# REMOTE SENSING AND FIRES – SUMMARY OF A JOINT NASA, NOAA AND EPA WORKSHOP

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## Introduction

This paper summarizes results and recommendations of a series of sessions on Remote Sensing (RS) and Fires conducted at the Joint US Environmental Protection Agency (US EPA) - National Aeronautics and Space Administration (NASA) - National Oceanic and Atmospheric Administration (NOAA) Technical Workshop on Remote Sensing, held in September 2004 in Chapel Hill, NC. The fire sessions discussed both ongoing uses and potential applications of remote sensing to support fire emissions estimation and included both presentations and discussions between wildland fire experts and experts in satellite-based remote sensing of pollutant transport, landscape characterization and forecasting. The discussions centered on fire detection, characterization of fire size, fuel type and fuel consumed, fire moisture, fire severity, direct RS-based estimates of fuel consumption & emissions (independent of traditional fire emission models), emissions / plume tracking and the need for new and improved sensors in future satellite platforms.

Fire emission estimates are needed for real time forecasting of fire plume impacts, both to alert the public of impending wildfire smoke impacts and also to help allocate requests for prescribed burning permits. Also, fire emission estimates are used in regional air quality planning studies, to support air regulatory programs.

Currently, fire emission estimates are prepared using fire emission models that rely on the following data: fire time, date, location and size, fuel type and condition, fire severity and emission factors per unit of fuel consumed. Fuel consumption and fire behavior are estimated within the fire emissions model. Emission estimates are done retrospectively with the exception of the Pacific NW, where the BlueSky system estimates the emissions in real time to support fire smoke forecasting and prescribed fires planning. There are many aspects of the fire emissions modeling system that can benefit from remote sensing, as discussed below. Much of this information exists but is either underutilized or not readily available; other important data may be available if appropriate research is directed at the problem.

## Fire Detection

Current ground-based datasets of fire occurrence (fire time, date & location) on Federal lands are incomplete, inconsistent and of indeterminate quality because the data collection efforts are field office-driven and are consolidated in a central location for only the larger wildfires (> 100 ac). Data for smaller wildfires, which could account for up to one-third of fire emissions in the southeastern US are not centrally consolidated. Likewise, information about prescribed fires is in local office records which is often not digitally stored and may be recorded using inconsistent criteria. Fire event databases for State, tribal or private land are usually not available.

Fire detection products are currently available that rely on pixel-by-pixel analysis of thermal signals from the MODIS and AVHRR IR instruments on AQUA, TERRA and GOES. However, these are not being used routinely for fire emissions characterization. One reason is the paucity of intercomparison studies between ground-reported fire events (& their reported size) with fire detection made by these remote sensing fire detection products.

The session participants recommend that the currently available fire detection products be evaluated so they can be defensibly integrated into operational fire emission estimates for fire forecasting. This evaluation should characterize the product's strengths and weaknesses, including e.g., regional performance differences, effect of cloud cover, temperature, fire size, fire duration, understory vs. crown fires. They also recommend that researchers continue to seek improvements to the current state-of-the-art techniques for using these instruments synergistically to detect fires and estimate the area burned. There is also interest in developing methods to detect smoldering fires. These emissions from these sources are significantly different from active, flaming fires to warrant research in this area.

Emissions modeling utilizing all available data sources will help lower the uncertainty in retrospective and forecast models. There exists a network of meteorological observations that can assist in fire emissions modeling. These include the NOAA Radiosonde database and NEXTRAD observations, which could be merged with coincident remote sensing measurements to improve the characterization of meteorological conditions in both time and space.

**Area Burned**
The area burned by a fire will likely rely on thermal signals from the MODIS, AVHRR IR instruments for real-time forecasting. However, air quality analysts routinely conduct baseline and future year projections of regional air quality to support planning and regulatory programs. These analyses must include accurate emission estimates for all relevant sources, including fires. Thus, retrospective analysis using remote sensing data may be useful to improve upon the initial estimates of area burned and burn severity that were obtained to support real time forecasting or permitting. The session participants recommend exploring the use of advanced RS technologies (e.g., SAR interferometry, optical polarimetry) to improve estimates of area burned.

**Fuel Type and Consumption**
Currently, fire emissions are estimated using fuel consumption and fire behavior models that rely on estimates of the amounts of fuel available and fuel characteristics including, e.g., vegetation type and the abundance and condition of accumulated fuels (size and moisture condition). These "default" fuel characteristics data are currently being refined and are at one km resolution. A five-year project (LANDFIRE) will improve resolution to 30 m resolution. Remote sensing Land Use Land - Characterization (LULC) products have been and are being used to produce these default maps. Further work is recommended to refine these default fuels characterization maps using RS. Also, the landscape is dynamic and fuels change constantly due to both man-made (prescribed fires and fuel bed treatments to reduce fire hazard) and natural (storms, drought, insect infestation, wildfires) alteration. Therefore, the session participants recommend research to examine the utility of RS tools to identify these alterations and to provide a basis for frequent updates these default maps to reflect changing fuel conditions.

**Fuel Moisture**
Fuel moisture estimates are currently made using climatologic models, coupled with a USFS/DOI land-based relative humidity & fuel temp network. The session participants recommend exploration of RS methods to determine if they can be correlated with data from the relative humidity and fuel temperature network to produce a better spatially resolved estimate of fuel moisture.

**Fire Severity**
Fire emission models rely on user-supplied estimation of the severity of the fire (i.e., whether the canopy was burned and qualitatively how much of the fuel was consumed) to guide the model's consumption estimates. The session participants recommend that researchers explore the development of "before & after" landscape indices using e.g., NEXRAD & the Haynes index to infer severity of fire.

**Emissions Model-independent Estimates of Fuel Consumption & Emissions**
Potentially, RS can be used to produce an estimate of fire emissions independent of fuel consumption and fire emission models. For example, fire radiant energy is currently measurable by RS. This can provide an estimate of heat released per unit area which can be coupled with the fuels maps to estimate fuel consumption per unit area directly. This fuel consumption per unit area can be combined with currently used emission factors (pollutant emitted per unit of fuel burned) to give a direct estimate of emissions. Also, aerosol optical depth (AOD) is a parameter derived from remote sensors. Although AOD cannot distinguish the aerosol concentration profile within the vertical column, (and thus cannot provide an estimate of ground-level pollutant concentrations), it can be used to derive a vertically integrated estimate of emissions through the total smoke column near the source.

The session participants recommend that traditional emission model-derived estimates of fire emissions and the model-independent estimates of emissions obtainable from RS (both fire radiant energy and AOD approaches) be intercompared and each approach evaluated to determine the appropriate ways to couple these independent estimates to yield an overall improvement in our fire emission estimates, both for use in fire AQ forecasting and in retrospective AQ planning analyses. They also recommend further research on remote sensing to vertically resolve and chemically characterize aerosols within the smoke column and also to derive ground-level concentration estimates for a suite of air pollutants.

**Plume Tracking**
Air quality models can and are being used to predict the path of fire plumes as they move toward population centers or other areas of concern. These estimates are used to gage how much prescribed burning is prudent on a given day and also to predict how a wildfire plume may impact populated areas. However, these estimates rely on transport models that sometimes have difficulty in rough terrain or where surface water or urban heat islands influence transport. Currently, RS is not used routinely in operational fire AQ forecasting systems and its use in research studies has been limited.

Satellites are currently able to estimate AOD and to identify plume outlines both visually and with remote chemical sensing. These fire products are either available or could be readily available and can be exploited to help improve real time estimates of where fire plumes are transported. Such information can be used to provide ongoing feedback to real time AQ model predictions and to make real time corrections to modeled estimates of the plume's path. This would make air quality index forecasts, health advisories and recommendations for activity curtailment by sensitive populations much more realistic and accurate. It would also provide a more accurate basis for 1) locating portable AQ monitors and 2) increasing sampling frequency of fixed-position monitors in the path of the plume. Also, such plume tracking can help in the evaluation of AQ models. These plume tracking products may need to be refined to optimize their benefit to fire emissions tracking and model evaluation.

**Sensors Planned For New Satellites**

A new satellite platform, CALIPSO, is being planned for launch in 2005. The session participants recommend establishing and maintaining a continuous dialogue among EPA, NASA & NOAA scientists on fire detection, area burned, fuel characterization and consumption, fuel moisture, fire severity, aerosol optical depth and plume tracking needs of the fire community so that optimal use can be made of instruments aboard current and future sensor platforms include both space-based and unmanned missions. For example, the data products from the upcoming launch of CALIPSO may meet some the fire emission information requirements. Dialog between instrument science and algorithm development teams and the user community will help in developing science products from CALIPSO that best fits with the needs of the fire emission research community. Several “wish-list” instrumentation needs were articulated, including: higher spatially-resolved thermal IR (ideally on a geospatial platform); AVHRR products to estimate area burned on a regional basis or at varying latitudes and identifying new sensors/strategies to estimate the vertical extent and chemical composition of plumes.