Asian Journal of Water, Environment and Pollution, Vol. 11, No. 1 (2014), pp. 3–11.

The Impact of Vegetation and Peat Fire Emissions in Indonesia on Air Pollution and Global Climate

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Received September 13, 2013; revised and accepted October 11, 2013

Abstract: Fire is used in Indonesia as a tool to clear tropical forest and to convert peat land for agricultural purposes. This use of fire has considerably increased in recent decades. Increased fire activity is also strongly connected with the decrease of precipitation during El Niño years when the usually moist peat swamps in Indonesia suffer from extreme drought and are thus very susceptible to fires. The emissions from such peat fires greatly exceed those produced by surface vegetation fires and generate smoke haze episodes downwind in Southeast Asia. Furthermore, the concentrations of climatically relevant trace species in the atmosphere are considerably enhanced by emissions from Indonesian peat fires. The motivation of this paper is to provide an overview of vegetation and peat fires in Indonesia in recent years and to present the local, regional and global implications of the associated emissions.

Key words: Peat fires, El Nino, deforestation, dry and rainy season, CO_2 storage destruction.

Introduction

Vegetation fires are an important and highly variable source of gaseous and particulate matter emissions to the atmosphere. Such fires represent a large perturbation to global atmospheric chemistry, especially in the tropics, where most biomass burning emissions are produced (Andreae and Merlet, 2001; Crutzen and Lelieveld, 2001). Most vegetation and peat fires are man-made. Natural fires, mainly from lightning, are estimated to make up only 10% of global biomass burning (Crutzen and Andreae, 1990). Generally, humans ignite fires for land conversion, as fire is a cheap and fast tool to remove the original vegetation and to prepare the land for different use such as plantation, cropland, grazing or settlement (Suyanto et al., 2004).

The major factors which determine the amount of emissions from vegetation fire are the combustion process, burned area and fuel load which strongly depend on the land cover type (vegetation and/or soil) (Langmann et al., 2009). All of these are subject to considerable uncertainty. Compared to surface vegetation fires, the uncertainty of emission estimates from peat fires are even higher, as peat can burn repeatedly to different depths so that not only the area burned but also the volume (depth) burned needs to be determined. In addition, the fire size and duration depend on natural climatic factors such as soil moisture and precipitation rates which may vary considerably from year to year. Dry weather conditions contribute to a lowering of the water table in peat soils (Usup et al., 2000) making not only drained but also undisturbed peat soils susceptible to fires (Zoltai et al., 1998).

Worldwide, wetlands cover an area of ~5×10^6 km^2 (IPCC, 2001), 75% of these are peat areas representing an important water and carbon storage. More than 90% of these peat lands are located in temperate to sub-polar climate zones and only about 10% in tropical regions. Peat areas in Indonesia (Figure 1) are located particularly in southern Borneo, eastern Sumatra, and Irian Jaya (Boehm and Siegert, 2001; Siegert et al., 2001) and contribute about 50% to the overall tropical

Figure 1: Geographical location of peat swamp areas in Indonesia based on the classification as histosols in FAO/ UNESCO (2003).

peat areas (Rieley and Page, 2005). The organic matter in the Indonesian peat deposits has been accumulated over the last 5000 to 10,000 years (Rieley et al., 1995) and is frequently more than 8 m in depth (Nichol, 1997). Due to the large fuel load, peat fires release particularly huge amount of emissions per area burned.

CO_2 and H_2O are the dominant products released during the combustion of vegetation into the atmosphere. Incomplete combustion results in numerous additional compounds being emitted like CO, CH_4, higher alkanes and alkenes etc. (Andreae and Merlet, 2001). Particulate matter emitted by vegetation and peat fires consists mainly of carbonaceous material (Reid et al., 2005) and is the dominant pollutant causing ambient air quality thresholds to be exceeded on the regional scale (e.g. Heil and Goldammer, 2001; Langmann and Heil, 2004).

Here we provide an overview of the causes and trends of deforestation and peat fires in Indonesia (in next section), followed by 'vegetation and peat fire emissions' in Indonesia, 'fire related air pollution' and 'climate impacts' in subsequent sections. An outlook is given in last section.

Deforestation and Peat Fires in Indonesia —Trends and Causes

The tropical and wet climate in Indonesia is characterised by uniformly high temperature, high humidity, relatively constant atmospheric pressure and weak wind velocities, but highly variable precipitation rates. The latter has major implications for fire occurrences and fire-induced air pollution, as rain-out presents a major cleaning process of the atmosphere. During the wet season from about November to March, the winter monsoon brings heavy rainfall to the maritime continent. The dry, southerly monsoon season from about June to September is influenced by the Australian continent and generally drier. An additional suppression of precipitation occurs during El Niño years, in particular in the southern equatorial regions (Aldrian and Susanto, 2003), associated with a large scale warming of the equatorial Pacific and diminished Walker and Hadley circulation.

Fires are set in Indonesia every year during the dry season to clear vegetation for land conversion (Olson et al., 1999). Usually, the burning activities cease with the beginning of the northern monsoon rains. Small farmers in Indonesia traditionally use slash-and-burn methods to clear hectares of forest for growing crops. Their activities—though applied for hundreds of years—did not lead to pronounced deforestation. In 1950, more than 80% of Indonesian land area was still covered by forests (Hannibal, 1950).

Particularly over the last four decades, the pressure on the Indonesian forest increased dramatically due to (a) growing population along with agricultural expansion and transmigration programmes, (b) intensified conversion of forests into plantations such as palm oil or rubber, and (c) over-exploitation of the forests for timber and plywood as well as pulp and paper (legal and illegal) (Stibig et al., 2003; Field et al., 2009). When originally inaccessible forests are made accessible by roads and canals, these forests are increasingly degraded and deforested due to increased establishment of settlements and farmlands. Besides intentionally set land clearing fires, the higher fire susceptibility of anthropogenically influenced forests (Cochrane et al., 1999) contributes to the increased fire occurrence in Indonesia (Siegert et al., 2001). These forests which are usually resistant to fires can become flammable under dry conditions because the microclimate is drier in comparison to forests with a closed canopy which efficiently reduces solar irradiation and wind below the canopy. In addition, the amount of biofuel that can be easily ignited is increased due to biomass left in the forest by humans. Thus, there is a high likelihood that fires in these areas become uncontrolled. This is also the case for drained peat swamps in Indonesia. In comparison to surface vegetation fires, fires in peat swamps may also burn underground.

Peat fires are also more long-lasting and more difficult to extinguish (Bowen et al., 2000). Especially during the last three decades climate variability coupled to the El Niño phenomenon contributed significantly to repeated periods of prolonged droughts in Indonesia (1982-83, 1986-87, 1991-92, 1994-95, 1997-98, 2002-03, 2006-07). Prolonged droughts not only increase the overall susceptibility to fire of the vegetation and peat and the probability of uncontrolled fires, but also the intensity of land clearing activities (Goldammer and Price, 1998).

Observations of the yearly area burned from July to June in Indonesia (Giglio et al., 2010) clearly reveal the strong influence of different El Niño conditions on fire occurrences (Figure 2). Indonesian peat swamps are considerably less affected during normal and La Niña years (compare Figures 1 and 2). The seasonal cycle of the area burned shows a maximum during the dry season in the second half of the year (Figure 3). In some years another maximum occurs during the first half of the year, for example in 1998 in East Kalimantan, in 2005 on Sumatra in Riau.

It has been estimated that between 1985 and 1997 the forest coverage in Indonesia decreased from 63 to 50%, especially on the islands of Sumatra, Borneo and Sulawesi (FWI/GFW, 2002). The corresponding annual deforestation rate was among the highest in the tropical regions of the world (FWI/GFW, 2002; Archard et al., 2002) and largely threatens the unique biodiversity of these ecosystems (Kinnaird et al., 2003); for example, the only remaining wild orangutan habitats are located in Northern Sumatra and Central Kalimantan (Morrogh-Bernarda et al., 2003). Based on Giglio et al. (2010), the total area burned in Indonesia from 1997 to 2009 is estimated to be 23 Mha with 12 Mha on Kalimantan, 7 Mha on Sumatra and 1 Mha on Irian Jaya. The maximum of burned area occurs during El Niño years with 9.0 Mha in 1997-98, 1.9 Mha in 2002-03 and 2.1 Mha in 2006-07.

Vegetation and Peat Fire Emissions

The fires in Indonesia release significant amounts of trace gases and aerosols into the atmosphere. Several studies have demonstrated that fires in peat areas are of particular importance for the overall fire emissions budget as they may release up to 50 times more emissions per unit area burned than fires in surface vegetation (Nichol, 1997; Levine, 1999; Page et al., 2002). In 1994, peat areas contributed 3% of the total area burned, but 55% to the total particulate matter emissions (Nichol, 1997) and in 1997, 20% of the total area burned while producing 94% of the total emissions (Levine, 1999). 0.81-2.57 Pg of carbon (C) are estimated to be released during the 1997 peat and forest fires in Indonesia by Page et al. (2002), with the above surface vegetation contributing only 18%.

Since the huge Indonesian fires in 1997, the awareness of the importance of peat fire emissions has grown internationally. Today, two global fire emission inventories contain estimates of Indonesian peat fire

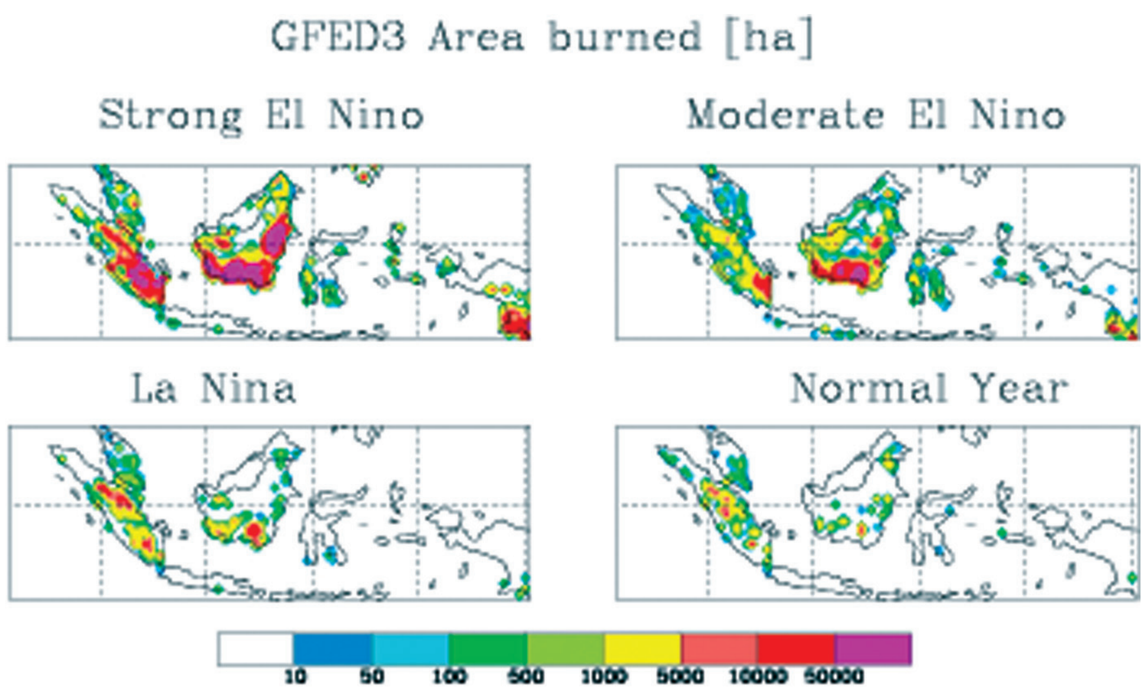

Figure 2: Observations of the yearly area burned (ha) per 0.5° grid cell from July to June for conditions of a strong and moderate El Niño year (1997-98 and 2002-03), normal year without El Niño or La Niña (1999-2000) and a La Niña year (1998-99) based on Giglio et al. (2010). Classification of El Niño and La Niña based on http://ggweather.com/enso/years.htm.

emissions. These are the Global Fire Emission Dataset GFED3, 1997-2009 (van der Werf et al., 2010) and RETRO[1], 1960-2000 (Schultz et al., 2008). Total carbon emissions from vegetation and peat fires based on van der Werf et al. (2010) are presented in Figure 4. Peat fire emissions represent those emissions released from sub-surface fires. Above-ground fires such as deforestation, grassland or agricultural fires may release additional emissions if these land cover types correspond with those of the peat areas.

In van der Werf et al. (2010), the spatial and temporal variability of fire emissions on a 0.5° grid is based on biogeochemical modelling using various high resolution data sets (500 m-1 km) from satellite observations (e.g. area burned, hot spots, photosynthetically active radiation, land cover type including tropical peat cover as underlying soil) in combination with lower resolution data (0.5-1°) of precipitation and temperature. The fraction of fire emissions in Indonesian peatlands is derived from the fraction of burned area identified as peat. In addition to these sub-surface peat fires, deforestation fires are the first type of above-ground fires determined on a 0.5° grid from persistent burned scars. The remaining burned area within a 0.5° grid cell is then partitioned into herbaceous (e.g. agriculture, savannah and grassland) and woodland fires according to land cover and fraction of tree cover. For more details we refer to van der Werf at al. (2010). Emission strength in Figure 4 and area burned in Figure 3 are clearly connected. The contribution from peat fires exceeds 50% during El Niño years, with a maximum of 65% in 1997. Deforestation fires represent the second highest contribution to the total carbon emissions from fires in Indonesia of about 50% in non-El Niño years. In comparison to these two major sources, emissions from grassland, forest fires and agricultural waste burning are negligible. For some trace species, e.g. CH_4 and CO, the contribution from peat fires is even higher than for the total C emissions, as peat fires are smouldering fires which favour the production of less oxidised compounds.

Schultz et al. (2008) and van der Werf et al. (2010) present comprehensive comparisons of estimated fire emissions in various regions of the Earth. During 1997-2009, Indonesia contributed 9.5% to the global carbon emissions from vegetation fires, presenting the fourth highest contributor region after Southern Hemisphere South America (13.4%), Northern Hemi-sphere Africa (23.9%) and Southern Hemisphere Africa (27.7%) (van der Werf et al., 2010). In contrast to the African vegetation fire emissions which exhibit

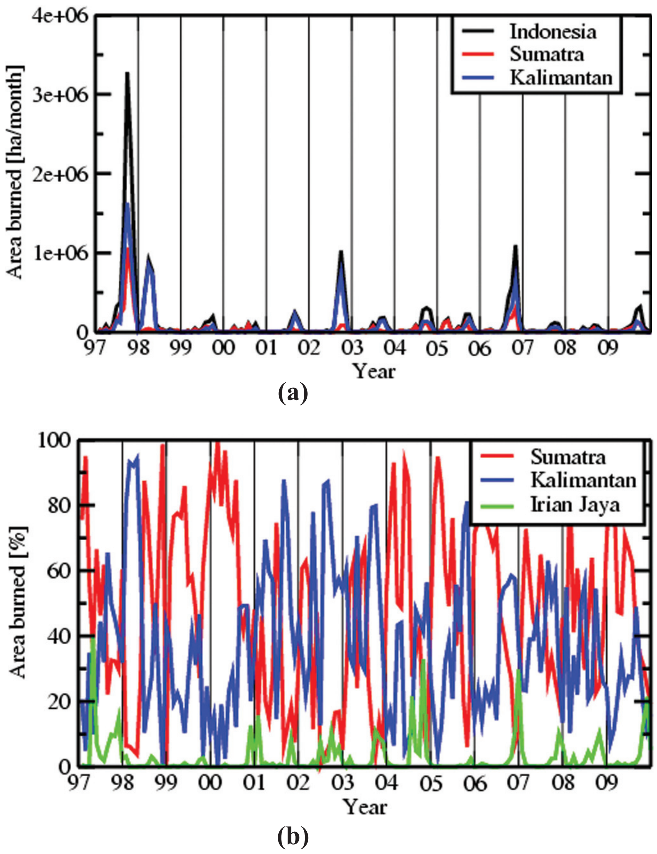

Figure 3: (a) Monthly burned area from 1997 to 2009 in Indonesia, Sumatra and Kalimantan according to Giglio et al. (2010) and (b) percentage contribution of the islands of Sumatra, Kalimantan and Irian Jaya to the total Indonesian area burned shown in (a).

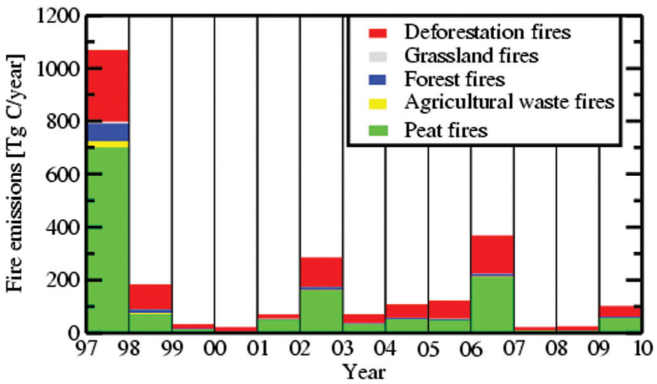

Figure 4: Contribution of various kinds of fires to the total carbon emissions in Indonesia from 1997 to 2009 based on van der Werf et al. (2010).

[1] REanalysis of the TROpospheric chemical composition over the past 40 years.

small year-to-year variability, the inter-annual variability of the Indonesian vegetation fire emissions is extremely pronounced.

Fire-related Air Pollution

Smoke haze episodes caused by vegetation and peat fires affect Indonesia every year. During El Niño events the fire emissions even affect the neighbouring countries Singapore, Malaysia and Brunei (Heil and Goldammer, 2001). Decreased precipitation and large scale downward motion favours the accumulation and wide distribution of fire emissions in the planetary boundary layer. As a result, ambient air quality declines significantly. The pollutant of major concern with respect to human health issues is particulate matter (WHO, 1998), especially the fine particle fraction.

During the 1997 fire and smoke haze episode which lasted from July to November, the smoke haze layer covered an area of up to 10 million km^2 from the eastern coast of India to the Pacific, east of New Guinea (Nakajima et al., 1999). At Palangkaraya in Kalimantan and Jambi on Sumatra, both located close to vegetation fires in 1997, up to 4000 μg/m^3 total suspended particulate matter was measured (Heil and Goldammer, 2001), exceeding the Indonesian national ambient air quality standard by a factor of 15. For comparison: the current air quality standards of the European Union allow a maximum PM10 (particulate matter with diameters below 10 μm) concentration of 50 μg/m^3 as a daily average not to be exceeded more than seven times per year. Maximum particulate matter concentrations at Pekanbaru reached 2000 μg/m^3 during September 1997. In Kuching, on Borneo, Malaysia ambient particle concentration rose up to 1000 μg/m^3 and up to 400 μg/m^3 at Petaling Jaya on Peninsula Malaysia (Figure 5). Strong transboundary smoke haze periods took place also in earlier El Niño years, e.g. in the Malaysian Klang Valley region in 1991 and 1994 when particulate matter concentrations exceeded the ambient air quality standard by a factor of two (Soleiman et al., 2003).

The quality of daily life is significantly limited during the fire-induced smoke periods in Indonesia and the adjacent countries. People suffer from respiratory and heart disorder, asthmatic reactions, lung ailments, severe nosebleeds, eye irritations, skin rashes and other allergies caused by the increase of fine particulate matter in the air. Repeated haze episodes will most probably increase the overall susceptibility of the population to

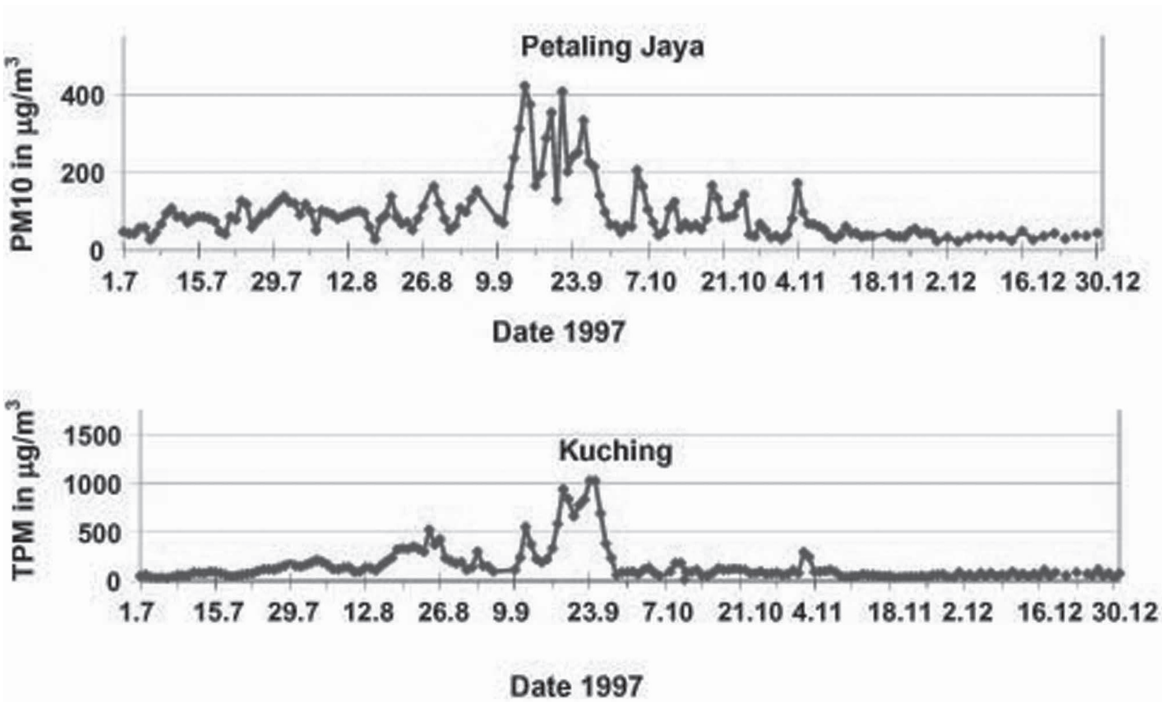

Figure 5: Observed ambient particle concentrations during the second half of 1997 at Petaling Jaya (3.06°N, 101.39°E) on Peninsular Malaysia and Kuching (1.48°N, 110.30°E) on Borneo, Malaysia as shown in Langmann and Heil (2004). (PM10: Particulate matter with diameter less than 10 μm, TPM: Total particulate matter, ratio PM10/TPM ~80%). Reproduced by permission of Copernicus Publications.

experience chronic haze related health impacts (Brauer, 1997; WHO 1998). Most people do not have any possibility to escape the smoke as many homes and schools in the tropics don't have windows, and those that do often are not air-conditioned. Moreover, large parts of the population cannot afford to refrain from outdoor work. People are advised to wear masks, but those, which offer protection against small particles, are often well beyond the people's budgets. The scarcity of air quality monitoring data in Indonesia strongly limits an assessment of fire-related health impacts. Indonesia, in contrast to its neighbouring countries, has no countrywide real-time air quality monitoring network available and particulate matter measurement data are of low temporal and spatial resolution and of uncertain quality (Heil and Goldammer, 2001). Due to the tremendous reduction of visibility (sometimes down to a few metres), transport and tourism also decline during the smoke periods in Indonesia, Singapore and Malaysia. Flights are cancelled or experience delays and episodically, air ports have to be closed. Shipping in the Straits of Malacca may also be considerably affected during the smoke haze periods.

Animals also suffer respiratory ailments from the haze and may be forced to leave the forests to escape the fires and search for food. This acute life-threatening situation together with the long-term destruction of forests, the usual habitats of wildlife (e.g. elephants, tiger, rhinoceros, tapirs) increased the number of reports of conflicts between wildlife and humans (Nyhus and Tilson, 2004).

Climate Impacts

The release of trace gases and aerosols from the forest and peat fires in Indonesia affects climate on both regional and global scales.

The particulate matter emissions from the Indonesian forest and peat fires lead to direct (scattering and absorption of solar and terrestrial radiation) (Podgorny et al., 2003) and indirect (influencing cloud microphysical processes) (Rosenfeld and Lensky, 1998) modifications of the radiative balance of the atmosphere. The direct aerosol effect depends on the chemical composition, the hygroscopicity, size distribution and the resulting optical properties of the aerosol. It leads to a reduction of solar radiation reaching the Earth surface, thereby also reducing surface temperatures and influencing crop yields. During the strong El Niño event in 1997, for example, the Indonesian smoke-haze aerosol reduced the seasonal average solar radiation absorbed by the equatorial Indian Ocean by 30–60 W m^{-2} (Podgorny et al., 2003). Close to the fires, the surface radiative forcing even exceeds 150 W m^{-2} (Duncan et al., 2003) in 1997 and in 2006 (Ott et al., 2010).

The indirect effect is related to the cloud droplet spectrum. In general more and smaller cloud droplets are formed if more aerosols are available to act as cloud condensation nuclei. Thereby cloud albedo, cloud lifetime and precipitation formation is influenced (Kaufman and Fraser, 1997). The local effect near the fire aerosol source regions is a further suppression of precipitation. Therefore more water vapour stays in the atmosphere to form precipitation elsewhere thereby increasing the potential of floodings and erosion. With the tropics, in particular Indonesia, being the main centre of deep tropical convection, the modification of precipitation formation in deep convective clouds is of special importance since the release of latent heat—due to condensation of water vapour and fall out of rain from cumulus convection—is the most important source of available potential energy in the free troposphere driving global circulation (Nober et al., 2003).

The huge emissions from the 1997 fires in Indonesia represent 17% of the global yearly carbon emissions from the burning of fossil fuel according to the GFED3 dataset (van der Werf et al., 2010). Even though this is less than the maximum amount of 40% estimated by Page et al. (2002), it still represents a significant impact on global climate by the increase of atmospheric CO_2 contributing to global warming. Here it should be emphasised again that CO_2 emissions are released mainly from fires in peat areas, thereby representing the destruction of a long-term carbon storage where carbon has been accumulated over the last 5000 to 10,000 years (Rieley et al., 1995). Therefore peat fires represent a considerable disturbance of the global carbon cycle which is different to CO_2 released from agricultural, grassland and partly even forest fires where the emissions can be balanced by carbon uptake during re-growth on annual or decadal timescales.

Indonesian vegetation fire emissions also increase column concentrations of photo-chemically active trace species such as O_3 or CO, in 1997 by more than 10 or 50%, respectively (Duncan et al., 2003; Ott et al., 2010). In particular an increase of CO in the upper troposphere-lower stratosphere region modifies the oxidising capacity of the atmosphere by reducing OH-radical concentration thereby increasing the atmospheric lifetime of climatically active trace gases e.g. CH_4, O_3, SO_2 and their cross tropopause transport.

The decline of coral reefs in the Indian Ocean west of Sumatra end of 1997 is also suggested to be caused by the Indonesian forest and peat fires (Abram et al., 2003). This effect together with satellite observations of chlorophyll (chlorophyll as a surrogate for phytoplankton) in surface sea water west of Sumatra during November and December 1997, which were the highest observed ones in this area until today (http://oceancolor.gsfc.nasa.gov/), highlight the potential of fire aerosols to fertilise the surface ocean thereby activating the biological CO_2 pump of the ocean (reduction of atmospheric CO_2 by phytoplankton formation and sinking of biological material into the deeper ocean thus generating a net effect on the carbon cycle). Ocean fertilisation is one of the topics discussed in geo-engineering techniques to counteract climate warming (Boyd, 2008). However, it is generally assumed that atmospheric deposition of aeolian dust dominates the external nutrient supply to the open ocean (Jickells et al., 2005), whereas the contribution of fire aerosols and volcanic ash (Langmann et al., 2010) has been largely underestimated so far.

Outlook

The development of Indonesian forest and peat fires causing large-scale smoke haze and CO_2 release into the atmosphere strongly depends on the prevailing meteorological conditions (Fuller and Murphy, 2006). Particulate matter emissions may accumulate in the absence of rainfall and persist in the atmosphere since wet deposition, the major removal process, is suppressed. Therefore, the dry conditions during El Niño years favour the development of severe smoke haze episodes with peat fire emissions mainly contributing to the development of severe transboundary air pollution episodes. In particular during such periods the pressure from the affected adjacent countries on the Indonesian government is growing. For mitigation measures and smoke haze management, fires from surface vegetation should be distinguished from peat fires. Prevention of fires in peat areas is of major importance (Heil et al., 2006). The government shall provide permissions for large scale land clearing activities by fire only in agreement with the meteorological agency, who should be involved in planning burning permission to mitigate impacts from large scale smoke haze. Illegal logging and land clearing by fires need to be considerably reduced by improving the inspections of the compliance of regulations and laws. Seeding of clouds to generate rainfall to extinguish the fires is difficult. However the sustainable use of peat swamps or their renaturation by removing drainage canals may be a promising development for fire prevention (Wösten et al., 2008; Jaenicke et al., 2010).

However, there seems to be no important incentive to stop setting fires in Indonesia because current land use and conversion policies stimulate rather than prevent the use of fires. Furthermore, poor law enforcement and corruption hinders the implementation of the existing regulations related to forest protection and fire prevention (Schindler, 2000). Thus, until no fundamental changes of the political, economic and social conditions in Indonesia take place, the only factor that brings the fire situation under control every year is the shift of the weather: the beginning of the northern monsoon rains.

Acknowledgements

The availability of the GFED3 and corresponding area burned information is gratefully acknowledged as well as Brendan McCormick's comments on the manuscript.

References

Abram, N.J., Gagan, M.K., McCulloch, M.T., Chappell, J. and W.S. Hantoro (2003). Coral reef death during the 1997 Indian Ocean dipole linked to Indonesian wildfires. *Science*, **301:** 952-955.

Aldrian, E. and R.D. Susanto (2003). Identification of three dominant rainfall regions within Indonesia and their relationship to sea surface temperature. *Int. J. Clim.*, **23:** 1435-1452.

Andreae, M.O. and P. Merlet (2001). Emission of trace gases and aerosols from biomass burning. *Glob. Biogeochem. Cycl.*, **15:** 955-966.

Archard, F., Eva, H.D., Stibig, H.J., Mayaux, P., Gallego, J., Richards, T. and J.P. Malingreau (2002). Determination of deforestation rates of the World's humid tropical forests. *Science*, **297:** 999-1002.

Boehm, H.-D.V. and F. Siegert (2001). Ecological impact of the one million hectare rice project in central Kalimantan, Indonesia, using remote sensing and GIS. Proc. ACRS 2001 - 22nd Asian Conference on Remote Sensing, 5-9 November 2001, Singapore. Vol. 1.

Bowen, R.M., Bompard, J.M., Anderson, I.P., Guizol, P. and A. Gouyon (2000). Anthropogenic Fires in Indonesia: A View from Sumatra. *In:* Forest Fires and Regional Haze in South East Asia. Radoievic, M. and Eaton, R. (eds). Nova Science, New York, USA.

Boyd, P. (2008). Ranking geo-engineering schemes. *Nature Geoscience*, **1:** 722-724.

Brauer, M. (1997). Assessment of health implications of haze in Malaysia. Mission Report RS/97/0441 Rev.1, November 1997. WHO Regional Office for the Western Pacific, Manila.

Cochrane, M.A., Anderson, H.R., Ostro, B. et al. (1999). Positive feedbacks in the fire dynamics of closed canopy tropical forests. *Science*, **284:** 1832-1835.

Crutzen, P.J. and M.O. Andreae (1990). Biomass Burning in the Tropics: Impact on Atmospheric Chemistry and Biogeochemical Cycles. *Science*, **250:** 1669-1678.

Crutzen, P.J. and J. Lelieveld (2001). Human Impacts on Atmospheric Chemistry. *Annual Review of Earth and Planetary Sciences*, **29:** doi:10.1146/annurev.earth.29.1.17.

Duncan, B.N., Bey, I., Chin, M., Mickley, L.J., Fairlie, T.D., Martin, R.V. and H. Matsueda (2003). Indonesian wildfires of 1997: Impact on tropospheric chemistry. *J. Geophys. Res.*, **108:** doi:10.1029/2002JD003195.

FAO/UNESCO (2003). Digital soil map of the world and derived soil properties.

Field, R.D., van der Werf, G.R. and S.S.P. Shen (2009). Human amplification of drought-induced biomass burning in Indonesia. *Nature Geoscience*, **2:** doi:10.1038/NGEO443.

Fuller, D.O. and K. Murphy (2006). The Enso-fire dynamic in insular Southeast Asia. *Climatic Change*, **74:** 435-455.

FWI/GFW (2002). The State of the Forest: Indonesia. Forest Watch Indonesia, Bogor, Indonesia and Global Forest Watch, Washington DC.

Giglio, L., Randersson, J.T., van der Werf, G.R., Kasibhatla, P.S., Collatz, G.J., Morton, D.C. and R.S. DeFries (2010). Assessing variability and long-term trends in burned area by merging multiple satellite fire products. *Biogeosciences*, **7:** 1171-1186.

Goldammer, J.G. and C. Price (1998). Potential impacts of climate change in fire regimes in the tropics based on MAGICC and a GISS GCM-derived lightning model. *Climate Change*, **39:** 273-296.

Hannibal, L.W. (1950). Vegetation Map of Indonesia. Planning Department, Forest Service, Jakarta. *In:* Forest Policies in Indonesia: The Sustainable Development of Forest Lands. Volume 3. International Institute for Environment and Development and Government of Indonesia. Jakarta, Indonesia.

Heil, A. and J.G. Goldammer (2001). Smoke-haze pollution: A review of the 1997 episode in Southeast Asia. *Reg. Environ. Change*, **2:** 24-37.

Heil, A., Langmann, B. and E. Aldrian (2006). Indonesian peat and vegetation fire emissions: Study on factors influencing large-scale smoke haze pollution using a regional atmospheric chemistry model. *Mitig. Adapt. Strat. Glob. Change*, **12:** 113-133.

IPCC (Intergovernmental Panel on Climate Change) (2001). Climate Change 2001: The Scientific Basis. Cambridge, University Press, Cambridge, UK.

Jaenicke, J., Wösten, J.H.M., Budiman, A. and F. Siegert (2010). Planning hydrological restoration of peatlands in Indonesia to mitigate carbon dioxide emissions. *Mitig. Adapt. Strat. Glob. Change*, **16:** DOI: 10.1007/s11027-010-9214-5.

Jickells, T.D., An, Z.S., Andersen, K.K. et al. (2005). Global iron connections between desert dust, ocean biogeochemistry, and climate. *Science*, **308:** 67-71.

Kaufman, Y.J. and R.S. Fraser (1997). The effect of smoke particles on clouds and climate forcing. *Science*, **277:** 1636-1639.

Kinnaird, M.F., Sanderson, E.W., O'Brian, T.G., Wibisonso, H.T. and G. Woolmer (2003). Deforestation trends in a tropical landscape and implications for endangered large mammals. *Conservation Biology*, **17:** 245-257.

Langmann, B. and A. Heil (2004). Release and dispersion of vegetation and peat fire emissions in the atmosphere over Indonesia 1997/1998. *Atmos. Chem. Phys.*, **4:** 2145-2160.

Langmann, B., Duncan, B., Textor, C., Trentmann, J. and G.R. van der Werf (2009). Vegetation fire emissions and their impact on air pollution and climate. *Atmos. Environ.*, **43:** 107-116.

Langmann, B., Zaksek, K., Hort, M. and S. Duggen (2010). Volcanic ash as fertiliser for the surface ocean. *Atmos. Chem. Phys.*, **10:** 3891-3899.

Levine, J.S. (1999). The 1997 fires in Kalimantan and Sumatra, Indonesia: Gaseous and particulate emissions. *Geophys. Res. Lettr.*, **26:** 815-818.

Morrogh-Bernarda, H., Hussona, S., Page, S.E. and J.O. Rieley (2003). Population status of the Bornean orangutan (Pongo pygmaeus) in the Sebangau peat swamp forest, Central Kalimantan, Indonesia. *Biological Conservation*, **110:** 141-152.

Nakajima, T., Higurashi, A., Takeuchi, N. and J.R. Herman (1999). Satellite and ground-based study of optical properties of 1997 Indonesian forest fire aerosols. *Geophys. Res. Lettr.*, **26:** 2421-2424.

Nichol, J. (1997). Bioclimate impacts of the 1994 smoke haze events in Southeast Asia. *Atmos. Environ.*, **31:** 1209-1219.

Nober, F., Graf, H.-F. and D. Rosenfeld (2003). Sensitivity of the global circulation to the suppression of precipitation by anthropogenic aerosols. *Global Planet. Change*, **37:** 57-80.

Nyhus, P. and R. Tilson (2004). Agroforestry, elephants, and tiger: Balancing conservation theory and practice in human-dominated landscapes of Southeast Asia. *Agriculture, Ecosystems and Environment*, **104:** 87-97.

Olson, J.R., Baum, B.A., Cahoon, D.R. and J.H. Crawford (1999). Frequency and distribution of forest, savanna, and crop fires over tropical regions during PEM-Tropics A. *J. Geophys. Res.*, **104:** 5865-5876.

Ott, L., Duncan, B., Pawson, S., Colarco, P., Cin, M., Randles, C. Diehl, T. and E. Nielsen (2010). Influence of the 2006 Indonesian biomass burning aerosols on tropical dynamics studied with the GEOS-5 AGCM. *J. Geophys. Res.*, **115:** D14121, doi:10.1029/2009JD013181.

Page, S.E., Siegert, F., Rieley, J.O., Boehm, H.-D.V., Jaya, A. and S. Limin (2002). The amount of carbon released from peat and forest fires in Indonesia during 1997. *Nature*, **420:** 61-65.

Podgorny, I.A., Li, F. and V. Ramanathan (2003). Large aerosol radiative forcing due to the 1997 Indonesian Forest Fire. *Geophys. Res. Lettr.*, **30:** 281-284.

Reid, J.S., Koppmann, R., Eck, T.F. and D.P. Eleuterio (2005). A review of biomass burning emissions. Part II: Intensive physical properties of biomass burning particles. *Atmos. Chem. Phys.*, **5:** 799-825.

Rieley, J.O., Page, S.E. and G. Sieffermann (1995). Tropical peat swamp forests of Southeast Asia: Ecology and environmental importance. *Malaysian Journal of Tropical Geography*, **26:** 131-141.

Rieley, J.O. and S.E. Page (2005). Wise use of tropical peatland: Focus on southeast Asia. ALTERRA-Wageningen University and Research Centre and the EU INCO-STRAPEAT and RESTORPEAT Partnership. Report. ISBN 90327-0347-1, *www.restorpeat.alterra.*wur.nl/download/WUG.pdf.

Rosenfeld, D. and I.M. Lensky (1998). Satellite-Based Insights into Precipitation Formation Processes in Continental and Maritime Convective Clouds. *Bulletin of the American Meteorological Society*, **79:** 2457-2476.

Schindler, L. (2000). Fire in Indonesia and the Integrated Forest Fire Management Project – IFFM. IFFN No. **23:** 12-16.

Schultz, M.G., Heil, A., Hoelzemann, J.J., Spessa, A., Thonicke, K., Goldammer, J.G., Held, A.C. and J.M. Pereira (2008). Global Emissions from Vegetation Fires from 1960 to 2000. *Glob. Biogeochem. Cycl.*, **22:** GB2002, doi:10.1029/2007GB003031.

Siegert, F., Ruecker, G., Hinrichs, A. and A.A. Hoffmann (2001). Increased damage from fires in logged forests during droughts caused by El Niño. *Nature*, **414:** 437-440.

Stibig, H.-J., Beuchle, R. and F. Archard (2003). Mapping of the tropical forest cover of insular Southeast Asia from SPOT4-Vegetation images. *Int. J. Remote Sens.*, **24:** 3651-3662.

Soleiman, A., Othman, M., Shamah, A.A., Sulaiman, N.M. and M. Radojevic (2003). The occurrence of haze in Malaysia: A case study in an urban industrial area. *Pure and Applied Geophysics*, **160:** 221-238.

Suyanto, S., Applegate, G., Permana, R.P., Khususiyah, N. and I. Kurniawan (2004). The role of fire in changing land use and livelihoods in Riau-Sumatra. *Ecology and Society*, **9:** 15.

Usup, A., Takahashi, H. and S.H. Limin (2000). Aspect and mechanism of peat fire in tropical peat land: A case study in Central Kalimantan 1997. Proceedings of the International Symposium on Tropical Peatlands, Bogor, Indonesia, Hokkaido University and Indonesian Institute of Science.

Van der Werf, G.R., Randerson, J.T., Giglio, L., Collatz, G.J., Mu, M., Kasibhatla, P.S., Morton, D.C., DeFries, R.S., Lin, Y. and T.T. van Leeuwen (2010). Global fire emissions and the contribution of deforestation, savanna, forest, agricultural, and peat fires (1997-2009). *Atmos. Chem. Phys.*, **10:** 11707-11735.

WHO World Health Organisation (1998). Report on the biregional workshop on health impacts of haze-related air pollution, Kuala Lumpur, Malaysia, 1-4 June 1998. World Health Organisation, Kuala Lumpur, (WP)EHE(O)/ICP/EHH/004-E.

Wösten, J.H.M., Clymans, E., Page, S.E., Rieley, J.O. and S.H. Limin (2008). Peat-water interrelationships in a tropical peatland ecosystem in Southeast Asia. *Catena*, **73:** 212-224.

Zoltai, S.C., Morrissey, L.A., Livingston, G.P. and W.J. de Groot (1998). Effects of fires on carbon cycling in North American boreal Peatlands. *Environmental Reviews*, **6:** 13-24.

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