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An Atmospheric Dispersion Index for Prescribed Burning

Leonidas G. Lavdas

Southeastern Forest Experiment Station
P.O. Box 2680
Asheville, North Carolina 28802

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Leonidas G. Lavdas, Research Meteorologist
Southeastern Forest Experiment Station
Macon, Georgia

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ABSTRACT

A numerical index that estimates the atmosphere's capacity to disperse smoke from prescribed burning is described. The physical assumptions and mathematical development of the index are described in detail. The index is expressed as a positive integer in such a way that doubling the index implies a doubling of the estimated atmospheric capacity. The dispersion index is conceptually similar to ventilation factor but is better able to describe diurnal changes within the lower atmosphere. The index provides a guide to the effect of prescribed burning activity on atmospheric smoke concentration during a portion of a day. The index does not replace smoke dispersion models designed to analyze smoke concentration from individual fires at specific locations, nor does it describe smoke effects on visibility.

Keywords: Smoke management, air pollution potential, ventilation factor, Gaussian dispersion, mesoscale air-quality estimation, Pasquill stability class, area pollution sources.

The effect of human activities on air quality is closely related to the rate of dispersion of pollutants within the atmosphere. Most polluting activity, such as automobile traffic, manufacturing, or power generation, generally takes place with minimal attention to the varying capacity of the atmosphere to dilute pollutants to acceptable levels. Exceptions occur when air-pollution episodes create the need for reduced polluting activity, but in most areas such episodes are rare. Although there is an association between some polluting activities (such as heating and power generation) and weather variables (chiefly temperature), very few are directly associated with atmospheric dispersion rate.

An association between dispersion rate and a significant polluting activity, such as prescribed burning, might be expected--particularly when smoke management is being practiced. Prescribed fires, which represent a temporary source of pollution, can be successfully conducted only under certain weather conditions (Mobley and others 1978). Windspeed, both near the ground and aloft, is an important determinant of both fire behavior and smoke concentrations. Much of the range of weather conditions acceptable for forestry prescribed burning overlaps with that associated with good dispersion of pollutants, so that with proper management neither the smoke nor the fire will be a hazard. Unlike most human polluting activities, prescribed fires can be conducted or allocated on a day-by-day basis according to prevailing and forecast weather conditions.

Some of the guidelines needed for smoke management have been published in "Southern Forestry Smoke Management Guidebook" (Southern Forest Fire Laboratory Staff (SFFLS) 1976) and the FWIS "User Manual" (Paul and Clayton 1978). By use of look-up tables or interactive computer programs, these publications offer adaptations of U.S. Environmental Protection Agency (EPA) models for use in calculating ground-level downwind smoke concentrations from a low-intensity prescribed fire in specified forest fuels. These models are designed for single-fire smoke management to help assure that individual fires are conducted a safe distance from a highway or town. The models become increasingly awkward and expensive to use as the number of sources (fires) and receptors (smoke-sensitive areas) in the computational process rises. If many fires are conducted in a given region, the atmosphere may be overloaded with smoke even if the available models do not indicate a problem from any one fire. Where prescribed fire is intensively used, there is a need to coordinate burning activity based on current and forecast weather conditions to avoid regional smoke overload. Some States, including Oregon, North Carolina, and Florida, have adapted smoke management systems that allow or, in some cases, allocate burning activity based on a weather categorization scheme. For example, the Oregon smoke management system, which has been largely adapted by several Southeastern States, categorizes permissible burning activity

according to ventilation factor (the product of mixing height and transport windspeed). The ventilation factor represents the atmosphere's ultimate dispersion capacity at a given time, which in some cases is a logical basis for regional smoke management. However, the ultimate dispersion capacity of the atmosphere is not always attained due to relatively low dispersion rates within the mixing layer. Also, the ventilation factor is not easily related to dispersion under stable conditions when the mixing height is effectively zero. This Paper proposes an atmospheric dispersion index that takes dispersion rate as well as capacity into account and can be used in unstable, stable, or neutral conditions.

Dispersion Rate--
The Pasquill-Gifford-Turner Stability Classification System

The rate of pollutant dispersion within the atmosphere is largely dependent on stability. Atmospheric stability is determined by the rate of temperature change with respect to height within the atmosphere. A dry atmosphere that cools at a rate in excess of about 0.01 K m^{-1} (5.5 °F per 1,000 ft) is unstable; one that cools at a lesser rate or which becomes warmer with height is stable. Direct measurements of temperature with height are not routinely available except at widely separated upper-air observing stations on a twice-daily basis. There is no clear-cut relationship between dispersion rate and temperature changes with height, given an unstable atmosphere. The air tends to rapidly turn over, given an initial impetus, in an attempt to readjust an unstable temperature profile to a more neutral one. Hence, a measured unstable temperature profile tends to reflect local factors, such as friction within the atmosphere near the ground and the thermal properties of the soil or vegetative cover, more than dispersion rate (Gifford 1975). Because of the difficulties in obtaining and, in some cases, interpreting temperature profiles, the atmospheric dispersion rate near the ground has often been indirectly estimated by use of readily observed weather variables such as surface windspeed, cloud cover, ceiling height, and insolation. The most common estimation scheme is that of Pasquill (1961, 1974), modified by Gifford (1962), and reformulated for computerized applications by Turner (1961, 1964). This scheme assigns a dispersion rate to the lower atmosphere according to one of seven stability classes ranging from extremely unstable through neutral to extremely stable. The class is determined from solar elevation angle, windspeed, opaque cloud cover, and cloud ceiling height. Details for estimating the stability class are given in appendix A. As can be seen from the procedure, the atmosphere tends to be unstable or neutral during the day and stable or neutral at night. Neutral conditions are most likely during cloudy or windy regimes.

Dispersion Capacity--
Mixing Height and Transport Windspeed

The dispersion rate, estimated by use of stability class, generally occurs only within the lower atmosphere at and below the mixing height. Above the mixing height, the dispersion rate is typically very low. The net effect of dispersion at a slow rate overlaying dispersion at a much faster rate near the ground is to create the appearance of a "lid" within the atmosphere, below which most ground pollutants are trapped. The mixing height changes markedly during the course of the day. On a clear night with light winds, the dispersion rate near the ground, particularly in rural areas, may be about as slow as that at great heights. In such conditions, the mixing height is effectively zero, and pollutants spread very slowly above the ground. After sunrise, the ground heats up and the lower atmosphere is warmed from below, creating a mixing layer that typically increases in depth (increasing mixing height) until early afternoon. The mixing height generally reaches a steady state through the afternoon hours until about sunset. By dark, cooling temperatures at ground level create a

stable layer of air that traps ground pollutants, and the mixing height effectively returns to zero. During cloudy or very windy days, the above trends generally do not hold; the mixing height may be determined by frontal zones or other factors that may be rapidly changing as a storm system moves across an area.

During fair weather regimes, when most prescribed fires are conducted, mixing height can be determined fairly accurately by comparing the current surface air temperatures with the upper-air temperature profile measured during early morning hours (1200 G.m.t. or 0700 e.s.t.) (Holzworth 1972). During the day, the surface temperature will typically be higher than that given as surface temperature within the early morning upper-air profile. By comparing the temperatures and pressures of the surface and upper-air observations and assuming a dry adiabatic process of atmospheric mixing (Hess 1959), the mixing height associated with the current surface temperature can be ascertained. The smoke from most prescribed fires can be assumed to be confined below this mixing height for smoke travel times up to 12 hours (Pharo and others 1976).

Pollutants within the mixing layer are directly diluted by the transport windspeed (the average windspeed within the mixing layer). Transport windspeed is generally regarded as having the most profound effect on pollutant concentrations. When multiplied by mixing height, transport windspeed yields ventilation factor.

The effect of transport windspeed or ventilation factor on atmospheric smoke concentrations can perhaps best be visualized by conceiving the atmosphere as a box into which pollutants are being poured. The height of the box is typically the mixing height. Consider smoke being emitted along the upwind edge of the box for a fixed period of time; e.g., 1 hour. During that period, the area downwind covered with smoke would depend on the windspeed within the box; for example, a 16-km per hour (10 mi/h) windspeed would make the box 48 km long in 1 hour. Half that windspeed results in a box of half the size and doubles the concentrations of smoke.

Ventilation factor has been used by the National Weather Service to help determine where stagnation episodes, associated with high pollution levels in urban areas, might occur.[1] It has utility particularly in considering pollutant buildup or dispersal for a day or more. Because dispersion rate within the conceptual "box" is neglected, ventilation factor does not describe the effect of individual pollution sources, nor the effect of all sources during portions of the day. Dispersion rate and the ventilation factor are considered in EPA dispersion models. One such model, the Climatological Dispersion Model (Busse and Zimmerman 1973), appears to lend itself to the construction of a dispersion index that may be able to indicate the amount of prescribed fire activity which can be accommodated in a 50- by 50-km area (approximately 1,000 mi^2 or roughly 30 by 30 mi) over a period of several hours.

Mathematical Basis of the Dispersion Index

The dispersion index that is proposed for prescribed fire smoke management is based primarily on the Climatological Dispersion Model (CDM) and ventilation factor. For the purpose of constructing the index, a slight modification to the CDM model is made to differentiate between typical dispersion conditions during day and night in rural terrain, according to the suggested dispersion rates given by Pasquill (1974). The dispersion index is optimized for application to burning activity within a 50- by 50-km area. It is constructed to reflect the amount of emissions within the area that will result in a fixed incremental increase of concentrations at the downwind edge of the area. (The

[1]National Weather Service Technical Procedures Bulletin 204, Air Stagnation Guidance. NOAA Tech. Dev. Lab., Silver Spring, MD. 10 pp.

downwind edge of a uniform area emission source with zero plume rise receives the greatest impact from such emissions.)

Ventilation Factor

The concentration of pollutants in the atmosphere at the downwind edge of a uniform area source shaped as a square, assuming complete mixing from ground to the mixing height (box model assumption) is

$$\chi = \frac{kQ}{LHW} \tag{1}$$

where:
- χ = concentration due to emissions within the area
- Q = total emission rate within the area
- L = length of the area source
- H = mixing height
- W = transport windspeed
- k = a constant, which reflects the units chosen for χ, Q, L, H, and W (k = 1, if any internally consistent set of units, e.g., SI units, are chosen)

Note that since the area is square, then

$Q = q_A L^2$ where q_A is the uniform area emission rate of the square.

Equation (1) neglects the concentration of pollutants that might be transported from an area farther upwind from the square area considered. A visual conception of equation (1) is shown in figure 1, but the effect of transport windspeed on the concentration χ is not shown. The windspeed effect is due to the concentration being a function of emission rate. The emissions which enter a block of air moving through the emission area are proportional to the amount of time required for the block to pass over the area, which is merely $L\,W^{-1}$, thus

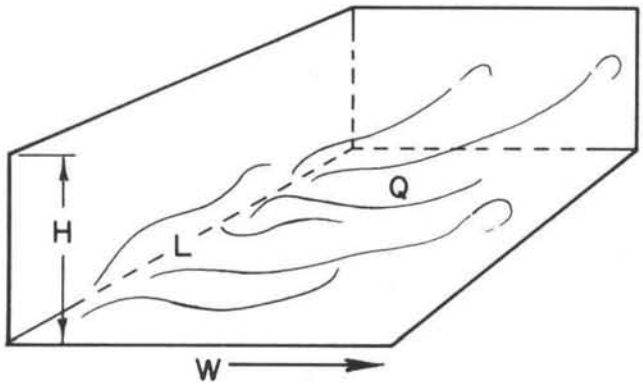
$$\chi = q_A L\,(HW)^{-1} \tag{1A}$$

represents the concentration at the downwind edge of the box due to emissions within the box.

Now, let χ_{max} be some maximum allowable increment of pollutant concentration at the downwind edge of some square area due to burning activity within the area. The maximum acceptable emission rate for the area as a whole according to the box model is

$$Q_{max} = \frac{\chi_{max}\,LHW}{k} \tag{2}$$

The quantity, HW, the product of mixing height and transport windspeed, is ventilation factor. If the box model perfectly reflected atmospheric dispersion rate, acceptable levels of burning activity, Q_{max}, would be proportional to ventilation factor.



Box model assumption: Smoke Q is emitted along line L, transported by wind W, and trapped within a box of depth H.

Figure 1.--Box model concept.

In general, the equation (2) model does not describe dispersion rate within the box. Typically, dispersion rates within the atmosphere are such that pollutants tend to approach uniform concentrations within the mixing layer. The rate of approach to uniformity, however, can be an important factor in determining ground-level concentrations. The rate of approach is a function of dispersion rate within the mixing layer when that rate is much greater than dispersion rate above the mixing height. The Gaussian dispersion model represents a frequently used method to account for the rate of dispersion within the mixing layer, as well as for many instances when the mixing height is effectively zero.

Gaussian Dispersion Modeling for Area Sources

Gaussian dispersion models (Turner 1970) are considered state of the art (EPA 1978) for modeling air-quality impact of individual sources for distances up to 50 km. More refined models are available, and sometimes necessary, but the Gaussian plume approach represents a compromise between cost, general applicability, known performance, and availability of efficient computerized algorithms. This approach has been used for sources of widely varying configurations, including individual prescribed fires (SFFLS 1976). For a uniform area source shaped as a square, emitting at ground level, the concentration at the downwind edge of the area according to the Gaussian dispersion model is:

$$\chi = q_A \int_0^L \frac{2}{\sqrt{2\pi}\,\sigma_z(x,H,S)\,W}\,dx \qquad (3)$$

where: $\sigma_z(x,H,S)$ is the vertical dispersion coefficient, a function of downwind distance, x, mixing height, H, and stability class, S.

...dx represents an integration with respect to downwind distance

π is 3.14159...

and it is assumed that the units of q_A, L, x, σ_z, H, and W are internally consistent (i.e., k = 1).

The stability class, S, in equation (3) does not represent a specific numerical quantity but refers to the classification system given in appendix A.

In steady-state Gaussian dispersion modeling, mixing height and wind are presumed to be constant in a given area for some period of time. Thus, under steady-state conditions, only σ_z needs to be integrated with respect to x.

The mathematical form of σ_z is:

$$\sigma_z = \text{minimum}\left(ax^b, \frac{2}{\sqrt{2\pi}}H\right) \qquad (4)$$

(but σ_z must not exceed 5,000 m)

where: a and b are constants within a stated range of x (a > 0, b > 0)

Note that if ax^b exceeds $\frac{2}{\sqrt{2\pi}}H$ within the range of distances x_{low} and x_{high}, the solution of the integral within equation (3) is:

$$\frac{x_{high} - x_{low}}{HW}$$

which is to say that if ax^b exceeds $\frac{2}{\sqrt{2\pi}}H$ over some range of distances, the box model is applicable for that range of distances:

$$\chi\,(x_{low} \text{ to } x_{high}) = \frac{q_A\,(x_{high} - x_{low})}{HW} \qquad (5)$$

where: $\chi\,(x_{low}$ to $x_{high})$ denotes concentration due to emissions within the portion of the area lying at distances x_{low} to x_{high} upwind of the downwind edge of the square area.

A "critical" distance, x_c can be defined in such a way that the following relationship is true:

$$\sigma_z = a\,x_c^{\,b} = \frac{2}{\sqrt{2\pi}}H \qquad (6)$$

if a and b are applicable at the distance x_c.

For a given mixing height and stability class, equations (3), (4), and (6) may be combined to yield

$$\chi = q_A \frac{2}{\sqrt{2\pi}\,W} \int_0^{A_M} \frac{1}{ax^b}\,dx + q_A \frac{L - A_M}{HW} \qquad (7)$$

where: A_M = minimum (L, x_c)

Values of a and b for each stability class are given in appendix C for ranges of downwind distance. For the most part, these are the same as those given by Busse and Zimmerman (1973). The values of a and b for near-neutral stability during daylight hours are modified to cause σ_z to be generally equivalent

to the recommendations of Pasquill (1974, p. 368, fig. 6.10). This modification of the CDM model was found to be necessary to produce a dispersion index that would not be unduly sensitive to small changes in weather variables used to estimate stability class.

Specification of Prescribed Fire Activity as an Area Source

Prescribed fires emit smoke into the atmosphere at varying heights according to the heat of the fires, windspeed, and properties of fire convection columns (such as entrainment of smoldering smoke). The specification of one or more plume heights as ranges of heights within a 2,500-km^2 area is necessarily arbitrary. To maintain relative mathematical simplicity, yet show the differing scopes of smoke impact due to fires with considerable plume rise versus smoldering smoke not associated with significant rise, the following assumptions are made:

Assumption 1. One-half of smoke emissions undergo extensive plume rises of varying heights in such a way that the aggregate effect is uniform mixing of smoke up to the mixing height.[2]

Assumption 2. One-half of smoke emissions undergo very limited plume rise with an aggregate effect being a ground-based Gaussian distribution of smoke with an initial value of 30 m (about 100 ft) for σ_z.

Assumption 1 requires no additional mathematical development. Assumption 2 may be accommodated through use of the EPA accepted "virtual distance" concept (Petersen 1978). This concept involves a "replacement" of the source, mathematically, at a distance, x_v, upwind of its actual location. Direct use of the Gaussian dispersion equations may be made with the x_v distance added to all downwind distances before computations are made. The value of x_v is dependent on initial (source configuration related) dispersion coefficient (30 m, according to Assumption 2) and stability class. Values of x_v are given in appendix C, table 3.[3]

To account for virtual distance, equation (7) is modified to:

$$\chi = q_A \frac{2}{\sqrt{2\pi}\, W} \int_{x_v}^{A_v} \frac{1}{ax^b}\, dx + q_A \frac{(L + x_v) - A_v}{HW} \quad (8)$$

where: A_v is minimum $(L + x_v, x_c)$.

Combining Assumptions 1 and 2 by use of equations (1A) and (8) leads to

$$\chi = \frac{0.5\, q_A L}{HW} + \frac{q_A}{\sqrt{2\pi}\, W} \int_{x_v}^{A_v} \frac{1}{ax^b}\, dx + 0.5\, q_A \frac{(L + x_v) - A_v}{HW} \quad (9)$$

The first and third terms in equation (9) can be combined but are kept separate to allow inspection of the separate effects of Assumptions 1 and 2. The quantity $\int_{x_v}^{A_v} \frac{1}{ax^b}\, dx$ may be integrated by the following means: Consider a and b within a given range of x as constants, then within that range of x, (x_{low} to x_{high})

$$\int_{x_{low}}^{x_{high}} \frac{1}{ax^b}\, dx = \frac{1}{a\,(1 - b)} \left[x_{high}^{(1-b)} - x_{low}^{(1-b)} \right] \quad (10)$$

The results of the integration can be used as a term within a series within equation (9) as follows:

$$\chi = 0.5\, q_A \frac{L}{HW} + \frac{q_A}{\sqrt{2\pi}\, W} \sum_{i=1}^{3} \left[\frac{A_R^{(1-b_i)} - x_R^{(1-b_i)}}{a_i^{(1-b_i)}} \right] + 0.5\, q_A \frac{(L + x_v) - A_v}{HW} \quad (11)$$

where: A_R is minimum (x_{high}, A_v)
x_R is maximum (x_{low}, x_v)

and the series has three terms, since three ranges of x (three sets of x_{low} and x_{high}) are given in appendix C.

[2] If the atmosphere is stable (stability class 5, 6, or 7), mixing height is zero. During these conditions, the smoke emissions affected by plume rise are assumed to be uniformly mixed in a layer of depth, H_s. The method for obtaining H_s is given in appendix D, equation (38), derived from the box model equation (1).

[3] The CDM model does not consider virtual distance when utilizing an initial dispersion coefficient. The use of virtual distance allows the integral in equation (8) to be evaluated directly, saving computer space and time.

Note that both $x_R < A_v$ and $A_R > x_v$ must be true if the ith term of the series in equation (9) is to be evaluated; if either condition is not met, the ith term is zero.

Conversion of Concentration/Emissions Relationships to a Dispersion Index

The relationships among emission rate, weather parameters, and concentration given by equation (11) may be converted to a dispersion index by assigning a constant value to the area emission rate, q_A, solving for the concentration, χ, then letting the reciprocal of concentration be the dispersion index. For the dispersion index considered here, let:

$$q_A = 0.002\ \mu g\ m^{-2}s^{-1} \tag{12}$$

$$L = 50{,}000\ m \tag{13}$$

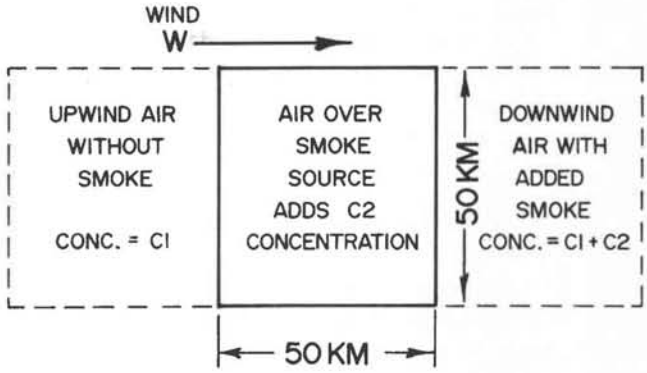
and the units of χ be expressed in μg. Thus, the dispersion index determined from equations (11), (12), and (13) is:

$$\overline{DI} = \left(\frac{50}{HW} + \frac{0.002}{\sqrt{2\pi}\,W}\sum_{i=1}^{3}\left[\frac{A_R^{(1-b_i)} - x_R^{(1-b_i)}}{a_i^{(1-b_i)}}\right] + \frac{0.001\,(50{,}000 + x_v - A_v)}{HW}\right)^{-1} \tag{14}$$

where: $\overline{DI}$ signifies dispersion index in $m^2\ s^{-1}$.

The estimated concentration, along with the inversely proportional relationship between dispersion index and assumptions given by equations (12) and (13), implies that the dispersion index estimates the average (or total) emission rate within a square area that would result in a specific incremental increase of ground-level crosswind-averaged concentrations within a mass of air as it moves over the area (fig. 2).

The computer code in ANSI FORTRAN 77 language (Am. Natl. Stand. Inst. 1978) for determining the dispersion index, given stability class, daylight or dark, mixing height, and transport windspeed, is given in appendix E. The dispersion



$$C2 \cong \frac{(\text{constant}) \times (\text{emissions})}{(\text{dispersion index})}$$

or if C2 is restricted to a given value, the allowable emissions are: $Q \cong (\text{constant}) \times (\text{dispersion index})$

Figure 2.--Dispersion index concept (top view).

index of equation (14) may be thought of as being a 50:50 weighting of the index based on a ventilation factor:

$$\overline{DI_v} = \frac{HW}{100} \tag{15}$$

and a modified CDM model ground-level source-based dispersion index:

$$\overline{DI_c} = \left(\frac{0.004}{\sqrt{2\pi}\,W}\sum_{i=1}^{3}\left[\frac{A_R^{(1-b_i)} - x_R^{(1-b_i)}}{a_i^{(1-b_i)}}\right] + \frac{0.002\,(50{,}000 + x_v - A_v)}{HW}\right)^{-1} \tag{16}$$

The 50:50 weighting of equations (15) and (16), on a harmonic mean basis (see appendix B), is a direct result of Assumptions 1 and 2.

The relationship between any of the dispersion indices given by equations (14), (15), or (16) and maximum emission rate is:

$$Q_{max} = 5\chi_{max}\,\overline{DI'} \tag{17}$$

or

$$(q_A)_{max} = 0.002\chi_{max}\,\overline{DI'} \tag{18}$$

where: Q_{max} is maximum total emission rate ($g\ s^{-1}$) within the entire area

$(q_A)_{max}$ is maximum area-averaged emission rate ($\mu g\ m^{-2}s^{-1}$)

X_{max} is maximum (acceptable) incremental increase in crosswind-averaged concentrations due to emissions within the area ($\mu g\ m^{-3}$)

and $\overline{DI'}$ is any of the dispersion indices, $\overline{DI}$, $\overline{DI}_v$, or $\overline{DI}_c$

Thus, the dispersion index can be used as an estimate of the level of prescribed fire activity that can be conducted in a given area without resulting in unacceptably high increases in smoke concentrations on an areawide basis.

None of the dispersion indices is a valid indicator for localized smoke management because the variation of concentrations due to fire locations within the area is not accounted for. A dispersion index could be constructed for an individual fire. However, since fires vary widely in size, energy release rate, convection column orientation, and distance to potential smoke-sensitive areas, no single indexing procedure would likely be applicable for more than a small fraction of all prescribed fires.

It must be stressed that steady-state (unchanging) weather conditions must prevail throughout the area where the dispersion index is being determined for equations (14)-(16) to be valid. Steady-state weather should be maintained, at minimum, for the length of time, Δt, required for smoke emitted at the upwind edge of the area to reach the downwind edge:

$$\Delta t \geq \frac{L}{W} = \frac{50{,}000}{W} \qquad (19)$$

where: the units of Δt are s, and W are $m\ s^{-1}$.

The mean value of transport windspeed in the 48 contiguous States is about $5\ m\ s^{-1}$ (Holzworth 1972), so the weather parameters used to determine dispersion index over the area should reflect conditions over at least a 3-hour period. If the index is to be used on a comparative basis for purposes of smoke management meteorology, a period of 6 hours should be considered so that the relative effect of weather during high versus low transport windspeed conditions can be directly compared with minimal error. Recommendations on use of the dispersion index are made in a later section.

Response of the Dispersion Index to Meteorological Parameters

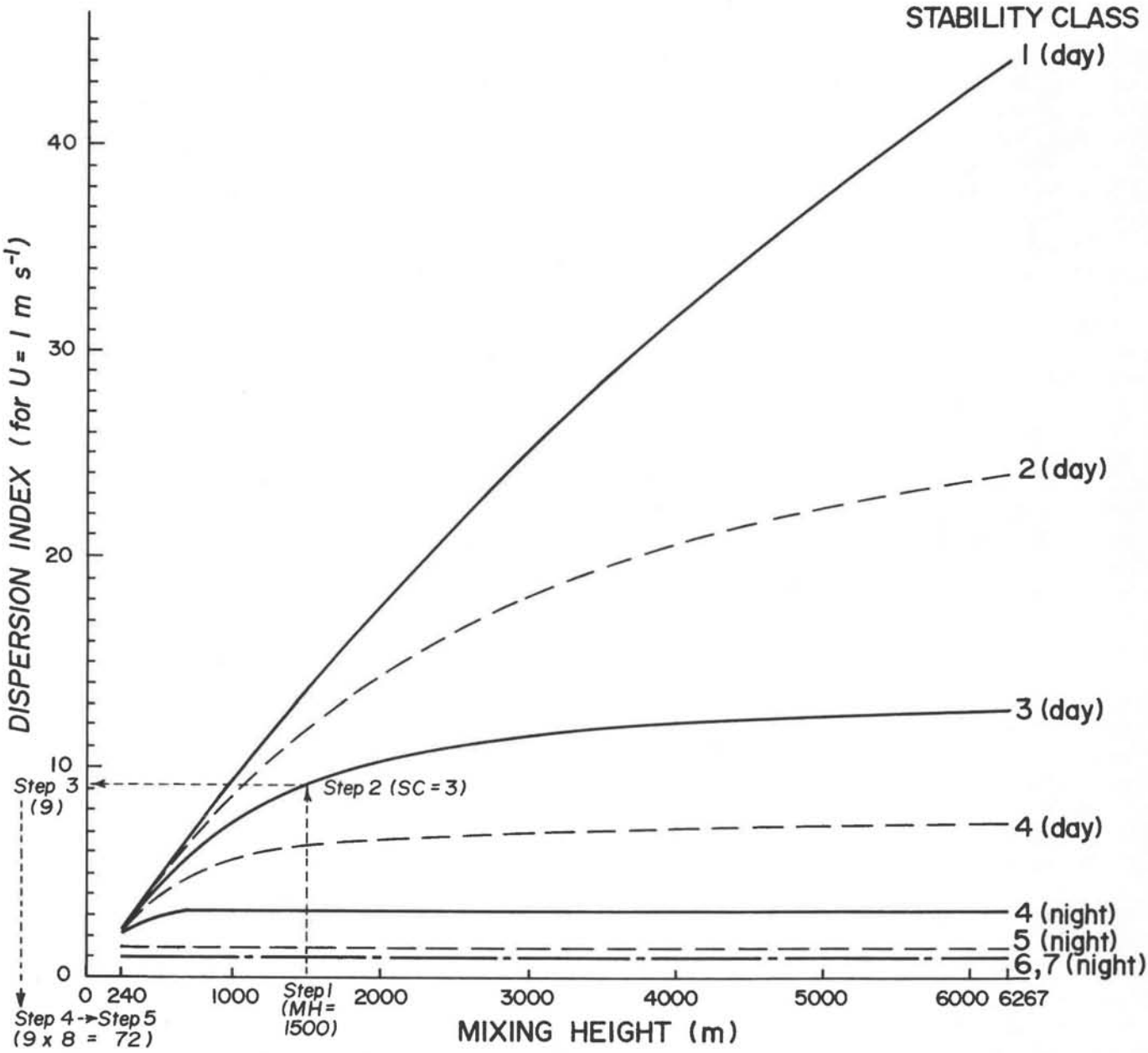
The dispersion index, $\overline{DI}$, given by equation (14) (accounting both for well-mixed and ground smoke), is directly proportional to transport windspeed. For example, with unchanged mixing height and stability class, doubling transport windspeed doubles the dispersion index. Doubling the mixing height will also increase dispersion index, but due to incomplete mixing within the mixing layer (see the summation term within equation (14)) the index may not double. Dispersion index also is increased when the stability class indicates a more unstable atmosphere (i.e., a lower class letter or number, according to the estimation method in appendix A). Figure 3 shows the response of dispersion index versus mixing height for each stability class, with transport windspeed set to the minimum recommended value (Turner and Novak 1978a, 1978b) of $1\ m\ s^{-1}$. Note that for the most unstable category, the response tends to be close to that expected from ventilation factor alone (equation (15)). This response results from the highly efficient mixing process attributed to a very unstable atmosphere by the CDM model algorithm. Certain restrictions on the value of mixing height, H, have been made in constructing figure 3 to reflect reasonable meteorological conditions:

$H = H_s \geq 240$ m (daytime; also nighttime when stability class is near neutral) (20)

$H = H_s \leq 600$ m (nighttime; near neutral stability only) (21)

$H_s = 180$ m (if stability class is slightly stable) (22)

$H_s = 150$ m (if stability class is moderately stable or very stable) (23)



STEPS FOR GRAPHICAL DETERMINATION OF DISPERSION INDEX:

1. Find mixing height along X axis (e.g., 1500 m)
2. Trace vertically until intercepting appropriate stability class (e.g., SC = 3)
3. Trace horizontally (to left) until intercepting Y axis (the U = 1 m s^{-1} dispersion index) (e.g., approx. 9)
4. Multiply Y axis value by the transport windspeed (in meters per second) (e.g., 9 x 8 m s^{-1})
5. Result is dispersion index (e.g., approx. 72)

Figure 3.--Response of dispersion index to mixing height, by stability class (transport windspeed = 1 m s^{-1}).

where: H_s in equations (20) to (23) is the depth of the smoke-burdened atmospheric layer, due to plume rise.

Equation (20) allows for the effect of plume rise from prescribed fires during neutral or unstable atmospheric conditions near the ground with some penetration or slow mixing into an overlying stable layer very near the ground. Equation (21) accounts for the at least slightly subadiabatic conditions usually observed near the ground at night, regardless of the indicated stability category (Lavdas 1981). Superadiabatic conditions resulting in nocturnal mixing heights calculated by the parcel method (Hess 1959) being significantly nonzero are a likely indicator of dangerous fire weather (Byram 1959). The 600-m restriction represents the estimated effective extent of mixing from a ground-level source in near-neutral conditions after 100 km of travel (Lavdas 1982; Turner 1970). Conditions as expressed by equations (22) and (23) represent values of H_s, not mixing height (which is zero), during stable conditions (classes 5, 6, and 7). These values of H_s take into account stable plume rise from Briggs (1972) due to point sources of sensible heat flux up to 1,000 m^4 s^{-3}, as well as the effect of dispersion during downwind transport (see appendix D).

The curve labeled 4-DAY in figure 3 represents the only substantial alteration to models or modeling practices currently approved by the EPA. This curve corresponds to the D(1) stability category of Pasquill (1974, p. 368). The adaptation of this procedure removes the most serious of the dispersion index discontinuities, which are created by the use of stability classes rather than a continuous stability function. The mixing height (referred to by Pasquill as "the top of the dry-adiabatic layer") directly contributes to the value of the vertical dispersion coefficient, σ_z, in the D(1) stability class, although it does so for no other category. In the computation of dispersion index, the mixing height dependence of σ_z is accounted for in the calculation of the critical distance, x_c, beyond which uniform mixing is assumed by the CDM model. This uniform mixing assumption allows the 4-DAY stability values of σ_z to be calculated without explicitly considering mixing height. The constants a and b, given in appendix C, are the same as those given by Busse and Zimmerman (1973) except for the 4-DAY class. For the 4-DAY class, the CDM constants for less than 500 m are applied at all distances, which yield a linear curve on a log-log graph of σ_z versus x, as is shown by Pasquill.

Use of the Dispersion Index

The dispersion index offers a means of allocating prescribed fire emissions within an area, according to prevailing weather conditions, to avoid regional smoke overload. The index is based on the EPA-approved CDM model and constructed around the crosswind-averaged concentration impact at the downwind edge of a 50- by 50-km area (about 1,000 m^2) due to fire activity within the area. Smoke concentrations at specific locations are not accounted for; methods such as those given in SFFLS (1976) should be used to avoid overload due to individual fires. The dispersion index does not give a direct indication of the impact of smoke that travels in excess of 50 km. The likely effects of smoke upwind of the basic 50- by 50-km area should be considered before attempting a specific limitation on emissions based on a mandated value of X_{max}. Because of the assumptions used in constructing the index and the inherent limitations of the CDM model, it is suggested that the dispersion index be calibrated against prescribed fire activity in areas of similar fuel types and firing practices. The dispersion index is designed to have a one-to-one correspondence to the emissions from prescribed fire acceptable from an area-averaged, air-quality standpoint. A subjective interpretation of the dispersion index based on stagnation criteria, climatological values of ventilation and stability, and weather

conditions frequently sought for prescribed burning activity is given in table 1.

Table 1.--Preliminary interpretation of dispersion index values

Dispersion index	Interpretation
>100	Very good (but may indirectly indicate hazardous conditions; check fire weather)
61-100	Good (Southern Forest Fire Laboratory Staff 1976; typical-case burning weather values are in this range)
41-60	Generally good (climatological afternoon values in most inland forested areas of the United States fall in this range)
21-40	Fair (stagnation may be indicated if accompanied by persistent low windspeeds)
13-20	Generally poor; stagnation, if persistent (although better than average for a night value)
7-12	Poor; stagnant at day (but near or above average at night)
1-6	Very poor (very frequent at night; represents the majority of nights in many locations)

As already pointed out, the dispersion index should be based on weather conditions within the area that are representative over a 6-hour period. For example, a forecast of maximum surface temperature, expected afternoon cloud cover, and windspeeds combined with the projected upper-air conditions would generally yield values of mixing height, transport windspeed, and stability class that would be representative of conditions throughout the afternoon. If a dispersion index climatology is being constructed from hourly observations, it is suggested that it be calculated as the harmonic mean of six hour-by-hour "raw indices." The harmonic mean is suggested since the dispersion index corresponds to the reciprocal of concentration impact, and concentration impact is normally arithmetically averaged. Calculation of the harmonic mean is shown in appendix B.

When using surface and upper-air observations or forecasts to obtain mixing height, transport windspeed, and stability class over a 6-hour period of interest, keep the following points in mind:

1. Consider the variability of the atmospheric conditions (sun angle, cloud cover, ceiling, and windspeed) used to estimate stability class. Be sure a representative class is chosen, particularly if hour-by-hour computations are not made.

2. Consider the likely changes in mixing height, particularly the mixing that is likely to affect the smoke from both active and smoldering fires. The effective mixing height often drops rapidly to a low value around sunset as a surface-based nocturnal inversion forms. (The "parcel method," based on an early morning sounding, may give an anomalously high value for this purpose.) The restrictions on mixing height--conditions expressed by equations (20)-(23)--may be applicable. Consider the depth of atmosphere likely to contain smoke as being perhaps a more applicable estimate of mixing height than the definition given by strict thermodynamics considerations.

3. Consider the reliability of available data for the area of interest when evaluating the information. For instance, a nearby 1-hour-old surface-wind report should be given increased consideration when averaged against a more distant sounding that is several hours old. Smoke impact is often a ground-based phenomenon. Giving the

latest surface-wind observation 50 percent weight in determining the transport windspeed may be reasonable, particularly if the wind report is representative of the overall surface-wind pattern. In general, the surface windspeed report within the upper-air sounding should be disregarded unless that report is recent and representative.

Finally, it should be stressed that a burn/no burn decision for a given prescribed fire should not be based solely on the index. Dispersion index is not designed to account for the effect of high relative humidity on visibility in smoke. It is necessary for the prescribed burner to avoid smoke emissions during high-humidity periods, especially during poor-dispersion conditions. Also, no matter how good the dispersion index, it is possible for a fire to overload the atmosphere at nearby smoke-sensitive locations. The index is designed as an indicator of the atmosphere's capability to disperse pollutants on an areawide basis. It does not account for locally high smoke concentrations or the effects of smoke concentrations on visibility in high humidity.

List of Symbols

A_M - Minimum value of either the downwind length of the area source model, or x_c (m).

A_R - Minimum value of either the longest downwind distance for which the power law constants (a and b) are applicable, or the downwind length of the area source model plus virtual distance, or x_c (m).

A_V - Minimum value of either the downwind length of the area source model plus virtual distance, or x_c (m).

a - A value, which depends on stability class and is constant for a range of downwind distances, which is used in the power law expression, ax^b, to compute the vertical dispersion coefficient from downwind distance (dimensionless).

a_I - Specific value of the constant, a, which is applicable for one of these ranges of downwind distances: 100-500 m, 500-5,000 m, > 5,000 m (dimensionless).

b - A value, dependent on stability class and constant for a range of downwind distances, used to compute the vertical dispersion coefficient (dimensionless) (see the definition of a).

b_I - Specific value of the constant, b (dimensionless) (see definition of a_I).

$\overline{DI}$ - Dispersion index, based both on ventilation factor and the concentration at the downwind edge of a uniform area source according to the Climatological Dispersion Model ($m^2\ s^{-1}$).

$\overline{DI}_c$ - Dispersion index based solely on the concentration at the downwind edge of a uniform area source according to the Climatological Dispersion Model ($m^2\ s^{-1}$).

$\overline{DI}_v$ - Dispersion index based solely on ventilation factor ($m^2\ s^{-1}$).

$\overline{DI}'$ - Any of the three above dispersion indices ($m^2\ s^{-1}$).

exp(...) - Denotes exponentiation of the quantity in parentheses (no associated dimensions).

F - Sensible heat flux from some source, such as a prescribed burn ($m^4\ s^{-3}$).

g - Acceleration due to gravity ($m\ s^{-2}$).

H - Mixing height; the height at and below which atmospheric dispersion is rapid (may be zero at night) (m).

H_{MEAN} - The unweighted harmonic mean (units of individual entities that are calculated).

H_{MEANW} - The weighted harmonic mean (units as for H_{MEAN}).

H_S - Depth of a uniformly mixed ground-based smoke layer due to effects of both plume rise from fires and atmospheric dispersion (m).

Δh - Plume rise due to the heat of the fire (m).

k - A multiplicative units-dependent constant used when computing concentration in a box model ($k = 1$ in this study; often $k = 10^6$ to account for micrograms per gram) (dimensionless).

L - Downwind length of the area source model for computing concentrations (50,000 m in this study) (m).

n - Number of quantities considered in an averaging process (dimensionless).

$P(Z,\sigma_z^{-1})$ - Integral of the normal distribution, expressed in terms of the ratio of $(Z\sigma_z^{-1})$ dimensionless).

$\overline{P(Z,\sigma_z^{-1})}$ - The mean value of the above integral within a 50 x 50 km square area (dimensionless).

Q - The total emission rate of the area source (kg s^{-1}).

$(Q_H)_{Mcal}$ - Total sensible heat release rate from a prescribed fire (megacalories s^{-1}).

$(Q_H)_{MW}$ - Total sensible heat release rate (megawatts).

Q_{max} - Maximum acceptable emission rate of the area source (i.e., that which results in the maximum acceptable incremental increase of pollutant concentration at the downwind edge of the area) (kg s^{-1}).

Q_x - Emission rate from a vertical plane at some specific upwind distance, x, from a reference receptor; conversely, emission rate associated with relative concentration at some specific downwind distance, as derived in appendix D (kg s^{-1}).

Q_Z - Total emission rate from a line source at height, Z(kg s^{-1}).

q_A - The uniform area-averaged emission rate (kg m^{-2} s^{-1}).

$(q_A)_{max}$ - The maximum acceptable uniform area-averaged emission rate (analogous to Q_{max}) (kg m^{-2} s^{-1}).

S - The Pasquill-Gifford-Turner stability class, expressed as a number from 1 to 7 (dimensionless).

Δt - Length of time required for emissions at the upwind edge of the area source to be transported to the downwind edge of the area (s).

W - Transport windspeed, the average windspeed in the mixing layer (if atmospheric stability is unstable or neutral), or in the portion of a surface-based stable layer containing significant amount of pollutants (if the atmospheric stability is stable) (m s^{-1}).

W_h - Representative windspeed within the layer of atmosphere through which plume rise occurs (m).

wf - Weighting factor in an averaging process (dimensionless).

x - Downwind distance from the real or virtual origin of emissions from a point or line source (m).

x_c - Critical downwind distance, x, at which vertical Gaussian dispersion from a ground-based source is equivalent to vertically uniform dispersion trapped between the ground and the mixing height, H (m). (If the atmospheric stability is stable, x_c is regarded as being much larger than 50,000 m.)

x_{high} - Longest downwind distance for which specific values of the power law coefficients (a_I, b_I) are applicable (m).

x_{low} - Shortest downwind distance for which specific values of the power law coefficients (a_I, b_I) are applicable (m).

x_r - Maximum of x_{low} (associated with specific values of a_I and b_I), or the virtual downwind distance, x_v (m).

x_v - Virtual downwind distance increment; a nonpoint source, which has a characteristic initial Gaussian distribution at the source origin (a vertical dispersion coefficient of 30 m is assumed in this study), has a concentration pattern (in steady-state uniform Gaussian dispersion modeling) identical to a "fictitious" point source at a location upwind of the actual nonpoint source. The distance from the fictitious point source to the actual source location is the virtual downwind distance (m).

y - A general quantity that is being averaged (see appendix B).

Z - Height above the ground of a smoke-emissions source (m).

θ - Potential temperature; i.e., that temperature an atmospheric parcel would have if its pressure changed to 1,000 millibars with no heating, using an ideal gas assumption (K).

$\frac{\delta\theta}{\delta Z}$ - Change of potential temperature with respect to height ($K\ m^{-1}$).

π - 3.14159. . . (dimensionless).

χ - Concentrations due to the emissions of a specific source or set of sources (e.g., all sources within an area, or a uniform area source) ($kg\ m^{-3}$).

χ_L - Concentration due to a line source ($kg\ m^{-3}$).

χ_{max} - Maximum acceptable increment of concentration that can be tolerated due to the emissions of a specific source or set of sources ($kg\ m^{-3}$).

χ_x - Concentration from a vertical plane at some specific upwind distance, x; conversely, concentration associated with relative concentration at some specific downwind distance, as derived in appendix D ($kg\ m^{-3}$). (Note: The general form of relative concentration is ($\chi\ Q\ W^{-1}$), with units of (m^{-2}).)

σ_z - The Gaussian vertical dispersion coefficient (m).

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APPENDIXES

APPENDIX A

Stability Class Estimation Method

Input data required to determine stability class[4] include solar elevation angle in degrees, total opaque cloud cover in tenths, ceiling height in feet, and surface windspeed in knots. If ceiling is undefined due to little or no cloudiness, it should be regarded as $\geq$99,000 ft; if ceiling is undefined due to surface-based obscuration, consider the sky as totally covered with opaque clouds, and the vertical visibility may be used in place of ceiling height. The other parameters are defined in the same way as in National Weather Service operations (for example, surface windspeed is the windspeed 20 ft above open terrain).

The stability class is determined through an estimate of net radiation and surface windspeed. A net radiation index is obtained by the following procedure:

I. If the total opaque cloud cover is 10/10 and the ceiling height is <7,000 ft, use net radiation index equal to 0 (whether day or night).

II. For nighttime (between sunset and sunrise):

   A. If total opaque cloud cover $\leq$4/10, use net radiation index equal to -2.

   B. If total opaque cloud cover >4/10, use net radiation index equal to -1. (Note that this will not apply for cases of 10/10 coverage when ceiling <7,000 ft, since such cases are determined by step I, above).

III. For daytime:

   A. Determine the insolation class number as a function of solar elevation angle according to the following:

Solar elevation angle (δ)	Insolation class number
$60° < \delta$	4
$35° < \delta \leq 60°$	3
$15° < \delta \leq 35°$	2
$\delta \leq 15°$	1

   B. If the total opaque cloud cover $\leq$5/10, the net radiation index is equal to the insolation class number.

   C. If the total opaque cloud cover >5/10, modify the insolation class number by following these six steps:

      1. Ceiling height less than 7,000 ft, subtract 2.

      2. Ceiling height greater than or equal to 7,000 ft but less than 16,000 ft, subtract 1.

      3. Total opaque cloud cover equal 10/10, subtract 1. (This will only apply to ceilings greater than or equal to 7,000 ft because cases with 10/10 coverage with ceiling less than 7,000 ft are determined by step I, above.)

      4. If neither steps 1 and 2 nor 3 immediately above are applicable, assume that the modified insolation class number is equal to the insolation class number.

      5. If the modified insolation class number is less than 1, let it equal 1.

      6. Set the net radiation index equal to the modified insolation class number.

The stability class is estimated as a function of net radiation index and surface windspeed according to table 2.

[4]The method in this appendix is the same as that used in Turner (1961, 1964).

The numerical value of stability class given in table 2 may be interpreted in the following manner:

Stability class	Interpretation
1 (or Pasquill A)	Very unstable
2 (or Pasquill B)	Moderately unstable
3 (or Pasquill C)	Slightly unstable
4 (or Pasquill D)	Near neutral
5 (or Pasquill E)	Slightly stable
6 (or Pasquill F)	Moderately stable
7 (or Pasquill _, sometimes G)	Very stable

When used in determining dispersion index from hour-by-hour surface weather observations, the stability class should not be allowed to vary by more than one class per hour. This restriction is imposed to help account for the effects of changing weather conditions on concentrations due to pollutants undergoing transport for several hours.

The system is the same as that used in most EPA atmospheric dispersion models. Occasionally, a given model may redefine certain stability classes to account for urban heating effects on a stable atmosphere. Such adjustments are not used in formulating a dispersion index because prescribed burning is a rural phenomenon; even its impact on the upwind edge of an urban area will reflect predominantly rural dispersion conditions. One adjustment is made for the near-neutral class 4--subclasses 4-DAY and 4-NIGHT are defined where 4-DAY refers to stability class 4 with the solar elevation angle above the horizon, and 4-NIGHT is applicable to the period from sunset to sunrise.

Table 2.--Stability class as a function of net radiation index and surface windspeed

Windspeed (knots)	Net radiation index						
	4	3	2	1	0	-1	-2
0-1	1	1	2	3	4	6	7
2	1	2	2	3	4	6	7
3	1	2	2	3	4	6	7
4	1	2	3	4	4	5	6
5	1	2	3	4	4	5	6
6	2	2	3	4	4	5	6
7	2	2	3	4	4	4	5
8	2	3	3	4	4	4	5
9	2	3	3	4	4	4	5
10	3	3	4	4	4	4	5
11	3	3	4	4	4	4	4
≥12	3	4	4	4	4	4	4

APPENDIX B

Calculating the Unweighted or Weighted Harmonic Mean

The unweighted (simple) harmonic mean, H_{MEAN}, of n values of y is

$$H_{MEAN} = \frac{n}{\sum_{i=1}^{n}\left(\frac{1}{y_i}\right)} \tag{24}$$

where y_i denotes an individual value of y.

For example, the simple harmonic mean of {4, 5, 10, 40, 50, 200} is

$$H_{MEAN} = \frac{6}{\left(\frac{1}{4}+\frac{1}{5}+\frac{1}{10}+\frac{1}{40}+\frac{1}{50}+\frac{1}{200}\right)} = \frac{6}{0.6} \tag{25}$$

or $H_{MEAN} = 10$

where the dimensions of H_{MEAN} are the same as for each and every individual value of y_i.

The weighted harmonic mean, H_{MEANW}, is calculated in an analogous manner. In this case, n is replaced by the sum of the individual weighting factors wf_i, associated with individual values of y_i, that is:

$$H_{MEANW} = \frac{\sum_{i=1}^{n}(wf_i)}{\sum_{i=1}^{n}\frac{(wf_i)}{(y_i)}} \tag{26}$$

For example, if there are three numbers {3, 5, 9} where 3 and 5 have weighting factors of 2, and 9 has a weighting factor of 3, then

$$H_{MEANW} = \frac{(2 \times 2 \times 3)}{\left(\frac{2}{3}+\frac{2}{5}+\frac{3}{9}\right)} = \frac{7}{\left(\frac{7}{5}\right)} \tag{27}$$

or $H_{MEANW} = 5$

Note that this result is identical to the simple harmonic mean of seven numbers {3, 3, 5, 5, 9, 9, 9} or

$$H_{MEAN} = \frac{7}{\left(\frac{1}{3}+\frac{1}{3}+\frac{1}{5}+\frac{1}{5}+\frac{1}{9}+\frac{1}{9}+\frac{1}{9}\right)} = 5 \tag{28}$$

APPENDIX C

Effect of Stability Class and Downwind Distance on the Vertical Gaussian Dispersion Coefficient σ_z, Critical Distance x_c, and Virtual Distance Increment x_v

The vertical Gaussian dispersion coefficient, σ_z, is computed by use of the formula

$$\sigma_z = ax^b$$

given that (29)

$$ax^b \leq \frac{2}{\sqrt{2\pi}} H$$

otherwise

$$\sigma_z = \frac{2}{\sqrt{2\pi}} H \qquad (30)$$

where: σ_z is in meters

x is downwind distance, in meters, from a point source

a,b are constants, given a stability class and a specific range of x

and H is mixing height in meters.

The virtual distance, x_v, is defined in a manner somewhat similar to x_c; that is, x_v is the value of x_y that satisfies the following equation

$$30 = a\,x_v^b \qquad (31)$$

where: a and b must be applicable for the specific value of x_v

and 30 is the assumed initial value of σ_z, in meters (this is analogous to the process performed in equation (6)).

Table 3 gives the values of the parameters a, b, and x_v as a function of stability class (and, in the case of a and b, downwind distance x). Note that x_v may be found from a knowledge of stability class only, while mixing height, H, and downwind distance, x, must also be available to determine σ_z.

Table 3.--Values of parameters a, b, and x_v as a function of stability class and downwind distance

Stability class	100 m < x < 500 m		500 m < x < 5,000 m		x > 5,000 m		x_v
	a	b	a	b	a	b	(30 m)
1	0.0383	1.2812	0.0002539	2.0886	0.0002539	2.0886	181.46
2	0.1393	0.9467	0.04936	1.1137	0.04936	1.1137	291.43
3	0.1120	0.9100	0.1014	0.9260	0.1154	0.9109	465.62
4-DAY	0.0856	0.8650	0.0856	0.8650	0.0856	0.8650	874.56
4-NIGHT	0.0856	0.8650	0.2591	0.6869	0.7368	0.5642	1010.0
5	0.0818	0.8155	0.2527	0.6341	1.2969	0.4421	1869.0
6 and 7	0.0545	0.8124	0.2017	0.6020	1.5763	0.3606	4061.3

Note: x_v depends on stability class only.

To obtain a value of σ_z, find a and b in table 3, then use equations (29) and (30) as appropriate. Equation (29) applies at all distances, x, less than the critical downwind distance, x_c. Equation (30) applies for distances greater than x_c. The critical distance, x_c, is defined by equation (6); when rearranged, this equation is:

$$x_c = \left[\frac{\sqrt{2\pi}\,H}{2a}\right]^{1/b} \tag{32}$$

where: a and b are the values from table 3 appropriate at distance x_c.

In most cases, the values of a and b for $x \geq 5{,}000$ m may be used in equation (32) to solve for x_c. This is because x_c is frequently greater than 5,000 m, particularly when the stability class is 4 or greater. For stability classes 1 and 2, x_c is often between 500 and 5,000 m, but the values for a and b are the same for all $x > 500$ m. For stability class 3, x_c is less than 5,000 m when mixing height, H, is less than 338.5 m. When the stability class is 5, 6, or 7, it is not necessary to determine x_c since mixing height is not defined for a stable atmosphere (in effect, the critical distance, x_c, is >50,000 m). Thus, to find x_c, follow either of these two steps:

1. If stability class is 1, 2, 3, 4-DAY, or 4-NIGHT

   a. If stability class is 3 and mixing height is <338.5 m, find a and b in table 3 for the $500 \text{ m} \leq x < 5{,}000$ m case, then solve equation (32) for x_c.

   b. If stability class is 3 and mixing height is ≥338.5, or stability class is 1, 2, 4-DAY, or 4-NIGHT, find a and b in table 3 for the $x \geq 5{,}000$ m case, then solve equation (32) for x_c.

2. If stability class is 5, 6, or 7, then x_c is in excess of (50,000 m + x_v); i.e., equation (30) is never used to find σ_z.

APPENDIX D

Depth of Prescribed Fire Smoke Layer in a Stable Atmosphere

The presence of smoke at a given height in the atmosphere over flat terrain (small ambient vertical velocity is assumed) is due to either the heat from a prescribed fire or an atmospheric dispersion process. In an unstable or nearly neutral atmosphere, the dispersion rate is sufficiently great to allow (for indexing purposes) the assumption of uniform mixing below the mixing height, H, for smoke associated with significant plume rise. This assumption fails in stable conditions; there is no thermally induced mixing height present. Thus, plume rise and dispersion processes are explicitly considered in determining the vertical disposition of smoke for stability classes 5, 6, 7.

According to Briggs (1972), plume rise from a point source in stable conditions may be determined from

$$\Delta h = 2.4 \left(\frac{F}{W_h \frac{g}{\theta} \frac{\delta\theta}{\delta Z}} \right)^{1/3} \qquad (33)$$

where: Δh is plume rise, in meters

F is sensible heat flux from the source ($m^4\ s^{-3}$)

g is acceleration of gravity ($m\ s^{-2}$)

W_h is representative windspeed within the plume rise layer ($m\ s^{-1}$)

θ is potential temperature (K)

and $\frac{\delta\theta}{\delta Z}$ is the change of potential temperature with respect to height ($K\ m^{-1}$).

Since plume rise in stable conditions (cube root dependency) is somewhat insensitive to the various independent variables in equation (33), it is possible to use representative variables of W_h for each stability class for determining a dispersion index. The U.S. Standard Atmosphere values for g and θ at sea level are 9.80665 $m\ s^{-2}$ and 287.1 K, respectively. In addition, Turner and Novak (1978b) use 0.020 $K\ m^{-1}$ (stability class 5) and 0.035 $K\ m^{-1}$ (stability class 6) for $\delta\theta/\delta Z$. The value of 0.035 $K\ m^{-1}$ is assumed to apply for stability class 7 as well, based on Lavdas (1981), who found that the Turner and Novak values were in excellent agreement with mean 0400 l.s.t. National Weather Service soundings for classes 5 and 6, and that the class 7 sounding was indistinguishable from class 6.

Surface windspeeds (in knots) associated with the various stability classes are shown in appendix A, table 2. For substantial values of Δh, W_h is in excess of the surface speed. Therefore, representative values of W_h are chosen to be 6.0 $m\ s^{-1}$ for stability class 5 and 3.5 $m\ s^{-1}$ for classes 6 and 7. The possibility of substantial variation of W_h from the above values in given cases would be important for most emission sources. It may be less important for actively burning prescribed fires because the rate of spread and intensity of a fire, hence F, increase with increasing windspeed (Rothermel 1972).

Sensible heat flux, F, varies widely among prescribed fires and during the life cycle of individual fires. The most intense fires generate enough heat to penetrate a typical nocturnal inversion during part of the life cycle. Such fires, however, represent a high enough potential smoke source to warrant the use of single-fire smoke management tools (SFFLS 1976) which are outside the scope of this paper. To determine F from low- to moderate-intensity prescribed fires, note that, according to Briggs (1975)

$$F \cong 8.9\,(Q_H)_{MW} \cong 37\,(Q_H)_{Mcal} \qquad (34)$$

where: $(Q_H)_{MW}$ is total sensible heat release rate in megawatts

and $(Q_H)_{Mcal}$ is the corresponding quantity in megacalories per second.

Values of $(Q_H)_{Mcal}$ from typical prescribed fires (SFFLS 1976) for actively burning nondebris fires range from about 5 to 140 Mcal s^{-1}. The median value of 26 Mcal s^{-1} is used with equation (34) to choose a representative value of 1,000 m^4 s^{-3} for F (applicable for stability classes 5, 6, and 7).

Substituting the various representative values into equation (33), one finds that

$$\Delta h \cong 150 \text{ m} \tag{35}$$

for stability classes 5, 6, and 7. Because this value represents the highest plume rise from a prescribed fire during its life cycle, and due to substantial unentrained or partially entrained smoke with respect to the convection column in many prescribed fires, the prescribed fire smoke source associated with actively burning fires is specified as uniformly mixed from the ground to 150 m.

It is now necessary to consider the effect of vertical dispersion during downwind transport on such a source. Consider the concentration impact at the downwind edge of the 50- x 50-km area as shown in figure 4. Note that it is possible to calculate this impact by the alternative method of averaging the

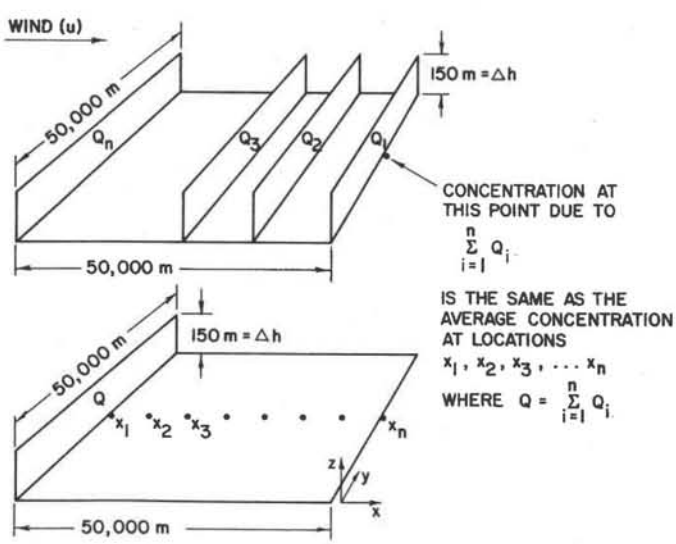

Figure 4.--Alternative methodologies for calculating concentrations from a series of vertical planes oriented perpendicular to the wind.

concentration along the ground-level center line from 0 to 50 km downwind from a vertical plane that extends from 0 to 150 m above the upwind boundary of the square area. The smoke concentration from a vertical plane may be obtained from integrating the effect of horizontal line sources along the plane. The equation for an essentially infinite line source, after Turner (1970), is

$$\chi_L = (2/\pi)^{1/2} W^{-1} \sigma_z^{-1} (Q_z/L) \exp(-0.5\, Z^2/\sigma_z^2) \tag{36}$$

where: χ_L is concentration at the ground from a line source at height Z (kg s^{-1})

Q_Z is total emission rate at height Z (kg s^{-1})

Z is height of source above the ground (m)

L is length of the area source

W is transport speed

σ_z is the Gaussian vertical dispersion coefficient (m).

To integrate equation (36) with respect to height, note that σ_z and χ_L are differential quantities. It is convenient to express equation (36) in terms of relative concentration and integrate from Z = 0 to Δh with respect to the ratio $(Z\sigma_z^{-1})$ obtaining an equation for relative concentration at a specific distance x

$$(\chi W Q^{-1})_x = (2L^{-1}\Delta h^{-1}) \int_{(0)}^{(\Delta h \sigma_z^{-1})} (2\pi)^{-1/2} \exp[-0.5\, Z^2/\sigma_z^2]\, d(Z\sigma_z^{-1}) \tag{37}$$

where: $(\chi W Q^{-1})_x$ is relative concentration at some downwind distance x(m^{-2})

$\begin{pmatrix}0\\ \Delta h\sigma_z^{-1}\end{pmatrix}$ and are the limits of integration with respect to $d(Z\sigma_z^{-1})$

and the integral as a whole is henceforth referred to as $P(Z,\sigma_z^{-1})$.

Note that $P(Z,\sigma_z^{-1})$ is simply the integral of the normal distribution function with respect to the ratio $(Z\sigma_z^{-1})$. There are numerous tables and analytical approximations for obtaining this integral. Values for a few values of downwind distance are given in table 4.

Before determining the average relative concentration in the range from 0 to 50,000 m, it is useful to consider the relative concentration predicted by a simple box model with a uniform height, H_s. From equation (1),

$$\chi W Q^{-1} = (LH_s)^{-1} \tag{38}$$

Using equations (37) and (38), one finds a relationship for the depth of a uniform smoke layer, H_s, that would yield the same ground-level concentration as that experienced at a specific downwind distance from a source like that shown in figure 4.

$$(\Delta h/H_s)_x = 2P(Z,\sigma_z^{-1}) \tag{39}$$

where: $(\Delta h/H_s)_x$ denotes the ratio between Δh and H_s applicable at a specific distance, x.

To obtain the value of H_s applicable for the entire 50- x 50-km area, it is only necessary to determine the mean value of $P(Z,\sigma_z^{-1})$ over the range from 0 to 50,000 m; i.e., $\overline{P(Z,\sigma_z^{-1})}$. Because $(\Delta h\sigma_z^{-1})$ decreases with increasing x, $\overline{P(Z,\sigma_z^{-1})}$ is a continuously decreasing function with respect to x.

To calculate $\overline{P(Z,\sigma_z^{-1})}$ with arbitrary accuracy, one may compute the average of several values of $P(Z,\sigma_z^{-1})$ that are known to form upper and lower bounds for given intervals of x. For example, for values of x, between 15,000 and 17,500, $P(Z,\sigma_z^{-1})$ for stability class 5 is between 0.450 and 0.438. Using table 4 in this way (taking the average of all upper and lower bounds of $P(Z,\sigma_z^{-1})$ over intervals of 2,500), one can establish that:

$$0.40905 \leq \overline{P(Z,\sigma_z^{-1})} \leq 0.41740 \text{ (stability class 5)} \tag{40}$$

$$0.49020 \leq \overline{P(Z,\sigma_z^{-1})} \leq 0.49155 \text{ (stability class 6 or 7)} \tag{41}$$

Thus, from equations (35) and (39),

$$H_s \cong 180 \text{ m (stability class 5)} \tag{42}$$

$$H_s \cong 150 \text{ m (stability class 6 or 7)} \tag{43}$$

which are the same as equations (22) and (23) in the main text.

Table 4.--Upper limit of integration ($\Delta h\,\sigma_z^{-1}$) and probability integral $P(Z,\sigma_z^{-1})$ for various downwind distances, x, in stable conditions

	Stability Class 5		Stability Classes 6 and 7	
x(m)	($\Delta h\,\sigma_z^{-1}$)	$P(Z,\sigma_z^{-1})$	($\Delta h\,\sigma_z^{-1}$)	$P(Z,\sigma_z^{-1})$
0	∞	0.500	∞	0.500
2,500	4.16	.500	6.70	.500
5,000	2.68	.496	4.41	.500
7,500	2.24	.487	3.81	.500
10,000	1.97	.476	3.44	.500
12,500	1.79	.463	3.17	.499
15,000	1.65	.450	2.97	.499
17,500	1.54	.438	2.81	.498
20,000	1.45	.427	2.68	.496
22,500	1.38	.416	2.56	.495
25,000	1.31	.406	2.47	.493
27,500	1.26	.396	2.39	.491
30,000	1.21	.387	2.31	.490
32,500	1.17	.379	2.25	.488
35,000	1.13	.371	2.19	.486
37,500	1.10	.364	2.13	.484
40,000	1.07	.357	2.08	.481
42,500	1.04	.351	2.04	.479
45,000	1.01	.345	2.00	.477
47,500	0.99	.339	1.96	.475
50,000	0.97	.333	1.92	.473

The lower bound of integration is zero for all cases, Δh is 150 m, σ_z is found by use of table 3 in appendix C, $P(Z,\sigma_z^{-1})$ is calculated from equation 26.2.17 of Abramowitz and Stegun (1965).

APPENDIX E

A FORTRAN 77 Subroutine Package for Computing Dispersion Index for a Specific Time

The following subroutine package, consisting of one subroutine and two functions, provides a means for automated computation of dispersion index. The package is written in the widely used FORTRAN 77 language, and conforms to ANSI X3.9-1978, American National Standards Institute (1978). The package is invoked by using a FORTRAN CALL statement like the following:

```
CALL DSPNHR (IDYNT, ISTAB, AMIX, U,
             DINDHR)
```

where IDYNT is an integer, IDYNT should be set to 1 if dispersion index is being calculated during daylight hours (just after sunrise to just before sunset), otherwise IDYNT should be set to 2 (sunset to sunrise)

ISTAB is an integer from 1 to 7, representing stability class (see appendix A)

AMIX is a nonnegative real, representing mixing height in meters

U is a nonnegative real, representing transport windspeed in meters per second

and DINDHR is a real variable, which will contain the value of dispersion index, $\overline{DI}$.

Please note that in case of erroneous input, the subroutine package will output an error message to unit 6 and stop the execution of the calling program. If this action is unsatisfactory for a given application, the user should modify lines 00002500 through 00004300 of SUBROUTINE DSPNHR. However, some equivalent error checking should be performed to avoid a program crash.

When executing properly, the subroutine package will provide values of DINDHR as shown in table 5.

Table 5.--Example runs of FORTRAN subroutine package to determine dispersion index, DINDHR

Input				Correct output
IDYNT	ISTAB	AMIX	U	DINDHR
1	1	120.	0.5	2.382
1	1	120.	1.	2.382
1	1	240.	1.	2.382
1	1	240.	2.	4.764
1	1	1200.	1.	11.259
1	1	5000.	1.	37.663
1	1	8000.	1.	44.208
1	2	240.	1.	2.358
1	2	1200.	1.	9.983
1	2	5000.	1.	22.479
1	3	240.	1.	2.320
1	3	1200.	1.	8.263
1	3	5000.	1.	12.487
1	4	240.	1.	2.237
1	4	600.	1.	4.435
1	4	1200.	1.	5.965
1	4	5000.	1.	7.358
2	4	240.	1.	2.093
2	4	600.	1.	3.152
2	4	1200.	1.	3.152
2	5	240.	1.	1.471
2	5	600.	1.	1.471
2	6	240	1.	0.986
2	6	600.	1.	0.986
2	7	240.	1.	0.986

In utilizing this subroutine package, the user should be careful to input values of IDYNT, ISTAB, AMIX, and U, which are representative for the period of interest. One possibility for certain kinds of analyses would be to invoke the subroutine package for 3 to 6 successive hours, then compute the harmonic mean of the corresponding values

of DINDHR. For operational applications, it is better to pick representative input values during a period when atmospheric conditions are relatively constant. For example, two estimates of dispersion index, one for the last 6 hours before sunrise and the other for the period from near noon to just before sunset, should provide operationally useful information to those responsible for prescribed burning and air-quality protection over areas of about 1,000 square miles.

Copies of the dispersion index program, with a more comprehensive test program and documentation of the subroutine package structure, are available from the author.

Definitions of Variables

ACOEFF - A 3 by 6 array of constants, according to downwind distance and stability class, used in the power law A * X ** B to obtain vertical dispersion coefficient.

AMIX - Mixing height (global variable).

AMIXT - Temporary local value of mixing height.

AMXMAX - Maximum possible temporary mixing height value, associated with a vertical dispersion coefficient of 5,000 m.

BCOEFF - A 3 by 6 array of constants (as in ACOEFF).

BPOWER - Exponent of the mathematical expression obtained when integrating the reciprocal of A * X ** B with respect to X.

CONUAR - Sum of concentrations due to the area source for the range of downwind distances considered.

CON1 - Concentration due to a given range of downwind distances, all of which lie at a distance greater than the critical distance XCRIT.

CON2 - Concentration due to a given range of downwind distances, all of which lie at a distance less than the critical distance, XCRIT.

CRITGT - Function and variable that correspond to CON1, if CON1 >0.

CRITLT - Function and variable that correspond to CON2, if CON2 >0.

DINDHR - Dispersion index due to steady-state weather conditions for a given hour (global variable).

DPSMOK - Depth of the smoke layer in stable atmosphere, determined from AMIXT for stability classes 1-4, or by use of appendix D for the remaining classes.

I - A do-loop index variable used to calculate the sum of concentrations from emissions within three specific ranges of downwind distances: 100-500 m, 500-5,000 m, and >5,000 m.

ICOEFF - Indexing variable used to select the appropriate value for downwind distance range of ACOEFF and BCOEFF.

IDYNT - Indicator for daylight versus night hours: = 1 if day, = 2 if night (global variable).

ISTAB - The Turner (1964) stability class from 1 to 7 (global variable).

ISTABT - Temporary local value of Turner stability class.

PRTOFT - Constant term resulting from the integration of the reciprocal of the power law relationship with respect to downwind distance, X (BPOWER is also a result of this integration).

QA - Uniform area source emission rate for use in the CMD portion of the code only (i.e., one-half the value given in equation (12)).

TINTGL - Complete result of integrating the reciprocal of the power law relationship with respect to downwind distance, X, a function of BPOWER, PRTOFT, and the range of X considered. (This range is always less than XCRIT.)

U - Transport windspeed or, if a surface-based inversion is indicated, the average windspeed in the smoke-laden surface layer of atmosphere (global variable).

UT - Temporary local value of transport windspeed.

XCRIT - Critical downwind distance at and beyond which the vertical dispersion coefficient may be regarded as constant for the purposes of computing ground-level concentration from a ground-based source.

XHIGH - Longest downwind distance considered in a given area source concentration calculation.

XLIMIT - Array of four downwind distances that are used to define the range of distances for a given concentration calculation.

XLOW - Shortest downwind distance considered in a given area source concentration calculation.

XMAXGT - Value of XHIGH when performing a concentration calculation at distances greater than XCRIT.

XMAXLT - Value of XHIGH when performing a concentration calculation at distances less than XCRIT; XMAXLT may not exceed XCRIT.

XMINGT - Value of XLOW when performing a concentration calculation at distances greater than XCRIT; XMINGT may not be less than XCRIT.

XMINLT - Value of XLOW when performing a concentration calculation at distances less than XCRIT.

XMINST - Array of seven values of virtual distance with respect to stability class and day-night factor.

XMIN30 - Virtual downwind distance associated with a source with a vertical dispersion coefficient of 30 m, according to the indicated stability class and day-night factor.

Source Code Listing for Dispersion Index Subroutine Package

```
C***
C***HOURLY DISPERSION INDEX CALCULATION ROUTINE
C***
      SUBROUTINE DSPNHR(IDYNT,ISTAB,AMIX,U,DINDHR)
C***RESTRICTIONS ON INPUT VALUES:
C***  IDYNT MUST BE 1 OR 2
C***  ISTAB MUST BE 1, 2, 3, 4, 5, 6, OR 7
C***  AMIX  MUST NOT BE NEGATIVE
C***  U     MUST NOT BE NEGATIVE
C***OUTPUT IS:  DINDHR, A POSITIVE REAL NUMBER
      LOGICAL ERRFLG
      DIMENSION ACOEFF(3,6),BCOEFF(3,6),XLIMIT(4),XMINST(7)
C***INITIALIZE ARRAYS AND AREA EMISSION RATE
C***CDM VALUES USED FOR ACOEFF, BCOEFF, AND XLIMIT
      DATA ACOEFF /.0383,.0002539,.0002539,.1393,.04936,.04936,
     & .1120,.1014,.1154,.0856,.2591,.7368,.0818,.2527,1.2969,
     & .0545,.2017,1.5763/
      DATA BCOEFF /1.2812,2.0886,2.0886,.9467,1.1137,1.1137,
     & .9100,.9260,.9109,.8650,.6869,.5642,.8155,.6341,.4421,
     & .8124,.6020,.3606/
      DATA XLIMIT /100.,500.,5000.,50000./
C***XMINST VALUES ARE VIRTUAL DISTANCE UNDER SPECIFIED CONDITIONS
      DATA XMINST /181.46,291.43,465.62,874.56,1010.0,1869.0,4061.3/
      DATA OK /.001/
C***CHECK AGAINST INVALID DATA, USING A SERIES OF IF BLOCKS
      ERRFLG=.FALSE.
      IF(IDYNT.NE.1.AND.IDYNT.NE.2) THEN
          WRITE(6,*) '      INVALID DATA:  IDYNT  = ',IDYNT
          ERRFLG=.TRUE.
      END IF
      IF(ISTAB.LT.1.OR.ISTAB.GT.7) THEN
          WRITE(6,*) '      INVALID DATA:  ISTAB  = ',ISTAB
          ERRFLG=.TRUE.
      END IF
      IF(AMIX.LT.0.) THEN
          WRITE(6,*) '      INVALID DATA:  AMIX   = ',AMIX
          ERRFLG=.TRUE.
      END IF
      IF(U.LT.0.) THEN
          WRITE(6,*) '      INVALID DATA:  U      = ',U
          ERRFLG=.TRUE.
      END IF
      IF(ERRFLG) STOP
C***CALCULATE "TEMPORARY" VALUES FROM INPUT DATA
      ISTABT=ISTAB
      IF(ISTABT.EQ.7) ISTABT=6
      AMIXT=AMIX
      AMXMAX=5000./.797885
      IF(AMIXT.GT.AMXMAX) AMIXT=AMXMAX
```

```
C***SET LOWER LIMIT ON AMIXT, SINCE IT IS NOT USED IN STABLE CONDITIONS
      IF(AMIXT.LT.240.) AMIXT=240.
      UT=U
      IF(UT.LT.1.) UT=1.
C***
C***CLIMATOLOGICAL DISPERSION MODEL (CDM) PORTION
C***DETERMINE CRITICAL DOWNWIND DISTANCE, XCRIT
C***FORTRAN 77 IF...THEN...ELSE USED TO FIND CRITICAL DOWNWIND DISTANCE
      IF(ISTABT.LE.4) THEN
          ICOEFF=3
          IF(ISTABT.EQ.3.AND.AMIXT.LT.338.5) ICOEFF=2
C***    THIS STATEMENT MODIFIES CDM ACCORDING TO PASQUILL(1974)
          IF(IDYNT.EQ.1.AND.ISTABT.EQ.4) ICOEFF=1
C***    .797885 IS CDM VALUE FOR SQRT(2./PI)
          XCRIT=(.797885*AMIXT/ACOEFF(ICOEFF,ISTABT))
     &          **(1./BCOEFF(ICOEFF,ISTABT))
      ELSE
          XCRIT=100000.
      END IF
C***END FORTRAN 77 IF...THEN...ELSE
C***DETERMINE VIRTUAL DISTANCE (30 METERS VERTICAL DISPERSION), XMIN30
      IF(ISTABT.LE.3) XMIN30=XMINST(ISTABT)
      IF(ISTABT.EQ.4.AND.IDYNT.EQ.1) XMIN30=XMINST(4)
      IF(ISTABT.EQ.4.AND.IDYNT.EQ.2) XMIN30=XMINST(5)
      IF(ISTABT.GE.5) XMIN30=XMINST(ISTABT+1)
C***INITIALIZE CONCENTRATION DUE TO UNIFORM AREA SOURCE, CONUAR
      CONUAR=0.
C***CALCULATE PARTIAL CONCENTRATIONS AND ADD TO TOTAL (WITHIN DO LOOP)
C***THE DO LOOP INDEX, I, HELPS CONTROL DOWNWIND DISTANCE RANGE LIMITS
      DO 10 I=1,3
          ICOEFF=I
C***    THIS STATEMENT MODIFIES CDM ACCORDING TO PASQUILL(1974)
          IF(IDYNT.EQ.1.AND.ISTABT.EQ.4) ICOEFF=1
C***    INITIALIZE PARTIAL CONCENTRATIONS, CON1 AND CON2
          CON1=0.
          CON2=0.
C***    DETERMINE DOWNWIND DISTANCE RANGE LIMITS
          XHIGH=XLIMIT(I+1)
          IF(XMIN30.GE.XHIGH) GO TO 10
          IF(I.EQ.3) XHIGH=XHIGH+XMIN30
          XLOW=XLIMIT(I)
          IF(XMIN30.GT.XLOW) XLOW=XMIN30
C***    NEXT TWO STATEMENTS REFERENCE FUNCTIONS
          IF(XHIGH.GT.XCRIT) CON1=CRITGT(XHIGH,XLOW,XCRIT,AMIXT,UT,OK)
          IF(XLOW.LT.XCRIT) CON2=CRITLT(XHIGH,XLOW,XCRIT,ACOEFF,BCOEFF,
     &                                  ICOEFF,ISTABT,UT,OK)
C***    END FUNCTION REFERENCES
          CONUAR=CONUAR+CON1+CON2
   10     CONTINUE
```

```
C***                                                                    00009900
C***VENTILATION FACTOR (V. F.) PORTION                                  00010000
C***DETERMINE "TEMPORARY" MIXING HEIGHT FOR V. F. (NO CHANGE IF DAY)    00010100
      IF(IDYNT.EQ.2.AND.AMIXT.GT.600.) AMIXT=600.                       00010200
C***DETERMINE DEPTH OF "UNIFORM" SMOKE LAYER FOR BOX MODEL              00010300
      IF(ISTABT.LE.4) DPSMOK=AMIXT                                      00010400
      IF(ISTABT.EQ.5) DPSMOK=180.                                       00010500
      IF(ISTABT.EQ.6) DPSMOK=150.                                       00010600
C***CALCULATE AND ADD V. F. CONCENTRATION TO CDM CONCENTRATION          00010700
C***THIS CONCENTRATION IS WEIGHTED 50/50 BETWEEN V. F. AND CDM          00010800
      CONUAR=CONUAR+50./(UT*DPSMOK)                                     00010900
C***CALCULATE THE DISPERSION INDEX                                      00011000
      DINDHR=1./CONUAR                                                  00011100
      RETURN                                                            00011200
      END                                                               00011300


C***                                                                    00000100
C***FUNCTION DETERMINES CONCENTRATIONS DUE TO DISTANCES .GT. XCRIT      00000200
C***                                                                    00000300
      FUNCTION CRITGT(XHIGH,XLOW,XCRIT,AMIXT,UT,OK)                     00000400
C***DETERMINE DOWNWIND DISTANCE RANGE LIMITS FOR THIS CALCULATION       00000500
      XMAXGT=XHIGH                                                      00000600
      XMINGT=XLOW                                                       00000700
      IF(XMINGT.LT.XCRIT) XMINGT=XCRIT                                  00000800
C***CALCULATE PARTIAL CONCENTRATION                                     00000900
      CRITGT=OK*(XMAXGT-XMINGT)/(UT*AMIXT)                              00001000
      RETURN                                                            00001100
      END                                                               00001200


C***                                                                    00000100
C***FUNCTION DETERMINES CONCENTRATIONS DUE TO DISTANCES .LT. XCRIT      00000200
C***                                                                    00000300
      FUNCTION CRITLT(XHIGH,XLOW,XCRIT,ACOEFF,BCOEFF,ICOEFF,ISTABT,UT,  00000400
     &                OK)                                               00000500
      DIMENSION ACOEFF(3,6),BCOEFF(3,6)                                 00000600
C***DETERMINE DOWNWIND DISTANCE RANGE LIMITS FOR THIS CALCULATION       00000700
      XMAXLT=XHIGH                                                      00000800
      XMINLT=XLOW                                                       00000900
      IF(XMAXLT.GT.XCRIT) XMAXLT=XCRIT                                  00001000
C***CALCULATE PARTIAL CONCENTRATION                                     00001100
      BPOWER=1.-BCOEFF(ICOEFF,ISTABT)                                   00001200
      PRTOFT=.797885/(ACOEFF(ICOEFF,ISTABT)*BPOWER)                     00001300
      TINTGL=PRTOFT*(XMAXLT**BPOWER-XMINLT**BPOWER)                     00001400
      CRITLT=OK*TINTGL/UT                                               00001500
      RETURN                                                            00001600
      END                                                               00001700
```

Lavdas, Leonidas G.

An atmospheric dispersion index for prescribed burning. Res. Pap. SE-256. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1986. 33 pp.

A numerical index that estimates the atmosphere's capacity to disperse smoke from prescribed burning is described. The physical assumptions and mathematical development of the index are given in detail. A preliminary interpretation of dispersion index values is offered. A FORTRAN subroutine package for computing the index is included.

KEYWORDS: Smoke management, air pollution potential, ventilation factor, Gaussian dispersion, mesoscale air quality, atmospheric stability classes, area pollution sources.

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