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Interactive Comment

Interactive comment on "An extreme CO pollution event over Indonesia measured by the MOPITT instrument" *by* F. Nichitiu et al.

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Interactive comment by Guido van der Werf (VU University Amsterdam) and Robert Field (University of Toronto)

The authors propose a new factor contributing to variability in fire events in Indonesia, that of a fire-lightning feedback during El Nino periods. According to the authors, this feedback could explain why fire activity in 2006 was much higher than in 2002, under similar El Nino conditions. We would like to suggest a simpler and, in our opinion, more plausible explanation of the difference in emissions between the years 2002 and 2006.

The paper hinges on the assumption that lightning strikes can be an important source of fire ignitions in Indonesia, in addition to those from anthropogenic activities. This has been questioned to some extent by the first referee, and the existing literature overwhelmingly attributes fires in Indonesia to human ignition. Stolle and Lambin [2003] and Stolle et al. [2003] allow for the possibility of lightning-caused fire, but in their detailed analyses, examine only human activity as potential ignition sources, similar to the study by Fuller and Murphy [2003]. Similarly, Gellert [1998] and Aiken [2004] consider only human activity as proximate causes, while describing underlying socio-political factors. We assume that the most likely reason for their omission of lightning as a cause is that it is simply not a major factor. More directly, Wibowo et al. [1997] states that "natural phenomena such as lightning are not a major cause of forest fire in Indonesia, because lightning usually comes together with rains".

Even if we allow for the possibility of lightning as an additional source of ignitions, it is not clear to us how the data supports the hypothesis: the authors attribute a 100 percent increase in fire hot spots between October of 2006 and September 2002 (the peak fire months of the two years) to only a 5 percent increase in flashes-per-storm (Figure 8a). The authors mention a saturation effect, but this highly non-linear relationship is not explained further. Furthermore, the authors refer, presumably in the context of fire ignitions, to Hamid et al. [2001] in linking increased lightning over Indonesia to El Nino conditions. The Hamid study, however, showed a lightning increase during March and April of 1998 associated with heavy precipitation during the northwest monsoon, long after the fires in southern Sumatra and southern Kalimantan had stopped. There was severe burning in East Kalimantan during March and April of 1998 under isolated drought conditions [Siegert et al., 2001], but with no lightning present [Figure 2a of Hamid et al. 2001].

In our view, a much more likely explanation for the increase in 2006 fire activity compared to 2002 is that conditions in several main biomass burning regions were simply drier. This is not evident from Figure 5 which we assume was based on precipitation rates over all of Indonesia, but requires a more detailed analysis of precipitation rates over the main biomass burning regions, given the variability in precipitation across the

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archipelago [Field and Shen, 2008]. The authors note that the 2006 peak fire month in Borneo was in October, one month later than in the year 2002. When examining precipitation rates in southern Borneo for only those grid cells where fires were pervasive, TRMM precipitation shows that the dry season (months with less than 100 mm precipitation / month) extended through October in 2006, one month longer than in 2002 (see table 1 below).

Table 1. Monthly fire hot spots detected in Borneo by Terra MODIS [Giglio et al., 2003] and TRMM precipitation rates [Iguchi et al., 2000] im mm /month for the years 2002 and 2006. Only 0.5 degree grid cells with over 80 fire detections per year were taken into account to capture precipitation variability in the main biomass burning regions. With this threshold, 90 percent of the total fire detections were captured. HSs = fire hot spot, PPT = precipitation. Note that in 2006, the dry season extended one month longer than in 2002.

Month	PPT 2002	HSs 2002	PPT 2006	HSs 2006
Jan	322	29	295	208
Feb	163	32	351	72
Mar	311	19	245	245
Apr	233	46	275	44
May	138	86	211	48
Jun	212	54	300	73
Jul	43	572	40	599
Aug	43	5460	35	3334
Sep	48	6283	85	5442
Oct	142	4028	67	8289
Nov	357	255	220	1961
Dec	329	65	354	144

This difference of a dry season being 4 vs. 3 months can be highly relevant in Indonesia; Field and Shen [2008] used a threshold-based model to show that over the primary burning region of southern Borneo, 4-month back-totaled precipitation was a useful and simple drought index in explaining variability in fire severity during 1997-

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2006. Below a certain amount of seasonal precipitation, a sufficiently low water table allows drained peat lands to dry to the point of combustion, which once ignited, smolder until the return of monsoon rains. Fires in peat lands are responsible for the bulk of emissions [Levine 1999, Page et al., 2002]. Due to thresholds and because humans take advantage of drought conditions to use fire more extensively [van der Werf et al., 2004], the fire environment in Indonesia is highly sensitive to drought [Field et al., 2008; Le Page et al., 2008; van der Werf et al., 2008]. We feel that this difference in drought severity is a more likely explanation for the variation in fire emissions than the much smaller increase in lightning strikes.

We also caution against the attribution of fire directly to ENSO, which is not the only large-scale circulation control on Indonesian precipitation variability. Positive Indian Ocean Dipole conditions can also lead to dry precipitation anomalies over Indonesia [Saji et al., 1999]. While ENSO conditions were indeed similar between 2002 and 2006 (Figure 4), the drier 2006 conditions can be explained in part by the strongly positive IOD conditions during that year, absent in 2002 [Field and Shen, 2008].

Fire in Indonesia is a serious environmental problem. The severity of the 2006 event reminds us of the importance of addressing the root causes of the fires, so that they can be better managed in the future. Although we do not argue against the possibility of the fire-lightning feedback at the core of this paper, based on the evidence presented we are not convinced that it could be the major cause of the increase in emissions in 2006 compared to 2002. This increase is better explained simply by drier conditions and the widespread use of fire as a land management tool in Indonesia.

Additional comments:

P1215L26: The analysis is based on average precipitation rates over a large region. However, there is considerable spatial variation in seasonal precipitation anomalies across the region of 60E to 150E between 10S and 10N. The 2002 rainfall deficit was centered north of Papua, with only a small rainfall deficit over Sumatra and Kalimantan.

The 2006 rainfall deficit was centered over the southeastern Indian Ocean, but with a considerable signature across Sumatra and Kalimantan. So while the time series in Figure 5 shows similar rainfall deficits averaged the broad region from 60-150E, the drought was in fact much more pronounced over the burning regions in 2006. The statement on P1216L2 that "from the point of view of temperature and rainfall all the last three El Nino events are similar and of moderate intensity" is not true for the main burning regions.

P1216L7-27: As also noted by the second referee, this section lacks references. The assumption made here is crucial for the importance of the paper, but not supported by literature. The only study referenced studied the boreal region; we feel that using their findings for the tropics requires a solid discussion.

P1216L24 - "A dry season during an El Nino warm period is a dry lightning season with a lot of fires." Again, this requires substantiation from the literature. The references cited in the sentence following do not support this phrase because they are either in a different fire environment (the US in the case of Goodman et al. [2001]) or refer to the wet season in Indonesia (Hamid et al. [2001]).

P1217L1: Increased convective storms would probably lead to precipitation.

P1219L3: It is not clear to us why flashes per storm is used as a measure of lightning activity, rather than total number of flashes. An absolute value would be better in our opinion; what if FPS increases as the result of there being fewer storms?

P1219L17: Because this time period coincides with the end of the dry season (including the first storms), a weekly breakdown instead of taking the average is required to draw any conclusions.

P1219L26: Here you mention that the feedback is not strong, but from the abstract and conclusions we learned that it is all about the feedback. Please clarify.

Fig. 5: Legend should be GPCP (we assume as this is used in the text), not GPCC,

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which is a different precipitation dataset.

Fig 8b: data is offset by 1 year

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