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INTEGRATION OF WILDFIRE EMISSIONS INTO MODELS-3/CMAQ WITH THE PROTOTYPES: COMMUNITY SMOKE EMISSIONS MODELING SYSTEM (CSEM) AND BLUESKY

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1. INTRODUCTION

Forest Service research has developed a set of tools to estimate fuel consumption and resulting emissions from wildland fire. These two models, CONSUME (Ottmar et al., 1993) and EPM (Emissions Production Model, McKenzie et al., 2002 and Sandberg and Peterson, 1984) have formed the basis for virtually every fire emissions inventory developed to date. However, with the application of new regulatory tools such as Models -3/CMAQ (US EPA, 1999) and the Regional Modeling System for Aerosols and Deposition (REMSAD) (ICF Consulting, 2002; http://www.remsad.saintl.com) for regional air quality assessments and the use of linked meteorological and dispersion models, such as CALPUFF (Scire et al., 2000) for permitting and smoke management, new versions and adaptations of CONSUME and EPM are required.

This paper describes two efforts to develop appropriate emissions models for wildland burning. One effort, the Community Smoke Emissions Model (CSEM), is specifically designed to provide historical fire emissions estimates for use in CMAQ and REMSAD. It is based on coupling CONSUME and EPM and utilizing national GIS coverage for estimated fuels used by the National Fire Danger Rating System. The second effort, BlueSky, couples CONSUME and EPM with real-time fire activity reports for the northwestern US to obtain fire specific emission estimates. BlueSky integrates a high-resolution mesoscale meteorological model (MM5, Grell et al., 1994) with the EPM PM emission profiles and a dispersion model (CALPUFF) to generate real-time estimates and forecasts of smoke impacts for active smoke management programs. In the near future the BlueSky framework will also be running the CMAQ Eulerian grid model. While both emission model efforts rely upon EPM and CONSUME, the input data are from different sources, thus results from each of these fire emissions generators will be presented and compared as an initial indication of performance.

Seven general steps are common to any smoke emissions modeling, they are:

1. Read fire description information (including location and fire start time) from inventory file for each fire.
2. Determine the fuel loading for the fire.
3. Read and or calculate appropriate local meteorological data for the fire.
4. **Calculate total fuel consumption (based on the CONSUME model) for each fire.**
5. **Calculate CO, CO2, CH4, particulate and heat emissions (based on the EPM model) for each fire.**
6. Calculate the plume rise for each fire

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7. Integrate fire emissions into the modeling system.

The steps in bold are common to the two smoke emissions modeling systems discussed here. The other steps are unique to the specific application.

2. COMMUNITY SMOKE EMISSIONS MODEL (CSEM)

The Community Smoke Emissions Model involves a number of approximations in order to calculate emissions from historical databases. The current version addresses data files that will be used in regional scale applications (on the order of 36 km resolution) of CMAQ and REMSED. The following databases and datasets are utilized in this version:

1. *Fire description information*. Fire data will be read from fire inventory databases. There are a number of alternative databases available for this, however, it is felt that the most accurate, and reasonable for use is the GEOMAC database. This database includes regular GIS shape files available on a daily basis, since 2000 that include all active fires in the United States. This database is used because it attempts to reconcile information from different fire reporting databases currently available. (Peterson 2001)

2. *Fuel loadings* Fuel loadings for the CSEM system are a significant problem. Eventually there will be fuel data available for the entire country, however at present, we use a default value developed from the National Fire Danger Rating (NFDR) System . Specifically, the NFDR Fuel Model Map was derived from a national GIS coverage derived from AVHRR and NDVI remote sensing data and extensive on-the-ground data collection. It provides 1 km resolution estimates of the appropriate fuel model for each location. To estimate loading, the NFDRS fuel map is combined with a recent Forest Service fire risk assessment that estimates the Fire Regime Current Conditions at a 1 km spatial detail. Fuel load is either typical of a natural condition, with a moderate additional load or extreme, depending on the fuel model and condition class of an individual grid.

3. *Meteorology.* The regional application reads meteorology files from historical MM5 (Grell et al., 1994) model data. It then calculates required historical fuel moisture content needed for the NFDR fuel models to estimate necessary inputs for CONSUME.

4. *CONSUME.* The CONSUME model (Ottmar et al., 1993) estimates the mass of fuel (i.e. woody material, litter and duff) consumed by a fire and the total emissions.

5. *EPM.* The Emissions Production Model (Sandberg and Peterson, 1984) then estimates timed rate of release of heat and PM, PM10, PM2.5, CO, CO2, and CH4 from the fire.

6. *Plume Rise.* At present Plume Rise is estimated using the plume rise algorithm currently implemented in SASEM (http://www.adeq.state.az.us/environ/air/assess/smp.html) a crude smoke permitting model utilized in many western States. Plume rise information is necessary to allocate emissions to upper model layers

7. *Integrate emissions* into the Sparse Matrix Operator Kernel Emissions (SMOKE) (http://www.emc.mcnc.org/products/smoke/) Processor

3. BLUESKY (www.*BlueSky*RAINS.org)

BlueSky is real-time smoke modeling framework that tracks daily emissions and predicts the cumulative concentrations of smoke from prescribed fire and wildfire. It is designed to rely upon real-time meteorological forecast data, and to take advantage of existing air quality models. It's prototype is being developed in the Pacific Northwest as part of a national effort to model smoke impacts through the Forest Service Fire Consortia for Advanced Modeling of Meteorology and Smoke (FCAMMS: www.fs.fed.us/fcamms). The initial implementation utilizes the CALPUFF (Scire et al., 2000) dispersion model and Hy-Split (Draxler and Hess, 1997) trajectory model to simulate smoke dispersion from prescribed burns. Special case studies are also underway that simulate smoke impacts from wildfires. The BlueSky system is also being integrated with the EPA's Rapid Access INformation System (RAINS), a GIS tool that will allow the predicted surface smoke concentrations to be overlain with sensitive receptors, geographic and political features, and meteorological information.

BlueSky relies upon the FASTRACS prescribed fire database to obtain the Fire Description (step 1) and Fuel Loading (step 2) information. As the BlueSky system migrates across the country and other reporting systems are integrated into its framework, other means are going to be necessary to obtain fuel loading information. BlueSky is designed to utilize MM5 forecast data systems, but is also designed to be flexible to incorporate other meteorological models such as the WRF model or RAMS. EPMv1.02 which is coupled with the CONSUME model are run based upon the FASTRACS data. The emission profiles from EPM/CONSUME and the meteorology (from MM5) are then input into the CALPUFF dispersion model and the Hy-Split trajectory model.

CALPUFF estimates plume rise by solving the set of equations similar to those derived by Weil (1988) except that the Boussinesq approximation is not applied. It includes effects of vertical wind shear, large initial plume size, and accounts for density differences between the plume and the ambient air. A pre-processing program, EPM2BAEM, is used to calculate flame height based upon Cetegen et al. (1982) using the heat released estimations from EPM. EPM2BAEM also calculates the vertical velocity of the smoke plume assuming conservation of buoyancy flux, which is proportional to the heat release rate. In this way step seven precedes step six when modeling fire emissions with a Gaussian plume model.

4. EMISSION MODEL RESULTS

The Quartz Mountain Complex of wildland fires in the Pasayton Wilderness of the Okanogan National Forest is being monitored for confinement strategy. Real-time animations of surface smoke concentrations have been available since September 10, 2002 from the BlueSky modeling system. Table 1 shows a critical scenario of fire description and fuel loading data that was estimated by field personnel who are monitoring the blaze. These data are input daily into the BlueSky system. Also included in Table 1 are similar estimations of fuel loadings obtained from the NFDR data as part of the CSEM modeling system. Figures 1a and 1b are the resulting PM10 and heat released profiles obtained from the EPMv1.02 model. These data were input into the BlueSky system providing smoke dispersion estimates as shown in Figure 2 via the CALPUFF model. Efforts are underway to incorporate the same emission profiles into the CMAQ model as part of the CSEM project.

Table 1. Burn Description and Fuel Loading Information input into the BlueSky and CSEM Fire Modeling Systems.

	BlueSky	CSEM
Area of Burnsite [acre]	500	500
0 - 0.25 inch fuel [tons/acre]	1.0	2.9
0.25 - 1 inch fuel [tons/acre]	2.2	2.3
1 - 3 inch fuel [tons/acre]	1.6	5.6
3 - 9 inch fuel [tons/acre]	5.4	13.2
9 - 20 inch fuel [tons/acre]	24.6	0
20+ inch fuel [tons/acre]	0.1	0
Duff depth [inches]	8.0	2.5
Burn-site slope [percent]	50	50
Ignition time [HHMM]	1400	1400
10-hr fuel moisture (%)	9	13.5
Surface wind speed (mph)	6	5.5

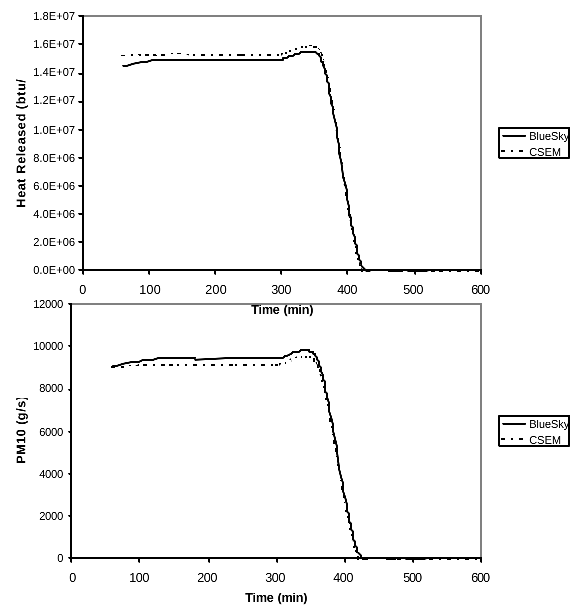

Figure 1. EPMv1.02 emission estimates for (a) PM10 and (b) Heat Released from the BlueSky and CSEM smoke emission modeling systems.

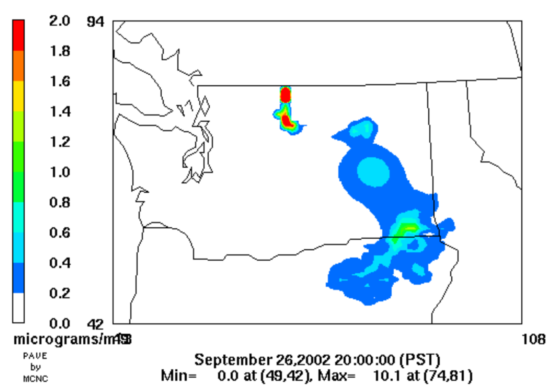

Figure 2. Quartz Complex wildfire simulation from the BlueSky modeling system.

5. SUMMARY

Based on a common calculation of consumption and emissions two approaches to calculate emissions from wildfires are presented. Only preliminary comparisons of the results from the different approaches are presented but they illustrate that the computations appear to yield similar results. Further testing and experience will clarify this in the future. It should be emphasized that the approaches are different in the input data they work with and the output models and applications they are used for. BlueSky is a real-time smoke modeling framework that tracks daily emissions and predicts the cumulative concentrations of smoke from prescribed fire and wildfire The Community Smoke Emissions Model (CSEM) is specifically designed to provide estimates of the historical fire emission contributions to regional air quality for use in regional planning and policy development calculations. CSEM is based on utilizing readily available national estimates of fuels. BlueSky is based on using detailed, real-time fuels information, and hense, should provide a more accurate result.

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