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10.4 PB-Piedmont: A Numerical Model for Predicting the Movement of Biological Material near the Ground at Night

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1. Introduction

Knowledge of air movement at night is becoming increasingly important to forest and agricultural land managers. From six to ten million acres of forest and agricultural land are burned each year in the southern United States, mostly during the period from January through March. Smoke or a combination of smoke and fog can become entrapped within slow-moving drainage flows. These drainage air masses have, at times, drifted across roadways and have contributed to poor visibility. Smoke and fog have been implicated in multiple-car pile-ups that have caused numerous physical injuries, heavy property damage, and fatalities.

PB-Piedmont is a numerical model designed to simulate near-ground smoke movement at night under clear skies and near calm winds over irregular terrain characterized by ridge/valley elevation differences of the order of 50 m. Although the model was developed for monitoring smoke at night, the model is equally suitable for monitoring movement of agricultural odors and airborne organisms with flight speeds and/or terminal velocities that are small relative to air speeds. These are the conditions for which biological material can be channeled by local terrain in unexpected directions for considerable distance and with little dispersion.

PB-Piedmont is designed to be run on a desktop computer by the non-technical land manager. This paper briefly describes the model design, valid predictive scales, assumptions and other limitations. Then, computer movies generated from model output are presented to show the accuracy of model simulations and to give examples of how local elevation differences on the scale of several 10's of meters redirect the near ground airflow during entrapment conditions at night.

2. Model Design

PB-Piedmont must be able to model smoke on the terrain scales that the smoke "sees". Smoke can move through shallow gaps in ridges and down road and stream cuts. Therefore, the mesh size for the model can be as small as 30 m, the minimum resolved grid distance in the digital elevation models (DEM) provided by the U.S. Geological Survey.

PB-Piedmont is a very fine mesh limited area time-dependent numerical model to be run in real-time by land managers as an aid for monitoring smoke. The need for speed for this very fine mesh model is realized by minimizing the number of computations. It is required that the mathematics be simple and the physical terms describing complex processes be simplified or replaced with empirical terms. Turbulent mixing is not a complicating factor as air movement in light winds under stable conditions is nearly laminar. Furthermore, the physics of drainage winds in the absence of larger scale forcing are already well known.

The very fine mesh restricts the spatial area the model can cover and still operate on desktop PC computers. The model design depends upon several

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assumptions regarding the meteorology of the Piedmont. First, because ridge-to-valley elevation differences are of the order of 50m, drainage flows can be approximated by a shallow layer near the ground. This drainage layer is "vertically integrated" meaning air movements within the layer are approximated by the mean wind for the layer. Three dimensional circulations do occur within the drainage layer however these are assumed to be insignificant for smoke transport relative to the mean flow within the layer. The model therefore is not applicable to the mountains where drainage flows may be much deeper than a few tens of meters.

Second, it is assumed that the meteorology of the Piedmont during clear sky and light wind episodes (prevailing weather when most smoke entrapment occurs) consists of two scales of motion - the regional scale pattern of low and high pressure centers and fronts which can be described by the National Weather Service network of surface weather stations, and the drainage scale which is characterized by the terrain of the Piedmont. Mesoscale disturbances that are too small to be resolved by the existing network of surface stations are assumed to be negligible or non-existent. The model therefore is not applicable for those coastal areas frequented by land and sea breezes.

Third, it is assumed that under conditions of light winds and clear skies the immediate surface layer effectively "decouples" from airmasses aloft. Therefore, it is only necessary to model the kinematics of the surface layer.

Fourth, because the domain size is limited, it is assumed that regional scale temperatures, winds, and pressure gradients can be represented by single values interpolated from surrounding weather stations to the center of the model domain.

3. Model Inputs

As PB-Piedmont is designed to answer the question, "Where does the smoke go?" the model does not predict concentrations. Therefore, model inputs are straightforward and simple. USGS 30-meter DEM elevation data are provided on a CD-ROM for the lower boundary along with the model. To date, the model is available for Georgia, South Carolina, Alabama, and Mississippi. It is planned to have the model available for all states in the Southeast within the year. The model inputs are:

1) Latitude and longitude of the release site
2) Time of release
3) Area of release in acres
4) Year, month, **day and time zone for** calculating local sunset
5) Radial distance (km) away from the release site that includes users **area of** interest
6) Grid spacing (m)
7) Hourly weather data downloaded from internet sites. The model decodes data and strips out weather data needed for initial and boundary conditions.

4. Model Example

A computer movie of PB-Piedmont validated against observed smoke at the ground at night will be presented. This case is one of regional scale forcings overcoming drainage winds to push smoke up-valley. It is an excellent example of the difficulties encountered in predicting where smoke or other biota trapped near the ground at night will be carried by the local winds.

Observations of smoke on the ground at night were obtained by a video camera equipped with a light-enhancing instrument. The camera was mounted in the belly of a King Air aircraft and flown during full moon over an experimental burn site in western Alabama. The smoke data were rectified and transferred to an elevation map for validation against PB-Piedmont. The model accurately reproduced the observed up-valley smoke movement and diversion into a side valley.