Smoke pollution in Equatorial Asia and implications for public health

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IGC6 2013

Harvard University

May 6-9, 2013

1. Land-use change is increasing fire activity

A major driver of biomass burning in Equatorial Asia is land-use change. Parts of this region are undergoing rapid land-use conversion to palm oil plantations, a process involving extensive burning.

Growing demand for biofuels across the region will likely increase the amount of land converted to palm oil plantation (Field *et al*., 2009).

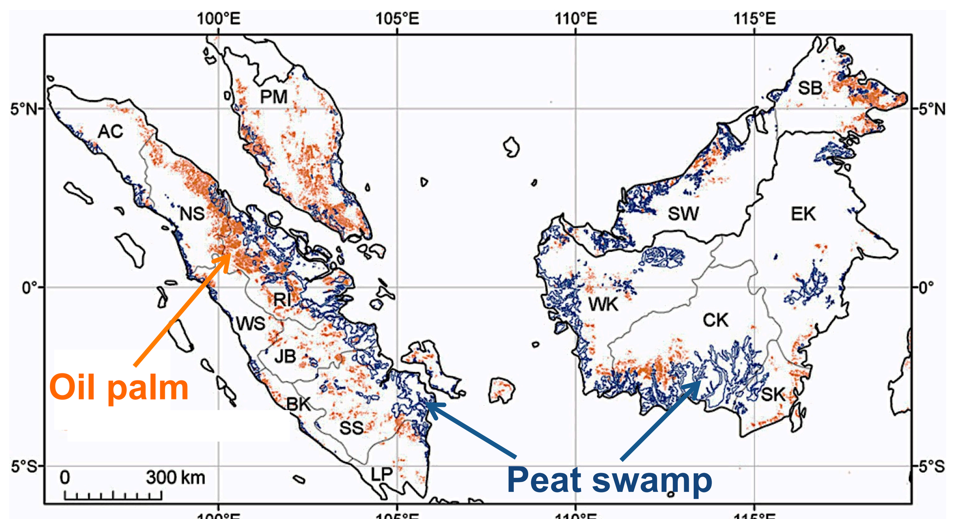


Figure 1. Distribution of oil palm plantations and tropical peatlands in the lowlands of Peninsular Malaysia, Borneo and Sumatra as of 2010 (Peninsular Malaysia; Sarawak; Sabah; Kalimantan; Aceh; Sumatra; Riau; Jambi; Bengkulu; Lampung).

Koh *et al*., 2011

The burning of peat swamp forests is of particular concern due to their high fuel loads and tendency to smolder for long periods of time.

Extensive land-use conversion to accommodate global markets is destroying unique biodiversity and poses a major health risk to nearby population centers.

Characterizing the magnitude and extent of the human health impacts associated with possible future pathways of land-use development will inform future policy decisions regarding best land-use practices in this region of the world.

2. Fire emissions strongly influenced by El Nino

In Equatorial Asia, the El Nino phase of the El Nino Southern Oscillation (ENSO) is linked to extended periods of drought lasting a few months to a year, particularly in areas undergoing land-use conversion to more fire-susceptible regimes such as the peatlands of Sumatra and Borneo (Page *et al*., 2009). Fire emissions in these areas have been observed to be as much as 30 times higher during El Nino compared to La Nina years (van der Werf *et al*., 2008).

ENSO also influences local and regional circulation patterns in Equatorial Asia, as well as deep convection and precipitation patterns relevant for particle transport and scavenging (Reid *et al*., 2012).

Other factors influencing the emission and transport of smoke in Equatorial Asia include the Indian Ocean Dipole (IOD), the migration of the Intertropical Convergence Zone (ITCZ), the Madden-Jullian Oscillation (MJO), tropical storms, and local land-sea breeze effects (Reid *et al*., 2012).

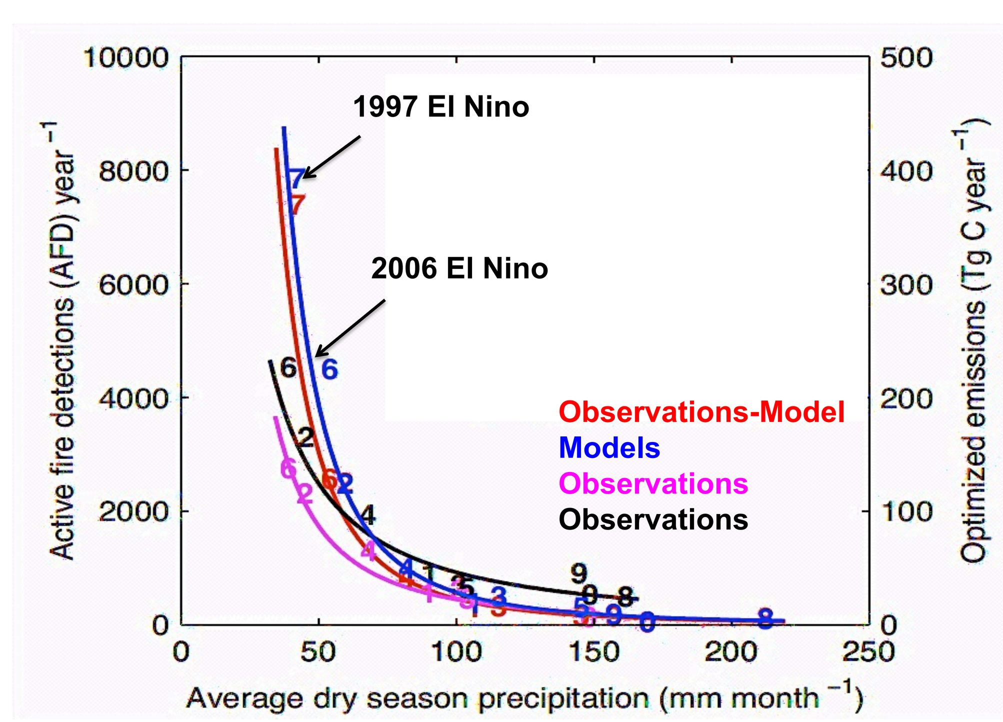


Figure 2. The non-linear relationship between dry season precipitation and fire emissions in Equatorial Asia

van der Werf *et al*., 2008

In order to capture the combined influence of the many processes driving interannual and intrannual variability in fire activity and meteorology, this work will examine patterns of smoke transport across multiple years (2005-2010) at a high spatial resolution.

3. Using GEOS-Chem to interpret satellite data

Direct air quality measurements from aircraft and surface stations in Equatorial Asia are nearly non-existent. Satellite observations offer a unique and so far under-exploited resource to quantify the transport of smoke pollution by providing continuous coverage of the Equatorial Asia region with high spatial density.

However, satellites often encounter limitations from retrieval errors, poor vertical resolution, and cloud interferences and therefore require a platform such as a global chemical transport model to connect the observations made from space to the surface concentrations relevant for human health.

Satellite Data

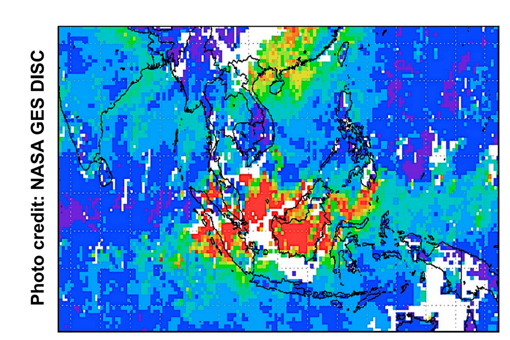
Provides global, near-daily measurements of atmospheric composition at high spatial resolution

Needs: Sensitivity to the surface, supplemental coverage for missing data

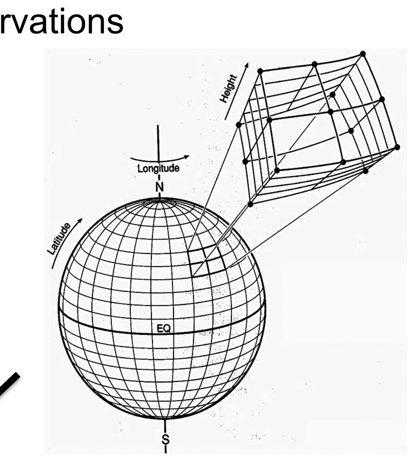
GEOS-Chem

Simulates global, 3-D tropospheric chemistry at high spatial and temporal resolution

Needs: Validation against observations



Aerosol optical depth for October 2006



Realistic surface concentrations

We will simulate smoke transport during the dry season (July-November) for 2005-2010. Preliminary results from the 2005 and 2006 burning seasons show an overestimate in modeled aerosol optical depth over burning regions but an underestimate of the plume extent when compared to observations from both the MODIS (below) and MISR (not shown) instruments.

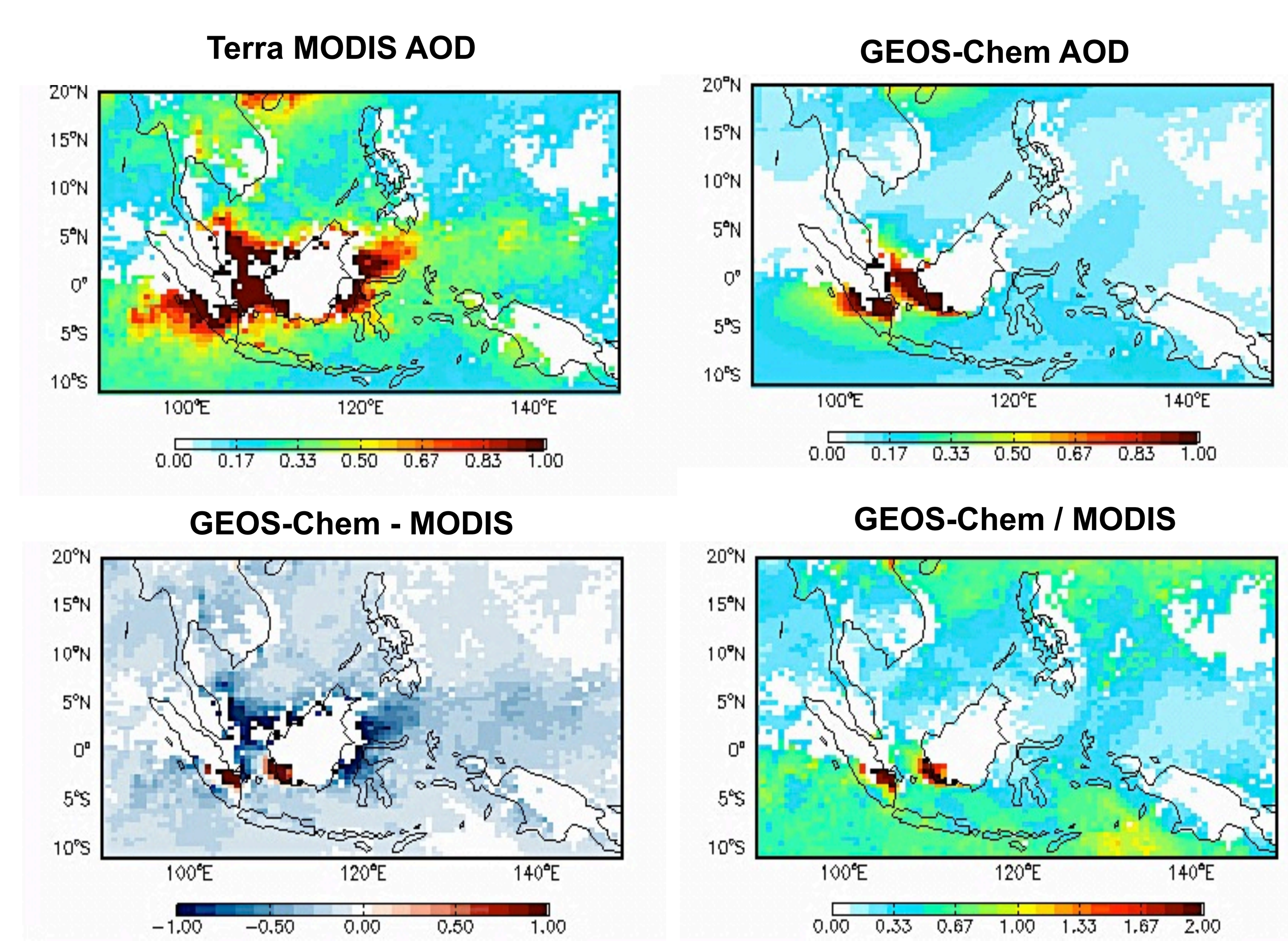


Figure 3. Comparison of GEOS-Chem and MODIS aerosol optical depth (AOD) for October 2006. GEOS-Chem appears to underestimate the spatial extent of the smoke plume but overestimate aerosol loading over source regions.

4. Implications for human health

Biomass burning poses a grave human health risk through emissions of aerosols and precursors for near-surface ozone (Langmann *et al*., 2009). Aerosols and ozone are both harmful respiratory irritants that increase morbidity and mortality rates in exposed populations.

Transport of smoke pollution to the high-density population centers of Equatorial Asia is of concern but the magnitude of the associated health effects is uncertain (Johnston *et al*., 2012).

Preliminary results show monthly average enhancements in surface $PM_{2.5}$ concentrations during the 2006 El Nino event of more than 30 μg/m^3 . These values are high compared to the World Health Organization 24-hour and annual guidelines of 25 μg/m^3 and 10 μg/m^3.

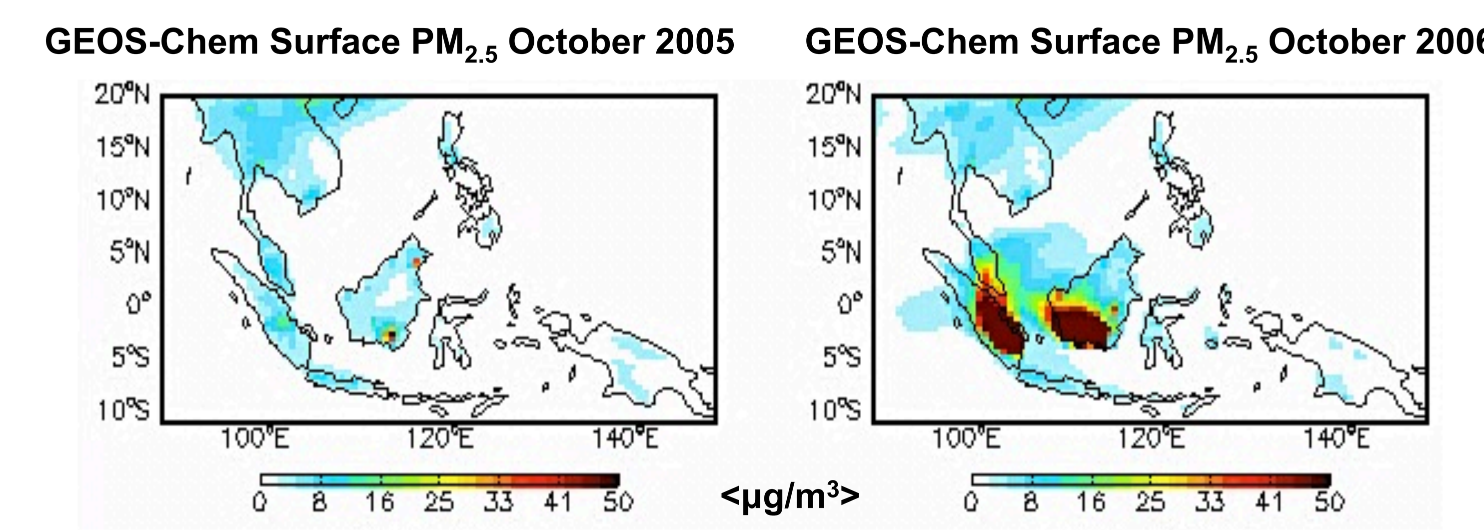


Figure 4. Surface $PM_{2.5}$ concentrations for 2005 and 2006. The 2006 dry season shows large increases in surface $PM_{2.5}$ compared to 2005.

Quantifying the contribution of fire emissions and transport to human health endpoints downwind will help establish land-use change as an issue of transnational importance and will aid in the development of a framework for assessing the impacts of land-use change on the regional scale.

5. Next steps

- Investigate influence of applying 3-hourly (instead of daily) fire emissions on transport of smoke in GEOS-Chem
- Evaluate consistency of parameterized aerosol optical properties in GEOS-Chem with observations of peat smoke
- Characterize influence of different planetary boundary layer and convective mixing schemes on smoke transport in GEOS-Chem

6. References

Johnston *et al.* (2012). Estimated global morality attributable to smoke from landscape fires. *Environmental health perspectives, 120*(5), 695.

Field, R. D., G. R. van der Werf, and S. S. Shen. (2009). Human amplification of drought-induced biomass burning in Indonesia since 1960. *Nature Geosci., 2*(3), 185-188.

Koh, L. P., Miettinen, J., Liew, S. C., and Ghazoul, J. (2011). Remotely sensed evidence of tropical peatland conversion to oil palm. *PNAS, 108*(12), 5127-5132.

Langmann, B., B. Duncan, C. Textor, J. Trentmann, and G. R. van der Werf. (2009). Vegetation fire emissions and their impact on air pollution and climate. *Atmos. Env., 43*(1), 107-116.

Page, S., *et al.* (2009). Tropical peatland fires in Southeast Asia. *Tropical Fire Ecology*, 263-287.

Reid, J. S., *et al.* (2012). Multi-scale meteorological conceptual analysis of observed active fire hotspot activity and smoke optical depth in the Maritime Continent. *Atmos. Chem. Phys., 12*, 2117-2147.

van der Werf, G. R., *et al.* (2008). Climate regulation of fire emissions and deforestation in equatorial Asia. *PNAS, 105*(51), 20350-20355.