Forest and Peat Fires in Indonesia: Influence of Climatic Factors on Fire Emissions, Smoke Dispersion, and Air Quality

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Motivation

Indonesian vegetation and peat fires have resulted in severe smoke-haze pollution episodes in the recent decades. During the most severe episode in 1997, an estimated 1.1 GtC were released by the fires. The particulate emissions caused exceedances of ambient air quality thresholds on a regional scale, with significant impacts on human health, visibility and economy (c.f. Heil & Goldammer 2001).

1997 was distinguished by prolonged drought associated with strong El-Niño conditions which increased the susceptibility of the vegetation to fire, enabling the clearing and conversion of more land. Many clearing fires escaped into drained peat swamps which release up to 50 times higher emissions per area than surface vegetation fires.

Climate Variability and Fire Emissions

Active fire count data for Indonesia (e.g. ATSR Fig 2a) show a strong positive correlation with the Multivariate ENSO index (MEI) (Fig 2b) with abnormally dry conditions during El-Niño providing the necessary preconditions for large-scale burning activities. An emission inventory for Indonesian fires has been developed by scaling ATSR fire counts to area burned statistics and by using a parameterized dependency of fire activity on MEI and deforestation rates. Vegetation and peat fire emissions are inventoried separately.

Sensitivity Experiments

Modeled ambient PM10 concentrations during the 1997 fire episode exceed ambient air quality standards (150 µg/m³ PM10 as daily average) across transboundary scales (Fig 5a, scenario EXP_REF, El Niño year 1997). In a scenario excluding peat fires (Fig 5a, EXP_NOPEAT), they are exceeded only in areas close to the main fires.

In years with normal meteorological conditions (Fig 5a, EXP_MET96, emissions same as EXP_REF, but 1996 meteorology), intermittent precipitation and associated wet deposition during the dry season are predicted to remove most of the particulate emissions close to the sources. Strongly reduced rainfall and generally stronger southeasterly winds during El-Niño years provide favourable conditions for larger smoke haze pollution (Fig 5a-c, 1997-1998 illustrates 1997 meteorology minus 1996 meteorology) (Heil et al. 2005).

Conclusions

- Climate variability associated with ENSO appears to largely control fire activity and emissions in Indonesia with dry El-Niño conditions providing the necessary preconditions for large-scale burning.
- Using an intermediate fire emission estimate equivalent to 1.1 GtC emitted in 1997 (range of 0.5 – 1.2 GtC), sensitivity experiments are presented showing how particulate emissions are realistically reproduced, indicating that the upper estimate reported by Page et al. (2002) is an overestimation.
- Fires in Indonesian peat areas play the predominant role in causing regional air pollution episodes.
- The particular meteorological conditions prevailing during an El-Niño year strongly aggravate smoke distribution to wider areas, including densely populated areas of northern Sumatra and Peninsular Malaysia including Singapore. Compared to normal years with similar fire emissions, El-Niño conditions strongly reduce removal of particles by wet deposition and favor the cross-equatorial transport of fire emissions.
- During El-Niño years, the risk of large-scale, sustained peat fires is much higher because the areas in Sumatra and Kalimantan that experience abnormal dryness contain exceptionally large portions of peat soil. Prevention of fires in peat areas, particularly during El-Niño years, is therefore of major importance to the mitigation of adverse health impacts from smoke haze pollution.
- Further model simulations will be performed to provide a lower estimate of the impact of fire-related air pollution on mortality and morbidity in the region.

Key Questions Addressed

Numerical modeling of fire-related smoke-haze episodes in Southeast Asia is important for both prediction and assessment of atmospheric impacts, especially when observational data are fragmentary, as is the case in Indonesia.

The key questions addressed in this study comprises:

- Is fire activity in Indonesia related to climate variability (ENSO)?
- To what extent do Indonesian vegetation and peat fires influence ambient air quality in the Southeast Asian region?
- What is the relative contribution of peat fire emissions?
- How do different meteorological conditions influence the dispersion of fire emissions to densely populated areas?
- What are the overall health impacts from increased smoke-haze pollution (morbidity and mortality)?

The study is part of the INSIDE (Indonesian Smoke induced by Drought Episodes) project within the EU-AsiaProEco Program (Fig1).

REMO Model

Regional Model (REMO) with Tracer Extension (http://www.mpimet.mpg.de/~langmann.baerbel/REMODE/remote1.html)

3 dimensional on-line atmosphere-chemistry model (Langmann, 2000)

Set-up for Indonesia:

- 0.5 deg horizontal resolution, 20 vertical layers
- ECHAM-4 physics ( Roeckner et al., 1998),
- forecast mode with 6 h ECMWF analysis data as initial and lateral boundary information
- due to high sulfur content of Indonesian fire aerosols (Gras et al., 1999), dry and wet deposition parameterisation as for sulfate
- injection height is lowest model layer

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