Exploring Land-Cover/Land-Use Change and Regional Aerosol Composition and Concentration in Mainland Southeast Asia

N. Xiao[1], D.K. Munroe[1], C.A. Calder[2], T. Shi[2], C.Q. Lam[2], D. Li[1], S. Wolfinbarger[1]
[1]Department of Geography; [2]Department of Statistics; The Ohio State University, Columbus, OH

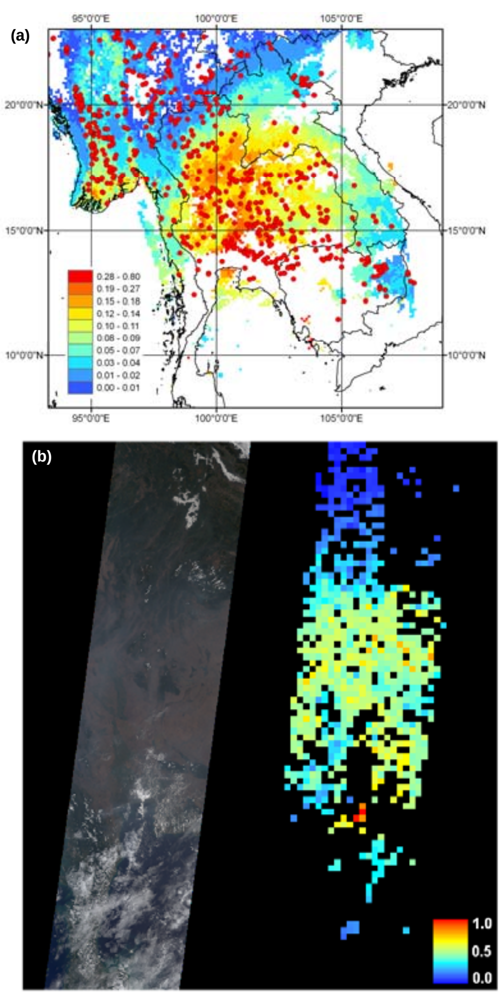
Motivation

Much research to date regarding the environmental consequences of land-cover/land-use change (LCLUC) has focused on the relationship between LCLUC and the carbon cycle (for a summary, see Houghton et al., [2004]). One component of the LCLUC/carbon cycle relationship that is not well understood is the process by which LCLUC affects aerosol distributions. The burning of biomass releases significant amounts of carbonaceous aerosols which may have negative human health impacts and could affect the radiation budget and climate, both directly and indirectly.

Due to the spatial and temporal variability of atmospheric transport patterns, local LCLUC can result in changes in regional aerosol distributions. More precise knowledge regarding the association between biomass burning and aerosols is needed in order to assess the impact of local LCLUC events on regional aerosol concentrations.

In this research, we will explore the relative effects of biomass burning (BB) in mainland Southeast Asia on the levels of carbonaceous aerosols within the region, directly accounting for the spatial structure of the biomass burning-aerosol relationship given air transport patterns.

Figure 1. Study area with fire occurrences and aerosol optical depth, January 30, 2004



Research Objectives

We propose a process-based statistical framework to model the relationship between biomass burning, aerosols and atmospheric circulation.

We hypothesize that (1) the associations between local biomass burning events and regional aerosol patterns can be identified by modeling the joint behavior of this system using a spatio-temporal statistical model with a covariance structure that is a function of "atmospheric distance"; *i.e.*, a distance metric that respects the circulatory patterns in the atmosphere; and (2) the relative effect of fire events can be identified by statistically examining the correspondence of these events compared to an observed underlying structure of carbonaceous aerosols also influenced by other activities such as industrial pollution.

The proposed research has four specific objectives. These are:

- To develop a hierarchical Bayesian framework to study the association between biomass burning and regional carbonaceous aerosol concentrations that incorporates a process-based description of aerosol transport over space and time;
- To quantify explicitly the uncertainty involved in the relationship between biomass burning and regional aerosols, given available data and the nature of complex, circulatory atmospheric transport patterns;
- To contribute to the understanding of the implications of current land-use changes in Southeast Asia given the measured effects of biomass burning in the last 5 years on regional aerosol concentrations; and
- To conduct scenario and sensitivity analyses at a regional level that advance the understanding of the implications of biomass burning.

Methods

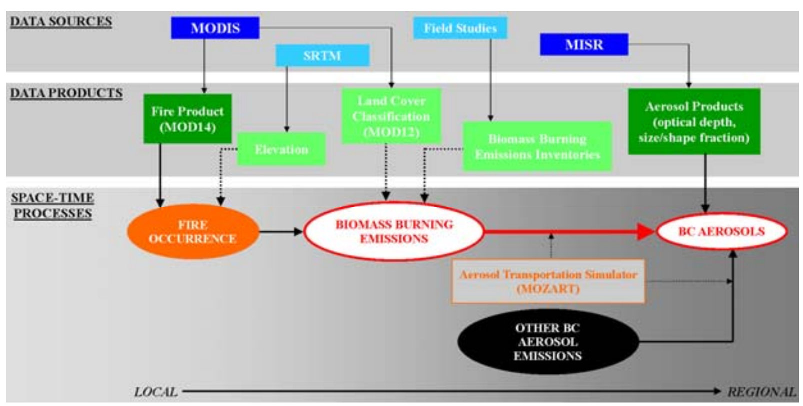
The key contribution of our research will be to develop a comprehensive statistical framework for analyzing the association between fire occurrences, biomass burning and the resulting spatial-temporal distribution of carbonaceous aerosols.

A process-based hierarchical Bayesian model allows us to integrate:

- Estimates from remotely-sensed data on aerosol distributions and fire occurrences;
- Ancillary data: land cover, rainfall, population density, and topography; and
- Numerical weather simulations describing atmospheric transport processes from which to identify the space-time covariance across pixels as a function of atmospheric distance.

Model components

- MODIS product "Fire and Thermal Anomalies": the center point of a 1km resolution pixel where a fire has occurred (Justice et al. , 2002)
- MISR products for aerosol composition: 17.6 km resolution optical depth, size and shape of aerosols, Angstrom component and single-scattering albedo (Diner et al. 1998)
- Model for Ozone And Related chemical Tracers (MOZART): atmospheric transport model, in conjunction with colleagues at the National Center for Atmospheric Research (NCAR)



Data Sources

MISR Level 1B2 Terrain Radiances; MISR Level 2 Aerosol Parameters; MODIS/AQUA AEROSOL 5-MIN L2 SWATH 10KM; MODIS 14 Land Cover Product (Land Cover 1: IGBP Classification; aggregated by authors); Shuttle Radar Topography Mission (SRTM) elevation data.

References

Diner, D., Beckert, J., Reilly, T., Bruegge, C., Conel, J., Kahn, R., Martonchik, J., Ackerman, T., Davies, R., Gerstl, S., Gordon, H., Müller, J.-P., Mynei, R., Seller, R., Pinty, B. and Verstraete, M. (1998). Multi-angle Imaging SpectroRadiometer (MISR) description and experiment overview. *IEEE Transactions on Geoscience and Remote Sensing*, 34, 4, 1072-1087.
Houghton, J.T., Ding, Y., Griggs, D.J., Nouguer, M., van der Linden, P.J., Dai, X., Maskell, K., and Johnson, C.A. (2001). Climate change 2001: the scientific basis. The third assessment report of Working Group I of the Intergovernmental Panel on Climate Change (IPCC)." Technical report, World Meteorological Organization and the United Nations Environment Programme, Geneva, Switzerland.
Justice, C.O., Kendall, J.D., Dowyt, P.R., and Scholes, R.J. (2002). The MODIS fire products. *Remote Sensing of Environment*, 83, 244-262.

Acknowledgements

This research was funded by NASA Research Opportunities for Space and Earth Science (ROSES-2005) Land-Cover/Land-Use Change Program Award # NNG06GD31G. Thanks to Jeff Fox and John Vogler at the East-West Center for ancillary data.

Project Outcomes and Deliverables

The Bayesian hierarchical statistical framework will allow us to address the following:

- The identification of the emissions sources driving regional aerosol patterns (*i.e.*, the relative contribution of varying anthropogenic processes);
- Assessment of the likely consequences of future LCLUC; and
- The determination of future aerosol patterns under a variety of different scenarios.

Biomass-burning aerosols measurements and classification schemes

With a successfully fitted model, we can derive:

- Estimates of the total contribution of biomass-burning aerosols from each fire to the spatial structure of pollution aerosols;
- The total amount of increase in biomass-burning aerosols associated with each land cover class; and
- The spatial-temporal properties of pollution within the study region

Scenario building

We will employ the statistical model as a simulator to forecast

- The spatial distribution of biomass-burning aerosols over time; and
- The likely changes in this distribution effected by policy changes.

Finally, we will develop a set of visualization tools to enable a user to explore these relationships by selecting model input, particular scenarios of interest, and display model output.

Progress

Developing Java-based applications to search, retrieve, modify and display MODIS and MISR data, as an initial step toward an interactive web-based application to support regional scale studies; and
Visualization and exploratory data analysis of the associations between fires, elevation, land cover, and aerosols.

Figure 2. Trend of associations between fires and aerosol concentration. (a) optical depth; (b) aerosol fractions.