Chapter 9

DISPERSION PREDICTION SYSTEMS

Smoke Dispersion Prediction Systems

Sue A. Ferguson

Smoke dispersion prediction systems are becoming increasingly valuable tools in smoke management. There are a variety of potential applications that can help current management issues. These include screening, where methods and models are used to develop "worst-case" scenarios that help determine if alternative burn plans are warranted or if more in-depth modeling is required. Such tools also help in planning, where dispersion predictions aid in visualizing what fuel and weather conditions are best suited for burning or when supporting data are needed to report potential environmental impacts. Also, prediction systems can be used as communication aids to help describe potential impacts to clients and managers. For regulating, some states use dispersion prediction systems to help determine approval of burn permits, especially if ignition patterns or fuel complexes are unusual. Other states require dispersion model output in each burn permit application as supporting proof that a burn activity will not violate clean air thresholds.

There are a variety of tools that can be applied to screening and some planning applications. The easiest of these are simple approximations of dispersion potential, emission production, and proximity to sensitive receptors. The approximations are based on common experience with threshold criteria that consider worst-case conditions or regulatory requirements. More detailed planning and many regulatory situations require numerical modeling techniques. While numerical models output a calculated physical approximation of dispersion features, they can be adjusted to predict worst-case scenarios by altering such things as emission production or trajectory winds. Often the easily applied numerical models are used for screening. Typically, more rigorous applications require the use of complex models by trained personnel.

Methods of Approximation

A first level of approximation can simply determine whether the atmosphere has the capacity to effectively disperse smoke by using indexes of ventilation or dispersion. These indexes are becoming widely used and may be a regular feature of fire weather or air quality forecasts in your area. Usually the ventilation index is a product of the mixing height times the average wind within the mixed layer. For example, a mixing height of 600 meters (~2,000 feet) above the ground surface with average winds of 4 m/s (~7.8 knots or ~8.9 mph) produces a ventilation index of 2,400 m^2/sec (~15,600 knots-feet). With similar wind speeds, the ventilation index would increase to 12,000 m^2/sec (~78,000 knots-feet) if the mixing height rose to 3,000 meters (~10,000 feet). Ventilation indexes calculated from model output may use the product of the planetary boundary layer (PBL) and lowest level winds (e.g., 10 to 40 meters above ground level). Others calculate the index by multiplying the mixing height by a determined transport wind speed,[1] which might be near the top of the mixed layer. Because of different methods of calculating ventilation index, the scales used for burning recommendations may vary.

It helps to gain experience with a ventilation index before making management decisions based on its value. Defining a uniform method for calculating the index and comparing it frequently with observed smoke dispersal conditions can do this. Ferguson et al. (2001) developed a national historical database of ventilation index based on model generated 10-meter winds and interpolated mixing height observations. It is useful in illustrating the spatial and temporal variability of potential ventilation all across the country. In South Carolina the index is divided into 5 categories that correspond to specific prescribed burning recommendations, where no burning is recommended if the index is less than 4,500 m^2/sec (28,999 knots-feet) and restrictions apply if it is between 4,500 and 7,000 m^2/sec (29,000-49,999 knots-feet) (South Carolina Forestry Commission, 1996). In Utah the ventilation index is referred to as a “clearing index” and is defined as the mixing depth in feet times the average wind in knots divided by 100. In this way, a clearing index of less than 200 would indicate poor dispersion and likely pollution; an index between 200 and 500 indicates fair dispersion, while indexes greater than 500 represent good to excellent dispersion. Commonly, the clearing index must be greater than 400 before burning is recommended. In the northwestern U.S., where a mesoscale weather model is used to predict ventilation index, the South Carolina scale has been slightly adjusted to match local burning habits and to accommodate for the slightly different way of computing the index. Table 9.1 gives common values of the ventilation index (VI) and associated smoke conditions.

Ventilation indexes have no value when there is no mixing height, which is common at night. Also, if the atmosphere is very stable within the mixed layer, the ventilation index may be too optimistic about the ultimate potential of dispersing a smoke plume. Therefore, to help

Table 9.1. Common values of the ventilation index (VI) and associated smoke conditions. The Index is calculated by multiplying mixing height (MH) or planetary boundary layer (PBL) times trajectory winds (Traj.), average winds through the depth of the mixed layer (Avg.), or winds at 40 meters above ground level (40m).

VI (knots-ft) MH x Traj.	**VI (knots-ft)/100 MH x Avg.**	**VI (m^2/sec) PBL x 40m**	**Smoke Condition**
0-28,999	< 200	< 2,350	Poor
29,000-37,999	200-400	2,350-4,700	Marginal
38,000-49,999	400-500	4,700-7,050	Fair
50,000-94,999	>500	>7,050	Good
> 95,000			Excellent dispersion - but burn with caution

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[1] Transport winds are those considered most likely to carry smoke away from a fire, usually near mid-level of the horizontal portion of a spreading plume.

determine the atmosphere's capacity to disperse smoke during all atmospheric conditions, Lavdas (1986) developed an Atmospheric Dispersion Index (ADI) that combines Pasquill's stability classes (see table 7.1) and ventilation indexes with a simple dispersion model. National Weather Service (NWS) fire weather offices are beginning to include the ADI as a regular part of their smoke management forecast. See table 9.2 for an explanation of the ADI categories. Commonly the ADI must be greater than 30 before burning is recommended.

Another way to approximate smoke impacts is through a geometric screening process that is outlined in "A Guide for Prescribed Fire in Southern Forests" (Wade 1989) and "Southern Forestry Smoke Management Guidebook" (USDA-Forest Service, Southern Forest Experiment Station 1976). The recommended steps include: 1) plotting the direction of the smoke plume, 2) identifying common areas of smoke sensitivity (receptors) such as airports, highways, hospitals, wildernesses, schools, and residential areas, 3) identifying critical areas that already have an air pollution or visibility problem (non-attainment areas), 4) estimating smoke production, and 5) minimizing risk.

It is suggested that the direction of the smoke plume during the day be estimated by considering the size of the fire and assuming a dispersion of 30° on either side of the centerline trajectory if wind direction is planned or measured and 45° if forecasted winds are used. At night, the guide suggests that smoke follows down-valley winds and spreads out to cover valley bottoms. Fuel type, condition, and loading are used to help estimate the amount of smoke that will be produced. In minimizing risk, it is suggested to consider mixing height, transport wind speed, background visibility, dispersion index, and various methods of altering ignition and mop-up patterns.

Because the guidebooks for southern forestry estimate emissions based on fuel types specific to the southeastern U.S., other methods of

Table 9.2. Atmospheric Dispersion Index (ADI) with its current interpretation (Lavdas 1986).

ADI	Interpretation
1-6	Very poor dispersion (common during nighttime)
7-12	Poor dispersion
13-20	Generally poor dispersion
21-40	Fair dispersion (but stagnation may occur if wind speeds are low)
41-60	Generally good dispersion (common in afternoon of U.S. interior)
61-100	Good dispersion (commonly related to good burning weather)
> 100	Very good dispersion (but may relate to high fire hazard)

estimating emissions are needed to employ geometric screening applications elsewhere. Existing models such as FOFEM (Reinhardt and others 1997) and CONSUME (Ottmar and others 1993) are designed for this purpose.

Schaaf and others (1999) describe a similar screening process for deciding the level of analysis for each project. The screening steps include: 1) determining fire size, 2) estimating fuel load, 3) identifying distance to sensitive areas, and 4) calculating emission production. Unlike the southern forestry screening method, which estimates downwind impacts from simple geometry, Schaaf and others (1999) recommend running a numerical dispersion model to help calculate smoke concentrations if initial screening thresholds are met. Further analysis or efforts to reduce potential impacts are then recommended only if predicted concentrations exceed specified standards.

Before relying on simple screening methods to determine if additional modeling may be required or if alternatives are necessary, it is helpful to define appropriate threshold criteria by consulting regulations, surrounding community opinions, and management concerns. For example, the criteria of sensitive receptor proximity may range from fractions of a mile to several miles. On the other hand, some places may base criteria on total tonnage of emissions, no matter how close or far from a sensitive area. Most often criteria are combinations of proximity to receptors and fire size, which vary from place to place.

Numerical Models

Most of the available dispersion prediction systems are in the form of deterministic numerical models and there are three types designed to estimate the timing and location of pollutant concentrations; dispersion, box, and three-dimensional grid models. Dispersion models are used to estimate smoke and gas concentrations along the trajectory of a smoke plume. Box models do not calculate trajectories of particles but assume smoke fills a box, such as a confined basin or valley, and concentrations vary over time as smoke enters and leaves the box. Grid models are like expanded box models in that every grid cell acts as a confined box. Because trajectories are not explicitly computed, box or grid models may include other enhancements, such as complex computations of chemical interactions. Currently, only dispersion and box models have been adapted for wildland smoke management applications. Work is underway to adapt grid models to smoke problems and this will help in estimates of regional haze because grid models can simulate large domains and usually include critical photochemical interactions. The following summary of numerical models currently used by smoke managers is updated from an earlier review by Breyfogle and Ferguson (1996).

Dispersion Models – Dispersion models track trajectories of individual particles or assume a pattern of diffusion to simplify trajectory calculations. Particle models typically are the most accurate way to determine smoke trajectories. They are labor intensive, however, and more often used when minute changes in concentrations are critical, such as when nuclear or toxic components exist, or when flow conditions are well bounded or of limited extent (e.g., PB-Piedmont by Achtemeier 1994, 1999, 2000). Diffusion models commonly assume that concentrations crosswind of the plume disperse in a bell-shape (Gaussian) distribution pattern. Both plume (figure 9.1a) and puff (figure 9.1b) patterns are modeled. The plume method assumes that the smoke travels in a straight line under steady-state conditions (the speed and direction of particles do not change during the period of model simulation). SASEM (Sestak and Riebau 1988), VSMOKE (Lavdas, 1996), and VSMOKE-GIS (Harms and Lavdas 1997) are examples of plume models. Plume models most commonly are applied in regions of flat or gently rolling terrain but can be used whenever a plume is expected to rise above the influence of underlying terrain. The puff method simulates a continuous plume by rapidly generating a series of puffs (e.g., NFSpuff: Harrison 1995; Citpuff: in TSARS+ by Hummel and Rafsnider 1995; and CALPUFF: Scire and others 2000a). Therefore, like particle models, puff models can be used at times when trajectory winds change, such as during changeable weather conditions or in regions where underlying terrain controls smoke trajectory patterns. Because particle trajectory models and Gaussian diffusion models use coordinate systems that essentially follow particles/parcels as they move (Lagrangian coordinates), sometimes they are referred to as Lagrangian dispersion models.

Particle and puff models must have high spatial and temporal resolution weather data to model changing dispersion patterns. This requires at least hourly weather information at spatial resolutions that capture important terrain features (usually less than 1km). For this reason, particle and puff models currently used for smoke management include a weather module that scales observations or input from external meteorological information, to appropriate spatial and temporal resolutions. For example, TSARS+ is designed to link with the meteorological model NUATMOS (Ross and others 1988) while CALPUFF is linked to CALMET (Scire and others 2000b). NFSpuff (Harrison 1995) and PB-Piedmont (Achtemeier 1994, 1999, 2000) contain internal algorithms that are similar to CALMET and NUATMOS. Most weather modules that are attached to particle and puff models solve equations that conserve mass around terrain obstacles and some have additional features that estimate diurnal slope winds and breezes associated with lakes and oceans at very fine scales.

Unlike most particle or puff models, plume models assume that mixing heights and trajectory winds are constant for the duration of the burn. Therefore, they do not require detailed weather inputs and are very useful when meteorological information is scarce. Plume models, however, will not identify changing trajectories or related concentrations if weather conditions fluctuate during a burn period. Also, when smoke extends beyond a distance that is reasonable for steady-state assumptions, which typically is about 50 km (30 miles), plume approximations become invalid. When terrain or water bodies interact with the plume, steady-state assumptions become difficult to justify, no matter how close to the source. Despite the limitation of plume models in complex terrain, they can be useful if plumes are expected to rise above the influence of terrain or if plumes are confined in a straight line that follows a wide valley when dispersion does not extend beyond the valley walls.

Box and Grid Models – The box method of estimating smoke concentrations assumes instantaneous mixing within a confined area, such as a confined basin or valley (figure 9.1c). This type of model usually is restricted to weather conditions that include low wind speeds and a strong temperature inversion that confines the mixing height to within valley walls (e.g., Sestak and others, unpublished; Lavdas 1982). The valley walls, valley bottom, and top of the inversion layer define the box edges. The end segments of each box typically coincide with terrain features of the valley, like a turn or sudden elevation change. Flow is assumed to be down-valley and smoke is assumed to instantaneously fill each box segment. The coordinates used to calculate box dispersions are fixed in space and time and thus called Eulerian coordinates. The box method provides a useful alternative to Gaussian diffu-

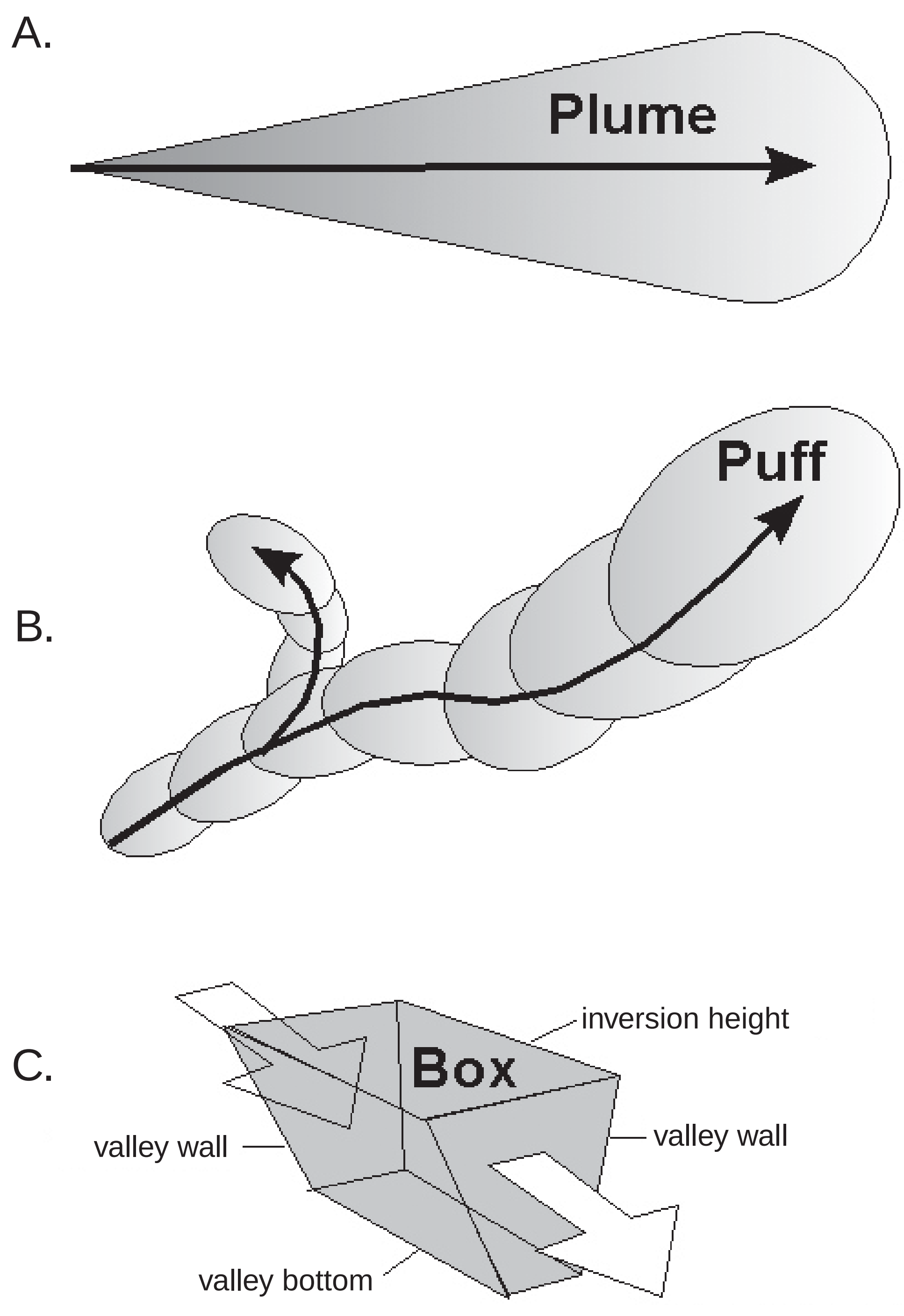

Figure 9.1. Schematic diagrams of numerical dispersion models; (A) Gaussian plume, (B) Gaussian puff, and (C) box.

sion models when understanding patterns of smoke concentrations in an isolated valley become critical.

Many grid models are called Eulerian grids because of their fixed coordinate system. The fixed coordinates make it difficult for grid models to track the impact of individual plumes but allows for easier evaluation of cumulative impacts from several plumes or chemical interactions of particles and gases within plumes. This makes grid models especially useful for evaluating the impact of smoke on regional haze. Work is underway to adapt at least two grid models (REMSAD: Systems Applications International 1998; and CMAQ: Byun and Ching 1999) for wildland fire applications. REMSAD has very simple chemistry thus is desirable for use in large domains or over long time periods. The CMAQ model is more fully physical and part of the EPA's Models 3 project, which is a "one-atmosphere" air quality modeling framework designed to evaluate all potential impacts from all known sources. At this time grid models require experienced modelers to initialize and run. Smoke managers, however, may be asked to provide input for grid models and could begin seeing results that influence application of regional haze rules.

Uncertainty

All prediction systems include some level of uncertainty, which may occur from the meteorological inputs, diffusion assumptions, plume dynamics, or emission production. Many dispersion models and methods have been compared to observations of plumes from point sources, such as industrial stacks, or tightly controlled experiments (e.g., Achtemeier 2000). In these cases, the greatest error usually occurs because of inaccuracies in the weather inputs; either from a poor forecast or an insufficient number of data points. If trajectories can be determined correctly then dispersion and resulting down-wind concentrations from point sources are relatively straightforward calculations. This is because emission rates and subsequent energy transmitted to the plume from industrial stacks, or controlled experiments, usually are constant and can be known exactly.

It is expected that the largest source of uncertainty in modeling smoke concentrations from wildland fires is in estimating the magnitude and rate of emissions. Highly variable ignition patterns and the condition and distribution of fuels in wildland fires create complex patterns of source strength. This causes plumes with simultaneous or alternating buoyant and non-buoyant parts, multiple plumes, and emission rates that are dependent on fuel availability and moisture content. Few comparisons of observations from real wildland fires to dispersion model output are available. Those that do exist are qualitative in nature and from the active phase of broadcast-slash burns (e.g., Hardy and others 1993), which tend to generate relatively well-behaved plumes.

To calculate the complex nature of source strength, components of heat and fuel (particle and gas species) must be known. For simulating wildland fires, additional information is required on: 1) the pattern of ignition, 2) fuel moisture by size of fuel, 3) fuel loading by size, 4) fuel distribution, and 5) local weather that influences combustion rates. Much of this information is routinely gathered when developing burn plans. Peterson (1987) noted that 83% of the error in calculating emissions is due to inaccurate fuel load values. Therefore, even the best burn plan data will introduce a large amount of uncertainty in predicted dispersion patterns.

The shift from burning harvest slash to using fire in natural fuel complexes for understory renovation and stand replacements has introduced another degree of uncertainty by the existence of decaying fuel and isolated concentrations of deep duff that have previously been neglected in pre-burn inventories. This has prevented emission models from accurately estimating the contribution of smoldering combustion, which is common in the porous elements of rotten wood and deep duff. Until this omission is corrected, users must manipulate source-strength models into expecting smoldering by inputting very long ignition periods and low fuel loads, which simulate the independent smoldering combustion that occurs in porous material.

Currently variable-rate emissions are determined by approximating steady-state conditions in relatively homogeneous burning segments of a fire (e.g., Sandberg and Peterson 1984; Ferguson and Hardy 1994; Lavdas 1996; Sestak and Riebau 1988) or by allowing individual fuel elements to control combustion rates (e.g., Albini and others 1995; Albini and Reinhardt 1995; Albini and Reinhardt 1997). The steady-state method has been adapted for many of the currently available puff, plume, and box models and is most useful when the pattern and duration of ignition are known ahead of time, either through planning or prediction. The fuel-element approach shows promise for calculating emissions simultaneously with ignition rates (fire spread) and may become particularly useful for coupled fire-atmosphere-smoke models, which currently are being developed.

Principal components (plume rise, trajectory, and diffusion) of all numerical dispersion models assume functions that are consistent with standard, EPA approved, industrial stack emission models. The models themselves, however, may or may not have passed an EPA approval process. Primary differences in the physics between the models appear to be the degree to which they fully derive equations. All models include some empirical coefficients, approximations, or parameterized equations when insufficient input data are expected or when faster computations are desired. The degree to which this is done varies between models and between components of each model. Note that it is not clear whether fully physical calculations of plume rise and dispersion are more accurate than approximate calculations in biomass burning because of the considerable uncertainty in the distribution and magnitude of available fuels in wildland areas.

Output

Useful output products for smoke managers are those that relate to regulatory standards, show impact to sensitive receptors, and illustrate patterns of potential impact. Regulatory standards require 24-hour averaged and 24-hour maximum surface concentrations of respirable particles at sensitive receptors. In addition, surface concentrations of carbon monoxide (CO), lead, sulfur oxides (SOx), ozone (O_3), nitrous oxides (NOx), and hydrocarbons (e.g., methane, ethane, acetylene, propene, butanes, benzene, toluene, isoprene) are needed to conform to health regulations. Quantifying the impact on regional haze is becoming necessary, which requires an estimate of fine particles, carbon gases, NOx, O_3, relative humidity, and background concentrations. Safety considerations require estimates of visibility, especially along roads (Achtemeier et al. 1998) and at airports. In addition to quantitative output, it is helpful to map information for demonstrating the areal extent of potential impact because even the smallest amount of smoke can affect human values, especially when people with respiratory or heart problems are in its path. For example, studies have shown that only 30 to 60 $\mu g/m^3$ in daily averaged PM_{10} (particulate matter that is less than 10 micrometers in diameter) can cause increases in hospital visits for asthma (Schwartz et al. 1993; Lipsett et al. 1997). These values are less than 1/3 of the national ambient air quality standard (U.S. Environmental Protection Agency 1997). Sometimes the mere presence of smoke, regardless of its concentration, is enough to force alteration of a burn plan.

The old adage, "you can't get out what you don't put in," aptly describes the output of dispersion prediction systems. In a geometric screening system (Wade 1989), only place of impact can be approximated because elemental constituents of the source emissions are not considered. The value in screening processes of this type, however, is that they allow an objective, first-guess estimate of smoke impacts so alternative measures can be taken if needed. Also, the process can be done on a map that illustrates potential receptors and estimated trajectory for others to see and discuss. Depending on the state or tribal implementation plan, a geometric screening may be all that is needed to conform to regulatory standards.

Numerical models disperse gases and particulates that are available from a source-strength model, which uses measured ratios of emissions to amount of fuel consumed (emission factors). Emission factors vary depending on fuel type, type of fire (e.g., broadcast slash, pile, or undisturbed) and phase of the fire (e.g., flaming or smoldering). Currently, emission factors available for wildland fire include total particulate matter (PM), particulate matter that is less than 10 micrometers (μm) in diameter (PM_{10}), particulate matter that is less than 2.5 μm in diameter ($PM_{2.5}$), carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), and non-methane hydrocarbons (NMHC). Emission factor tables (AP-42) are maintained by the U.S. Environmental Protection Agency (1995).

At this time, emissions of lead and SOx from biomass fires are considered negligible. Emission factors of NOx are uncertain and have not been quantified to a satisfactory level. It is assumed that ozone is not created at the source but develops downwind of the source as the plume is impacted by solar radiation. Currently, aside from grid models, only one dispersion model (CALPUFF: Scire and others 2000a) includes simple photochemical reactions for calculation of down-wind ozone.

Desired attributes within a dispersion prediction system vary in complexity by several orders of magnitude. To help potential users determine which systems may best apply to their specific need, three levels of complexity were estimated for each desired attribute as shown in table 9.3. The 1st level is the simplest; usually producing generalized approximations. At the 3rd level, attributes are determined with the best available science and often include a number of perspectives or options for output.

Using the estimated levels of complexity from table 9.3, it becomes possible to rank dispersion prediction systems for each potential application. For example, if graphical output is available, the location of impact can be determined. If surface concentrations of particles and gases are available, then the system can be used to determine health and visibility impacts. A quick estimate of visibility may require only a 1st level of complexity, while precise visibility determinations may require more complex approaches. A summary of attributes for each dispersion prediction system is provided in table 9.4. The numbers in the attribute columns refer to an estimated level of complexity from 1 to 3 as summarized in table 9.3. Ease of use is a subjective determination based on the work of Breyfogle and Ferguson (1996). It considers the number and type of inputs, the availability of inputs, required user knowledge, and effort needed to produce useful results. Because calculating a ventilation or clearing index is simply a product of two numbers, dispersion indexes typically are computed by others, and both commonly are available through fire weather or air quality forecasts, they are considered very easy to use.

Several methods/models can show cumulative impacts from a number of fires by generalizing the atmosphere's capacity to hold the total emissions (index values) or by displaying multiple plumes at once (VSmoke-GIS if separate projects are used as overlays, NFSpuff, TSARS+, and CALPUFF). The ability to numerically determine the cumulative impact, however, requires concentrations of intersecting plumes to be added together. Currently CALPUFF (Scire and others 2000a) is capable of additive concentrations.

Only two of the currently available models are specific to a geographic area. They are NFSpuff (Harrison 1995) and PB-Piedmont (Achtemeier 1994, 1999, 2000) that were built for ultimate ease by including digital elevation data so the user would not have to find it or adjust for different formats. Early versions of the NFSpuff model contain only elevation data from Washington and Oregon while later versions include all of the western states. The PB-Peidmont model includes data for the piedmont regions of

Table 9.3. Desired attributes of dispersion prediction systems are compared to estimated levels of complexity.

Attribute	1st Level	2nd Level	3rd Level
Communication Aids	Tables	Mapped concentrations	Mapped concentrations as time-sequence loops
Location of impact	At defined receptors	Maps of plume patterns	Maps of plume patterns overlain with sensitive receptor/area locations
Heath Effects	PM surface concentrations	Surface concentrations of $PM_{2.5}$ & CO	Surface concentrations of $PM_{2.5}$, CO, CH_4, NMHC
Visibility in Plume	TSP[a], relative humidity	TSP, relative humidity, $PM_{2.5}$, carbon, background	TSP, relative humidity, $PM_{2.5}$, O_3, carbon, background, NO_2
Regional Haze	Wind, mixing height, emissions	Wind, mixing height, emissions, background, TSP, relative humidity	Wind, mixing height, emissions, background, TSP, relative humidity, $PM_{2.5}$, O_3, carbon, NO_2
Complex Terrain	Generalized or specific to individual valley or basin	Spatial topography	Spatial topography, land-water, vegetation cover

[a] TSP – total suspended particles

Table 9.4. Dispersion prediction systems designed for wildland fire applications. Attributes are ranked by their level of complexity, with 1 being simplest and 3 being most complex, where a dash indicates that the attribute is unavailable. Ease of use is ranked from 1 being the easiest to 10 being the most difficult.

Type	**Method/Model**	**Comm. Aid**	**Impact location**	**Health**	**Visibility in plume**	**Haze**	**Complex terrain**	**Ease of use**
Approx.	Ventilation Index[a]	--	--	--	--	1	1	1
	Dispersion Index	--	--	--	--	1	1	1
	Geom. Screen	2	1	--	--	--	1	3
Box	ValBox	2	1	1	[b]	-	1	5
Plume	Sasem[a]	1	1	2	1	--	--	4
	Vsmoke	1	1	2	1	--	--	5
	Vsmoke-GIS	2	3	2	1	--	--	6
Puff	NFSpuff	3	2	2	[b]	--	2	5
	Citpuff/TSARS+	2	2	2	[b]	--	2	9
	CALPUFF[a]	3	3	3	2	--	3	8
Particle	PB-Piedmont	2	2	-	-	-	1	5

[a] Most likely to meet regulatory requirements (varies from state to state and tribe to tribe)

[b] Although not a direct output of the model, visibility may be approximated from concentration (Wade 1988)

southeastern United States. Other models do not require elevation data (e.g., SASEM and VSmoke) or allow the input of elevation data from anywhere as long as it fits the model-specified format (e.g., VSmoke-GIS, TSARS+, and CALPUFF). While there is some concern that version 1.02 of the Emission Production Model (EPM: Sandberg and Peterson 1984) is specific to vegetation types in Washington and Oregon, it has been adapted for use in the southeastern U.S. through VSmoke (Lavdas 1986) and can be adjusted to function elsewhere in the country (e.g., SASEM: Sestak and Riebau 1988). Newer versions of EPM (Sandberg 2000) and the BurnUp emissions model (Albini and Reinhardt 1997) are not geocentric but to date neither has been incorporated into any available dispersion prediction system.

Summary

For many projects a simple model often provides as good information as a more complex model. Regulations, however, may dictate the level of modeling required for each project. Other times, community values will determine the level of effort needed to demonstrate compliance or alternatives. Also, skills available to set up and run models or the availability of required input data may affect whether a prediction system is necessary and which one is most appropriate.

Because regulations vary from state to state and tribe to tribe and because expectations vary from project to project there is no simple way to determine what dispersion prediction system is best. It is hoped that the information in tables 9.3 and 9.4 can be used to help assess the value of available methods and models. For example, if a simple indication of visibility impacts is required, plume models can be used or visual indexes can be approximated from concentrations out of box, plume, or puff models. If more detailed visibility impacts are required, a sophisticated puff model should be used. Whatever the situation, whether smoke dispersion prediction systems are used for screening, planning, regulating, or simply game playing, it is helpful to remember their strengths and weaknesses.

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