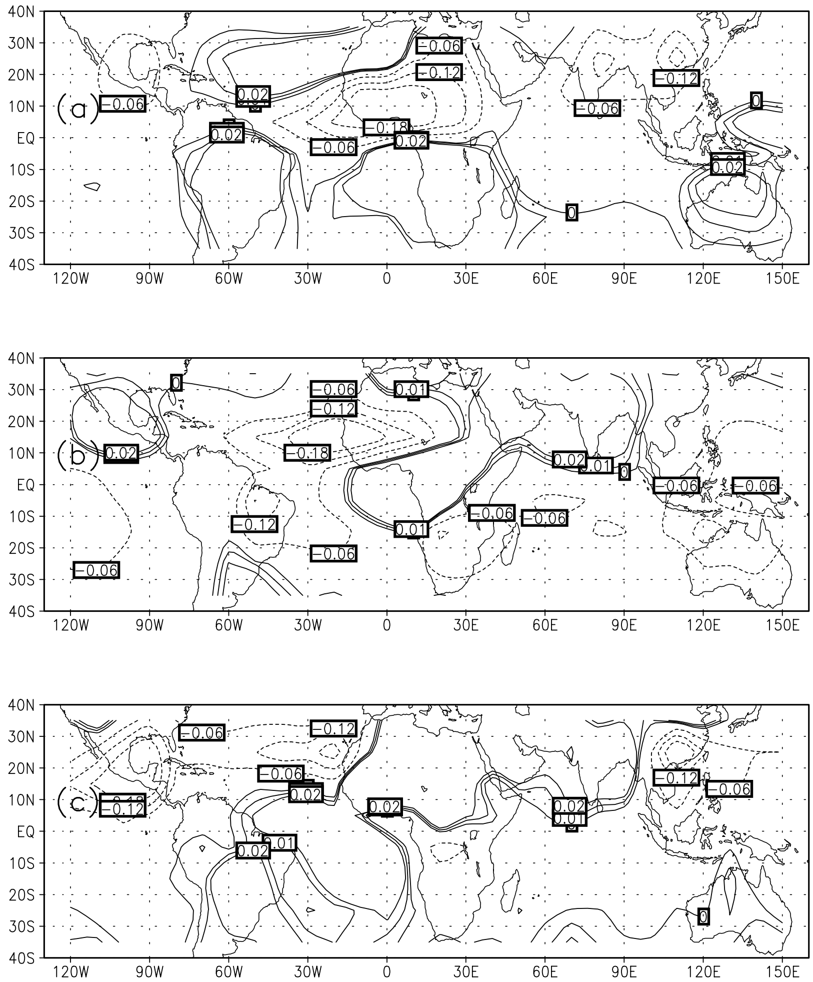

Figure 5. (a–c) First three leading eigenvectors of EOF analyses derived from TOMS global aerosol data in 1998 and 1999.

JS02 and G03, this degradation does not affect the dominant modes of annual cycle and intraseasonal variations. We repeated the EOF analyses using 1998/1999 data only. The eigenvectors for seasonal and intraseasonal modes (Figure 5) are only slightly different from the findings given by JS02.

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