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INDONESIAN SMOKE INDUCED BY DROUGHT EVENTS (INSIDE)

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ABSTRACT

The INSIDE project (Indonesian Smoke Induced by Drought Episodes) within the Asia Pro Eco Program of the European Commission aims to determine the amount and distribution of smoke-haze in Indonesia and the adjacent countries generated from vegetation and peat fires, and the related implications for human health (e.g. respiratory diseases) and climate (droughts, floods, aerosol-cloud interactions, CO_2 release). The main goal of the project is to provide, optimise and apply a regional model tool for Indonesia.

Key Words: Indonesia, Regional Modeling, Smoke-haze, Climate Impacts

1. INTRODUCTION

In recent years, fire and smoke-haze occurrence increased in Indonesia by intentionally set land clearing fires and higher fire susceptibility of disturbed forests. Especially during El Niño years with prolonged droughts in Indonesia, the land clearing fires become uncontrolled wildfires and produce large amounts of gaseous and particulate emissions. Fires in drained peat swamps are of particular importance for the overall emission production as peat fires release up to several orders of magnitude more emissions per unit area burned than fires in surface vegetation. In addition, they are difficult to extinguish.

Within the Asia Pro Eco Program of the European Commission a new project called INSIDE (http://www.mpimet.mpg.de/~langmann.baerbel/INSIDE/index1_web.html) has been established. It aims to determine the amount and distribution of air pollution in Indonesia focusing on smoke-haze generated from vegetation and peat fires. The related implications for human health (e.g. respiratory diseases) and climate (e.g. droughts, floods, aerosol-cloud interactions) are investigated. Due to the sparse air quality monitoring in Indonesia our initiative with the country-wide determination of ambient air quality offers guide to local decision makers in protecting human health and planning future agricultural activities. The main activity of the project is to provide and apply an optimised regional climate-chemistry/aerosol model tool for Indonesia. A state of the art regional three dimensional chemistry-climate model called REMOTE (Regional Model with Tracer Extension, http://www.mpimet.mpg.de/~langmann.baerbel/REMOTE/remote1.html) (Langmann, 2000) is chosen as core model tool of the INSIDE project. The major activities of the INSIDE project are indicated as circles in Figure 1. These include an estimate for the gaseous and particulate matter emissions from vegetation and peat fires in Indonesia, the determination of secondary smoke aerosol formation and the smoke particle chemical composition and size distribution. As wet deposition is the major removal process of the atmospheric smoke particles, a new convective cloud scheme will be applied, which also offers the possibility to determine heavy precipitation probabilities in dependence on land use changes. Local Sea Surface Temperature (SST) is an other major factor driving rainfall variability in Indonesia; therefore coupled atmosphere-ocean simulations will be carried out.

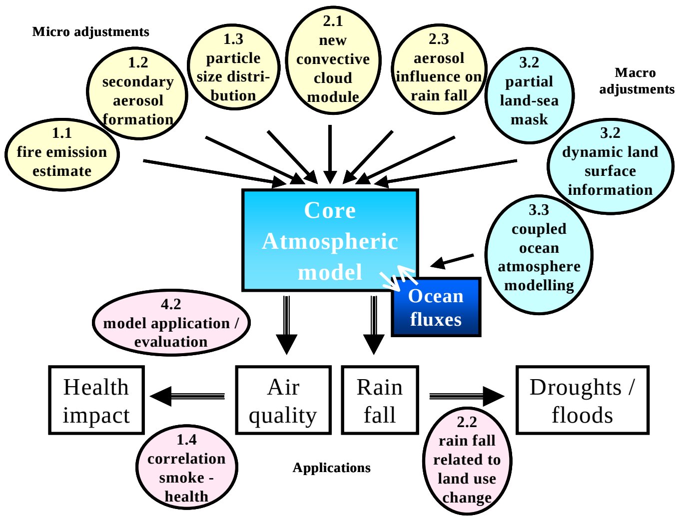

Figure 1. Major activities of the INSIDE project.

2. SELECTED PRELIMINARY RESULTS

First results of model simulations of the smoke-haze distributions in Indonesia during 1997/1998 showed that the model REMOTE is able to reproduce the spatial and temporal distribution of the smoke-haze (Langmann and Heil, 2004). An improvement of the methodology to estimate vegetation and peat fire emissions in Indonesia during 1997/1998 (Langmann and Heil, 2004) with respect to the spatial distribution of peat areas, emission factors and biomass load is given in Heil et al. (2005).

In addition to a reference model experiment (EXP_REF) carried out with REMOTE during 1997 (Figure 2), one simulation was carried out where emissions from peat fires were neglected (EXP_NOPEAT) and an other one, which investigates the influence of the meteorological conditions on smoke-haze dispersion by using 1996 meteorology (EXP_MET96). Simulation results illustrate the dominant role of peat fire emissions in creating severe trans-boundary air pollution episodes. When peat fires are excluded, ambient air quality standards are exceeded only in areas close to the main fires. Compared to normal years, El Niño conditions strongly reduce the removal of smoke particles from the atmosphere by wet deposition and favour the cross equatorial transport of fire emissions. A more detailed description is provided by Heil et al. (2005).

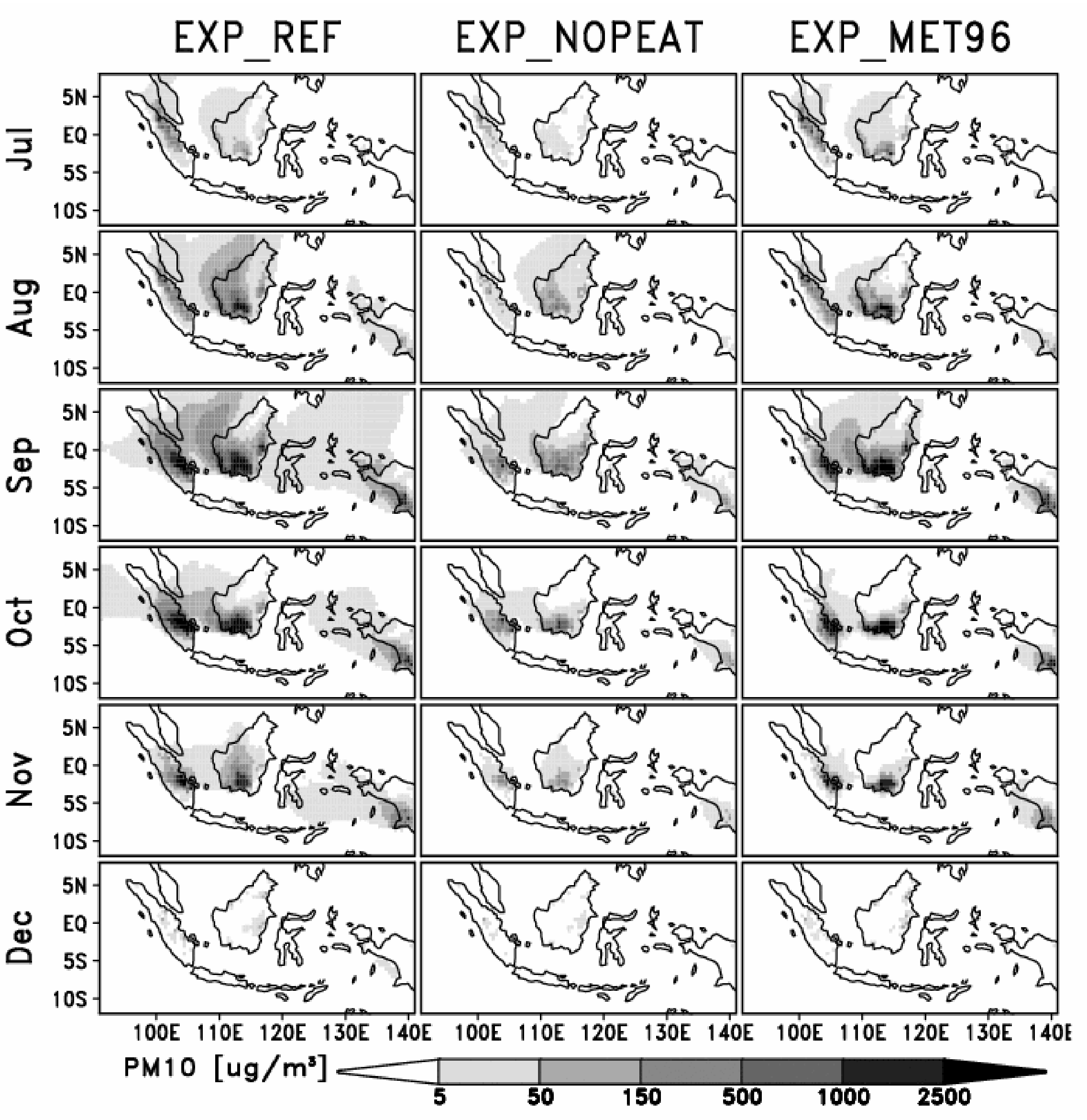

Figure 2. Monthly mean PM_{10} concentration during 1997 modelled with REMOTE for the lowest model layer for the scenario runs EXP_REF (left column), EXP_NOPEAT (middle column) and EXP_MET96 (right column).

For the period July 1997 to June 1998 the influence of smoke-haze aerosols on cloud properties and warm precipitation formation in Indonesia – the so called second indirect aerosol effect - is investigated with the REMOTE model (Langmann, 2005). The goal of this study is to analyse local to regional modifications of atmospheric properties over Indonesia, like a suppression of precipitation in smoke-haze regions (Rosenfeld, 1999) and a potential prolongation of smoke-haze episodes, or contrarily, increased precipitation lee side of the fires (Andreae et al., 2004) with potential heavy precipitation events.

The aerosol influence on warm precipitation formation is introduced into REMOTE by taking into account an additional dependency on cloud droplet number concentration in shallow and convective clouds, which in turn depends on the available aerosol concentration. The simulation results show a temporal and spatial redistribution of atmospheric moisture, precipitation and smoke-haze. Monthly mean values are difficult to interpret as they are the results of several overlapping effects. Daily total precipitation and precipitation from shallow clouds (stratiform precipitation) over Borneo during March 1998 is presented in Figure 3 - convective precipitation results from the difference of both. Figure 3 reveals that the aerosol-cloud INTERACTION simulation determines days with reduced as well as increased precipitation compared to the CONTROL simulation without aerosol-cloud interactions.

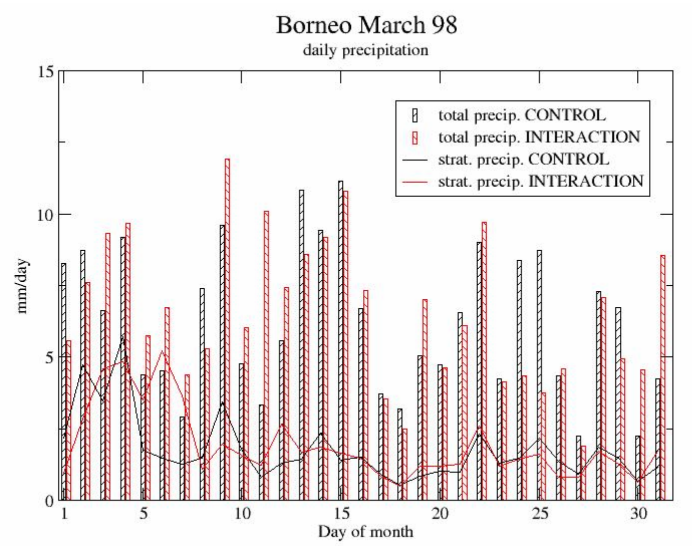

Figure 3. Daily precipitation over Borneo during March 1998 as determined by the REMOTE model simulations.

By separating precipitation decrease and increase events it becomes visible that precipitation decrease dominates over precipitation increase in the smoke-haze regions of Indonesia, and that both occur in the same areas and are compensating each other to a certain extent during one month. It becomes also visible that precipitation decrease events are accompanied by lower convective cloud top

heights, whereas precipitation increase events show higher convective cloud top heights and an increase in cloud water and ice content.
Compared with an observed event of reduced convective precipitation over Borneo on March 1, 1998 (Rosenfeld, 1999), the results of the REMOTE model experiments show a nearly complete suppression of more than 30 mm/6h in the same region affected by smoke-haze. Taking into account, that the model results are not only the results of aerosol-cloud interactions during the last few hours, but that they are also affected by preceding processes in other regions, the ability of the model to reproduce this single event can be regarded as pretty good. However, only very few observation data sets exist for the years 1997/1998 so that an overall evaluation of the presented model simulations on aerosol-cloud interactions is not possible.

3. CONCLUSION AND OUTLOOK

The particular meteorological conditions prevailing during El Niño years in Indonesia strongly aggravate smoke-haze dispersion to wider areas, including the densely populated areas of Northern Sumatra, Malaysian Peninsula and Singapore. Compared to normal years with similar fire emissions, El Niño conditions strongly reduce the removal of particles by wet deposition and favour cross equatorial transport of fire emissions. The study also illustrates the dominant role of peat fire emissions in creating severe transboundary air pollution episodes.

The model study on aerosol-cloud interactions adds an important contribution to the understanding of the non-linear aerosol-cloud effects in the atmosphere. In the smoke-haze regions in Indonesia the presented model results show events with decreased and increased precipitation considering the aerosol influence on warm precipitation formation. In total, the effects of precipitation suppression dominate pointing to a prolongation of smoke-haze periods due to the aerosol influence on clouds. Altogether, the model experiments suggest decreased convective activity due to aerosol cloud interactions accompanied by a small number of events with higher convective activity leading to modifications of the water, energy and trace species cycles in the atmosphere.

According to Hamid et al. (2001) who analysed the frequency of lightning events in Indonesia during 1998 and 1999, the number of convective storms decreases during El Niño years whereas the number of lightning events increases. These results indicate few but more intense convective storms with higher vertical extension and stronger glaciation during El Niño events and therefore point into the same direction as the REMOTE model results presented here. Andreae et al. (2004) described the coupled occurrences of precipitation suppression and increase during a field campaign in smoke-haze regions in Amazonian. Suppression of precipitation and the remaining atmospheric moisture leads to higher convective clouds which produce additional energy for higher vertical development due to the release of latent heat during the glaciation processes. Precipitation events with hail were only observed in smoke-haze regions by Andreae et al. (2004), under smoke free conditions hail showers did not occur. A model study of Khain et al. (2004) with a detailed two-dimensional atmospheric microphysical model reveals that suppression of precipitation due to aerosols induces an event with even stronger convection in the later course of the simulation which does not occur during an reference experiment under unpolluted atmospheric conditions. Again, these findings point into the same direction as the REMOTE model results. According to Andreae et al. (2004) the overall effect of the modification of total precipitation remains unknown until now.

Another important part of the INSIDE project is a reliable description of cumulus convection and associated tracer transport and precipitation formation within the REMOTE model as Indonesia represents the main center of deep tropical convection on the Earth. The standard convective cloud module of REMOTE is based on the scheme of Tiedtke (1989). It is one of the current cumulus convection parameterisations which are formulated as mass flux schemes (determination of the overall mass flux of all cumulus clouds in one grid column). This will be replaced by a new cloud field model (Nober and Graf, 2004) which determines for each grid column an explicit spectrum of different clouds. The information about the actual cumulus convection state in a grid column includes therefore the number of different cloud types. The degree to which part each cloud type participates in the whole cloud field is determined by the cloud field model.

First results from coupled ocean-atmosphere simulations with the MPI Ocean Model (Marsland et al., 2003) and REMOTE show a significant improvement for total precipitation, especially over the ocean (Aldrian, 2003) because intense ocean atmosphere interactions take place in Indonesia with the local SST being among the major factors that drive rainfall variability. Ongoing studies investigate how important these improvements are for the modelled distribution of smoke-haze, as wet deposition is the major loss process of particles from the atmosphere.

4. ACKNOWLEDEMENTS

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