National Database for Calculating Fuel Available to Wildfires

PAGES 57–58

In recent years, wildfires have emerged as an important part of the global environment. Carbon released from fires during combustion alters the global carbon balance. Smoke emissions are a health hazard to nearby communities [*Wegesser et al.*, 2009], can impair air quality and visibility for hundreds of kilometers downwind (Interagency Modeling of Protected Visual Environments; http://vista.cira.colostate.edu/improve/Data/IMPROVE/improve_data.htm, 2004), and contribute substantially to the global aerosol budget [*van der Werf et al.*, 2006]. As understanding about fire as a global ecosystem process improves [*Bowman et al.*, 2009] and as more and more global fire databases are being built [*Giglio et al.*, 2009], wildfires are increasingly emerging as an important component of Earth system models, particularly those that involve emissions from fires and their effects on climate.

Currently, there are few resources available for estimating emissions from wildfires in real time, at subcontinental scales, in a spatially consistent manner. Local air quality and fire managers use fine-scale data and models to estimate smoke pollution and schedule prescribed fires that restore ecosystems to desired conditions. Similarly, there are global products, such as the Global Fire Emissions Database [*Giglio et al.*, 2008], that provide coarse-scale estimates (on the scale of 0.5°) of emissions from fires based on satellite products. Developing subcontinental-scale databases and applications in fire science requires a framework that uses both fine-scale and coarse-scale data with attention to minimizing extrapolation errors, while ensuring spatial consistency in outputs. Ideally, this needs some accounting for the geographic variability in fuels at finer scales (of the order of 30 meters to 1 kilometer).

Fuels comprise the live and dead biomass at a fire location. Low-intensity fires typically burn only grasses, other nonwoody vegetation, and plant litter and small twigs. In contrast, high-intensity fires can consume everything except tree boles, including tree crowns, shrubs, grasses, woody fuels, litter, and organic soils. The estimation of actual fuel amounts is likely the greatest source of uncertainty in calculating carbon release and other emissions from wildfires, particularly large fires that burn multiple vegetation types. To reduce this uncertainty, the Fuel Characteristic Classification System (FCCS; http://www.fs.fed.us/pnw/fera/fccs/) provides both a conceptual framework and a software tool for quantifying fuels over spatial domains from a few square meters to many square kilometers. FCCS and other products that calculate wildfire emissions on the basis of FCCS are freely available and are used by the U.S. Forest Service and other land management agencies to assess the potential for wildfires and their effects on landscapes.

FCCS: Estimating the Contribution of Wildfires to Carbon Emissions

Unlike fire behavior fuel models, whose purpose is to provide parameters useful for predicting fire behavior and fire spread, FCCS specifies vegetation composition and fuel loading across 16 categories of live and dead fuels, which are easily connected to remotely sensed vegetation types [*McKenzie et al.*, 2007]. These categories, or "fuel beds," were mapped into a spatially continuous classification of fuels, on the basis of the FCCS, for the continental United States and Alaska (Figure 1). Maps were created using vegetation types generated by the Landscape Fire and Resource Management Planning Tools project (http://www.landfire.gov) at both 30-meter and 1-kilometer resolution. Geographically specific rules were developed for associating each of these vegetation types with an FCCS fuel bed. The database is publicly available (http://www.fs.fed.us/pnw/fera/fccs/maps.shtml) and can be used in diverse modeling efforts from real-time carbon emission calculations for individual fires to continental-scale simulations of air quality.

The Wildland Fire Emissions Information System (WFEIS; http://wfeis.mtri.org/) is a publicly available Web-based tool for computing emissions from wildland fires anywhere in the continental United States or Alaska. Using 1-kilometer-square FCCS fuel maps as core spatial data, WFEIS provides access to current and recent (1980s) past fire perimeter maps from a variety of sources, overlays them on the fuel maps, and calculates fuel consumption and daily emissions with the Consume model (http://code.google.com/p/python-consume/). Besides tabular results, WFEIS produces multiple vector and raster formats. The system is built from open-source software following international standards developed by the Open Geospatial Consortium (http://www.opengeospatial.org/).

A principal use of WFEIS outputs is spatially explicit estimates, at regional scales, of the effects of fire on the carbon cycle [*French et al.*, 2011]. FCCS provides a
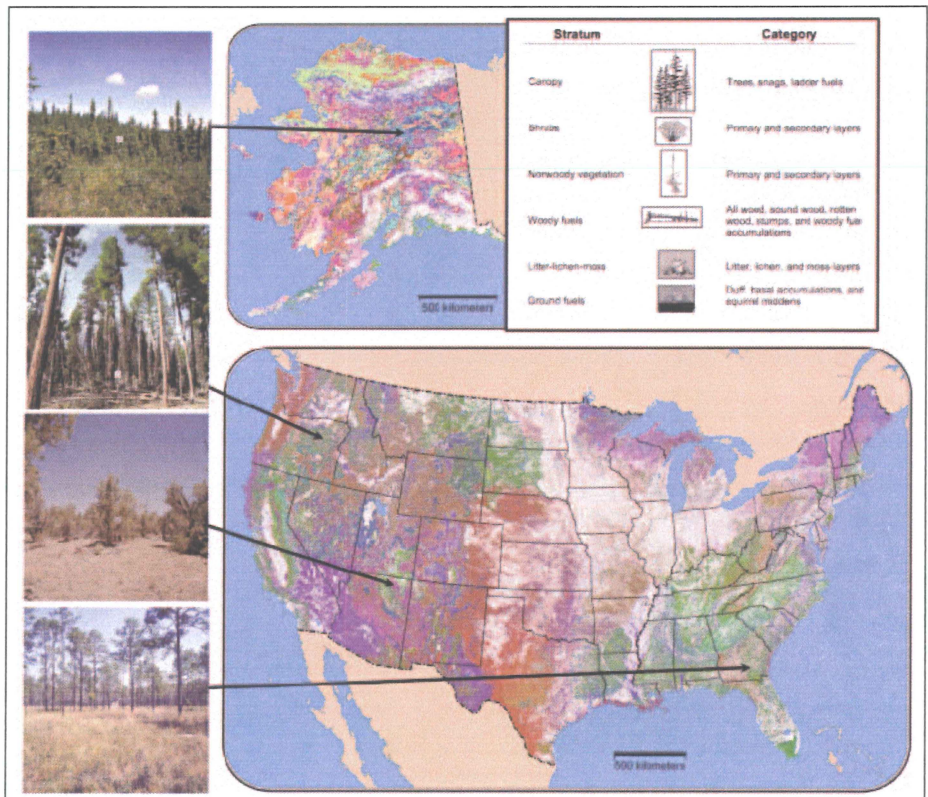

Fig. 1. Fuel Characteristic Classification System (FCCS) fuel bed maps for the continental United States and Alaska at 1-kilometer resolution. Each cell represents a "fuel bed," with up to six strata and 16 categories of fuels. There are more than 150 different fuel beds color-coded on the map, giving a picture of the diversity of fuels found throughout the United States. White areas represent locations with no fuels; these locations are either barren (desert, snow, rock, or ice), agriculture (crops are not part of the FCCS currently), or urban. Photos are of (top to bottom) Alaskan boreal black spruce forest, Pacific Northwest mixed conifer forest, Arizona pinyon-juniper woodland, and southeastern longleaf pine forest. Maps created by R. A. Norheim. Photos courtesy of the Digital Photo Series (http://depts.washington.edu/nwfire/dps/). Chart at top right shows the six strata and 16 categories of fuels (shrub and nonwoody layers are single categories) in the FCCS; not all fuel beds have all of the strata.

detailed accounting of the carbon content of fuels, and the proportional consumption of biomass in each fuel category (Figure 1) depends on both the fuel type (e.g., conifer versus deciduous forest) and environmental conditions such as fuel moisture and wind speed. Applications such as WFEIS that take advantage of the geographic variability of fuels captured by FCCS maps increase the accuracy of estimates of the contribution of wildfires to the carbon budget.

Other uses of FCCS map databases include emissions inventory, which involves responding to regulations requiring monitoring of pollutants from a variety of sources, including fires; air quality simulators, such as BlueSky [*Larkin et al.*, 2009], which links independent models of fire information, fuel loading, fire consumption, fire emissions, and smoke dispersion; and watershed-scale fire management when local fuel inventories are unavailable or of low quality [e.g., *Koziol et al.*, 2010].

Efficient Resource Management and Enhanced Basic Research

FCCS is used for both resource management and basic research that involves fire. Key users of data are fire management officers in U.S. national forests and regional-scale air quality modelers who incorporate fire emissions in their assessments. FCCS provides more detailed information on fuel characteristics than previous products, thereby enabling more accurate assessments of fire hazard and potential fire effects, at multiple spatial scales. Moreover, the database allows climate modelers the opportunity to assess how much fires in recent years have contributed to atmospheric carbon and aerosol loading. Planned future enhancements include a method for dynamically updating the fuel bed map, which may allow researchers to estimate how much a given future fire season might contribute to carbon and aerosol emissions. This will help illuminate the global consequences of future fires and enhance understanding of how wildfires will respond to and influence climate change.

References

Bowman, D. M. J. S., et al. (2009), Fire as an Earth system process, *Science*, *324*, 481–484, doi:10.1126/science.1163886.

French, N. H. F., et al. (2011), Model comparisons for estimating carbon emissions from North American wildland fire, *J. Geophys. Res.*, *116*, G00K05, doi:10.1029/2010JG001469.

Giglio, L., L. Giglio, G. R. van der Werf, J. T. Randerson, G. J. Collatz, P. Kasibhatla, D. C. Morton, and R. S. DeFries (2008), The Global Fire Emissions Database (GFED3) global burned area data set, *Eos Trans. AGU*, *89*(53), Fall Meet. Suppl, Abstract B31C-0307.

Giglio, L., T. Loboda, D. P. Roy, B. Quayle, and C. O. Justice (2009), An active-fire based burned area mapping algorithm for the MODIS sensor, *Remote Sens. Environ.*, *113*, 408–420, doi:10.1016/j.rse.2008.10.006.

Koziol, B. W., R. C. Owen, T. A. Erickson, and N. H. French (2010), Modeling particulate matter plumes from 2007 California wildland fires using a coupled emissions-transport system, Abstract NH41A-1476 presented at 2010 Fall Meeting, AGU, San Francisco, Calif., 13–17 Dec.

Larkin, N. K., S. M. O'Neill, R. Solomon, S. Raffuse, T. Strand, D. Sullivan, C. Krull, M. Rorig, J. Peterson, and S. A. Ferguson (2009), The BlueSky smoke modeling framework, *Int. J. Wildland Fire*, *18*, 906–920, doi:10.071/WF07086.

McKenzie, D., C. L. Raymond, L.-K. B. Kellogg, R. A. Norheim, A. G. Andreu, A. C. Bayard, K. E. Kopper, and E. Elman (2007), Mapping fuels at multiple scales: Landscape application of the Fuel Characteristic Classification System, *Can. J. For. Res.*, *37*, 2421–2437, doi:10.1139/X07-056.

van der Werf, G. R., J. T. Randerson, L. Giglio, G. J. Collatz, P. S. Kasibhatla, and A. F. Arellano Jr. (2006), Interannual variability in global biomass burning emissions from 1997 to 2004, *Atmos. Chem. Phys.*, *6*, 3423–3441, doi:10.5194/acp-6-3423-2006.

Wegesser, T. C., K. E. Pinkerton, and J. A. Last (2009), California wildfires of 2008: Coarse and fine particulate matter toxicity, *Environ. Health Perspect.*, *117*, 893–897, doi:10.1289/ehp.0800166.

—DONALD MCKENZIE, Pacific Wildland Fire Sciences Laboratory, U.S. Forest Service, Seattle, Wash.; E-mail: donaldmckenzie@fs.fed.us; NANCY H. F. FRENCH, Michigan Tech Research Institute, Michigan Technological University, Houghton; and ROGER D. OTTMAR, Pacific Wildland Fire Sciences Laboratory, U.S. Forest Service