Modeling Regional Air Quality Impacts from Indonesian Biomass Burning

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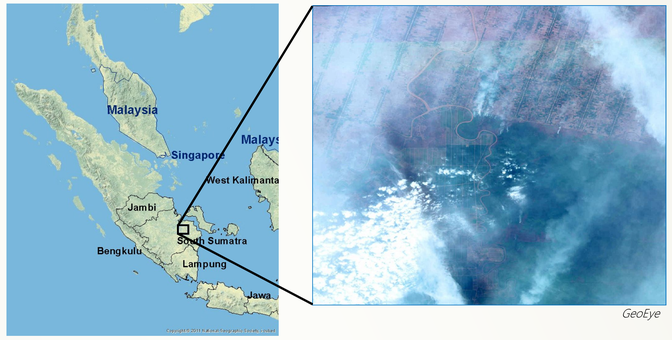
Introduction

Motivation

Smoke from wildfires in Indonesia has raised visibility and health concerns across southeastern Asia since the 1970s (Field et al., 2009). Land-clearing fires often burn out of control due to dry and windy El Niño conditions, burning millions of hectares and releasing significant amounts of greenhouse gases and particulate matter into the air (Applegate et al., 2001). These pollutants can have serious health impacts on the people of Indonesia.



Smoke from wildfires impacts part of South Sumatra on September 27, 2011.

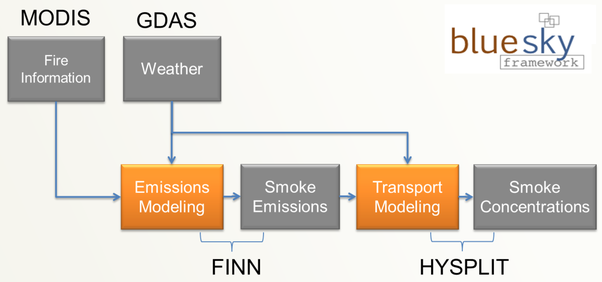
Predictive modeling of smoke is important for informing the public of high-risk days to limit exposure. This is particularly necessary in Indonesia, where air quality monitoring stations are sparse (Heil et al., 2007).

Goal

This study demonstrates how the USDA Forest Service's BlueSky Framework can be used to model emissions and smoke impacts from Indonesia's wildfires. In the past, the BlueSky Framework has been used for emissions modeling within North America alone; this effort demonstrates its international applicability.

The BlueSky Framework

The BlueSky Framework is a modeling architecture that links weather and fire data with state-of-the-science models to predict fire emissions and smoke transport (Larkin et al., 2009). The BlueSky Framework integrates multiple scientific models within each step of the smoke modeling chain, giving users the flexibility of choosing which models to use. This study uses the Fire INventory from NCAR (FINN) (Wiedinmyer et al., 2011) for emissions modeling, and the Hybrid Single Particle Lagrangian Integrated Trajectory model (HYSPLIT) for dispersion and transport modeling.

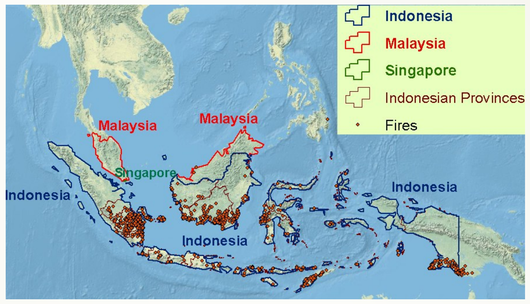


The smoke modeling chain shows the key steps involved in smoke prediction modeling. Gray boxes represent data, orange boxes represent modeling steps, and data sources and models are labeled in black.

Methods

Fire Information and Weather Data

Fire location data detected by the Moderate Resolution Imaging Spectroradiometer (MODIS) and meteorological data from the Global Data Assimilation System (GDAS) were input into the BlueSky Framework.



Location of fires across Indonesia on September 26-27, 2011, as detected by MODIS.

Emissions Modeling

The fire location data was passed to the FINN module within the BlueSky Framework. With its global database of emission factors and estimated fuel loadings, FINN predicted $PM_{2.5}$ emissions, E, as:

$$E = A_{(x,t)} * B_{(x)} * FB * ef_{pm2.5}$$

$A_{(x,t)}$ = area burned at location x and time t
$B_{(x)}$ = biomass loading at location x
FB = fraction of loaded biomass that burned
$ef_{pm2.5}$ = emission factor of $PM_{2.5}$

Transport Modeling

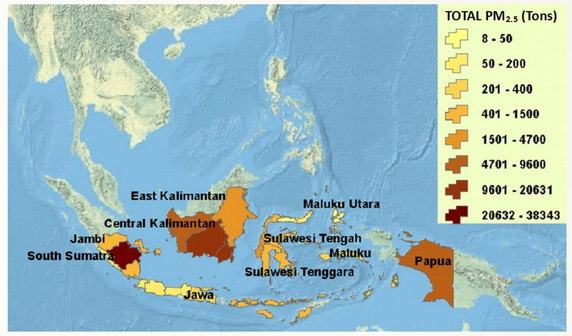
The BlueSky Framework passed the modeled emissions from FINN along with the GDAS weather data to HYSPLIT, which predicted dispersion and transport of the emitted $PM_{2.5}$ for the modeling period of September 26-27, 2011.

Results

Total $PM_{2.5}$ Emissions

The BlueSky Framework predicted the highest $PM_{2.5}$ emissions in South Sumatra, Central Kalimantan, and Papua. Indonesia's peat lands are located in these provinces. Peat fires smolder and release significant amounts of smoke.

The BlueSky Framework predicted a total of 93,518 tons of $PM_{2.5}$ emissions across Indonesia during the modeling period.



Total $PM_{2.5}$ emissions in tons by province during September 26-27, 2011, as predicted by the BlueSky Framework.

Dispersion and Transport

$PM_{2.5}$ concentrations in Central Kalimantan and South Sumatra at midnight on September 28, 2011, were predicted to be at unhealthy levels.

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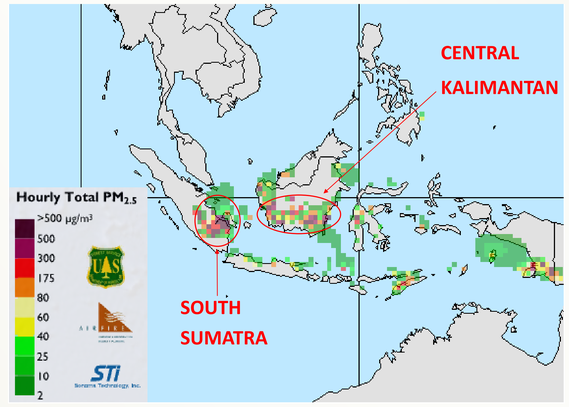
Smoke from forest fires set in Indonesia covers parts of Indonesia, Singapore, Malaysia (shown above), and Thailand.



Modeled $PM_{2.5}$ concentrations at midnight on September 28, 2011. Both Central Kalimantan and South Sumatra were predicted to have high levels of $PM_{2.5}$.

Conclusions

- South Sumatra and Central Kalimantan had the highest modeled total emissions of $PM_{2.5}$. Khezri and Webster (2012) confirm that, of all Indonesian provinces, Sumatra and Kalimantan are most known for clearing land with fire. Furthermore, Indonesia's peat lands are concentrated in these provinces and southern Papua (Langmann and Heil, 2004), and smoldering peat fires produce large amounts of smoke.
- The models predicted unhealthy levels of $PM_{2.5}$ at midnight on September 28, 2011, in Sumatra and Kalimantan. Anecdotally, this is confirmed by news and online articles, as well as satellite images. An online article from PROFOR (a pro-forests organization), for example, states that the smoke in Indonesia impaired visibility so much such that motorists were urged to turn on their headlights (Dewees, 2011).
- This demonstration of the capabilities of the BlueSky Framework is the first of its kind. In the past, the BlueSky Framework has been used for emissions modeling in North America alone, but with the incorporation of FINN within the BlueSky Framework, it is now possible to perform emissions modeling for regions all over the world.

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Poster presented by Loayeh K. Jumbam (ljumbam@sonomatech.com) at the AGU Fall Meeting, December 3-7, 2012, San Francisco, CA (STI-5437).

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