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USER'S GUIDE TO THE MATHEW/ADPIC MODELS

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NOTE: This is an intermediate version of this document, and as such is not in finalized form and would not normally be available for distribution. However, due to the importance of the updated material that is included, this version is being made available with the understanding that it will be replaced with an official or finalized version in the future.

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PREFACE

This user's guide documents the MATHEW and ADPIC transport and diffusion models and their supporting stream of codes. It includes a description of each code (Chapter I), its theoretical basis (Chapter II), and the preparation and interpretation of input and output data (Chapter III).

Table of Contents

I. INTRODUCTION TO THE MATHEW/ADPIC TRANSPORT AND DIFFUSION MODELS

This user's guide provides both an operational and theoretical summary of the MATHEW/ADPIC transport and diffusion models and supplemental codes needed to execute these models. The acronym, MATHEW, comes from **M**ass-**A**djusted **THR**ee-dimensional **W**ind field. ADPIC stands for **A**tmospheric **D**iffusion **P**article-**I**n-**C**ell model. These models calculate air concentration and ground deposition on a regional scale (up to 200 km) from continuous or instantaneous point sources.

MATHEW is a three-dimensional meteorological data-adjustment model which supplies ADPIC with mean wind fields that are mass-consistent and representative of the available meteorological measurements (surface, tower, and upper-air soundings). The bottom boundary in this model is determined by grid cell estimates of the actual topographic features of a given site and its environs, which can play a very important role in defining or modeling regional-scale patterns. ADPIC is a three-dimensional, particle-in-cell transport and diffusion code capable of calculating the time-dependent dispersion of inert or radioactive air pollutants.

In addition to MATHEW/ADPIC, three supplemental codes are required to provide input/output support. These codes, which are also discussed in this user's guide, are TOPOG, MEDIC, and PLCNT. TOPOG defines topographic features for MEDIC, MATHEW, and ADPIC. MEDIC builds a realistic three-dimensional wind field from the observed meteorological conditions. This input is used by MATHEW to compute the mass-consistent wind field required by ADPIC. PLCNT is a post-processing code used to plot contours of the particle data from ADPIC. PLCNT also handles the dose conversion from particle concentration to other units such as Roentgen equivalent man (Rem).

RSUS is another supplemental code which uses the output from PLCNT to construct the input files needed to make a resuspension MATHEW/ADPIC calculation.

An overview of MATHEW/ADPIC and the support routines follows in this section. A complete technical formulation of each code is found in Section II. Section III provides a user's guide to each code.

I.A. MATHEW

MATHEW (Sherman, 1978a) is a three-dimensional, diagnostic, regional wind field model that uses a variational analysis technique (Sasaki, 1958, 1970a, 1970b) to determine a mass-consistent velocity field. The condition of mass consistency is essential when considering atmospheric transport in areas of complex terrain since terrain can exert a strong influence on the flow configuration. Also, the use of topography without adjusting the interpolated wind field may lead to sources and sinks, thereby invalidating the results of a transport and dispersion calculation. The process of adjusting the interpolated winds is controlled through the Gauss precision moduli (GPM). These parameters, which depend on atmospheric stability and grid cell aspect ratio, define the allowable adjustments on velocities in the horizontal and vertical directions during the variational procedure. The w-components of the velocity, which are initially zero because of their unavailability in most operational situations, develop from the mass inconsistency in the interpolated field, the GPM, and topographic forcing.

I.B. ADPIC

ADPIC (Atmospheric Diffusion Particle-in-Cell) is a numerical, three-dimensional, Cartesian, particle-diffusion code capable of calculating the time-dependent distribution of air pollutants under many conditions including strongly distorted wind fields, calm conditions, wet and dry deposition, radioactive decay, and space- and time-variable diffusion parameters.

ADPIC solves the three-dimensional advection-diffusion equation in its flux conservative form (pseudo-velocity technique) for a given mass-consistent advection field (supplied by MATHEW) by finite difference approximations in Cartesian coordinates. The method is based on the particle-in-cell technique with the pollutant concentration represented statistically by Lagrangian marker particles imbedded in an Eulerian grid (Lange, 1973 and 1978). The code is suitable for the study of instantaneous or continuous releases near or on the surface over regional scales (10 to 200 km).

I.C. Support Routines

I.C.1. TOPOG

TOPOG creates the underlying surface for the MATHEW and ADPIC models. The surface is created by averaging terrain data from a regional terrain data base which has, as its source, high-resolution elevation data supplied by the U. S. Geological Survey (USGS).

TOPOG has three main functions: (1) It verifies that the MATHEW and ADPIC grids, as defined by the user, are oriented correctly with respect to each other and the regional terrain grid. (2) It averages terrain data from the regional data base to the newly defined model grid and then rounds these averaged heights to the nearest model level. This provides the appropriate block topography for the MATHEW and ADPIC models. (3) TOPOG examines each cell in the MATHEW domain and, in consideration of the finite difference pattern utilized in the wind adjustment model (MATHEW) and the model terrain surface, assigns descriptors to the cell which define permissible flows through the cell faces.

I.C.2. MEDIC

MEDIC extrapolates a three-dimensional gridded wind field from a combination of surface and upper air observations. The extrapolation is a complex process, controlled by a number of parameters specified by the user. The extrapolated wind field is sensitive to small changes in some of these parameters and, as a result, widely differing extrapolated fields can be produced, all of which are consistent with a given data set. MATHEW adjusts the winds to achieve mass consistency and then passes them to ADPIC. Because MATHEW makes the smallest necessary adjustments to the extrapolated field and because ADPIC assumes persistence over extended periods (typically one hour), any change in the extrapolated wind field will affect all the results of the ARAC models. Therefore, it is crucial for the user to provide the best extrapolated wind field that can be produced for a data set within the allowed range of the various parameter values. In turn, this means that the graphical output from MEDIC must be examined very carefully by the assessor to determine if the wind field is an acceptable model of the physical state of the atmosphere. If it is not, then MEDIC must be re-executed with revised parameter values until a reasonable representation is produced.

I.C.3. PLCNT

PLCNT uses two-dimensional arrays of cell-center concentrations output by ADPIC, averages the concentrations to a regular matrix of grid points, and then draws a set of smoothed contours around the resulting values. The levels at which contours are drawn can be chosen by the code or specified by the user. If determined by the code, five contours will be generated, each differing by an order of magnitude, as a function of the largest grid point concentration. The user has the option of overriding the code by initializing a select

number of variables in the input file (see Section III.B.8). As an example of the usefulness of this latter option, an environmental standard may have been established for a substance which has been accidently released into the atmosphere. On entering this value, the code will calculate and plot an isopleth which represents a threshold to this standard, thereby delineating the area of concern.

Our model results can be presented in three ways: deposition, integrated air concentration, and instantaneous air concentration. Deposition refers to material deposited on the ground since the beginning of a release. Integration is an accumulation of released material over a designated time and space at a selected level. Instantaneous refers to a picture of a (contoured) concentration field at a moment in time.

II.C.4. TIMHIS

In addition to the ability to obtain contours from PLCNT, a companion code TIMHIS (short for Time History) provides the capability to obtain concentrations for individual samplers (up to a maximum of 60) which can be arbitrarily poisitioned in the grid. This feature has proved useful in the past when comparing model concentrations against collections by actual samplers which had been placed in the field during a tracer experiment.

II.C.5. RSUS

RSUS produces a complete set of input files for a MATHEW/ADPIC calculation that will simulate the resuspension, transport, and diffusion of the particles deposited by a previous MATHEW/ADPIC calculation. The resuspension source term is based upon the amount and geometry of the original deposition pattern, as well as other parameters (such as surface characteristics and wind speed) input by the user.

II. Technical Discussion of ARAC Models

II.A. MATHEW

II.A.1. Formulation

The theoretical framework for the model equations was developed by Sasaki (1958, 1970a, 1970b), a pioneer in the use of variational techniques in a meteorological context. One of his proposed formalisms defines an integral function (functional) whose extremum minimizes the variance of the difference between observed and analyzed values subject to certain physical constraints. In MATHEW, we seek a solution that represents a minimal perturbation to a set of "observed" wind components in three dimensions and produces a mass-consistent field (the constraint).

As defined, the wind field adjustment problem requires the minimization of the integral expression

$$\int_{\Omega}(\underline{U}-\underline{U}^{0})^{T}\cdot\mathbf{D}^{-1}\cdot(\underline{U}-\underline{U}^{0})d\Omega$$

subject to

$$\nabla\cdot\underline{U}=0 \quad \text{in } \Omega\ ,$$

and

$$\underline{n}\cdot\underline{U}=0 \quad \text{on } \partial\Omega_{1}\ ,$$

where Ω refers to a general domain with an impenetrable boundary segment $\partial\Omega_1$. The quantities $\underline{U}$ are the velocity vectors to be adjusted, $\underline{U}^0$ are the corresponding interpolated vectors and $\mathbf{D}^{-1}$ is a weighting matrix, given herein by

$$D_{ij}^{\ -1}=\alpha_{ij}\delta_{ij}\ ,$$

whose diagonal elements regulate the velocity adjustments in the three dimensions.

To solve the above problem, we introduce the following functional:

$$E(\underline{U},\lambda,\overline{\lambda})=\int_{\Omega}[(\underline{U}-\underline{U}^{0})^{T}\cdot\mathbf{D}^{-1}\cdot(\underline{U}-\underline{U}^{0})+2\lambda\nabla\cdot\underline{U}]d\Omega$$
$$-\int_{\partial\Omega_{1}}2\overline{\lambda}\underline{n}\cdot\underline{U}d\partial\Omega_{1}\ , \qquad \text{(II.A.1)}$$

where λ and $\overline{\lambda}$ are Lagrange multipliers. The equations that minimize the functional E are derived by setting the appropriate Frechet derivatives to zero. In the case of $\underline{U}$, this requires

$$\frac{dE}{d\eta}(\underline{U}+\eta\underline{h},\lambda,\overline{\lambda})\mid_{\eta=0}=0\ .$$

The vector $\underline{h}$ represents an arbitrary variation of the function $\underline{U}$ and η is a parameter. Introducing this variation into E,

$$E(\underline{U}+\eta\underline{h},\lambda,\overline{\lambda}) = \int_\Omega [(\underline{U}+\eta\underline{h}-\underline{U}^0)^T\cdot\mathbf{D}^{-1}\cdot(\underline{U}+\eta\underline{h}-\underline{U}^0)]$$
$$[+2\lambda\nabla\cdot(\underline{U}+\eta\underline{h})]d\Omega - \int_{\partial\Omega_1}[2\overline{\lambda}\underline{n}\cdot(\underline{U}+\eta\underline{h})]d\partial\Omega_1 \ ,$$

then,

$$\frac{dE}{d\eta} = \int_\Omega [\underline{h}^T\cdot\mathbf{D}^{-1}\cdot(\underline{U}+\eta\underline{h}-\underline{U}^0) + (\underline{U}+\eta\underline{h}-\underline{U}^0)^T\cdot\mathbf{D}^{-1}\cdot\underline{h}]$$
$$[-2\lambda\nabla\cdot\underline{h}]d\Omega - \int_{\partial\Omega_1} 2(\overline{\lambda}\underline{n}\cdot\underline{h})d\partial\Omega_1 \ .$$

Setting $\frac{dE}{d\eta}\mid_{\eta=0} = 0$ gives

$$0 = \int_\Omega [\underline{h}^T\cdot\mathbf{D}^{-1}\cdot(\underline{U}-\underline{U}^0) + (\underline{U}-\underline{U}^0)^T\cdot\mathbf{D}^{-1}\cdot\underline{h} + 2\lambda\nabla\cdot\underline{h}]d\Omega$$
$$- \int_{\partial\Omega_1} 2(\overline{\lambda}\underline{n}\cdot\underline{h})d\partial\Omega_1 \ . \qquad \text{(II.A.2)}$$

Since the products in the first two terms in the Ω integrand are scalars and $\mathbf{D}^{-1}$ is a symmetric matrix [$\mathbf{D}^{-1} = (\mathbf{D}^{-1})^T$], it can readily be seen that these terms are equal. An integration by parts on $\lambda\nabla\cdot\underline{h}$ followed by the use of the divergence theorem is now required:

$$\int_\Omega \lambda\nabla\cdot\underline{h} = \int_\Omega \nabla\cdot(\lambda\underline{h}) - \int_\Omega \underline{h}\cdot\nabla\lambda$$
$$= \int_{\partial\Omega_1}\lambda\underline{n}\cdot\underline{h} + \int_{\partial\Omega_2}\lambda\underline{n}\cdot\underline{h} - \int_\Omega \underline{h}\cdot\nabla\lambda \ ,$$

where $\partial\Omega_2$ is the "flow-through" segment of the boundary. Collecting terms:

$$0 = \int_\Omega \{[\mathbf{D}^{-1}\cdot(\underline{U}-\underline{U}^0) - \nabla\lambda]\cdot\underline{h}\}d\Omega$$
$$+ \int_{\partial\Omega_1}[(\lambda-\overline{\lambda})\underline{n}\cdot\underline{h}]d\partial\Omega_1$$
$$+ \int_{\partial\Omega_2}(\lambda\underline{n}\cdot\underline{h})d\partial\Omega_2 \ . \qquad \text{(II.A.3)}$$

Since $\underline{h}$ is an arbitrary function. Eq. (II.A.3) can only be satisfied if

$$\mathbf{D}\cdot\nabla\lambda = \underline{U}-\underline{U}^0 \quad \text{in } \Omega \ , \qquad \text{(II.A.4)}$$
$$\lambda = \overline{\lambda} \quad \text{on } \partial\Omega_1 \ , \qquad \text{(II.A.5)}$$
$$\lambda = 0 \quad \text{on } \partial\Omega_2 \ . \qquad \text{(II.A.6)}$$

Having established the relationship between λ and $\overline{\lambda}$, a single minimization remains; namely,

$$\frac{dE}{d\gamma}(\underline{U},\lambda+\gamma g)\mid_{\gamma=0} = 0 \ ,$$

where g is a varied function in the direction of λ and γ is another parameter. Thus,

$$E(\underline{U};\lambda+\gamma g) = \int_\Omega [(\underline{U}-\underline{U}^0)^T \cdot \mathbf{D}^{-1} \cdot (\underline{U}-\underline{U}^0) + 2(\lambda+\gamma g)\nabla\cdot\underline{U}]d\Omega - \int_{\partial\Omega_1} 2(\lambda+\gamma g)\underline{n}\cdot\underline{U}d\partial\Omega_1 \ .$$

Setting $\frac{dE}{d\gamma}\mid_{\gamma=0} = 0$ gives

$$0 = \int_\Omega g\nabla\cdot\underline{U}d\Omega - \int_{\partial\Omega_1} g\underline{n}\cdot\underline{U}d\partial\Omega_1$$

which, since g is an arbitrary function, leads to

$$\nabla\cdot\underline{U} = 0 \quad \text{in } \Omega \ , \tag{II.A.7}$$

$$\underline{n}\cdot\underline{U} = 0 \quad \text{on } \partial\Omega_1 \ . \tag{II.A.8}$$

Minimization of E with respect to the Lagrange multipliers has therefore returned the original constraints.

Finally, we take the divergence of Eq. (II.A.4) to obtain

$$\nabla\cdot\mathbf{D}\cdot\nabla\lambda = -\nabla\cdot\underline{U}^0 \quad \text{in } \Omega \ , \tag{II.A.9}$$

having utilized the condition of incompressibility, Eq. (II.A.7).

II.A.2. Boundary Conditions

If the normal derivative of λ in Eq. (II.A.4) is set to zero, i.e.,

$$\underline{n}\cdot\mathbf{D}\cdot\nabla\lambda \ = \ \mathbf{D}\frac{\partial\lambda}{\partial n} \ = \ 0 \ = \ \underline{n}\cdot(\underline{U}-\underline{U}^0) \ ,$$

then it follows that the normal component of the observed and analyzed velocity vectors are equal. To obtain mass balance, adjustments must occur in those components which are tangent to an impenetrable boundary surface. Therefore, the condition $\partial\lambda/\partial n = 0$ is applied at "no-flow-through" boundaries ($\partial\Omega_1$) in conjunction with the specification $\underline{n}\cdot\underline{U} = 0$.

The "flow-through" condition, $\lambda = 0$, follows directly from Eq. (II.A.6). The derivative of λ normal to this boundary will, in general, be non-zero so that adjustment of the initial (face-centered) velocity components in the normal direction implies a change in the amount of mass entering or leaving the volume. Here, however, the tangential component of the velocity is unchanged.

II.A.3. Finite Difference Equations

The generalized finite difference analog to Eq. (II.A.9), formed after multiplying through by α_1^2, is given by

$$\frac{A_\ell \lambda_{(i-3/2,j+1/2,k+1/2)} - B_\ell \lambda_{(i+1/2,j+1/2,k+1/2)} + C_\ell \lambda_{(i-1/2,j+1/2,k+1/2)}}{(\Delta x)^2}$$

$$- \frac{A_m \lambda_{(i+1/2,j-3/2,k+1/2)} - B_m \lambda_{(i+1/2,j+1/2,k+1/2)} + C_m \lambda_{(i+1/2,j-1/2,k+1/2)}}{(\Delta y)^2}$$

$$- \left(\frac{\alpha_1^2}{\alpha_2^2}\right) \frac{A_n \lambda_{(i+1/2,j+1/2,k+3/2)} - B_n \lambda_{(i+1/2,j+1/2,k+1/2)} + C_n \lambda_{(i+1/2,j+1/2,k-1/2)}}{(\Delta z)^2}$$

$$= -2\alpha_1^2 \varepsilon^0 , \qquad \text{(II.A.10)}$$

where ε^0 is the divergence in the interpolated wind field, i.e.,

$$\varepsilon^0 = \frac{U_{i-1}^0 - U_i^0}{\Delta x} + \frac{V_{j-1}^0 - V_j^0}{\Delta y} + \frac{W_{k-1}^0 - W_k^0}{\Delta z} . \qquad \text{(II.A.11)}$$

Since vertical velocities are rarely available, the last term in Eq. (II.A.11) is excluded in the MATHEW program. A schematic of a divergence cell centered about an interior point $(i-1/2, j-1/2, k+1/2)$ is provided in Fig. II.A.1. The velocity components, shown in the schematic in a face-centered arrangement, are input to MATHEW as point values on a rectilinear grid; that is, MEDIC calculates U^0 and V^0 components at each vertex of a divergence cell. MATHEW's subsequent transformation to a "flux" form can be seen as an appropriate action for the removal (to a specified extent) of cellular divergence from an interpolated field.

The main function of TOPOG, one of MATHEW's supporting codes, is to restructure the terrain into a system of brick-like objects whose shapes facilitate the satisfaction of boundary conditions. This operation includes the assignment of values to the indices ℓ, m, and n in Eq. (II.A.10) at each grid point in the calculational volume. The indices, whose integer values range from one to eight, describe the relationship between the boundaries and the grid point position in the x, y, and z directions. These values have identical meaning in all directions, and describe restrictions to flow at the "upwind" and "downwind" faces of a divergence cell. The coefficients A, B, and C in Eq. (II.A.10) are modified in accordance with these boundary restrictions (Table II.A.1).

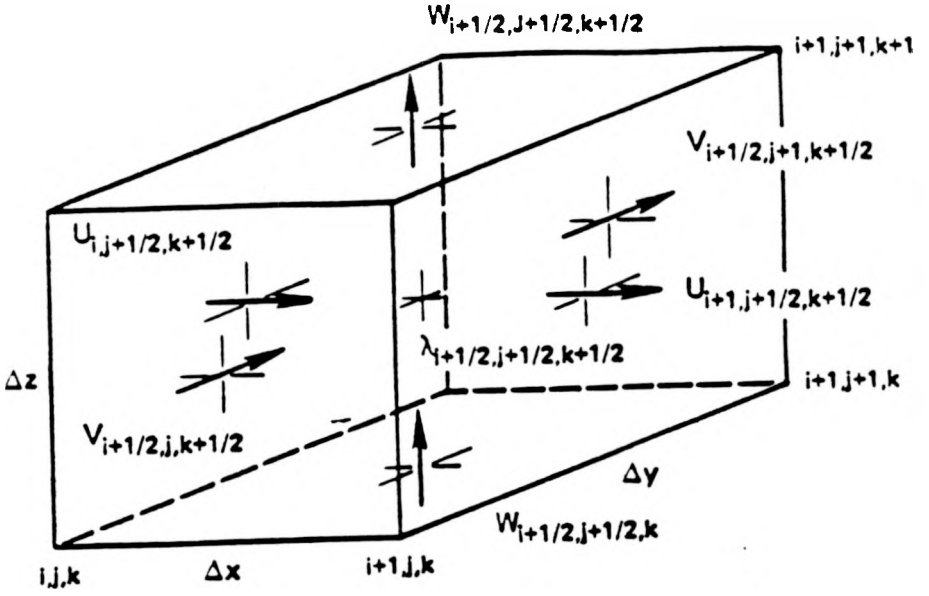


FIGURE II.A.1.

Schematic representation of a "divergence" cell centered at point $(i-1/2, j-1/2, k-1/2)$. Also shown are the face-centered velocities and the cell-centered Lagrange multiplier in the staggered grid formulation of MATHEW.

TABLE II.A.1

ℓ	A_ℓ	B_ℓ	C_ℓ	D_ℓ	E_ℓ
1	1	2	1	1	1
2	1	1	0	0	0
3	0	1	1	1	1
4	0	0	0	0	0
5	4/3	4	0	0	0
6	0	8/3	0	0	0
7	0	4	4/3	1	1
8	0	8/3	0	0	0

II.A.4. Solution Technique

The entire system consisting of a difference equation for each interior grid point can be written as

$$- \left[B_\ell + \left(\frac{\Delta x}{\Delta y}\right)^2 B_m + \left(\frac{\alpha_1}{\alpha_2}\right)^2 \left(\frac{\Delta x}{\Delta z}\right)^2 B_n \right] \lambda_{(i+1/2,j+1/2,k+1/2)}$$

$$+ A_\ell \lambda_{(i+3/2,j+1/2,K+1/2)} + C_\ell \lambda_{(i-1/2,j+1/2,k+1/2)}$$
$$+ A_m \left(\frac{\Delta x}{\Delta y}\right)^2 \lambda_{(i+1/2,j+3/2,k+1/2)} + C_m \left(\frac{\Delta x}{\Delta y}\right)^2 \lambda_{(i+1/2,j-1/2,k+1/2)}$$
$$+ A_n \left(\frac{\alpha_1}{\alpha_2}\right)^2 \left(\frac{\Delta x}{\Delta z}\right)^2 \lambda_{(i+1/2,j+1/2,k+3/2)} + C_n \left(\frac{\alpha_1}{\alpha_2}\right)^2 \left(\frac{\Delta x}{\Delta z}\right)^2 \lambda_{(i+1/2,j+1/2,k-1/2)}$$
$$= -2\alpha_1^2 (\Delta x)^2 \varepsilon^0_{(i+1/2,j+1/2,k+1/2)} \cdot \qquad \text{(II.A.12)}$$

This set of linear equations is solved iteratively with a successive over-relaxation method written as

$$\lambda^{n+1}_{(i+1/2,j+1/2,k+1/2)} = \lambda^n_{(i+1/2,j+1/2,k+1/2)} + \omega R^{n+1}_{(i+1/2,j+1/2,k+1/2)} \cdot \qquad \text{(II.A.13)}$$

The residual is given by

$$R^{n+1}_{(i+1/2,j+1/2,k+1/2)} = \left\{ B_\ell + \left(\frac{\Delta x}{\Delta y}\right)^2 B_m + \left(\frac{\alpha_1}{\alpha_2}\right)^2 \left(\frac{\Delta x}{\Delta z}\right)^2 B_n \right\}^{-1}$$

$$\times \left[A_\ell \lambda_{(i+3/2,j+1/2,k+1/2)} + C_\ell \lambda_{(i-1/2,j+1/2,k+1/2)} \right]$$
$$+ A_m \left(\frac{\Delta x}{\Delta y}\right)^2 \lambda_{(i+1/2,j-3/2,k-1/2)} + C_m \left(\frac{\Delta x}{\Delta y}\right)^2 \lambda_{(i+1/2,j-1/2,k+1/2)}$$
$$+ A_n \left(\frac{\alpha_1}{\alpha_2}\right)^2 \left(\frac{\Delta x}{\Delta z}\right)^2 \lambda_{(i+1/2,j+1/2,k+3/2)}$$
$$+ C_n \left(\frac{\alpha_1}{\alpha_2}\right)^2 \left(\frac{\Delta x}{\Delta z}\right)^2 \lambda_{(i+1/2,j+1/2,k-1/2)}$$
$$+ 2\alpha_1^2 (\Delta x)^2 \varepsilon^0 - \left\{ B_\ell + \left(\frac{\Delta x}{\Delta y}\right)^2 B_m \right\}$$
$$+ \left[\left\{ \left(\frac{\alpha_1}{\alpha_2}\right)^2 \left(\frac{\Delta x}{\Delta z}\right)^2 B_n \right\} \lambda^n \right] \cdot \qquad \text{(II.A.14)}$$

The iterations continue until the relative change at each grid point is less than a prescribed value. If the allowable relative error is comparable to the computational precision, the iterative solution sometimes oscillates at a few grid points. When this occurs, the MATHEW model switches to direct relaxation ($\omega = 1$) and convergence follows in a few iterations.

II.A.4.a. Overrelaxation Factor

The overrelaxation factor, ω, was determined experimentally using a scheme suggested by Forsythe and Wasow (1960). An optimal value for ω can be estimated from the relationship

$$2\left[1+\left(1-\frac{\| \Delta\lambda^n \|}{\| \Delta\lambda^{n-1} \|}\right)^{1/2}\right]^{-1} \rightarrow \omega_{\text{opt}} \quad \text{as} \quad n \rightarrow \infty \tag{II.A.15}$$

where

$$\| \Delta\lambda^n \|^2 = \sum_{i,j,k} \left(\lambda^n_{ijk} - \lambda^{n-1}_{ijk}\right)^2 .$$

The norm $\| \Delta\lambda^n \|$ is calculated by iterating with $\omega = 1$ in Eq. (II.A.13) and forming a value for Eq. (II.A.15) after each iteration. Since the MATHEW model allows arbitrary topography and the coefficient matrix of the equation set thus changes with each model application, ω_{opt} was estimated from Eq. (II.A.15) for a variety of mesh intervals and topographic specifications. When Δx is comparable to Δy and $\alpha_1 \Delta x$ is comparable to $\alpha_2 \Delta z$, the estimated value of ω_{opt} is 1.78. Generally the value of ω_{opt} is between 1.7 and 1.8.

II.A.4.b. Gauss Precision Moduli

The appropriateness of the final wind field is dependent on the selection of α_1 and α_2, the Gauss precision moduli (GPM). Our method of selection assumes that mass can move freely in the horizontal and vertical directions under neutral atmospheric conditions. Since the mass flux is proportional to the area being considered, it stands to reason that the ratio of the areas of the horizontal and vertical cell faces should provide the correct relative values for GPM, i.e., $\alpha_1/\alpha_2 = 4\Delta z \Delta x / 2\Delta x \Delta x = 2\Delta z/\Delta x$. This ratio is adjusted upward or downward to account for other Pasquill categories. Since the cell aspect ratio is partly chosen as a function of terrain steepness and complexity, the choice of a value implicitly includes the necessary scale information.

II.A.5. Output

The adjusted (mass-consistent) wind field values are calculated by introducing the λ's into the difference formulation of Eq. (II.A.4),

$$U_{(i,j+1/2,k+1/2)} = U^0_{(i,j+1/2,k+1/2)} + \left(\frac{1}{2\alpha_1^2}\right) \frac{D_\ell \lambda_{(i+1/2,j+1/2,k+1/2)} - E_\ell \lambda_{(i-1/2,j+1/2,k+1/2)}}{\Delta x} \tag{II.A.16a}$$

$$V_{(i+1/2,j,k+1/2)} = V^0_{(i+1/2,j,k+1/2)} + \left(\frac{1}{2\alpha_1^2}\right) \frac{D_m \lambda_{(i+1/2,j+1/2,k+1/2)} - E_m \lambda_{(i+1/2,j-1/2,k+1/2)}}{\Delta y} \tag{II.A.16b}$$

$$W_{(i+1/2,j+1/2,k)} = W^0_{(i+1/2,j+1/2,k)} + \left(\frac{1}{2\alpha_2^2}\right) \frac{D_n \lambda_{(i+1/2,j+1/2,k+1/2)} - E_n \lambda_{(i+1/2,j+1/2,k-1/2)}}{\Delta z} \tag{II.A.16c}$$

where no distinction has been made between the Gauss precision moduli in the x and y directions. The first term in Eq. (II.A.16c) is not included in the coding since W^0 is taken to be zero. Values for the coefficients D and E appear in Table II.A.1 as a function of boundary configuration.

The face-centered velocities (U,V,W) are interpolated to points in a standard rectilinear grid via an averaging procedure that preserves the mass consistency. These velocities, in combination with an information block which uniquely identifies the current problem and a two-dimensional array of mixing height values, is written to a VELnn file (see Section III.C.7.) for subsequent use by ADPIC.

II.B. ADPIC

II.B.1. Formulation -- Pseudo-velocity and particle-in-cell method

The pseudo-velocity method consists of the following: consider the nonlinear transport-diffusion equation

$$\frac{\partial \chi}{\partial t} - \underline{U} \cdot \nabla \chi = \nabla \cdot (K \nabla \chi) \,, \tag{II.B.1}$$

where χ is a scalar concentration, K the diffusion coefficient and $\underline{U}$ the (given) mass-consistent wind advection field (Sherman, 1978b). Under the assumption of incompressibility we can replace the $\underline{U} \cdot \nabla \chi$ term by $\nabla \cdot (\chi \underline{U})$. Upon combining the two divergence terms, we can rewrite Eq. (II.B.1) in its flux conservative (pseudo velocity) form

$$\frac{\partial \chi}{\partial t} - \nabla \cdot \chi \left(\underline{U} - \frac{K}{\chi} \nabla \chi \right) = \frac{\partial \chi}{\partial t} + \nabla \cdot (\chi \underline{U}_p) = 0 \,, \tag{II.B.2}$$

where $\underline{U}_p = \underline{U} - \frac{K}{\chi} \nabla \chi$ is the pseudo transport velocity.

The particle-in-cell method divides the pollutant into discrete mass particles representing the source in terms of a large number of "numerical" pollutant particles, which are transported and dispersed in the Lagrangian sense within a fixed Eulerian domain (Lange, 1973, 1978; Welch et al., 1965; Amsden, 1966; Sklarew, 1971).

The grid mesh of the code is represented by an Eulerian grid consisting of three-dimensional rectangular cells of uniform size. The concentrations χ are defined at the centers of the cells and the velocities $\underline{U}$, $\underline{U}_p$ and $-\frac{K}{\chi} \nabla \chi$ are defined at the cell corners. The locations of the particles, which represent the pollutant cloud, are defined by their individual Lagrangian coordinates within the Eulerian fixed grid.

A time cycle of the code is divided into an Eulerian step and a Lagrangian step and proceeds as follows:

- Eulerian Step: The concentrations χ, given for each cell at the beginning of the cycle, are used to calculate the diffusivity velocities $\underline{U}_D = -\frac{K}{\chi} \nabla \chi$ which are then added to the given wind advection velocities $\underline{U}$ to yield a pseudo-velocity $\underline{U}_p$ for each cell corner.
- Lagrangian Step: Each marker particle contained in a given cell is transported for one time step Δt with a velocity $\underline{U}_p$, which is computed from the pseudo-velocities $\underline{U}_p$ at the corners of the cell, and the particle coordinates $\underline{x}$ are determined by a volume weighting scheme

$$\underline{x}(\text{new}) = \underline{x}(\text{old}) + \underline{U}_p \Delta t \,. \tag{II.B.3}$$

  Finally, a new concentration distribution χ is calculated from the new particle positions, thus ending the cycle.

The chief advantage of using such a hybrid Eulerian-Lagrangian scheme is that the fictitious diffusion inherent in a purely Eulerian scheme is eliminated. The truncation

errors inherent in the finite difference algorithms remain, of course, and must be minimized by the choice of the time step.

II.B.2. Boundary Conditions

The boundary conditions are applied to a layer of boundary cells that surround or protrude into the grid in the form of topography.

II.B.2.a. Topography

Space-variable topography protrudes into the basic grid block of the code. The code recognizes individual flagged grid cells as topography and uses the applicable boundary conditions. The proper modeling of particle deposition on the ground is greatly dependent on the way topography is treated. Dry deposition of small particles and deposition of larger particles by gravity are treated by specifying a deposition velocity at the topographic surface, and a Stoke/McDonald-type fall velocity, respectively. This surface boundary condition is the same as for MATHEW and is supplied by the TOPOG routine.

II.B.2.b. Flux Boundary Conditions

Flux boundary conditions representing inflow or outflow of pollutant particles from the grid are cast in the form of conservation of total flux, i.e., $(\underline{U}_p\chi)$ = constant and $(\underline{U}_p\chi) = 0$ at the surface [see Eq. (II.B.2)]. An inversion layer capping the region of interest can be specified by a reflecting boundary condition, making the total flux $(\underline{U}_p\chi) = 0$ at the inversion layer.

Due to the part-Eulerian, part-Lagrangian makeup of ADPIC, one set of boundary conditions is imposed on the Eulerian velocity field and another set is imposed on the Lagrangian particles. Both sets must be consistent with each other.

The two basic boundary conditions imposed on the pseudo-velocity field in ADPIC $(\underline{U}_p = \underline{U} - \underline{U}_D)$ are constant mass flow, $(\chi\underline{U})$ = constant, corresponding to inflow and outflow of particles, and zero mass flow $(\chi\underline{U}) = 0$, corresponding to reflection of particles from the boundary. There are intermediate cases as, for example, deposition of particles at the topography, in which case a deposition velocity is specified. The chief cause of error incurred by velocity boundary conditions is the inability to specify the variability of the outflow boundary conditions. The concentration field is generally smooth enough by the time it reaches the outflow boundary that the boundary velocities can be specified by postulating a constant flux of particles through the boundary grid cell layer.

The particle boundary conditions are very simple. If a particle leaves the grid during a cycle, it is either destroyed, counted as deposited, or is reflected, according to the type of boundary specified.

II.B.3. Diffusion Parameters

Because ADPIC is a three-dimensional Cartesian code and uses the turbulent flux diffusivity pseudo-velocity

$$\underline{U}_D = -\frac{\mathbf{K}}{\chi}\nabla\chi \,, \tag{II.B.7}$$

it can, in principle, accommodate the full Cartesian eddy diffusivity tensor $\mathbf{K} = k_{ij}$. In practice, isotropy of turbulence in the atmosphere is assumed, and only the diagonal terms K_{xx}, K_{yy}, and K_{zz} survive. In addition, it is generally assumed that the horizontal components of the diffusivity coefficients are the same, so that $K_{xx} = K_{yy}$. Even with these simplifications, the capability of ADPIC to model diffusion in three-dimensions with topography and inversions, under conditions of wind shear and with space- and time-variable

diffusivity coefficients, cannot presently be fully exploited largely because of the lack of a unified theory of diffusion in the atmosphere from which such diffusion coefficients can be obtained. Consequently, the partially empirical theories of diffusion in the atmosphere which have been tested must be combined in a consistent way to provide diffusion coefficients for ADPIC.

For present purposes, diffusivity coefficients must be found that are valid for single puff or continuous plume releases which range initially from meters to kilometers. With time periods of about 12 h and geographical radii of about 100 km, the turbulent diffusivities are scale-dependent. Additionally, since the pollutant cloud may extend vertically through the entire turbulent mixing layer, the atmospheric thermal stability must be taken into account. Constant K-theory is not adequate for such requirements, and similarity theories have been chosen as the primary available framework upon which to base horizontal and vertical diffusivity coefficients (Batchelor, 1947 and 1950). ADPIC computes both horizontal and vertical diffusivities, K_h and K_z, in a variety of forms based on accepted diffusion theory.

II.B.3.a. Horizontal Diffusion Coefficients

II.B.3.a.i. Continuous Sources

For continuous sources, the horizontal diffusivity K_h is based on the semi-empirical expression (Draxler, 1976)

$$\sigma_y = \sigma_\theta U t f\left(\frac{t}{\tau}\right) \; ; \; f\left(\frac{t}{\tau}\right) = \left(1 + \frac{t}{\tau}\right)^{-1/2} \tag{II.B.8a}$$

combined with the analytical relationship

$$K_h = \sigma_y \frac{d\sigma_y}{dt} \; , \tag{II.B.8b}$$

where σ_y is the horizontal standard deviation of the pollutant plume width, σ_θ is the standard deviation of the fluctuation of the wind direction, U is the mean wind speed, t is time, and $f(t/\tau)$ is a function of time and an empirical time constant τ which will assure that Eq. (II.B.8a) will go to the Taylor limit ($\sigma_y \propto t^{1/2}$) for times $t \gg \tau$. Note that K_h is a function of height also, through the height dependence of σ_θ.

II.B.3.a.ii. Instantaneous Clouds

A large number of experimental studies have been summarized (Crawford, 1966) to show the validity of similarity theory in the inertial subrange of the atmosphere for the horizontal spreading of clouds in the atmosphere from meter to kilometer sizes over times from minutes to several days. The conclusion drawn is that for such scales the horizontal diffusivity coefficients take the form

$$K_{xx} = K_{yy} \propto \varepsilon^{1/3} (\sigma_y^2)^{2/3} \; , \tag{II.B.9}$$

where ε is the rate of eddy-energy transfer in the inertial range and is a scaled function of height Z and average horizontal windspeed $U(Z)$ above the surface,

$$\varepsilon \propto \frac{[U(Z)]^3}{Z} \; , \tag{II.B.10}$$

and σ_y^2 is the average horizontal dispersion of the cloud. The expression for scale dependent diffusion (Walton, 1973)

$$\sigma_y^2 = \left(\sigma_o^{2/3} + \frac{2}{3} C \varepsilon^{1/3} t\right)^3 \qquad \text{(II.B.11)}$$

is substituted into Eq. (II.B.9) and provides K_{zz} and K_{yy} as a function of t and ε. For early times, when the initial cloud size in terms of its standard deviation σ_0 is important, the time rate of change of the dispersion is proportional to time t,

$$\frac{d(\sigma_y^2)}{dt} \propto (\varepsilon \sigma_0)^{2/3} t \ . \qquad \text{(II.B.12)}$$

At late times, when $\sigma_0^2 \ll \sigma_y^2$, the time rate of change of the dispersion becomes

$$\frac{d(\sigma_y^2)}{dt} \propto \varepsilon t^2 \ . \qquad \text{(II.B.13)}$$

II.B.3.b. Vertical Diffusivity Coefficient

For the vertical diffusivity coefficient K_{zz}, the turbulent diffusion due to both the mechanical shear induced by the drag of the earth's surface on the atmosphere and the vertical thermal convection within the atmosphere must be taken into account. Within the surface layer of the atmosphere, the original similarity concepts of Monin and Obukhov (1954), based on constant momentum and heat flux, are used to calculate diffusivities. The Monin-Obukhov similarity parameter $\xi = Z/L$, where L is the Monin-Obukhov length and Z is the vertical height, is the primary independent variable representing the state of stability of the atmosphere in the surface layer. It is used to obtain the vertical diffusivity coefficient $K_{zz}(\xi)$,

$$K_{zz} = U_* k Z \frac{1}{\phi_m} \ , \qquad \text{(II.B.14)}$$

where U_* is the friction velocity, k is the von Karman constant, $\phi_m = (kZ/U_*)(\partial U/\partial Z)$ is a dimensionless wind shear, and U is the average horizontal wind speed. The function ϕ_m depends in the following way on the stability of the atmosphere:

$$\underline{\text{Stable :}} \qquad \phi_m = 1 - \Upsilon_1 \xi \ , \quad \xi > 0 \ , \quad L > 0 \qquad \text{(II.B.15)}$$

$$\underline{\text{Neutral :}} \qquad \phi_m = 1 \ , \quad \xi = 0 \ , \quad L \to \infty \qquad \text{(II.B.16)}$$

$$\underline{\text{Unstable :}} \qquad \phi_m = (1 - \Upsilon_2 \xi)^{-1/4} \ , \quad \xi < 0 \ , \quad L < 0 \ . \qquad \text{(II.B.17)}$$

Here Υ_1 and Υ_2 are empirical constants ranging from 4 to 5 and 14 to 16, respectively (Businger et al., 1971). The Obukhov length L has the form

$$L = -\frac{U_*^3 C_p \rho T}{k g H} \ , \qquad \text{(II.B.18)}$$

where C_p is the specific heat of air at constant pressure, ρ is the density of air, T is the temperature, H is the heat flux, and g is the gravitational acceleration. When L is not known, it can be found from its functional relationship to the Richardson number.

Above the surface layer and up to the turbulent mixing height, turbulence due to the surface stress eddies, thermal convection, and wind shear decreases with height until it essentially "disappears" at the top of the mixing layer (Holzworth, 1964). The similarity assumptions of constant momentum and heat flux are no longer valid in this region, and very little consensus exists among investigators at the present time as to the values of vertical diffusion parameters. This is largely due to the complex interactions of wind shear, lapse rate, Coriolis force, pressure gradients, eddy diffusivity, and buoyancy in this region. It is generally assumed that the vertical diffusivity coefficient K_{zz} either remains constant up to the top of the mixing or inversion height, where it sharply drops to a minimum value, or approaches a minimum based on a smooth functional dependence on height above the surface layer.

The vertical diffusivity K_z is computed in ADPIC separately for the atmospheric surface layer and the outer boundary layer. For the surface layer, K_z is based on similarity theory (Businger et al., 1971)

$$K_z = \frac{kU_* z}{\phi(z/L)} , \qquad \text{(II.B.19)}$$

where k is the von Karman constant, U_* is the friction velocity computed by the code, z is the height above terrain, and $\phi(z/L)$ is the atmospheric stability function based on z and the Monin-Obukhov scale length L. In the outer atmospheric boundary layer, K_z is computed by the empirical form

$$K_z = CU_* z e^{-(z/h)} , \qquad \text{(II.B.20)}$$

where C is an empirically-derived proportionality coefficient (Start et al., 1975; Crawford, 1974), and h is the mixing height of the atmosphere boundary layer.

Another reasonable value for K_z above the surface layer is a statistically obtained power law profile for the vertical standard deviation σ_z of the form

$$\sigma_z = a\sigma_\theta x^b , \qquad \text{(II.B.21)}$$

where a and b are observationally obtained stability dependent constants, σ_θ is the horizontal wind fluctuation over a time interval, and x is the downwind distance from the source. From the relation between K-theory and statistical diffusion theory, the vertical diffusivity coefficient K_z then becomes

$$\frac{d[\sigma(t)]^2}{dt} = 2K_z , \qquad \text{(II.B.22)}$$

where t is the time of travel from the release point (Slade, 1968; Pasquill, 1971).

II.B.4. OPTIONS IN ADPIC

II.B.4.a. Sources

Up to nine separate pollutant source configurations (combinations of source type, rate, geometry, etc.) are allowed. The release rate and source center height of each pollutant source can vary with time. The effective times of the time-varying source parameters (TSRATEi and TZSCHi) are controlled by the timing parameters IDATSRC and ITIMSRC.

The way in which ADPIC describes pollutants in terms of discrete mass (activity) particles makes the implementation of decay rate calculations straightforward. Such processes as radioactive decay of pollutants in conjuction with atmospheric dispersion under complex terrain conditions can be modeled.

II.B.4.b. Source Geometry

The initial position (x, y, and z coordinates) of each marker particle representing the pollutant material is computed by using a Gaussian or normal probability distribution function. The probability of the distance that each particle will be from each of the three orthogonal axes through the source center is determined by the shape of a Gaussian distribution. The number of particles to be generated for each source is specified by the user by the use of the ITOT parameter. Several thousand particles per ADPIC source provide a fairly good representation of a sample population.

In all, ten parameters are used to control the representation of the initial stabilized source geometry. The first three are standard deviations of the Gaussian distribution, SIGX, SIGY and SIGZ, in the x, y and z directions, respectively. These control how peaked or flat the source distribution will be along each axis, as shown in Fig. II.B.2. The Gaussian distributions are then truncated as shown in Fig. II.B.3 using six source cutoff parameters, XR, XL, YR, YL, ZT, and ZB, where R is for right, L for left, T for top, and B for bottom. The last source geometry parameter is the height above ground of the source center, ZSCH.

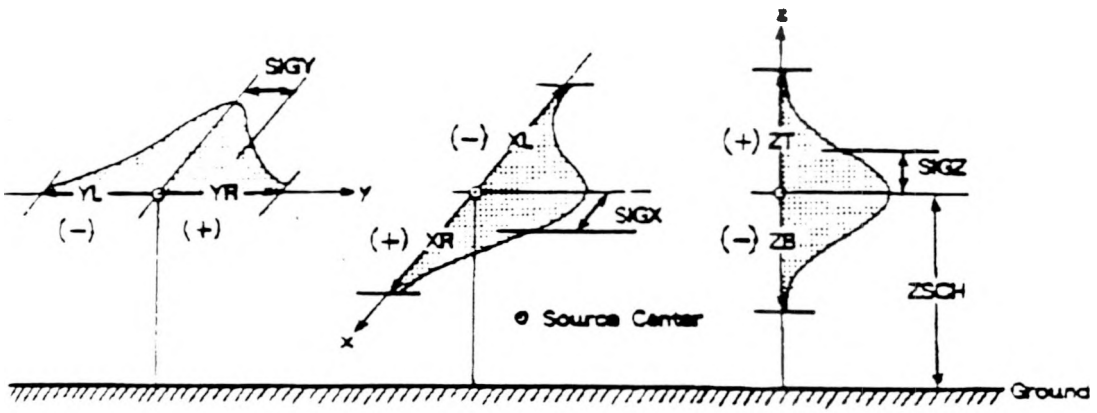


Fig. II.B.2. Gaussian source geometry parameters

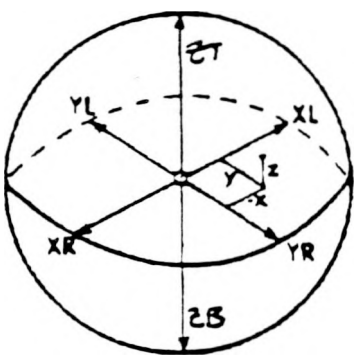


Fig. II.B.3. Cutoff parameters for a spherical-shaped source

If very little truncation of the Gaussian curves is desired, the radius of the entire source is typically used for the cutoff values and the radius divided by 2.5 to compute the standard deviations. This is based on the fact that about 99% of the area in the Gaussian distribution lies within 2.5 standard deviations of its center.

When the pollutant distribution covers fewer than two grid cell lengths, the concentration gradients are ill-defined and the code diffuses the particles too slowly, in which case a special sub-grid treatment of the source particles is employed for the diffusion only. The initial source parameters maintain a Gaussian shaped plume independently in the horizontal and vertical until those respective standard deviations become as large as the grid cell size. At that time, the diffusion scheme specified by the user (Gaussian, gradient, or Monte Carlo, controlled by the parameter IDIF) takes over. If it is desired to extend Gaussian plume shape past this point, the PICIN parameters OQNSH and OQNSV can be used to override the default time at which the diffusion scheme specified by IDIF replaces the extension of the Gaussian source geometry.

The ten source source parameters may be used to describe a wide variety of sources, with the three most common shown in Fig. II.B.4. Releases from stacks are usually assumed to be spherical (equal sigma and cutoff values in each direction). Puffs or clouds from fires or explosions are usually elongated in the vertical. If necessary an explosion may be described by two source terms, one for the lower stem and one for the upper cloud.

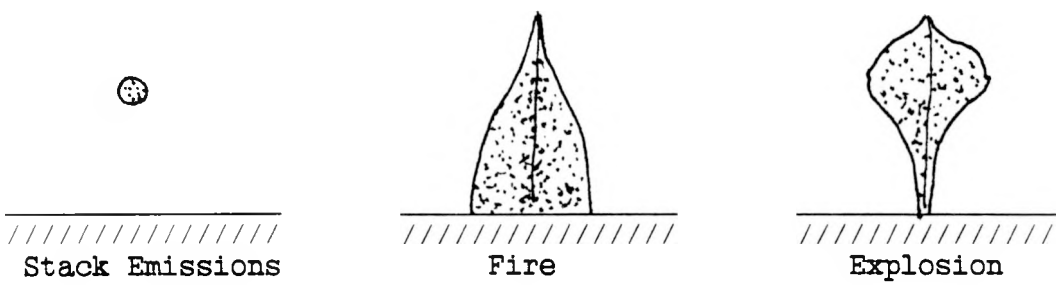
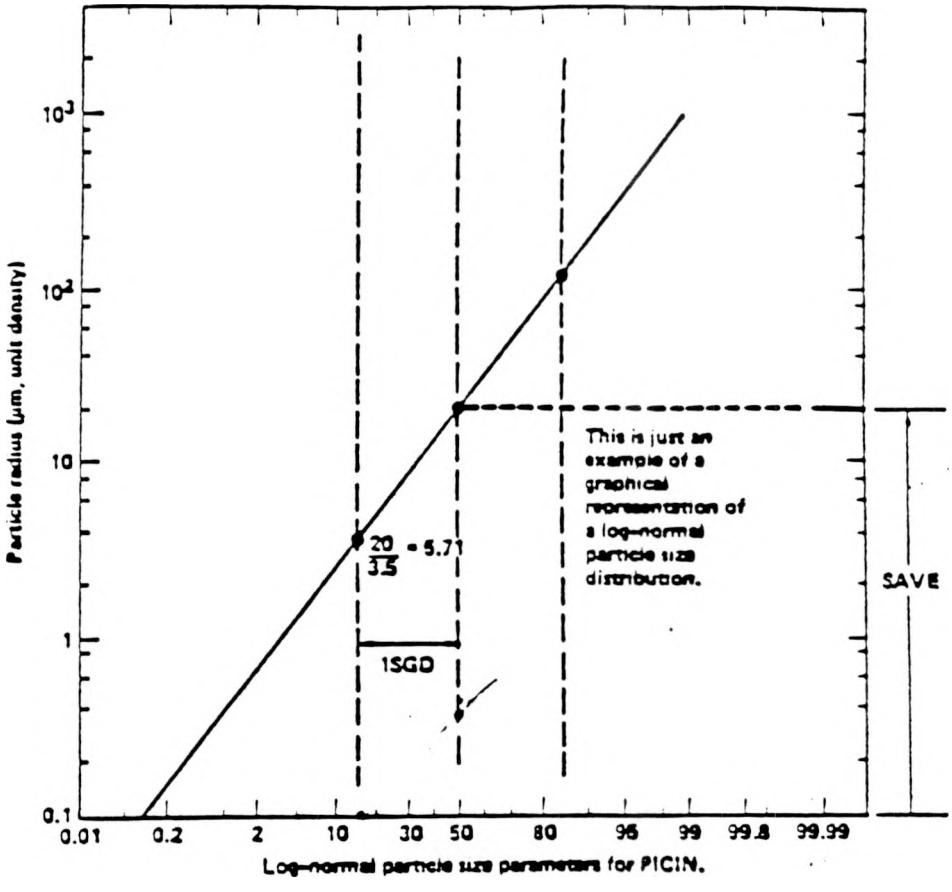


Fig. II.B.4. Example source geometries

II.B.4.c. Particle Size Distribution

The distribution of the particle size range as log-normal can be specified in ADPIC by using the parameters SMIN, SMAX, SGD, and SAVE. An example showing the graphical derivation of these values is shown in Fig. II.B.5.



Percent less than stated size

Input parameters	Description
SGD	Standard geometric deviation: the ratio of $\frac{r \text{ at } 50\%}{r \text{ at } 16\%}$ or $\frac{r \text{ at } 84\%}{r \text{ at } 50\%}$
SAVE (μm)	Median radius: radius of 50% point
SMAX (μm)	Maximum radius of particles
SMIN (μm)	Minimum radius of particles

Fig. II.B.5. Log normal particle size distribution

Usually particle sizes are normalized to a particle density of 1 g/cm3 (1000 kg/m3). If actual particle sizes are used, then the actual particle density (PRHO) must be specified.

II.B.4.d. Dry Deposition

The removal of material from the atmosphere through dry deposition is modeled separately by ADPIC via two processes: gravitational settling of material, and flux of material from the surface layer to the ground surface itself (represented by the deposition velocity).

The settling velocity is modeled by ADPIC with either the Stokes law or the McDonald method (McDonald, 1960) based on particle size (SAVE), particle density (PRHO), and altitude. The McDonald method is used for cases when the Reynold's number is greater than 1 and the Stokes Law is invalid (e.g. particle diameters greater than approximately 3.5 um at standard ground-level conditions). The parameters SAVE and PRHO are used not only to specify the median particle size radius and the particle density, respectively, but are also used as flags: if either SAVE or PRHO is zero, the ADPIC particles are treated as passive material with no gravitational settling velocity.

The surface deposition velocity, which is modeled separately from the gravitational settling velocity, represents the affinity of the material for the ground. The deposition velocity is typically a function of effluent chemistry, particle size, atmospheric stability, and surface type (e.g. soil, vegetation, etc.). Fig. II.B.6 shows how deposition velocity varies with particle diameter in laboratory and field measurments made by McMahon and Dennison (1979).

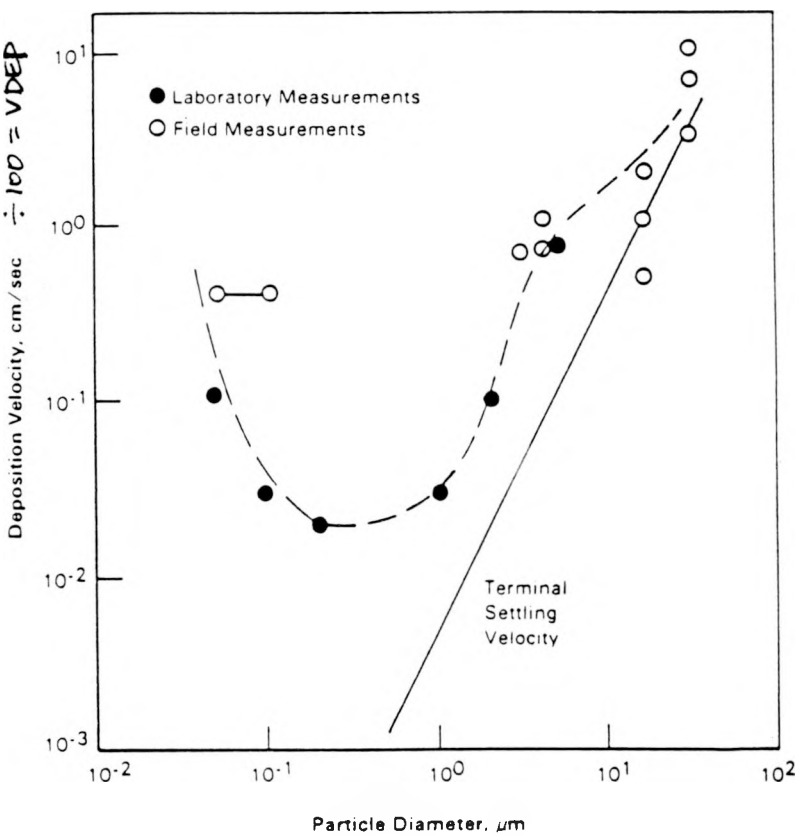


Fig. II.B.6. Laboratory and Field Measurements of Deposition Velocity to Grass vs. Particle Size (McMahon and Dennison, 1979)

The deposition velocity used by ADPIC is linearly weighted according to the distance from the bottom of the cell, from zero at the top of the cell to the full value of VDEP at the bottom of the cell. A non-zero deposition velocity will cause an ADPIC particle to be deposited if it is in the lowest grid cell and at a height which is less than or equal to the weighted VDEP (in m/sec) times the time step (in sec). A VDEP value of zero will result in no removal of ADPIC particles via the deposition velocity mechanism.

If either SAVE or PRHO is zero, and if VDEP are zero, the ADPIC particles are treated as passive material and no dry deposition will result. Although material can be moved into the surface layer from above via advection by the mean wind and by turbulent diffusion, material cannot be moved from the surface layer to the ground through either of these two methods as modeled by ADPIC. Any material that impacts the ground through either advection or diffusion will be reflected from the ground.

II.B.4.e. Washout

At present, the basic assumption for model removal of debris particles in ADPIC is that the base of the rain cloud is above the debris cloud. For surface or near-surface pollutant releases, this seems to be a reasonable assumption to about 100 km downwind. Thus, ADPIC in its present form does not treat in-cloud rainout, but has provisions for below-cloud washout (Crandall et al, 1973).

Washout is treated in the following way in ADPIC. For a specified rain rate over a given surface area, a washout coefficient $\Lambda(r)$ is assumed as a function of particles of size r. Because of their limited number, each ADPIC particle is only a representation of a certain amount of an actual pollutant. Therefore, an ADPIC mass particle is initially considered to represent an integrated pollutant particle size distribution over sizes such that

$$M(0) = \int_{r=0}^{\infty} m(r,0)dr \ , \tag{II.B.4}$$

where $M(0)$ is the initial mass of an ADPIC particle and $m(r,0)$ is the mass per unit radius of a pollutant particle of radius r at time 0. Constant density is assumed for the pollutant particles. $M(t)$, the mass of an ADPIC particle remaining after a time t in the rain for a given constant rain rate and raindrop size distribution, can be written as

$$\begin{aligned} M(t) &= \int_{r=0}^{\infty} m(r,t)dr \\ &= \int_{r=0}^{\infty} m(r,0)e^{-\Lambda(r)t}dr \ . \end{aligned} \tag{II.B.5}$$

To account for the diffusion and transport of pollutants as calculated by ADPIC, this function $M(t)$ is obtained from a table at each ADPIC time step Δt. The fraction of mass $F(\Delta t)$ of an ADPIC particle washed out and deposited on the surface during one ADPIC time cycle then becomes

$$F(\Delta t) \ = \ \frac{M(t) - M(t+\Delta t)}{M(t)} \ = \ 1 - \frac{\int_{r=0}^{\infty} m(r,0)e^{-\Lambda(r)(t-\Delta t)}dr}{\int_{r=0}^{\infty} m(r,0)e^{-\Lambda(r)t}dr} \ . \tag{II.B.6}$$

This fraction of mass loss per cycle for each ADPIC particle is stored cumulatively each cycle in a two-dimensional, surface deposition array.

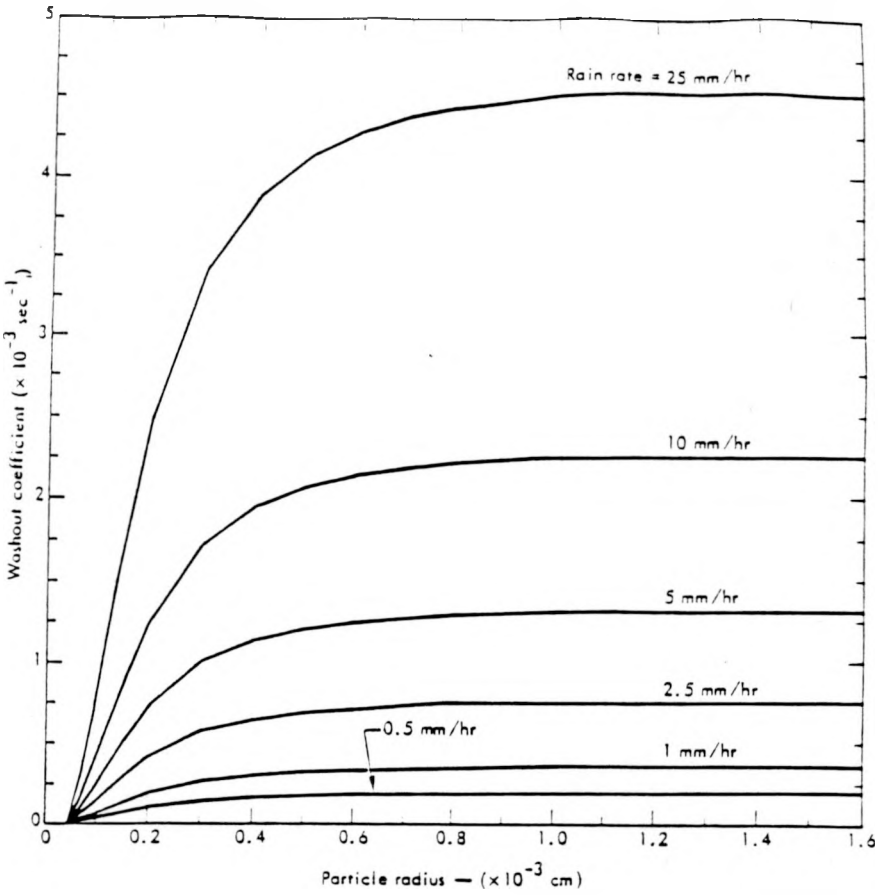


Fig. II.B.7. Washout coefficient versus particle radius for various rain rates.

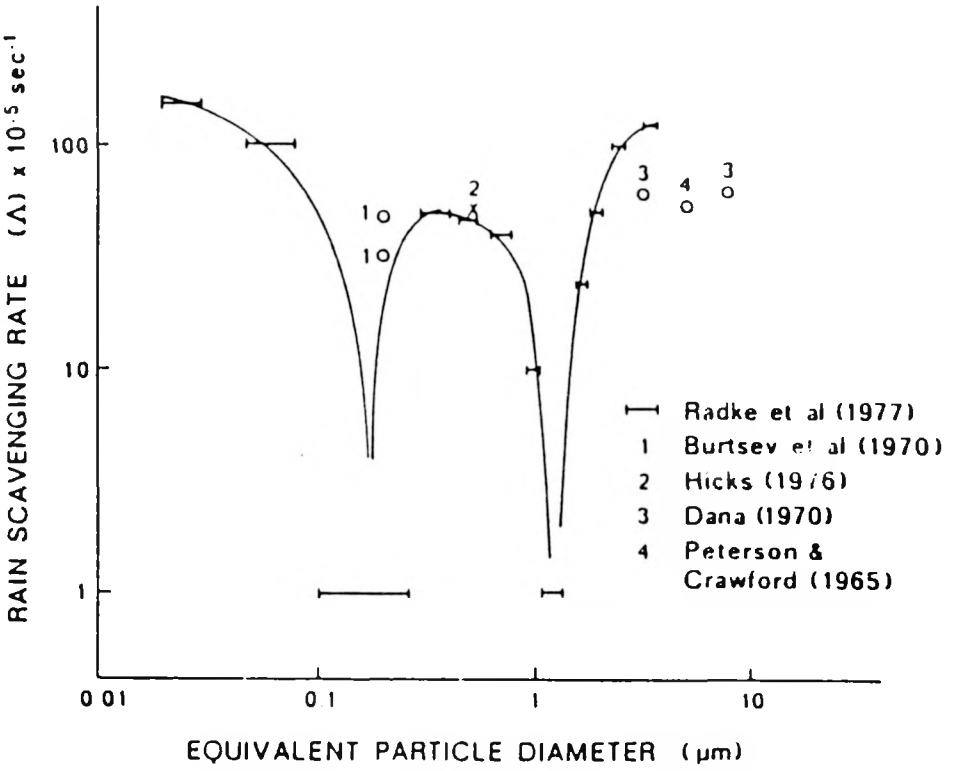


Fig. II.B.8. Measured Values of Scavenging Coefficient vs. Particle Size (McMahon and Dennison, 1979)

II.B.4.f. Plume Rise

Plume rise can significantly affect ground level concentrations from stack releases into the atmosphere. It becomes important and needs to be evaluated when the exit velocity and/or temperature are sufficiently higher than ambient. Generally, this problem is solved by calculating an effective stack height (physical stack height plus a final plume rise height increment). ADPIC, however, can calculate the time- dependent plume rise of a stack release given the stack emission and meteorological parameters. The parameterization developed for ADPIC by Desiato and Lange (1986) are used. These parameterizations rely primarily on the work of Briggs (1975) except for the unstable cases where the work of Weil and Hoult (1973) is used. Seperate plume rise equations are used for the various combinations of momentum and buoyancy plume rise, vertical and bent-over plumes, and stability class.

The plume rise calculations are controlled with two groups of parameters input via the PICIN file. The first group are stack parameters for each source: plume rise flag for each source (IPLRIS) internal radius of stack (RSRC), vertical exit velocity of gas (WSRC), temperature of gas emitted from stack (TSRC), and optional sensible heat emission rate (QSRC). The second group are time-varying meteorological parameters for each source: ambient air temperature (TAMBSRCi), height of strong inversion affecting plume rise (HINVSRCi) and vertical temperature gradient (VGRDSRCi).

II.B.4.g. Explosive Cloud Rise

An explosive cloud rise module has been incorporated into ADPIC which simulates additional forces acting upon the ADPIC particles due to their proximity to the thermal environment resulting from the detonation of a chemical explosive. When employed, this module generates additional vertical and horizontal components of motion applied to each particle remaining within the calculated effects of the rising thermal cloud.

A full description of the explosive cloud rise integral model code is found in Boughton and Delaurentis (1987), with further discussion of its use in ADPIC discussed in Foster, et. al. (to be published). Briefly, the code provides a time evolution of the physical and thermodynamic properties of a bouyant cloud formed when a chemical explosive is detonated. The model is based on integrating the three dimensional conservation equations of mass, momentum, and energy over the cloud's cross section. With some simplifying assumptions the integral equations reduce to a set of ordinary differential equations which can be solved for the cloud radius, centerline height, temperature, and velocity as a function of time. These solutions are sensitive to the input parameters describing the ambient atmospheric conditions, especially the atmospheric temperature profile. The initial size and conditions of the cloud are determined using these atmospheric conditions and amount of explosive mass.

Once the cloud's characteristics are determined at each cloud rise model time step (which may be shorter than ADPIC's advection time step), the influence of this bouyant volume must be coupled to the ADPIC particles. There are two considerations in coupling the marker particles to the cloud, the initial loading of the particles into the calculational grid and their subsequent motion while they remain within the bouyant environment. All of the marker particles are initially loaded into the spherical cloud volume at the specified source release time. They have a Gaussian distribution within this volume with radial cutoff values equal to the initial cloud radius as determined by the cloud model. The standard deviations of this distribution are scaled to the cloud radius and are controlled through a scaling factor used to adjust the "flatness" of the initial distribution. For surface explosions, this initial sphere is tangent to the surface (e.g. it is centered at a height equal to the cloud radius).

As the cloud rises with time it is assumed to contain an environment of enhanced turbulence with entrainment occurring along its surface. Particles remaining inside the sperical cloud volume are treated differently than those moving beyond the cloud radius. Specifically, diffusion velocities are neglected while particles remain within the bouyant cloud. In addition, a fraction of the cloud's vertical motion is applied to each particle within radius, R, of the cloud center. The vertical motion imparted to each particle due to its proximity to the rising cloud is a function of its distance, r, from the cloud center, and is given by:

$$w = W \exp(-c(r/R)^{**}2)$$

where

w = the particle's vertical lift due to the rising cloud (in addition to the vertical advection velocity),
W = the cloud's vertical lift motion,
c = a velocity coupling coefficient (= 0.35),
r = the particle's distance from cloud center, and
R = the cloud's radius.

Another difference in the treatment of particles within the cloud is a radially outward adjustment to maintain the particle's relative position between the cloud center and cloud edge as the cloud increases in size. This adjustment "velocity" simulates the effects of a well-mixed cloud, as it grows through entrainment, by redistributing the particles throughout the entire cloud volume. This velocity due to the cloud's expansion is independent from the particle's movement relative to the cloud center due to gravitational fall, the particle's vertical motion w, and potential differences in advection of the cloud and particles due to the spatial variation in the winds.

Therefore, particles remaining within the extent of the cloud are moved by applying the appropriate advection, expansion, fall, and vertical lift velocities. Once a particle leaves the influence of the rising thermal (usually due to the particle's gravitational fall velocity moving the particle beyond the cloud radius), only the usual advection, diffusion, and fall velocities are applied.

The dynamics of the cloud are followed until its vertical velocity decreases below a predetermined limit. At this point all particles are treated as though the cloud no longer exists and the cloud calculation is bypassed for the remainder of the problem. A similar effect occurs if the cloud center rises above the top of the computational grid.

II.B.4.h. Meteorological Parameters

Several time-varying meteorological or meteorological-related parameters that affect the diffusion and/or deposition of pollutant sources in ADPIC can be input via the PICIN namelist file. These time-varying met parameters (ITIDIF, ITISTAB, TBMOLI, TSMOLI, TTOPML, TSIGTHFACT, TRRATE, and TQLAM) may have up to 50 values, with the IDATMET and ITIMMET parameters controlling the start date and time that each value will become effective.

ADPIC output is in the form of mass (or activity) concentrations, with coordinates of the Lagrangian particles representing the pollutant mass and the advection, diffusion, and friction velocities. If the advection and sampling grid cells have the same resolution, the concentrations near the source area are chronically low because of an excessively high volume of dilution. (Concentrations are calculated by summing the mass contributions in each cell and dividing the result by the cell volume at specific times.) This problem corrects itself when the horizontal spread of the pollutant reaches the horizontal dimension of the sampling grid cell. A system of nested grids has been devised to improve the near-source resolution of concentration. The largest grid in Fig. II.B.9. represents ADPIC's standard advection and sampling grids, dimensioned 40 × 40 cells. All interior grids represent nested grids of diminishing size, each having 20 × 20 sampling cells at half the resolution of the preceding grid. In all cases, the vertical dimensions of the advection and sampling cells are identical. As suggested in Fig. II.B.9., the source, denoted by a dot in the smallest

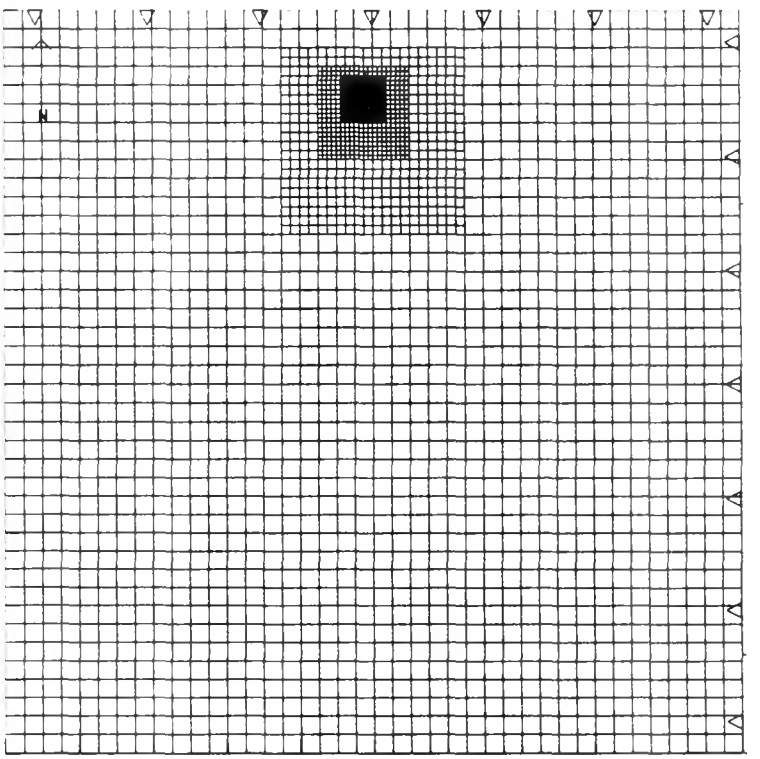


Fig. II.B.9. Nested grids for improving near-source sampling.

box, maintains the same relative position in each of the five grids. To demonstrate how these grids are situated in relation to one another, assume that the UTM easting and northing coordinates of the source are 410.5 km and 4011.3 km, respectively, and that the assessor selects an advection grid for ADPIC whose lower-left coordinates are 400 km and 4000 km in the easting and northing directions. (Skewing the grid in this fashion would be appropriate when the prevailing winds and the winds in the foreseeable future are from the southwest.) Assuming a standard ADPIC grid having 40 × 40 cells in the horizontal with Δx and Δy equal to 2 km, the source would then occupy the advection cell whose index location is $i = 6$ and $j = 6$. Since the nested grids have 20 × 20 cells, the source should reside on or within the $i = 3$, $j = 3$ cell of all nested grids. (The word "should" is used here since a nested grid, if necessary, is shifted to the east and south so that its boundary falls on the nearest mesh lines of the next largest grid.) After receiving this coordinate information from the GRIDIN file (see Section III.C.1.), ADPIC correctly positions each of the four nested grids.

ADPIC produces a set of five two-dimensional arrays of concentration at each level (the user can specify up to 10 levels). These arrays are used by the plotting code, PLCNT, to generate isopleths of concentration. It should be clear from the previous discussion that several arrays can share a common space. When this occurs, PLCNT will always choose, in a spatial sense, the more highly resolved values of concentration. Use of the nested grid approach does, however, create complications; immediately beyond the extremity of any nested grid, the cell volume increases by a factor of four. This causes discontinuities in a contour when it spans two or more nested grids because of an abrupt drop in concentration. To improve the presentation, a routine has been developed that smooths the concentrations at the interface of two nested grids. However, use of this routine places a constraint on the ADPIC grid definition: the source must never be within two cells of the advection grid boundary. Returning to our example, a UTM source location of 402 km east and 4010 km north would violate the two-cell condition, assuming that all grid selections remained the same.

There are four nested grids that are used along with each of these arrays. Each of the nested grids has a Δx and Δy one-half that of its next larger neighbor. These nested grids are only used for sampling concentrations. The standard computational grid is the only one used for advection and diffusion. These nested grids are fixed in that there are always four of them and their cell size is determined by the size of the computational cells.

The placement of the nested grid is determined by the placement of the source in the computational grid. The nested grid is automatically placed such that the source is in the same relation to the nested grid as the source has with the computational grid. The only restriction is that when the grid is originally set up, the source must be at least two grid cells away from the computational boundary. If the source has been placed too close to the outside, a warning message will be printed out in ADPIC with the option to continue or start over.

These concentration arrays are used by PLCNT to plot contours of the concentations. In addition to these concentrations, ADPIC can also print out such things as particle coordinates, advection and diffusion velocities, cell concentrations, and friction velocities.

II.B.4.j. Output

The contents of up to ten different ADPIC output bins may be specified using the parameters ISPEC, IOPT, and SAMHGT. Any particular ADPIC source may be entered more than once. Also, combinations of ADPIC source numbers may be entered to sum the contributions from more than one ADPIC source.

II.B.5. Accuracy of ADPIC

Because the ADPIC time cycle is part Lagrangian and the original particle placement is determined by a random number generator, the discussion of the accuracy of ADPIC must remain largely empirical.

II.B.5.a. Finite Difference Algorithms

As mentioned earlier, the cell concentrations are defined at the cell centers and the pseudo velocities $\underline{U}_p$ are defined at cell corners. The pseudo velocities contain both the advection velocities $\underline{U}$ and the diffusion velocities $\underline{U}_D$. Figure II.B.1 shows the diffusion velocity algorithm resulting from this arrangement, displayed in two dimensions for simplicity.

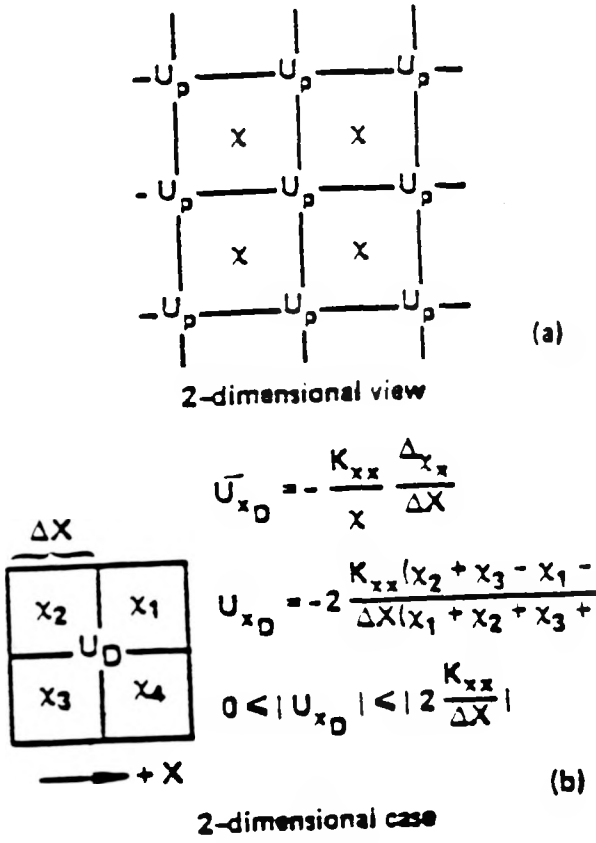


FIGURE II.B.1
Velocity algorithm: (a)grid mesh; (b)diffusivity.

The truncation errors contained in the ADPIC diffusion velocity algorithm can be investigated by expanding it in a Taylor series. Consider the one-dimensional case.

$$U_{i+1/2} = -\frac{K_{i+1/2}}{\Delta X}\frac{(\chi_{i+1}-\chi_i)}{\chi_{i+1/2}}. \qquad \text{(II.B.23)}$$

Let the subscript be dropped for $i + 1/2$ and expand χ_{i+1} and χ_i in Taylor series about $i + 1/2$ to the first contributing error term:

$$U = -\frac{K}{\Delta X \cdot \chi}\left[\chi + \chi'\frac{\Delta X}{2} + \frac{1}{2}\chi''\left(\frac{\Delta X}{2}\right)^2 + \frac{1}{6}\chi'''\left(\frac{\Delta X}{2}\right)^3\right]$$
$$-\left[\left\{\chi - \chi'\frac{\Delta X}{2} - \frac{1}{2}\chi''\left(\frac{\Delta X}{x}\right)^2 - \frac{1}{6}\chi'''\left(\frac{\Delta X}{2}\right)^3\right\}\right] ; \qquad \text{(II.B.24)}$$

$$U = -\frac{K}{\Delta x \cdot \chi}\left[\chi'\Delta X - \frac{1}{24}\chi'''\Delta X^3\right] = -\frac{K\chi'}{\chi} - \frac{K}{24}\frac{\chi'''}{\chi}\Delta X^2 . \qquad \text{(II.B.25)}$$

The first term on the right-hand side is the exact differential expression for the diffusivity velocity; the second term is the first contributing error term. Forming the ratio of the ADPIC diffusion velocity, Eq. (II.B.24), to the exact differential diffusion velocity, we obtain a measure of the importance of the error term

$$\frac{U_{\text{ADPIC}}}{U_{\text{EXACT}}} = 1 - \frac{\chi'''}{\chi'}\frac{(\Delta X)^2}{24} . \qquad \text{(II.B.26)}$$

II.B.5.b. The Number of Eulerian Cells Per Problem

It is important to have enough grid cells to resolve a given particle distribution so as to make the concentration gradients calculated from the cell concentrations representative of the actual gradients. While the particle positions per cell may indicate some subgrid resolution, it is important to point out that the numerical solutions of the diffusion equation are defined on the Eulerian grid. To get a feeling for how well a distribution must be resolved to give reasonable answers, consider Eq. (II.B.26) above for the case of a one-dimensional Gaussian distribution:

$$\chi = \frac{Q}{\sigma}e^{-X^2/2\sigma^2} . \qquad \text{(II.B.27)}$$

The derivatives χ' and χ''' are

$$\chi' = -\frac{QX}{\sigma^3}\,e^{-X^2/2\sigma^2} . \qquad \text{(II.B.28)}$$

$$\chi''' = \frac{QX}{\sigma^3}\left(3 - \frac{X^2}{\sigma^2}\right)e^{-X^2/2\sigma^2} . \qquad \text{(II.B.29)}$$

Substituting Eqs. (II.B.28) and (II.B.29) into (II.B.26),

$$\frac{U_{\text{ADPIC}}}{U_{\text{EXACT}}} = 1 - \frac{1}{24}\left(\frac{X^2}{\sigma^2} - 3\right)\frac{(\Delta X)^2}{\sigma^2} . \qquad \text{(II.B.30)}$$

Since 99% of all particles in a one-dimensional Gaussian distribution lie within $X = 3\sigma$, we can substitute $X = 3\sigma$ in Eq. (II.B.30) and obtain

$$\frac{U_{\text{ADPIC}}}{U_{\text{EXACT}}} = 1 - \frac{(\Delta X)^2}{4\sigma^2} . \qquad \text{(II.B.31)}$$

This indicates that when the cell size ΔX is large compared to the standard deviation of a particle distribution, ADPIC diffuses too slowly.

Equation (II.B.30) shows that for $X^2 = 3\sigma^2$ the error term vanishes regardless of the grid spacing. In this case, $\chi''' = 0$ and higher-order derivatives in the Taylor expansion of χ must be retained to get a meaningful expression.

II.B.5.c. The Number of Particles Per Cell

Inasmuch as the ADPIC particles represent a quantized density, it is desirable to have as many particles per cell as possible. The upper limit of this number is obviously dictated by computer storage. ADPIC assigns a fictitious cell volume to each particle of the same size and shape as the basic grid cell. Thereby, in calculating the concentration field from the particles, each particle will contribute some fractional part of its mass to eight nearest-neighbor cells in proportion to the overlap of its "volume" with the cell volumes of the neighbor cells. This procedure smooths out the concentration field and, in turn the diffusion velocity field which is computed from it. This is consistent with the fact that the Eulerian part of the cycle cannot resolve sub-grid-scale phenomena. From many prior calculations, we find that, due to this smoothing technique as few as one particle per cell on the average will yield meaningful results. With fewer particles per cell than that, i.e., when particles have no neighbors within one cell length around them, the ADPIC diffusivity velocity algorithm (see Fig. II.B.2.) moves the particle to a grid point and "freezes" it there in the absence of any advection.

II.B.5.d. Time-step Calculation

ADPIC stability is rather insensitive to the length of the time step per cycle; however, since the ith particle transport is done by a forward differencing scheme,

$$\underline{X}_i^{n+1} = \underline{X}_i^n + \underline{U}_p^n * \Delta t_i \ , \qquad \text{(II.B.32)}$$

diffusion occurs too fast when Δt_i becomes too large. The most satisfactory arrangement is to limit the transport of the fastest particle in the problem to one cell per time step. However, this rule can be relaxed in many cases. To calculate the time step, ADPIC finds the largest total velocity $\underline{U}_p = \underline{U} + \underline{U}_D$ that any particle sees and computes a mean time step (Δt) according to the following equation:

$$\Delta t = F \cdot \text{Minimum of } \left[\frac{\Delta X}{|U_{PM}|}, \frac{\Delta Y}{|V_{PM}|}, \frac{\Delta Z}{|W_{PM}|} \right] \ , \qquad \text{(II.B.33)}$$

where F is an input number between 0 and 1. ΔX, ΔY, and ΔZ are the cell lengths and $|U_{PM}|$, $|V_{PM}|$, and $|W_{PM}|$ are the absolute values of the maximum pseudo-velocities

at any cycle. The individual particle time step (Δt_i) is then generated by calling a random number generator, which generates Δt_i subject to the constraint $0 \leq \Delta t_i \leq 2\Delta t$.

II.B.5.e. Sub-grid Scale Diffusion

As shown in the section entitled "Accuracy of ADPIC," when the particle distribution in ADPIC cannot be resolved by the grid mesh, errors in diffusion rates occur. This situation is found when one tries to model sources that are initially considerably smaller than a cell volume. Under such conditions, an assumption is made about the shape of the source particle distribution at early times until the distribution has spread out enough to represent an extended source, resolved by the grid mesh. The source particles can be diffused in accordance with such a distribution until such a time. The sole purpose of this source particle treatment is to provide ADPIC with a reasonably representative extended source for the study of larger-scale three-dimensional phenomena involving varying meteorology, diffusion parameters and topography over distances at which the effect of the source is not important. If effects near the source are to be investigated, the close-in ADPIC problem will have to be run separately. With this in mind, it is assumed the sub-grid scale source is Gaussian in character and that it remains locally Gaussian until its standard deviation σ is approximately equal to the size of a grid cell and represents an extended source. At this point, the locally Gaussian assumption is discarded and ADPIC calculates diffusion by its concentration gradient method. It will now be shown how this assumption leads to a sub-grid scale diffusivity velocity, and how this velocity is integrated to diffuse source particles. This approach treats horizontal and vertical diffusion of the particles independently. For simplicity, the case for the cross-wind (y) direction is illustrated.

For a Gaussian distribution, the concentration field for a puff is described by

$$\chi = \frac{Q}{(2\pi)^{1/2}\sigma_y} \exp\left(-\frac{1}{2}\frac{y_D^2}{\sigma_y^2}\right) \tag{II.B.34}$$

where χ is the particle concentration, Q is the source, σ_y is the standard deviation and y_D is the distance of the particle from the center of the distribution. By dividing the diffusion flux

$$\chi V_D = -K_y \frac{\partial \chi}{\partial y} \tag{II.B.35}$$

through by χ, the definition of diffusion velocity is obtained

$$V_D = -\frac{K_y \partial \chi}{\chi \partial y} = -K_y \frac{\partial (\ell n \chi)}{\partial y}, \tag{II.B.36}$$

where V_D is an average diffusion velocity and K_y the diffusion parameter. Calculating $\ell n(\chi)$ from Eq. (II.B.34) and substituting in (II.B.36), the diffusivity velocity becomes

$$V_D = -K_y \frac{\partial}{\partial y}\left[\ell n \frac{Q}{(2\pi)^{1/2}} - \ell n \sigma_y - \frac{1}{2}\frac{y_D^2}{\sigma_y^2}\right] = \frac{K_y y_D}{\sigma_y^2}. \tag{II.B.37}$$

Substituting Eqs. (II.B.9) and (II.B.11) into the equation for V_D (C has been set equal to 1), Eq. (II.B.37) yields

$$V_D = \frac{y_D}{\left(\frac{\sigma_0^2}{\varepsilon}\right)^{1/3} + \frac{2}{3}t} \,. \tag{II.B.38}$$

This diffusivity velocity is independent of the ADPIC grid mesh and is defined at the coordinate (y_D, t) of a given source particle. The quantity y_D is the absolute value of the distance from the particle to the diffusion (puff) center, as can be seen from its definition in Eq. (II.B.34). The variable t represents the "age" of the particle since its creation and coincides with the actual ADPIC problem time only in the case of a single puff source.

Equation (II.B.38) shows that in the case of a true point source, when $\sigma_0 = 0$, or at a late time when $(\sigma_0^2)^{1/3} \ll \frac{2}{3}t$ for any size source,

$$V_D = \frac{y_D}{\frac{2}{3}t} \,. \tag{II.B.39}$$

Hence it is a property of Gaussian diffusion that all those particles, for which the diffused distance y_D divided by the diffusion time t is a constant ratio, will have the same diffusion velocity V_D. Also, Eq. (II.B.38) shows that if a particle gets generated as part of a Gaussian source distribution of size σ_0 at a distance y_0 at $t = 0$, its initial diffusion velocity is

$$V_D = \frac{y_0}{\left(\sigma_0^2/\varepsilon\right)^{1/3}} \,. \tag{II.B.40}$$

For the case of constant K, Eqs. (II.B.9) and (II.B.11) become, respectively,

$$K = K_{\text{constant}} \tag{II.B.41}$$

$$\sigma^2 = \sigma_0^2 + 2Kt \,. \tag{II.B.42}$$

A derivation similar to the scale-dependent case leads to an expression for the diffusivity velocity

$$V_D = \frac{y_D}{\frac{\sigma_0^2}{K} + 2t} \,. \tag{II.B.43}$$

Since the diffusivity velocity can also be expressed as

$$V_D = \frac{\partial y_D}{\partial t} \,, \tag{II.B.44}$$

Eq. (II.B.43) can be integrated over time as long as neither σ_0 nor K are assumed strong functions of y or t. This integration is carried out each ADPIC cycle over the applicable time step Δt. From Eqs. (II.B.43) and (II.B.44) for the constant K case, the integral equation is

$$\int_{y_D}^{y_D - \Delta y} \frac{dy_D}{y_D} = \int_t^{t+\Delta t} \frac{dt}{\frac{\sigma_0^2}{K} + 2t} \,. \tag{II.B.45}$$

Integrating, and solving for Δy_D,

$$\Delta y_D = y_D \left\{ \left[1 - \frac{\Delta t}{(\sigma_0^2/2K) + t} \right]^{1/2} - 1 \right\} \tag{II.B.46}$$

where Δy_D is the distance diffused by the source particle during time step Δt, y_D is the diffused distance at the beginning of the cycle, Δt is the ADPIC time step and t is the "age" of the source particle at the beginning of the cycle.

A similar integration of Eq. (II.B.38) for scale-dependent diffusion results in

$$\Delta y_D = y_D \left\{ \left[1 - \frac{\Delta t}{\frac{3}{2}\left(\frac{\sigma_A^2}{\varepsilon}\right)^{1/3} - t} \right]^{3/2} - 1 \right\} . \qquad \text{(II.B.47)}$$

The actual distance traveled by a source particle during one cycle in the ADPIC grid can now be computed by adding the distance Δy_A from advection to the distance Δy_D diffused during a time step:

$$\Delta y = \Delta y_D - \Delta y_A = \Delta y_D - V_A \cdot \Delta t \qquad \text{(II.B.48)}$$

where V_A is the interpolated advection velocity obtained in the same way as for regular non-source ADPIC particles.

The various updated values at cycle $n - 1$, the actual source particle coordinate y, the diffusion distance y_D, and the particle age t are then calculated and stored for each individual source particle for the next cycle, i.e.,

$$y^{n-1} = y^n - \Delta y \qquad \text{(II.B.49)}$$

$$y_D^{n-1} = y_D^n - \Delta y_D \qquad \text{(II.B.50)}$$

$$t^{n-1} = t^n - \Delta t . \qquad \text{(II.B.51)}$$

For continuous sources, newly-generated puffs are composed of source particles having Gaussian distributions of size σ_0. All particles generated during the same cycle will have a variety of initial diffusion distances y_D according to the Gaussian distribution, but all will have the same initial age, namely $t = 0$. After one cycle of diffusion in the manner discussed above, their age will be $t = \Delta t_1$, where Δt_1 is the particle diffusion time for its first cycle, and after two cycles $t = \Delta t_1 - \Delta t_2$ and so on. So at any time there will exist several puffs of source particles, each of different age. When a given puff of source particles that started out with a standard deviation σ_0 representative of the source size has diffused to a distribution size with a standard deviation $\sigma \simeq \Delta Y$, where ΔY is the ADPIC cell length, the whole set is considered a suitable extended source. It is therefore released from its source particle status and is considered to consist of regular ADPIC particles. The test for release is made against t, the age of the particle set, at every time step. In the meantime, source particles are subject to the same boundary conditions as regular particles. While the source particles are treated independent of regular ADPIC particles as a sub-grid scale distribution, they are counted together with the regular particles in determining the particle concentration field in ADPIC, which is used to calculate the diffusion velocities for the regular particles.

II.C. Support Routines

II.C.1. TOPOG

The construction of a solid bottom boundary for the MATHEW and ADPIC models is accomplished through TOPOG. The boundary can be viewed as a system of blocks which approximate the shape of the actual terrain. Therefore the results of subsequent MATHEW and ADPIC runs will reflect the major topographic features in the area of interest. The system of blocks is derived by averaging data from a local terrain data base (see Section III.B.3.) to a grid volume defined by the user (see Section III.B.1.). Because of the large amount of processing that has been applied to the original digitized terrain data in generation of the system of blocks, the model terrain produced automatically by TOPOG may not be the best representation of terrain possible for a given grid resolution. ARAC's in-house version of TOPOG allows a user to selectively and interactively raise or lower individual boundary cells so as to more closely conform to the actual surface.

The definitions of the MATHEW and ADPIC grid volumes produced by TOPOG are made up of grid parameters, terrain heights for each horizontal grid cell, and a descriptor for each grid cell which defines permissible flows through the cell faces. The user selects a grid by assigning values to certain grid parameters in TOPIN. The ADPIC and MATHEW grids are subject to a number of constraints in order to ensure proper averaging. TOPOG checks the grid parameters and if they define an illegal grid, TOPOG either halts with diagnostic errors or makes minor adjustments to some of the parameters in an attempt to create a legitimate grid.

In a typical ARAC problem, the user specifies the ADPIC grid origin in Universal Transverse Mercator (UTM) coordinates and the x, y, and z dimensions of an individual cell. A terrain data base is also normally available. Since the number of grid points is normally left constant, the cell size inherently defines the overall dimension of the ADPIC grid (e.g., an ADPIC grid having 41 by 41 by 15 points with a cell size of 1 km by 1 km by 50 m defines a grid volume of 40 km by 40 km by 700 m). The MATHEW grid is defined on the basis of the user's ADPIC grid. They have the same grid cell sizes, but the number of points in MATHEW's grid system (in any direction) must, at a minimum, be as great as the number in ADPIC's grid system. The MATHEW grid surrounds the ADPIC grid so that a band of cells borders on all sides of the ADPIC grid. This has a buffering effect that protects ADPIC from possibly poor adjustments of the winds near MATHEW's boundaries. For the standard ARAC model grid dimensions (MATHEW: 51 by 51 by 15 grid points, ADPIC: 41 by 41 by 15 grid points), the band surrounding the ADPIC grid is usually five grid cells wide.

The averaging process currently used in TOPOG places a number of constraints on the MATHEW and ADPIC grids selected in this manner. The terrain averaging is done on MATHEW double cell areas, i.e., two grid cell by two grid cell areas, and requires that the vertices of the double cell regions lie on top of grid points in the terrain data base grid. This requires that both of the horizontal grid cell lengths (DELX, DELY) must be integer multiples of one-half the resolution of the terrain data base. Since standard terrain grids have grid cells which are 500 m by 500 m, legitimate values for DELX and DELY are integer multiples of 250 m. The overlaying of the appropriate grid points also requires that

the MATHEW grid origin lie on a terrain data base grid point. The constraints on the cell size are absolute. TOPOG will halt if illegal values for DELX and DELY are specified; however, TOPOG will shift the MATHEW and ADPIC grids to ensure the overlaying of the proper points. The origins will be shifted as little as possible from the positions given in TOPIN. The other constraint on the grids is that no part of the MATHEW grid may lie outside of the MATHEW grid. If the ADPIC grid, as specified, lies within the terrain data base grid and the default MATHEW grid does not, then TOPOG will attempt to shift the MATHEW grid to create a legal system of grids (See Fig. II.C.1.). The user may override the default MATHEW grid chosen by TOPOG (see UTMXMAT, UTMYMAT in Section III.B.1.). All the constraints described above are enforced in this case, except that TOPOG will not shift the MATHEW grid if it lies outside the data base grid.

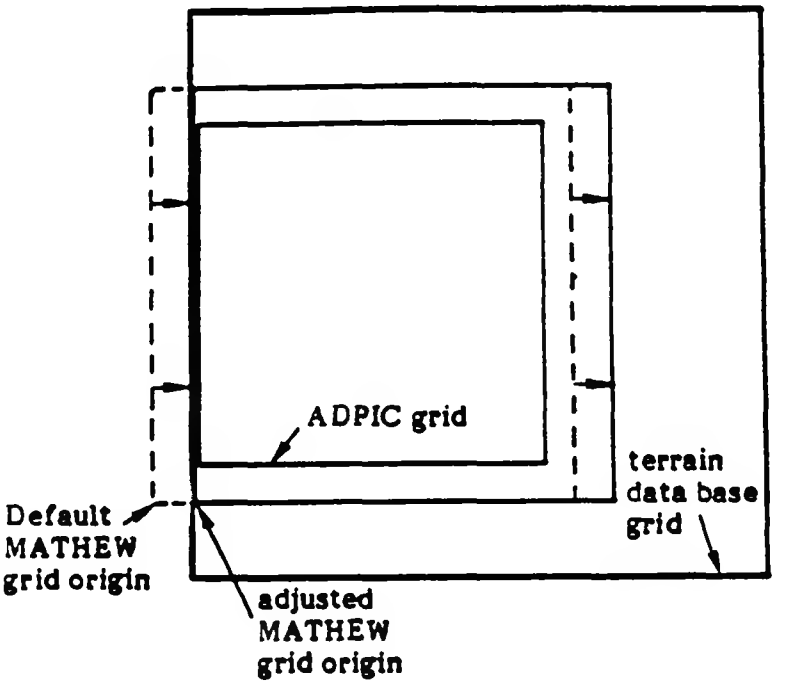


FIGURE II.C.1.

Example of the automatic shift of the MATHEW grid by TOPOG to create a permissible system of grids.

If the user indicates that no terrain data base grid is to be used (see IFLATTOPO in Section III.B.1.), then there are no constraints on the MATHEW and ADPIC grids with respect to the terrain data base grid. Independently the user may specify that ADPIC will not be used for a given problem (see JUSTMAT in Section III.B.1.) In this situation the user must specify a MATHEW grid; this grid has no limits placed on it due to the ADPIC grid. Regardless of the means of selecting a grid (or even if errors are discovered during validation), all grid parameters are displayed on the terminal and in the ECHOTOPOG file

to allow the user to determine the acceptability of the model grids produced by TOPOG, or to determine the cause of any errors.

The legal MATHEW grid, along with the vertical grid spacing (DELZ) selected by the user, defines a system of grid cells filling a grid volume. Terrain is represented by specifying which grid cells in a vertical column are open (wind is permitted to pass through at least one of the cell's faces) and which cells are closed (i.e.,underground). The terrain height for each column of grid cells is represented by an integer indicating the number of grid cells that lie underground. Thus the system of blocks that represent terrain are described by a two-dimensional array of integers with each element in the array specifying the terrain for the corresponding column of grid cells in the MATHEW grid.

TOPOG generates this system of blocks by averaging the data in the local terrain data base over the newly defined MATHEW grid. The standard terrain data file specifies elevations for a region covered by a grid of square cells oriented along the appropriate UTM coordinate system. The data base grid is typically dimensioned 400 by 400 with each grid cell being 500 m, so that the area described is 200 km by 200 km. The terrain file contains an array of values with each value being the average height, in meters above sea level, of the corresponding grid cell. At present the averaging in TOPOG is done over areas defined by two MATHEW grid cells along each horizontal axis, i.e., four MATHEW grid cells define a MATHEW double cell. Since the grid has been accepted by TOPOG before the averaging begins, the vertices of each MATHEW double cell lie on top of terrain data base grid points. As a result, the number of data base grid cells in a MATHEW double cell is always an exact integer, and the average height of a MATHEW double cell can be found by simply averaging the heights of the data base grid cells it contains. The averaging along the edges of the MATHEW grid may be somewhat more complex if there is an odd number of grid cells along one of the MATHEW grid axes and the MATHEW grid cell size is an odd multiple of one-half the data base grid cell size along the same axis. In this case there will be a band of incomplete MATHEW double cells at the maximum extent of that axis and, as a result, there will be terrain data base grid cells which are only partially contained in the MATHEW grid. The averaging within the band of incomplete MATHEW double cells is done as an area weighted average on that portion of the data base grid contained within the MATHEW grid. On completing this step a height in meters above sea level is associated with each MATHEW double cell.

To complete the averaging, each cell height is rounded to the nearest integer multiple of DELZ. The lowest value for any cell in the grid is then subtracted from each value in the grid, thereby re-defining the bottom of the MATHEW grid volume. The integer height of each double cell is then assigned to the four MATHEW grid cells it covers. The ADPIC cell heights are extracted directly from this array. At this point the bottom of the grid is indexed to zero. However, MATHEW requires its terrain heights to be offset so that the bottom of the grid has a value of one; each terrain level in the MATHEW array is therefore incremented by one. An illustration of the terrain representation is shown in Fig. II.C.2.

The double cell averaging in TOPOG eliminates undesirable situations that may arise in ADPIC, but at the cost of decreasing resolution. Single cell averaging would allow the generation of "holes" (isolated depressions) in the terrain dimensioned DELX by DELY. The MATHEW boundary conditions do not allow the assignment of wind components in a single-cell depression. ADPIC particles can nevertheless diffuse into the hole, thereby becoming trapped. Forcing the terrain to be averaged over double cell areas is a way

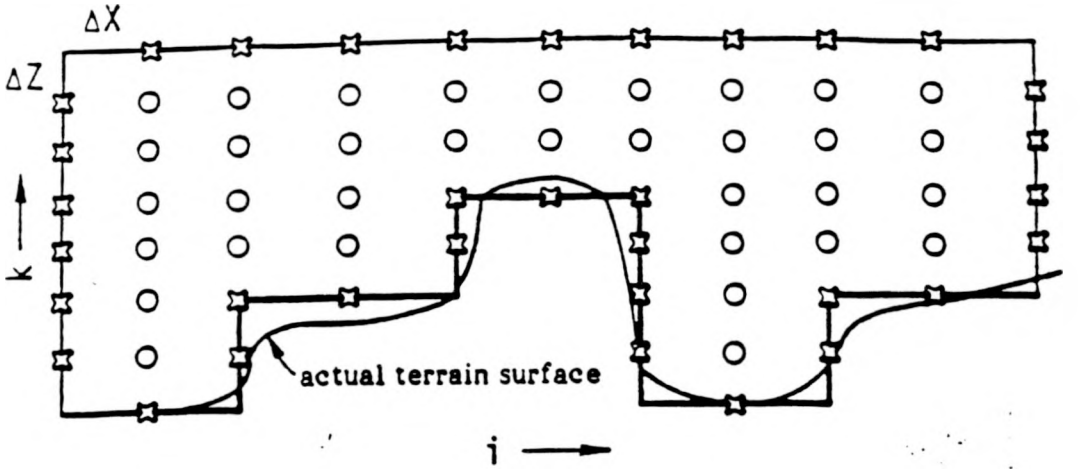


FIGURE II.C.2.
Illustration of the topography specification in two dimensions.

of preventing particle stagnation. The ARAC in-house version of TOPOG may soon be changed to allow single cell averaging (this does not violate the MATHEW formulation in any way) in order to increase the terrain resolution. The interactive capability of the in-house TOPOG will allow the user to remove single cell holes which will be graphically highlighted as a warning of a potential problem area. Versions of TOPOG without appropriate interactive capabilities will continue to use double cell averaging.

The assignment of cell descriptors to each cell in the MATHEW grid volume completes the description of the site to be used by the ARAC models. These descriptors are used by MATHEW to select the appropriate coefficients for its difference equations. TOPOG assigns to each cell a three digit decimal integer with each digit describing the cell with respect to one of the three grid axes. A grid cell has two faces normal to each axis; a face may be open (flow is permitted) or closed (flow is not permitted). The first digit (highest order) of the three digit descriptor characterizes the two faces normal to the x-axis, the second digit characterizes the faces normal to the y-axis and the last digit (low order) corresponds to the z-axis. These three digits correspond to ℓ, m, and n, respectively, in Eq. (II.A.10). Each digit can range in value from one to eight with any particular value identifying the correct coefficient to be used in the finite difference equation (see Table II.A.1). The first four values (1,2,3,4) of the index refer to internal grid cells, while the second four refer to cells along the minimum and maximum extent of the grid. The various index values and the geometries they specify are diagrammed in Fig. II.C.3. for one dimension (along the x-axis). As a simple example of the encoding scheme, internal grid cells that are remote from terrain have the descriptor 111 indicating that all faces are open. A descriptor of 444 means that the cell is underground, i.e., all faces are closed. It should be noted that an index value of four indicates that both faces are closed for all grid cells including those at the grid boundaries.

While the model terrain generated by TOPOG captures the major topographic features of a site, the representation of the actual topographic surface is coarse. We have

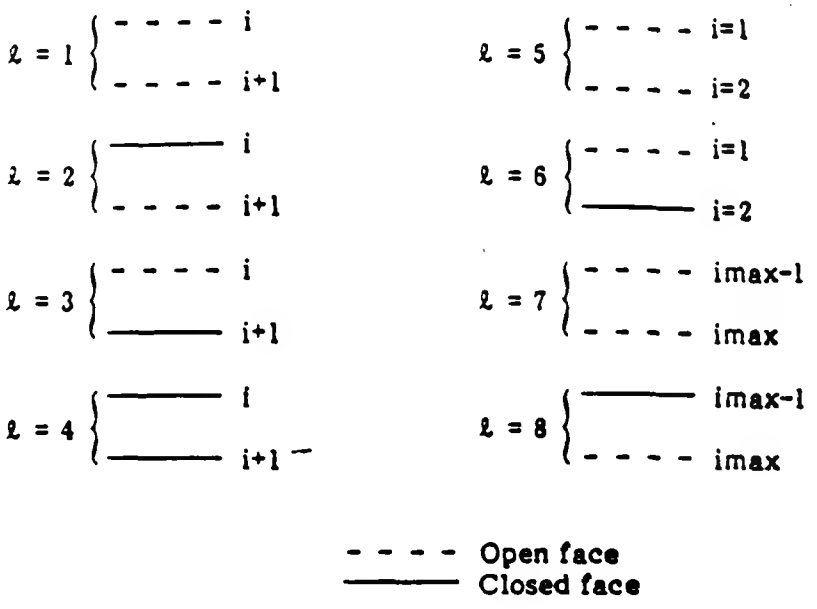


FIGURE II.C.3.

Correspondence between the value of cell descriptor ℓ and the "flow-through" status of cell faces along the x-axis.

investigated, and continue to investigate more powerful numerical techniques (e.g., terrain-following coordinate methods, and the finite element method) which permit a more realistic representation of the bottom boundary. While these techniques offer the potential for future advancements, at present they are not readily adaptable to arbitrary sites and they require more complex algorithms. As a result, they are appreciably slower in all phases of generating a result. The simple terrain representation provided by TOPOG appears to be an appropriate compromise between the quality of the modeling and the necessity for a fast response at an arbitrary site.

II.C.2. MEDIC

The use of variational techniques in MATHEW is premised on the assumption that a reasonable, first-guess field of wind velocities, $\underline{U}^0$ in Eq. (II.A.1), can be supplied by MEDIC, the wind extrapolation code. This statement follows from the fact that MATHEW adjusts the extrapolated winds by the *minimum* necessary amount in producing a mass-consistent arrangement. Attention to detail in the preparation of the extrapolated field is therefore critical. The situation is further complicated because fairly minor variations in the parameters input to MEDIC can lead to grossly different wind fields, all of which are consistent with the measured data. For this reason, we rely heavily on the interpretive ability of an experienced meteorologist to determine the acceptability of a result. If necessary, the model is rerun with altered input until the desired result is achieved. Using the

tools of his trade (e.g., weather maps, local observations, upper air data, pilot reports), a meteorologist can factor in all of the known and relational information (in the form of model input) to produce a realistic and meteorologically consistent wind field. This procedure is extremely important in that physical processes, many of which are not modeled in MATHEW, can be implicitly represented in the structure of the extrapolated field.

The creation of an extrapolated gridded wind field from available wind observations is accomplished by one of two related algorithms. The first method uses surface observations and user-defined parameters to construct the required three-dimensional wind field with minimal upper air data being needed. This method is referred to as parameterized extrapolation; it is used when no upper air soundings are available or when the credibility of a sounding is in doubt. The other approach makes use of all surface *and* upper air observations in the wind extrapolation process. This approach is called profile extrapolation; it is the preferred method if at least one local upper air sounding, taken within the past six hours, is available. Profile extrapolation is the default in MEDIC (see IPROFIL in Section III.B.5.). Both of these procedures produce two three-dimensional arrays of horizontal wind components, one array for the u-components and the other array for the v-components. These component arrays define wind vectors at each grid point of a volume having the same dimensions as the MATHEW grid. However, unlike the MATHEW grid, the extrapolation grid volume is adjacent to but entirely above the model terrain surface (i.e., in the extrapolation grid, heights above grid bottom are always equal to heights above model terrain). On completion of the extrapolation, model terrain is pushed up through the grid bottom with a corresponding upward shift in the extrapolated winds. Thus, the atmospheric layers defined in the extrapolation process (Z_{sl} and Z_{bl}) are flat in the extrapolation grid volume and have the shape of the terrain in the MATHEW grid volume (see Fig. II.C.4.). This produces the wind fields that are passed to MATHEW. The u- and v-component winds are defined at the same grid points, and it is left to MATHEW to transform the winds into face-centered components for ease of calculation (see Section II.A.3.). The parameterized extrapolation method will be discussed first in order to familiarize the reader with the various extrapolation parameters that have a common usage in both schemes. The more complicated profile extrapolation scheme will then be described, followed by a discussion of the means of including terrain.

II.C.2.a. Parameterized Extrapolation

Parameterized extrapolation involves two basic steps. First, wind speed and direction values must be assigned to each column of grid points in the extrapolation grid volume at two levels above terrain. One level is near the surface and the other level is at or above the top of the grid. Second, winds along the columns of grid points are determined by interpolating between the wind values at the two levels, and by extrapolating to the surface below the lower level. The interpolations and extrapolations are controlled by a number of user-defined variables that aid in simulating the vertical structure of the atmosphere.

The near-surface wind for each column of grid points is derived from the surface wind observations. First, all surface speed measurements are normalized to a user-specified height above terrain, using the standard power law applied to the surface layer. This height is called the reference height (see REF in Section III.B.5.). In order to minimize the

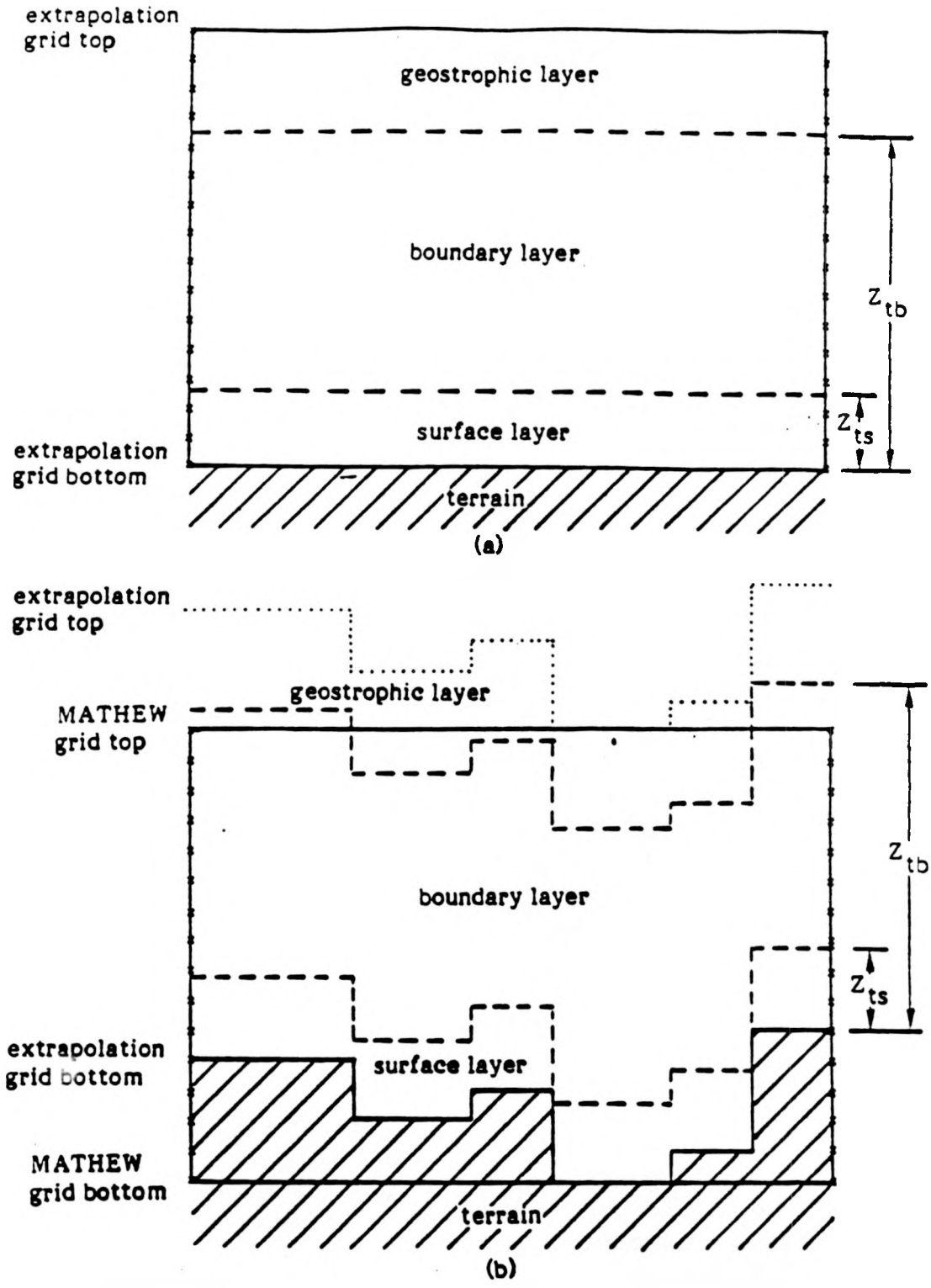


FIGURE II.C.4.

Schematic of a MATHEW grid in two dimensions: (**a**) before, and (**b**) after the introduction of model terrain.

alteration caused by normalization, REF is usually chosen to be the height above terrain of most of the observing instruments. The power law formula used in the normalization is

$$S_{\text{norm}} = S_{\text{obs}}(Z_{\text{ref}}/Z_{\text{obs}})^{\Upsilon_{sl}}, \tag{II.C.1}$$

where S_{norm} is the wind speed at height REF, S_{obs} is the observed wind speed, Z_{ref} is the reference height, Z_{obs} is the observation height, and Υ_{sl} is the power law exponent for the surface layer (see SFC and PWRSL in Section III.B.5., and SFCSTN in Section III.B.4.). Wind directions are not altered when normalization occurs since directions rarely show significant changes for typical adjustment heights. The reference level speed and direction for a column of grid points are derived from the normalized measurements by an extrapolation based on the inverse square of the distance to nearby observation points from the location of the column. The speed extrapolation is made according to the formula:

$$S_{\text{ref}} = \frac{\sum_{n=1}^{N} S_n / R_n^2}{\sum_{n=1}^{N} 1 / R_n^2} \tag{II.C.2}$$

where S_{ref} is the reference level speed for the grid point column, N is the number of nearest observations being used in the extrapolation, S_n is the normalized speed measurement for a given station, and R_n is the distance from the horizontal location of the column to the station. The three nearest stations are normally used, although this can be changed (see PARAMS in Section III.F.3.). The reference level direction for the column is calculated by separate inverse-square extrapolations of the sines and the cosines of the observed values. The extrapolations are based on formulas which are analogous to Eq. (II.C.2.). The sines and cosines are extrapolated separately to avoid the discontinuity caused by interpolating through 0°(360°). The extrapolated sine and cosine are used to generate a consistent angle using an arctangent function. The subset of the observation stations used to determine direction may not be the same as the subset for speed since a station may report only speed *or* direction. The selection of the nearest observation stations is performed separately for the speed and direction extrapolations so that partial reports may be utilized. At least one surface speed and one surface direction observation, not necessarily at the same point, must be input to allow the extrapolation to proceed.

The upper level wind along a grid point column is generated from upper air wind observations. The upper level wind is usually determined at the top of the extrapolation grid volume. However, if the top of the boundary layer is above the top of the extrapolation grid, then the wind is determined at the top of the boundary layer. A value for the wind must be found for each measured upper air profile at the height of the upper level wind. In order to extract values at arbitrary heights from the discrete measurements provided by a sounding, it is assumed that the winds vary linearly between successive measurement heights. Directions vary through an arc describing the smallest angle between two measurements. Winds are also assumed to remain constant with height above the highest measurement level. Winds below the lowest measurement level are assumed to be constant down to the top of the surface layer and to obey a power law for speed within the surface layer. The speed and direction values found for the upper air soundings are used in the same extrapolation procedure used at the reference level to assign a speed and direction at the upper level of the particular grid point column [see Eq. (II.C.2)]. Profiles with speed measurements only or direction measurements only will be accepted as input.

At least one upper air speed measurement and one upper level direction measurement, not necessarily at the same location, must be input to allow the extrapolation to proceed.

Having extrapolated winds at two levels, values can now be assigned to all the grid points in a column using an interpolation method that reflects the basic structure of the atmosphere. Three separate layers of the atmosphere are recognized when interpolating in the vertical. The surface layer is the lowest layer and is the region in which surface effects predominate; no direction shear with height is allowed. The highest layer, the geostrophic layer, is the region of the atmosphere where surface effects have virtually dissipated and the winds reflect larger-scale synoptic flow. Wind speed and direction are assumed to be constant with height in this layer, i.e., there is no wind shear. The central layer, or boundary layer, is the region where conditions are intermediate between the surface and geostrophic layers; both speed and directional shear can occur.

For grid points in the surface layer, the same power law used in the reference level normalization (Eq. II.C.1) is used to vary the reference level wind speed as a function of height, i.e.,

$$S(Z) = S_{\text{ref}}(Z/Z_{\text{ref}})^{\Upsilon_{sl}} \qquad \text{(II.C.3)}$$

where S is the speed at a surface layer grid point, Z is the height of the surface layer grid point, and S_{ref} is the reference level speed for this column of grid points. This formula is also used to extrapolate below the reference level down to the surface. A surface slip velocity is generated by applying Eq. (II.C.3) at the surface roughness height, Z_{srh} (see SRH in Section II.A.5.). The reference level direction is assigned directly to the surface layer grid points of the column. The upper level speed and direction are assigned to all the grid points in the column that are in the geostrophic layer.

Winds in the boundary layer are computed so as to provide continuity between the surface layer winds and the geostrophic layer winds. The simplest way of satisfying this condition is to linearly interpolate between the winds at the top of the surface layer and the top of the boundary layer. This capability is provided and is adequate for many situations. However, atmospheric conditions can arise which require greater generality in the interpolation. For example, the speed shear in the boundary layer is often variable, with the greatest change occurring near the top. This frequently happens when the top of the boundary layer coincides with a temperature inversion. This effect is parameterized by interpolation according to a power function where the exponent is a user-defined parameter. Another important consideration in the boundary layer is the variation of direction with height. The difference between any two angles can be determined along two directions of rotation, clockwise or counterclockwise. As a result, there are two possible interpolations between the direction at the top of the surface layer and the direction at the top of the boundary layer. In middle latitudes of the northern hemisphere, winds usually change in a clockwise direction with increasing height, i.e., they "veer" with height. Therefore, it is not always advisable to determine angular difference through the smallest angle. There are also cases where the wind directions turn counterclockwise with height, i.e., they "back." This can occur, for example, when a front moves through an area. It is important for an assessor to be able to control the sense of the directional shear in the boundary layer, a capability which is provided in MEDIC.

Interpolation in the boundary layer is accomplished using the following formulas:

$$S(Z) = \frac{\Delta S_{bl}(Z - Z_{ts})^{\Upsilon_{bl}}}{(\Delta Z_{bl})^{\Upsilon_{bl}}} , \qquad \text{(II.C.4a)}$$

$$\theta(Z) = \frac{\Delta' \theta_{bl}(Z - Z_{ts})^{\Upsilon_{bl}}}{(\Delta Z_{bl})^{\Upsilon_{bl}}} , \qquad \text{(II.C.4b)}$$

where Υ_{bl} is the boundary layer extrapolation exponent (see PWRBL in Section III.B.5.). ΔS_{bl} is the speed shear over the depth of the boundary layer, i.e., $\Delta S_{bl} = S_{tb} - S_{ts}$ where S_{tb} and S_{ts} are the speeds at the top of the boundary layer and the top of the surface layer, respectively. ΔZ_{bl} is the depth of the boundary layer, i.e., $\Delta Z_{bl} = Z_{tb} - Z_{ts}$ where Z_{tb} and Z_{ts} are the top of the boundary layer and the top of the surface layer heights, respectively (see TOPBL and TOPSL in Section III.B.5.). $\Delta' \theta_{bl}$ is the direction difference over the depth of the boundary layer. This difference is a function of θ_{tb} and θ_{ts}, the directions at the top of the boundary layer and the surface layer, respectively. It is also a function of θ_r, a user-defined parameter (see IROT in Section III.B.5.) which is used in the following way:

$$\Delta\theta = \theta_{tb} - \theta_{ts} . \qquad \text{(II.C.5)}$$

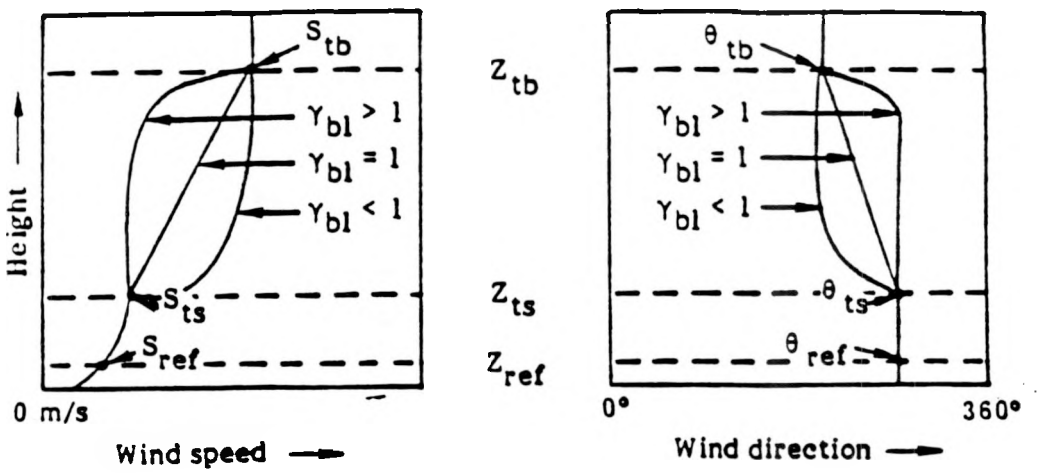
If $\theta_r - 360° \leq \Delta\theta \leq \theta_r$, then $\Delta' \theta_{bl} = \Delta\theta$;
if $\Delta\theta < \theta_r - 360°$, then $\Delta' \theta_{bl} = \Delta\theta + 360°$;
if $\Delta\theta > \theta_r$, then $\Delta' \theta_{bl} = \Delta' \theta - 360°$.

The assignment of a value to $\Delta' \theta_{bl}$ causes wind directions to veer with height if the directional shear, determined in the clockwise sense, is less than θ_r; it causes wind directions to back with height if the clockwise shear is greater than θ_r. Equations (II.C.4a) and (II.C.4b) are evaluated at the heights of all the grid points within the boundary layer. When the entire process described above is completed for every column of grid points in the grid, the extrapolation volume is ready to be examined by the assessor. The assessor can adjust the parameters in the extrapolation ($Z_{srh}, Z_{ref}, Z_{ts}, Z_{tb}, \Upsilon_{sl}, \Upsilon_{bl}$, and θ_r) if the extrapolated field does not provide a reasonable picture of the atmosphere. The effects of two of the parameters, Υ_{bl} and θ_r, are demonstrated in Figs. II.C.5a–d.

As mentioned previously, the parameterized extrapolation method is normally used only in the absence of acceptable upper air data. When upper air data is unavailable for a site, an estimate of the upper level winds must be supplied. A reasonable evaluation of the wind speed and direction might be extracted from synoptic charts for an appropriate height. If no other basis can be found for a selection, climatological data might be helpful in providing an estimate. If a recent, nearby upper air sounding is available, then the profile extrapolation method should be used because this procedure takes greater advantage of the available information.

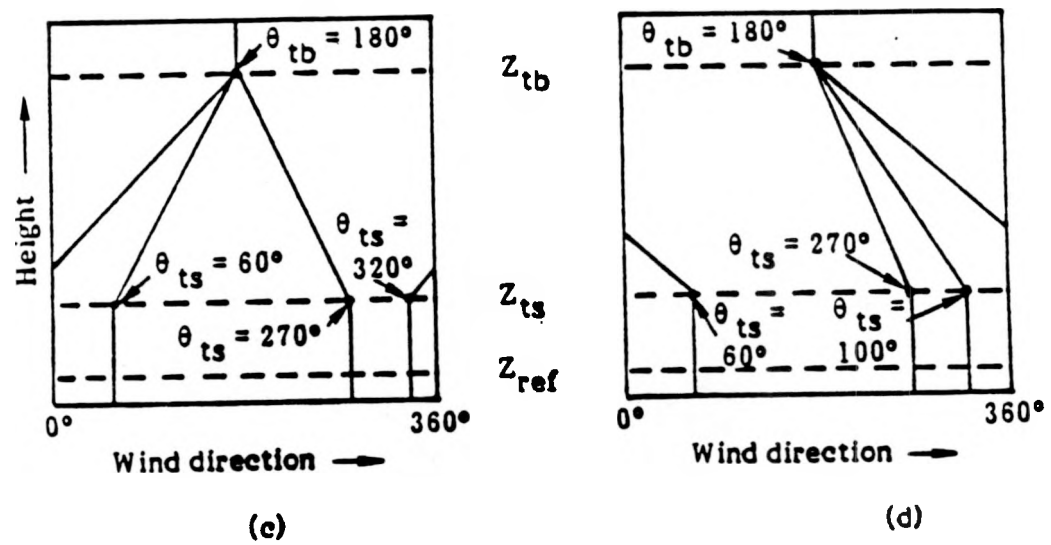
II.C.2.b. Profile Extrapolation

The profile extrapolation method provides a mechanism for the controlled melding of surface and upper air wind observations. The control is provided by the same variables used in the parameterized method, although some of the variables are used in slightly



a. Effect of γ_{bl} on speed in parameterized profile method.

b. Effect of γ_{bl} on direction in parameterized profile method.



(c)

(d)

FIGURE II.C.5.

Effect of $(c)\theta_r = 240°$ and $(d)\theta_r = 100°$ on various values of θ_{ts} in parameterized profile method.

different ways. Assumptions which are implicit in this method are that surface observations provide the most reliable picture of the actual winds in the lower levels of the atmosphere and should be weighted more heavily than upper air observations in any interpolation scheme. This follows from the fact that the density of surface stations is almost always much higher than the density of upper air stations. For a typical grid dimension in the vertical, an upper air sounding provides the best wind information for extrapolation near the top of the grid, while at intermediate grid point levels, the relative importance of the surface and upper air observations will vary with the meteorological conditions. It is also assumed in this method that the "shape" of a measured profile, i.e., its general features, can be applied to different locations in a region, even if the actual speed and direction values at a given level do not match those for the other positions.

Three main steps are required in the profile extrapolation method. First, a wind speed and direction derived from the surface observations must be assigned to each column of grid points in the MATHEW grid at a level near the bottom of the extrapolation grid. Next, each grid point in a column is assigned speed and direction values which are derived entirely from the upper air soundings, i.e., a profile is synthesized for the grid point column from the upper air data alone. Finally, the surface wind is combined with the synthesized profile to give an extrapolated wind at each grid point in the column. The surface and upper air components are weighted differently at different heights, with the weighting being controlled by various user-defined parameters.

The near-surface wind along the column of grid points is found at the reference height, Z_{ref}, by exactly the same procedure used in the parameterized extrapolation. The synthesized profile is found by determining, from the upper air data, the wind speed and direction for each grid point in the column as well as for the reference level, the top of the surface layer (Z_{ts}), and the top of the boundary layer (Z_{tb}). The synthesized profile value for speed and direction at a given height, $S_{syn}(Z)$ and $\theta_{syn}(Z)$ is generated by inverse-square extrapolation of the nearest upper air observations at the same height. Extraction of upper air values at the required heights from the discrete measurements of a sounding is done exactly as it is in the parameterized extrapolation. The inverse square extrapolation for a given height is done in the same way as for the surface winds.

In general, the near-surface wind derived from the surface data will not match the wind derived from the upper air data. The desired characteristics of the extrapolation are implemented by a correction term which is added to the synthesized profile value at each grid point in the column. The correction term is a function of height, and is chosen to adjust the synthesized profile value to the wind derived from the surface data for heights near the surface. The corrections goes to zero at the top of the boundary layer, i.e., the extrapolated profile merges with the synthesized profile. The correction terms for speed and direction are similar, with the speed correction term given by:

$$C_s(Z) = \frac{-\Delta S_{ref}}{Z_{tb} - Z_{ref}}(Z - Z_{ref}) + \Delta S_{ref} \quad \text{for} \quad Z_{ref} \le Z < Z_{tb}, \qquad \text{(II.C.6a)}$$

$$C_s(Z) = 0 \qquad \text{for} \quad Z \ge Z_{tb}, \qquad \text{(II.C.6b)}$$

where Z_{tb} and Z_{ref} are the heights of the boundary layer and the reference level, and Z is the height above terrain of the point under consideration. ΔS_{ref} is the discrepancy between the reference level wind speed and the speed from the synthesized profile at the

same height, i.e., $\Delta S_{ref} = S_{ref} - S_{syn}$ at Z_{ref}. Thus the extrapolated wind speed for a grid point in the column is:

$$S(Z_k) = S_{syn}(Z_k) + C_s(Z_k) \quad \text{for} \quad Z_k \geq Z_{ref} \tag{II.C.7}$$

where Z_k is the height of the grid point of interest. From examination of Eqs. (II.C.6) and (II.C.7), it can be seen that when $Z = Z_{ref}$, then $C_s(Z_{ref}) = \Delta S_{ref}$ and $S(Z_{ref}) = S_{ref}$. When $Z \geq Z_{tb}$, then $C_s(Z) = 0$ and $S(Z) = S_{syn}(Z)$. The correction term varies linearly between Z_{ref} and Z_{tb}, so as the height approaches the top of the boundary layer, the influence of the surface observations goes gradually to zero. For any grid points below Z_{ref} the wind speed is found according to Eq. (II.C.3) and the slip velocity is found by applying Eq. (II.C.3) at the surface roughness height. A sample extrapolation for a column of points is shown in Fig. II.C.6.

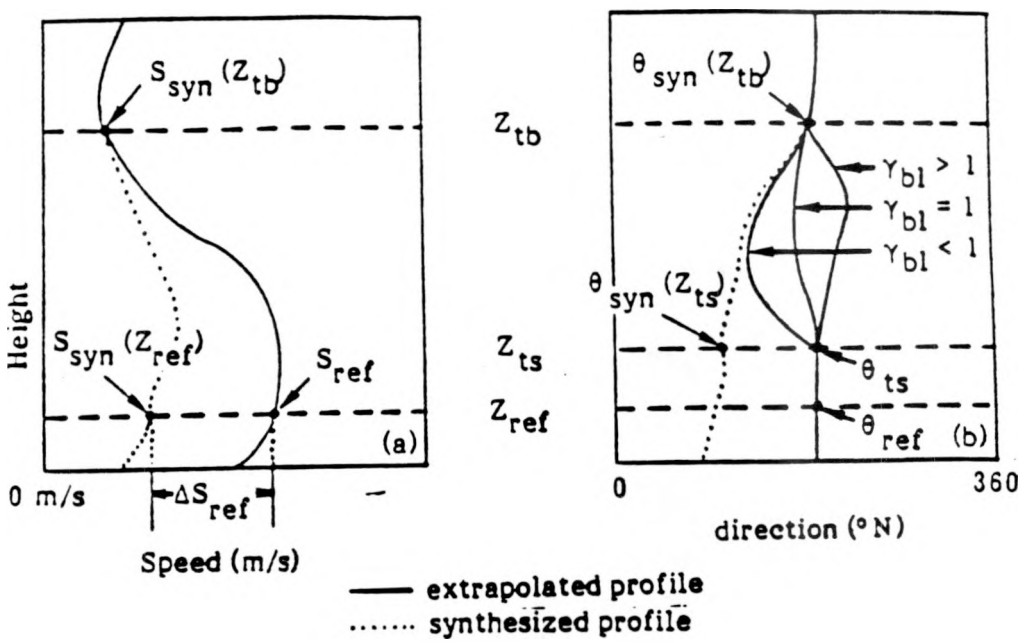


FIGURE II.C.6.

Examples of (**a**) speed and (**b**) direction extrapolation (as a function of Υ_{bl} using the profile method.

The direction correction is applied to the same three vertical layers as in the parameterized extrapolation method, i.e., the surface layer, the boundary layer, and the geostrophic layer. No directional shear takes place in the surface layer, and surface observations have no influence in the geostrophic layer. The directional shear in the boundary layer is controlled by the same parameters as in parameterized extrapolation (Υ_{bl} and θ_r). Since there is no direction shear with height in the surface layer, the reference level direction, θ_{ref}, is used for all grid points in the layer (it is always assumed that the reference height is within the surface layer). The direction at the top of the surface layer is the reference level direction,

i.e., $\theta_{ts} = \theta_{ref}$ (upper air observations have no influence in this layer). The effect of the upper air soundings begins at the top of the surface layer and increases with height in the boundary layer. Thus the correction term for direction is related to the discrepancy between the synthesized direction, based on upper air data, at the top of the surface layer and the reference level direction used throughout the surface layer. The correction term for direction is given by:

$$C_\theta(Z) = \frac{\Delta'\theta}{(\Delta Z_{bl})^{\Upsilon_{bl}}}(Z - Z_{ts})^{\Upsilon_{bl}} - \Delta'\theta \quad \text{for} \quad Z_{ts} \le Z < Z_{tb}, \qquad \text{(II.C.8a)}$$

$$C_\theta(Z) = 0 \quad \text{for} \quad Z \ge Z_{tb}, \qquad \text{(II.C.8b)}$$

where ΔZ_{bl}, Z_{tb}, Z_{ts}, and Υ_{bl} have the same definitions as in the parameterized method, Z is the height of the point under consideration, and $\Delta'\theta = \theta_{syn}(Z_{ts}) - \theta_{ts}$ is the direction discrepancy at the top of the surface layer between the surface observations and the profile synthesized from the upper air data. The sense of how this discrepancy is resolved (via backing or veering) is controlled by θ_r in a manner analogous to Eq. (II.C.5), except that $\Delta\theta = \theta_{syn}(Z_{ts}) - \theta_{ts}$. It is important to note that θ_r in the profile method is used for comparing angles at the top of the surface layer, while θ_r in the parameterized method is used to compare angles at two different vertical levels (the extremes of the boundary layer). The extrapolated wind for a grid point in the column is given by

$$\theta(Z_k) = \theta_{syn}(Z_k) + C_\theta(Z_k) \quad \text{for} \quad Z_k \ge Z_{ts}, \qquad \text{(II.C.9)}$$

where Z_k is the height of the grid point of interest. From examination of Eqs. (II.C.8) and (II.C.9), it can be seen that $\theta(Z_{ts}) = \theta_{ts}$ and $\theta(Z_{tb}) = \theta_{syn}(Z_{tb})$. The correction term varies between Z_{ts} and Z_{tb} as a function of Υ_{bl}. If $\Upsilon_{bl} = 1$, then the influence of the surface observations goes linearly to zero at the top of the boundary layer. If $\Upsilon_{bl} \gg 1$, the influence of the surface observations is maintained throughout most of the boundary layer before vanishing at the top. If $\Upsilon_{bl} \ll 1$, then the synthesized profile has the only significant effect on the extrapolated winds through most of the boundary layer. The effects of selected choices for Υ_{bl} are shown in Fig. II.C.6.b. When the process described above is completed for each column of points in the extrapolation grid volume, these winds can be examined by the assessor. As in the parameterized case, all the user-defined parameters in the process are available for adjustment if the extrapolated wind field fails to give an acceptable description of the atmosphere.

II.C.2.c. Terrain Incorporation

In both methods the final product must be grids of u- and v-component winds, so the speed and direction extrapolated to each grid point is broken down to its component parts. The two resulting arrays must now be transformed to the MATHEW grid volume, i.e., terrain must be included. Each column of grid points is shifted upwards by the number of grid points along the column that are at, or below, the block terrain surface in the MATHEW grid volume. The grid point terrain values used in the shifting process must be generated from the cell-center terrain generated by TOPOG. The terrain level along a column of grid points is simply the highest of the (usually four) cell-center terrain levels adjacent to the column. All that remains is for slip velocities to be assigned along vertical

faces of the terrain surface. This assignment is done with the u- and v-components of the slip velocity at the bottom of the extrapolation grid volume. Components that are tangential to a vertical terrain surface are assigned to the related grid point unless, at the same point, the component is normal to another vertical terrain surface. Once the slip velocities are assigned, the winds, subject to the assessor's approval, are ready to be passed to MATHEW.

II.C.3. PLCNT

PLCNT is a plotting code for processing the concentrations produced by ADPIC. The ADPIC output is passed to PLCNT in DPOUTnn (see Section III.C.10), a file which may hold several datasets (a maximum of 6), each with up to 10 two-dimensional arrays of concentrations (or ADPIC bins). A DPOUTnn dataset is created at each ADPIC output time, where the output interval is specified by IOUT.

ADPIC produces concentrations at cell centers. PLCNT prepares this field for contouring by first smoothing and then averaging the concentrations to a regular system of grid points (KI by KJ). Smoothing minimizes the effects that random fluctuations in the particle distribution have on the concentration values, particularly near the edge of the plume.

Concentrations can be expressed in three ways: instantaneous, time integrated, and total deposition. (Future plans include addition of a fourth way: integrated deposition.) Contours of instantaneous air can be considered "snapshots" of concentration (or dose) at a given point in time and at a specific level above the surface. Contours of integrated air depict the total amount of pollutant passing a given point during a specified time interval. If a dose conversion factor is specified, then the contours represent the total dose to an unshielded human from exposure to a plume or puff. Contours of deposition show distributions of material deposited since the beginning of the release to the time of output. In an ARAC context, results are generally expressed as micrograms per square meter (ug/m2), curies per square meter (Ci/m2), or a dose to the skin or through inhalation or ingestion.

To produce a desired plot, the user must appreciate the interplay between certain parameters in PICIN and CPLIN. The critical parameters in PICIN are ISPEC (the source number), IOPT (the type of concentration), and SAMHGT (the sampling height). These arrays are all dimensioned 10 with corresponding elements of each array referring to one of the ten two-dimensional concentration arrays, or ADPIC bins, in a DPOUTnn set. Thus, the first element of ISPEC indicates to ADPIC which of the nine sources is to be considered in the first ADPIC bin; the first element of IOPT indicates whether the first ADPIC bin is to be integrated, instantaneous, or deposition; the first element of SAMHGT indicates the height above terrain at which the first ADPIC bin is to be placed. The second elements of each array describe the second ADPIC bin, and so on.

PLCNT can be thought of as having a dose conversion function and a contour plotting function. The three parameters that control the dose conversion are ADPTODOSE, DCON, and DOSETOCONn, which are contained in the CPLIN file. The first two parameters allow the user to combine bins to produce combined nuclide dose plots (e.g., combined dose from multiple nuclides or multiple hybrid sources), and to re-use bins to produce different contour plots (e.g., thyroid dose and effective WB dose) from the same ADPIC bin (e.g., integrated air concentration). ADPTODOSE specifies how the ADPIC bins are to be assigned to the dose bins; DCON specifies the dose conversion factors and/or scaling factors to be applied to the dose bins (also see description for DCON in Section III.A.8); DOSETOCONn specifies how the dose bins are to be assigned to the contour bins. Examples and their translations are shown in Figure II.C.7.

```
        /   SPECIES     =  'I-131'  'Kr-88'  'Pu-239'
       /    ISPEC       =  1    2    3
   A  <     IOPT        =  1    1    1
       \    SAMHGT      =  1.5  1.5  1.5
        \

       /    ADPTODOSE   =  1        1        2         3        3
   B  <     DCON        =  3.60E2   7.63     3.65E-1   1.13E5   3.96E5
       \

       /    DOSETOCON1  =  1
   C  <     DOSETOCON2  =  2 3 4
       \    DOSETOCON3  =  5
```

Translation of A:

ADPIC bin #1 will contain integrated (at 1.5m height) air concentration of I-131 source.

ADPIC bin #2 will contain integrated (at 1.5m height) air concentration of Kr-88 source.

ADPIC bin #3 will contain integrated (at 1.5m height) air concentration of Pu-239 source.

Translation of B:

Dose bin #1 will contain ADPIC bin #1 with a dose conversion factor for I-131 Thyroid dose via inhalation.

Dose bin #2 will contain ADPIC bin #1 with a dose conversion factor for I-131 Effective WB dose via inhalation.

Dose bin #3 will contain ADPIC bin #2 with a dose conversion factor for Kr-88 Effective WB dose via immersion.

Dose bin #4 will contain ADPIC bin #3 with a dose conversion factor for Pu-239 Effective WB dose via inhalation.

Dose bin #5 will contain ADPIC bin #3 with a dose conversion factor for Pu-239 lung dose via inhalation.

Translation of C:

Contour bin #1 will contain dose bin #1 (data for thyroid dose plot from I-131).

Contour bin #2 will contain dose bins #2, #3, #4 (data for Effective WB dose plot from all three nuclides).

Contour bin #3 will contain dose bin #5 (data for lung dose plot from Pu-239).

Figure II.C.7. Example of interplay between ADPIC and PLCNT parameters to produce desired types of plots.

The SLOTn parameter controls the timing of the plotting of the contour bins. To request a particular plot, the user must provide a date, time, and interval via the SLOTn parameter. The date and time collectively iden the valid time of the first contour plot; the interval specifies the time between succeeding plots. For instantaneous air concentration, the contours represent the state of a puff or plume at a given time. The contours for deposition represent an accumulation of material on the ground up until the time of output. For integrated air concentrations, successive records from ADPIC will be added together until the interval is satisfied. For example, let us assume that ADPIC runs for three hours and dumps an output record to the DPOUTnn file after each hour. If SLOTn is given a date and time corresponding to the first hour into our hypothetical run and an integration interval of one hour, then PLCNT will generate three plots. The first record will be the only one utilized by the code in producing the first plot. The second plot will represent a summation of records one and two, and the third plot will be created by adding all three records. If, on the other hand, the sigh of the integration interval is negative, then the code is directed to separately integrate over periods designated by the interval. Following through on the example given above, if we make the one hour interval negative, then PLCNT will once again produce three plots. However, the first plot will reflect the contents of the first record, the second plot will only reflect the second record, and the third contour plot will have been derived only from the third record.

Since ARAC provides a service to more than one customer, and each customer has slightly different needs, limited flexibility of plot layout has been allowed for, primarily focused on the lower half of the plot legend. In addition, the exact wording contained in almost all of the legend is also under user control. The layout and wording of the contour plot is controlled by a multitude of parameters. Figs. II.C.8, II.C.9, and II.C.10 show examples of three of the more common layouts and the values of the CPLIN parameters which control the resulting appearance.

PLCNT will generate contour levels in the absence of user-specified values. The code will select the largest value of the form 1.0En or 3.0En that is lower than the highest grid point value. This becomes the value of the innermost contour. For example, if the maximum grid point concentration is 6.9E8, then the innermost contour will be 3.0E8. If the maximum grid point concentration is 2.4E8, then the innermost contour will be 1.0E8. Up to four more contours, each decreasing by an order of magnitude, are then computed to fill out the maximum desired number of contours (specified by MAXCONTRSn). The above example applies only if no restrictions are made on the minimum area to be be covered by the maximum contour. (See descriptions for AREAMAX and CONTRLVLSn in Section III.A.8 for more information).

The ability to specify the area to blow up (or "window") for plotting is provided by the XXMIN, XXMAX, YYMIN, and YYMAX parameters. These four parameters specify the coordinates of the area to be blown up. Be aware that the areas specified in the legend of a blown-up plot refer to the areas covered by the contours in the original-size plot.

The ability to automatically generate a mosaic of subplots covering a specified area at a specified scale is provided by the following parameters: MAPSCLFLGn, MAPSCALE, SRCOCTANT, BLOWUPSRC, PLTSIZCM. Up to 225 subplots (15 by 15) can be generated for a specified scale and output device. The placement of the ADPIC source location in the subplot containing it is controlled by SRCOCTANT. The area to be split into subplots can be narrowed down by use of the blowup parameters mentioned in the previous paragraph.

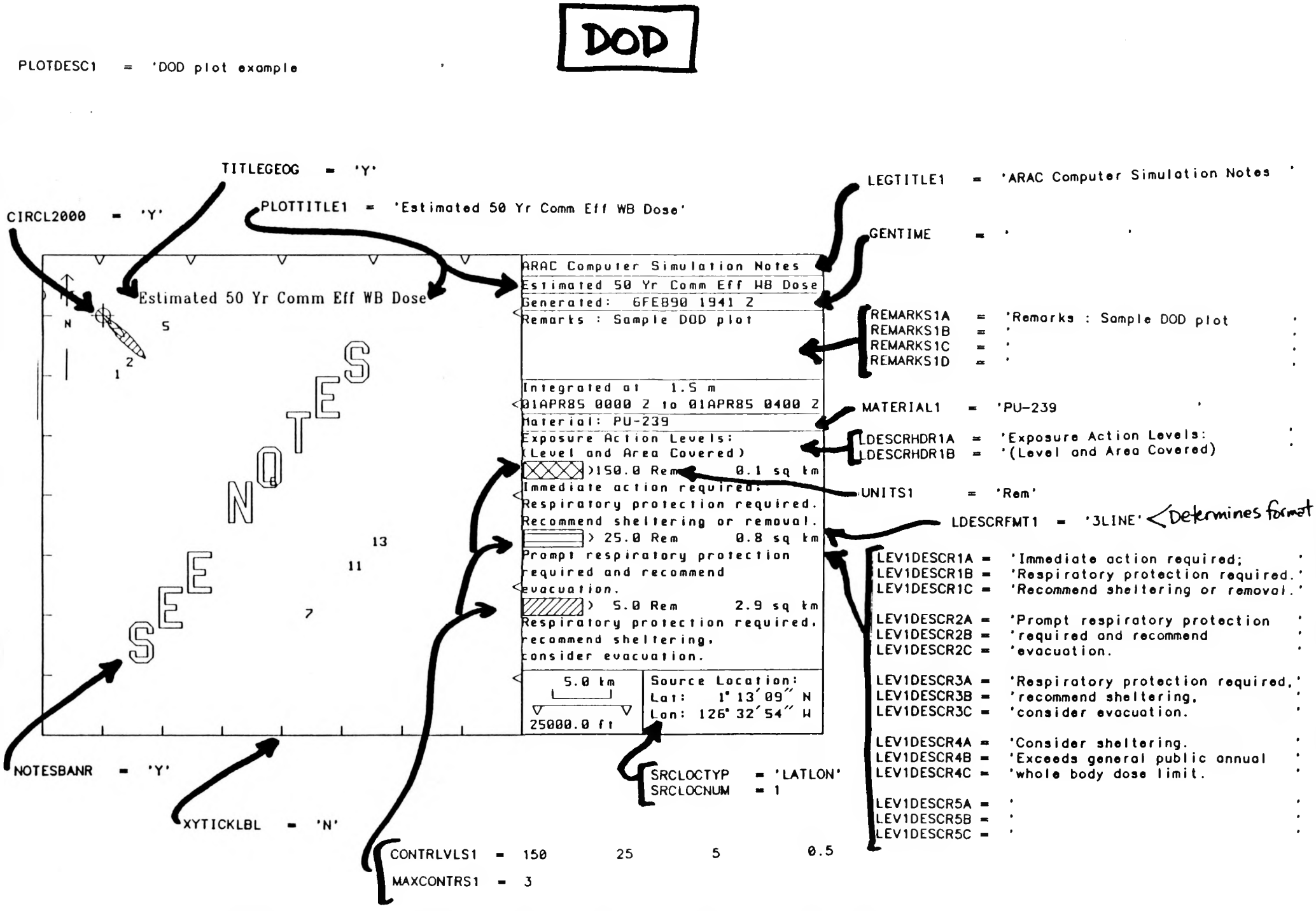


Figure II.C.8. Example of plot layout for DOD plots and CPLIN parameters which control the layout and wording.

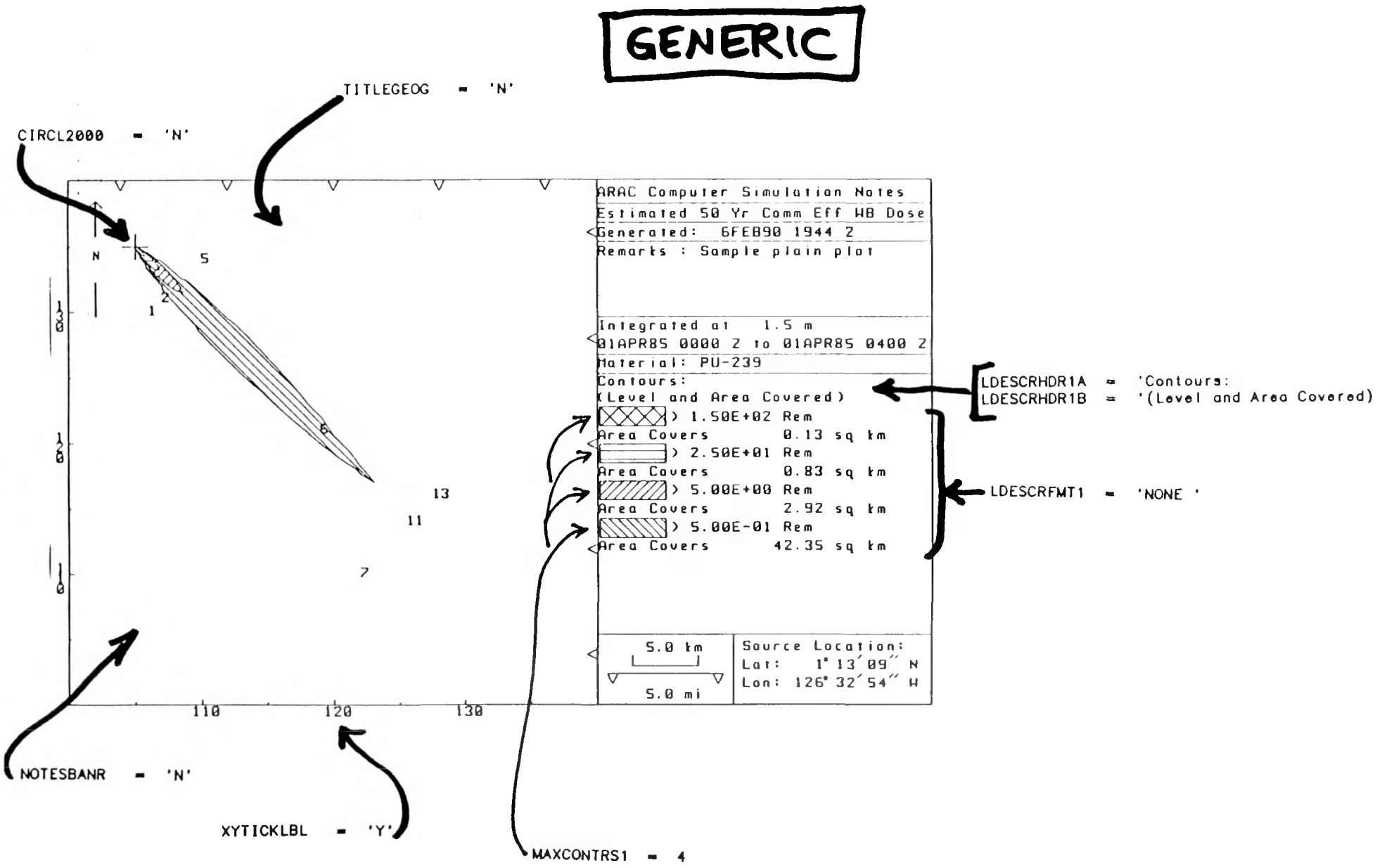


Figure II.C.9. Example of plot layout for plain plots and CPLIN parameters which control the layout and wording.

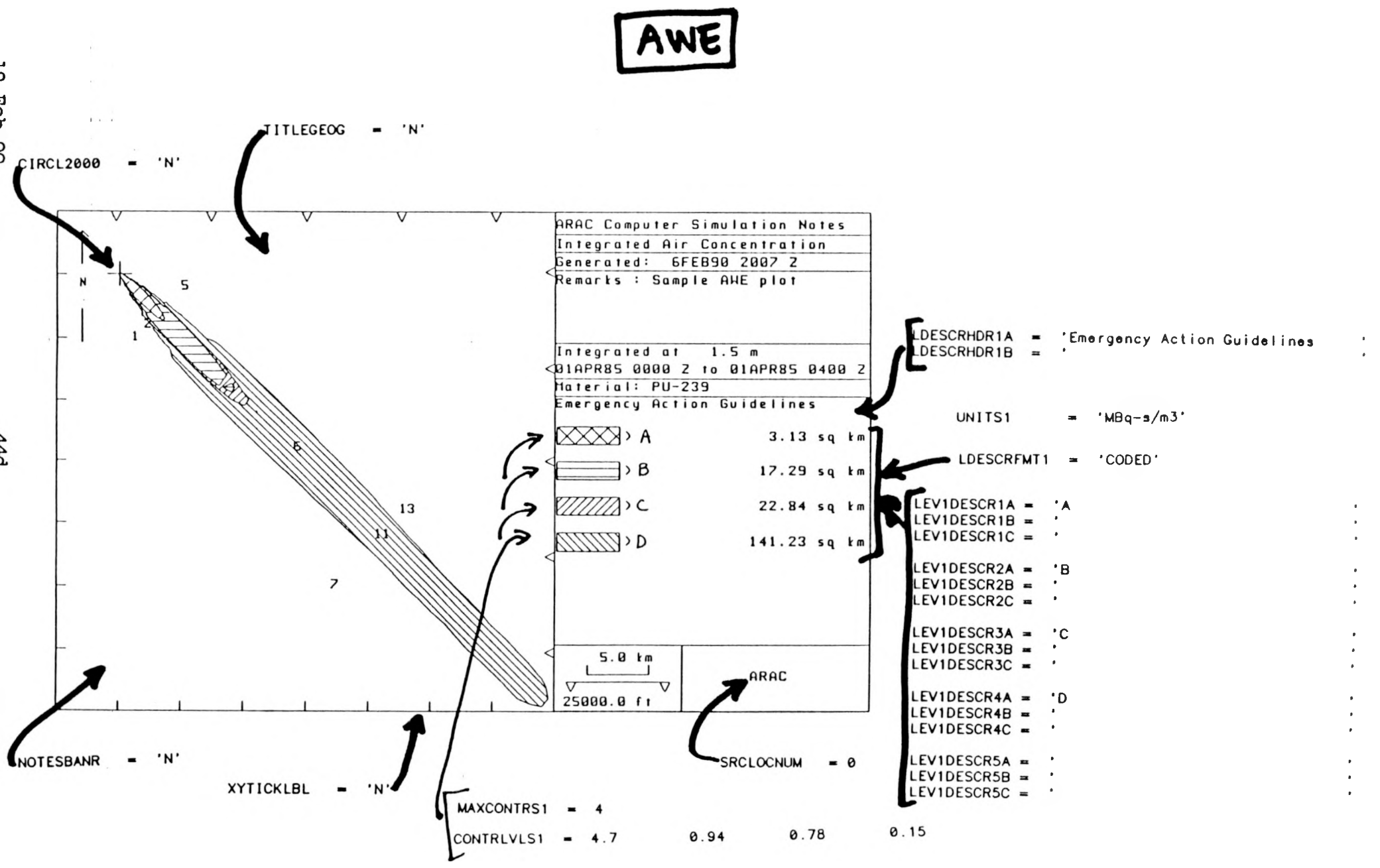


Figure II.C.10. Example of plot layout for AWE plots and CPLIN parameters which control the layout and wording.

II.C.4. TIMHIS

The Time History (TIMHIS) code is an offspring of the PLCNT code. Concentration values calculated by the model for specific point locations (up to 60 locations can be entered via the SAMINFO and SAMNAM parameters) at the times and intervals specified by the SLOTn parameter will be tabulated in the ECHOPLOT file as well as be plotted on a semi-log plot (log concentration vs time). The number of data points per plot is controlled by the NRPERPLT parameter.

If actual measurement values are available, these values can also be input via the SAMINFO parameter, and will appear on the plots along with the model-calculated values for the specified locations and times.

II.C.5. RSUS

RSUS is a supplemental code which uses a given source term and geometry (via RSUSGEO) and user input (via RSUSIN) to produce a complete set of input files for a MATHEW/ADPIC calculation that will simulate the resuspension, transport, and diffusion of particles deposited by a previous MATHEW/ADPIC calculation (Porch et al., 1983; Mitchell et al., 1985).

When the option "RESPEND = 1." is inserted in CPLIN, PLCNT will sum the deposition concentrations of the cells that are greater than 10% of the maximum deposition

(continued on next page)

concentration. The geometry of the area specified by these cells is then represented by a rectangle, with the distribution of particles within this rectangle assumed to be Gaussian. The source term geometry extends in the vertical from 0 m to 2 m with a standard deviation of 1 m. The source term concentration and geometry is contained in RSUSGEO, an output file created by PLCNT.

User input (supplied by RSUSIN) needed to compute the vertical particulate flux includes the surface type (sandy, loam, clay, or snow), drag coefficient, and the surface wind speed. The deposited toxic particles are assumed to be attached to the ground material to some degree, so that the resuspension of the toxic particles is based upon the resuspension of the ground material.

The check for the setting of various "fine tuning knobs" is the resuspension factor (K) defined by Fish (1964):

$$K(m^{-1}) = \frac{\text{airborne concentration (units/m}^3)}{\text{contamination level (units/m}^2)} .$$

Page 64 of Fish (1964) gives a resuspension factor range of ? for Pu239 obtained from experimental results of nuclear weapon trials at Maralinga. The resuspension factor is calculated by RSUS and is contained in the ECHORSUS file. Its order of magnitude should be checked before making the resuspension MATHEW/ADPIC calculation.

The length of the resuspension run is one hour, which is arbitrary. It should take weeks before all of the deposited material is resuspended, so there is no problem with running out of deposited material. But there is the problem of ADPIC's inability to simultaneously simulate the original cloud and resuspended material, i.e., the material is continually being deposited and resuspended, but we can only follow one source at a time.

RSUS creates five files (SITE, TOPIN, WINDY, PICIN, CPLIN) for use in the resuspension MATHEW/ADPIC calculation. You may change the input files to suit your scenario, but you should be aware of the following caveats.

The TOPIN file is set up such that the source is located near (about four grid cells) the edge or corner of the ADPIC grid so that as much of the plume will be displayed on the plot as possible. The grid size may be changed if desired, but remember that any changes will affect the correction factor for the average air concentration (thereby affecting the resuspension factor) if you are running with the non-nested version of the codes.

The WINDY file is set up for the surface wind speed and direction specified in RSUSIN, has no speed or direction shear in the vertical, and is for neutral stability. You can also edit this file, but be forewarned that the experimental data upon which resuspension source term is based is for neutral stability, and that the magnitude of the resuspension source term is dependent upon the surface wind speed specified in RSUSIN. Surface and upper air metdata from other regional stations may be added to the WINDY, but it should be consistent with the surface wind speed and direction specified for the resuspension source location.

The cloud parameters and source rate in PICIN should not be changed. The data available for plotting should also include an integrated plot for air concentration in g*sec/m^3 at a height of 2 m to use as a double check for the value calculated by RSUS. Plots for integrated lung dose and total deposition are also specified since these are the usual plots requested. The FRSAMSZ parameter is the ratio of the vertical sampling grid size (which

should be 2 m, since this is the height used for calculating the resuspension factor) to the vertical advection grid size (e.g., FRSAMSZ = 0.04 for a 50 m vertical advection grid size).

The CPLIN is set up for the above-mentioned three plots. The integrated lung dose DCON was calculated as follows:

$$\text{DCON} = (8.02 \times 10^{-2}\text{Ci/g})^{*}(4.0 \times 10^{5}\text{Rem}^{*}\text{m}^{3}/\text{Ci/sec}) = 3.21 \times 10^{4},\ \text{UNITS} = \text{Rem}\ .$$

The total deposition DCON was calculated as follows:

$$\text{DCON} = (8.02 \times 10^{-2}\text{Ci/g})^{*}(1.0 \times 10^{6}\mu\text{Ci/Ci}) = 8.02 \times 10^{4},\ \text{UNITS} = \mu\text{Ci/m}^{2}\ .$$

The SLOT times were arbitrarily set for 15-minute interval plots.

II.D. MATHEW/ADPIC Validation and Error Analysis

Because of the expense in computer time, the complexity of the three-dimensional transport and diffusion models, and the ensuing large number of variable parameters involved, no comprehensive error analysis of MATHEW/ADPIC has yet been undertaken. However, a number of tracer validation studies have been conducted and others are still in progress.

The codes were validated against closed, Gaussian solutions to the diffusion-advection equation (Lange, 1973), including simple wind shear. The standard deviations were found to be accurate to within 5%.

Regional tracer studies using an ^{131}I release at Idaho Falls and ^{41}Ar plumes at Savannah River Laboratory were used to validate ADPIC against regional field data using fixed high-volume sampler, Υ-detector-equipped cars, and helicoptors (Lange, 1978; Sherman, 1978). Without "tuning" the model to any given site, type of source, or sampling method, there emerged a uniformity in the accuracy to which ADPIC modeled regional scenarios of pollutant dispersal as indicated in Fig. II.D.1. Typically, 60% of the time ADPIC was within a factor of 2 of field data while 96% of the time it agreed within an order of magnitude.

There are presently two MATHEW/ADPIC validation tracer studies under way: one is a validation against the ^{85}Kr purge at Three Mile Island (TMI), and the other is an ongoing program of Atmospheric Studies in Complex Terrain (Dickerson and Gudiksen, 1980). Results from these studies will be available sometime in 1983.

While a detailed sensitivity analysis of MATHEW/ADPIC has not been undertaken, a consensus has nevertheless emerged as to the degree of model sensitivity toward certain important variables. Aside from numerical parameters, which are discussed in the technical descriptions of the codes, the main parameters affecting the quality of MATHEW/ADPIC results, in order of decreasing importance, are:

- Wind direction. A difference of 10 degrees in wind direction can have a substantial effect on the agreement of model concentrations with individual sampler measurements. This is especially true on small horizontal scales (e.g., 10 km). Errors in model calculations are commonly caused by the lack of a sufficiently large set of meteorological (wind) measurements for extrapolation to MATHEW's grid. Also, we must contend with the fact that the NOAA and FAA only report wind directions to the nearest ten degrees.
- Topography. There is close interaction between topography and the wind field, especially near the surface. Because of the limitations on the number of computational cells available, the resolution of important topographical features, such as riverbeds, ridges, and canyons, is frequently poor. This is most severe in complex terrain situations and under stable atmospheric conditions.
- Diffusion parameters. Most turbulent diffusion theory is semi-empirical, even for homogeneous turbulence. To describe diffusion parameters in space and time for all but the most trivial atmospheric conditions is very difficult. Factors of two to five in concentration differences computed by MATHEW/ADPIC can appear because of uncertainties in diffusion parameters.

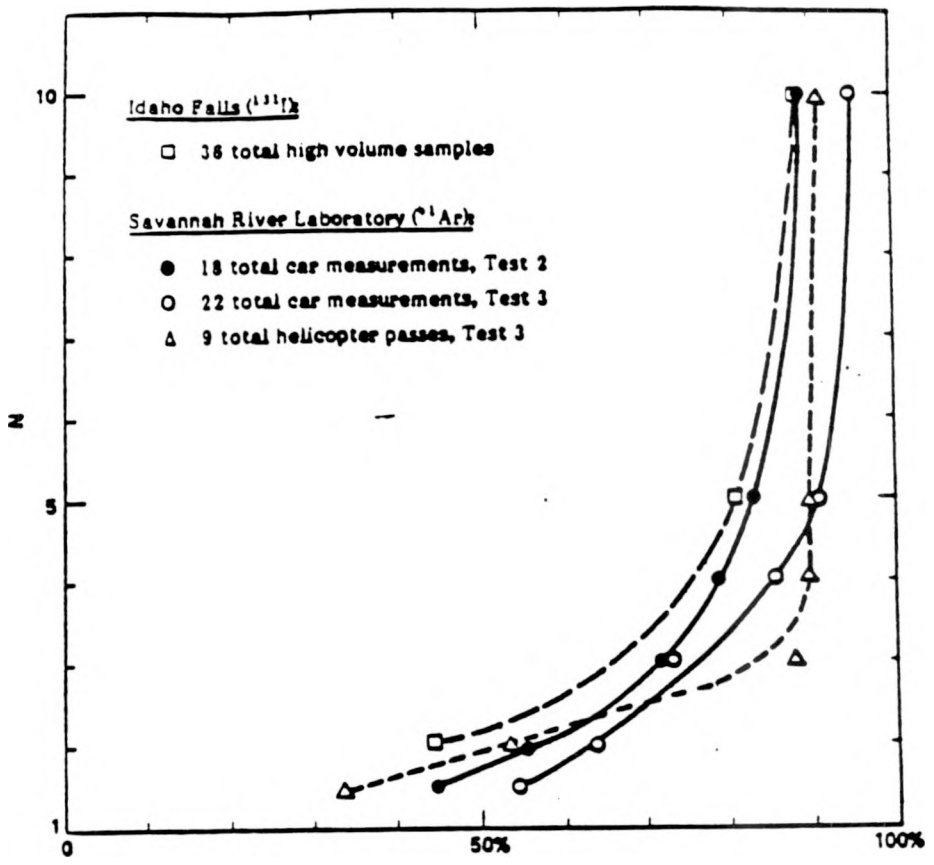


FIGURE II.D.1.

Percentage of cases in which MATHEW/ADPIC results are within a factor N of field data.

- Wind speed. While much less likely to produce errors than the wind direction, the wind speed can, nevertheless, produce errors of factors of two quite easily. Model errors due to wind speed are harder to detect because they are difficult to separate from errors caused by the diffusion parameters.
- Source strength. In controlled experiments the source strength is generally well known; however, in accident situations this is not always true. During an emergency response to an accident, the uncertainty of the source term and the properties of the source material can introduce significant errors into the model results.

III.A. ARAC MODEL SYSTEM FLOWCHARTS

Fig. III.A.1 illustrates the flow of the overall MATHEW/ADPIC model system. The step-by-step progression through each of the five executable programs is shown by bolded arrows. (The TIMHIS program is only used in conjuction with sampler measurement data.)

The five input files TOPIN, WINDY, MINV, PICIN, and CPLIN contain model parameters in namelist format. These namelist input files are created and modified by the user. Each executable produces an echo file (primarily a journal file used for debugging purposes) and a graphics file, as well as other files which are described in this section.

TOPOG uses model parameters from TOPIN and terrain data to create the underlying model grid cell heights, which are written to the GRIDIN file.

The regional metdata parameters are contained in the WINDY file. MEDIC can access meteorological data and met station locations by two different methods: (1) Problem Station Library and Problem Metdata Files, or (2) SITE namelist file and WINDY namelist file. The former method is the primary method used by ARAC operational responses, while the latter is used primarily when neither the Problem Station Library nor the Problem Metdata Files exist. The second method is especially useful for canned metdata or when the AEROS modelling environment is not available. MEDIC produces MVEL files (one for each met dataset, containing the three-dimensional gridded wind fields), and a default MINV namelist input file.

MATHEW takes the gridded winds from the MVEL files and using the model parameters from the MINV file, adjusts the wind fields to make them mass-consistent. These mass-adjusted three-dimensional wind fields are written to VEL files (one for every six MVEL files).

ADPIC uses the model parameters from the PICIN file to release marker particles which simulate the actual release of effluent into the wind field. The grid cell concentrations for specified heights for specified plot types for a specified time interval are written to DPOUT files (one DPOUT file for every six time intervals). Information for individual particles can be saved in the ADUMP file, so that an ADPIC run can be restarted.

PLCNT uses the model parameters from the CPLIN file to generate contour plots of the concentration data from the DPOUT files. TIMHIS also uses the same CPLIN file and DPOUT files to generate semi-log time history plots of the concentration data.

Fig. III.A.2 illustrates the overall flow of the Hemispheric MATHEW/ADPIC models. The flow is very similar to that for the regional MATHEW/ADPIC models. The primary differences are the input of metdata (via AFGWC Grid Files instead of Problem Metdata Files or WINDY file) and the fact that HMATHEW can be bypassed entirely (since HMEDIC produces VEL files that can be used by HADPIC).

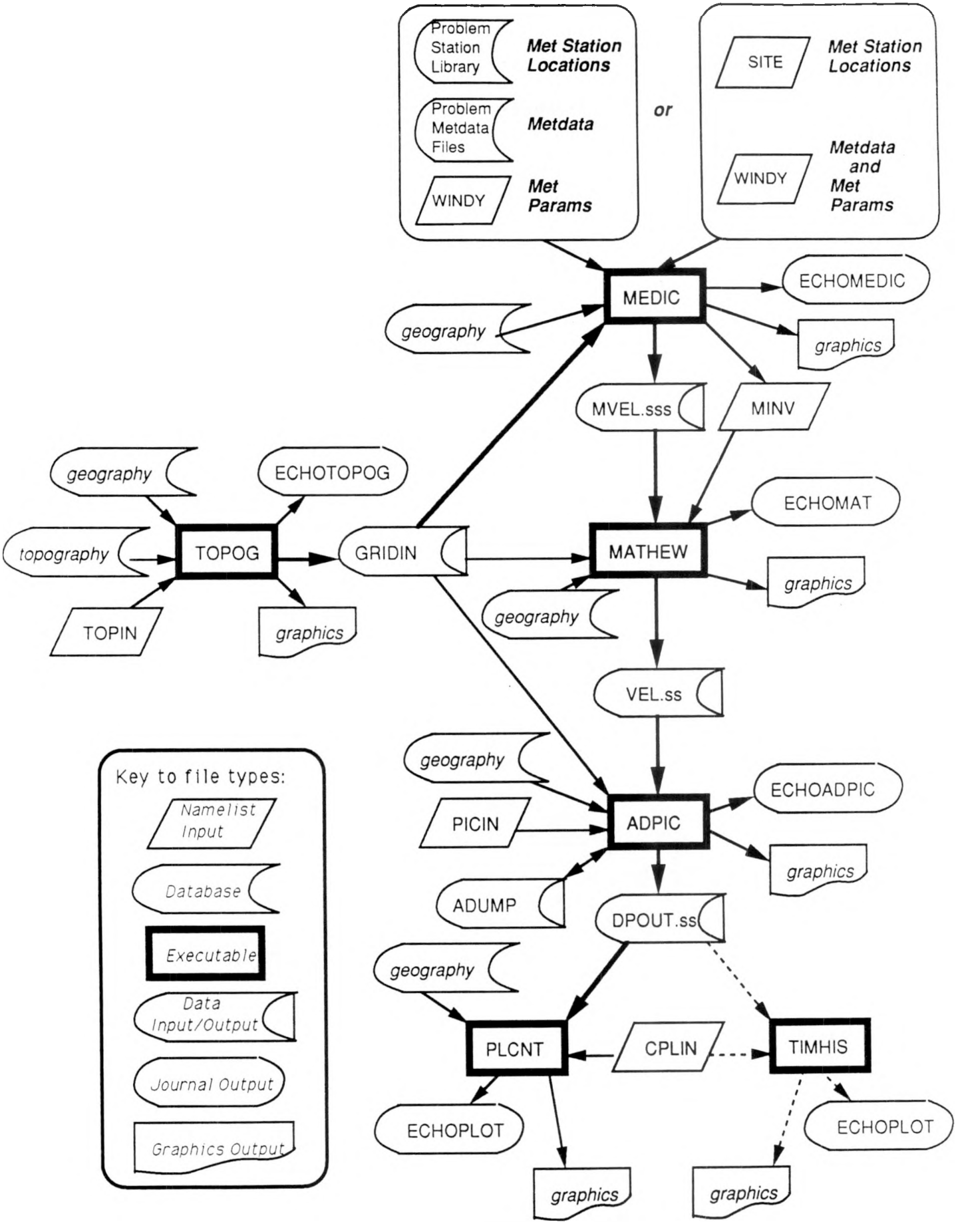


Fig. III.A.1. MATHEW/ADPIC Models Flowchart

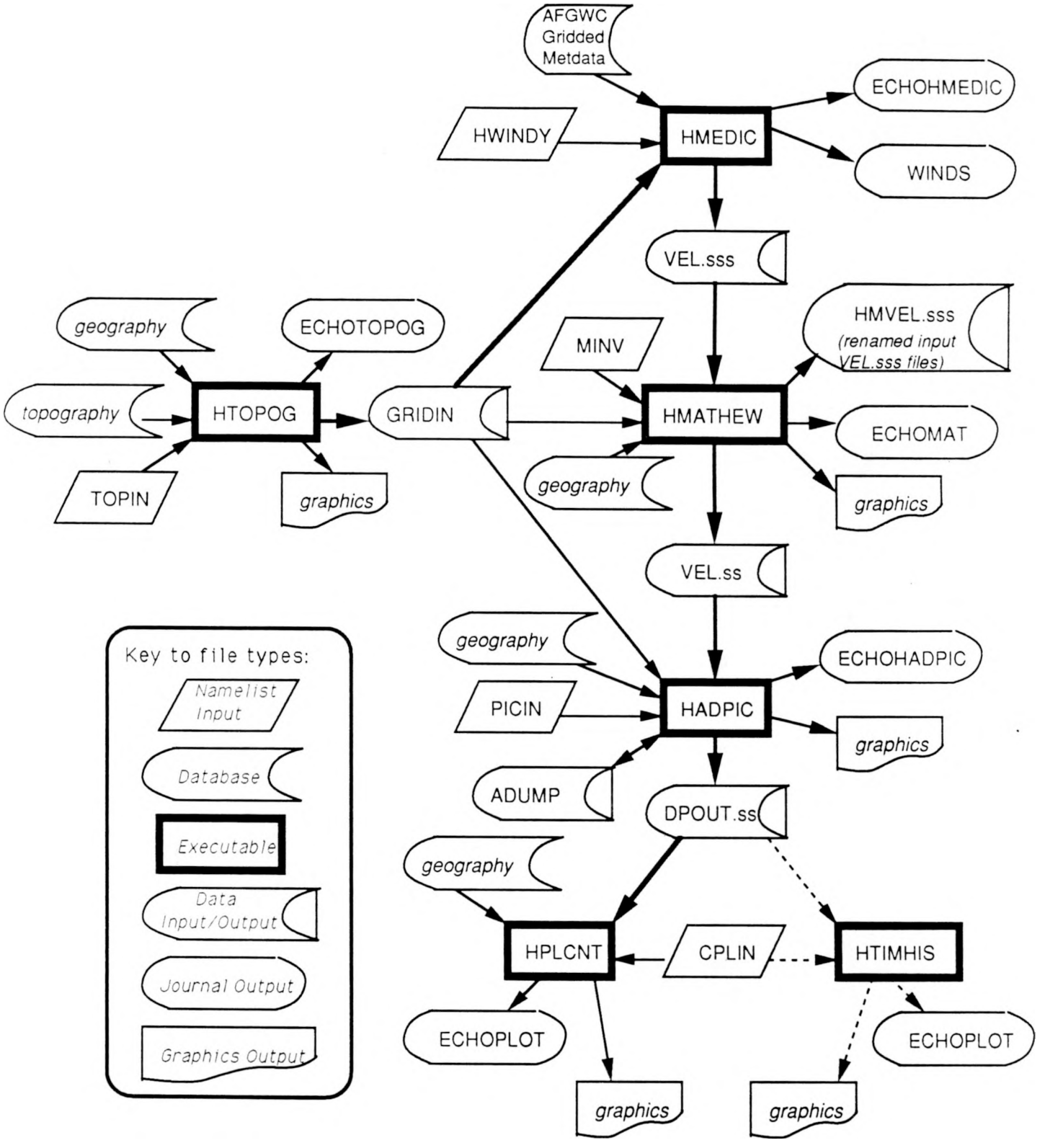


Fig. III.A.2. Hemispheric MATHEW/ADPIC Models Flowchart

III.B. INPUT FILES

III.B.1. TOPIN

TOPIN is the input file of grid size and position information for the TOPOG code. Since TOPOG creates a grid that is fixed in space, a large enough area must be chosen to account for the wind and stability conditions that might affect the effluent as the problem unfolds. An overview of the input is necessary because of the appreciable interplay between the individual parameters in TOPIN as will as other parameters in the code system.

Since the TOPIN input defines a three-dimensional grid for ADPIC, the first step in preparing the file is to estimate the area of interest for the duration of the problem. The overall objective is to keep at least 90% of the particles within the grid volume so as to maximize resolution of the effluent puff or plume. We have found streamline analyses using past, present and, if available, forecast weather maps to be extremely helpful in estimating the effluent trajectory. A calculated mean wind speed in conjuction with this directional information will then serve to guide the analyst in choosing the proper horizontal (x and y) grid dimensions. In selecting the vertical grid dimension, it is necessary to consider the height of the release, topography, upper air winds, and the stability of the atmosphere. Topography is one of the more important considerations in this decision process. TOPOG assigns a zero height to the lowest terrain elevation in the grid. The top of the grid is generally chosen to be above the highest topographic feature. There are two exceptions to this rule: (1) if an isolated mountain peak extends well above the nearby topography, the peak should be allowed to protrude through the top of the grid so as to improve the resolution elsewhere, and (2) if it is highly unlikely that the effluent cloud would rise above a particular terrain level, it may be advantageous to lower the grid top to that level.

There are two ways of altering the grid dimension: (1) the size of the grid cell can be varied in the TOPIN file as described below, and (2) the number of grid points along each axis can be varied. (The standard MATHEW and ADPIC grids have 51 by 51 by 15 points and 41 by 41 by 15 points, respectively.) The first option is the one of choice in most ARAC problems. However, there may be times when it is desirable to change the number of grid points to achieve the optimum grid resolution for a given grid volume. In order to do this, the grid point parameters must be changed in each source and the codes recompiled. The parameter names in TOPOG, MEDIC, and MATHEW are IPICMXP, JPICMXP, and KPICMXP for the ADPIC grid and IMATMXP, JMATMXP, and KMATMXP for the MATHEW grid. In ADPIC and PLCNT, KI, KJ, and KK must be changed. (Computer memory and execution speeds are limiting factors in choosing a total number of grid points.)

For a typical ARAC problem the following variables are used.

CTDEL

The model terrain contour interval in meters. (Default: CTDEL = DELZ)

Warning errors: none
Fatal errors: CTDEL ‹= 0.0
CTDEL › 1000.0 (M/A)

DELX

The grid cell size in kilometers along the x-axis. There are 40 grid cells for ADPIC and 47 grid cells for HADPIC. DELX must be an integer multiple of one-half the terrain database resolution. For a standard ARAC terrain file for an M/A run, the resolution is 0.5km, so DELX must be a multiple of 0.25km. DELX must be 381.0 for HM/A.

Warning errors: DELX › 10.0 (M/A)
Fatal errors: DELX ‹= 0.0
DELX › 100.0 (M/A)

DELY

The grid cell size in kilometers along the y-axis. There are 40 grid cells for ADPIC and 51 grid cells for HADPIC. DELX must be an integer multiple of one-half the terrain database resolution. For a standard ARAC terrain file for an M/A run, the resolution is 0.5km, so DELX must be a multiple of 0.25km. DELX must be 381.0 for HM/A.

Warning errors: DELY › 10.0 (M/A)
Fatal errors: DELY ‹= 0.0
DELY › 100.0 (M/A)

DELZ

The grid cell size in meters along the z-axis. There are 14 grid cells (15 levels) in both M/A and HM/A.

Warning errors: DELZ › 100.0 (M/A)
Fatal errors: DELZ ‹= 0.0
DELZ › 3000.0 (M/A)

IFLATTOPO

Integer flag (0 or 1) indicating if flat terrain is to be used. Special Note for HM/A: valid values for the terrain file (defined by the "Select Topography" menu option) are: NHEMISTD, NHEMIAVG, NHEMIMAX. (Default: IFLATTOPO = 0 -› do not use flat terrain)

IGOOF = 1
ZZZZZ

IGOOF is a flag to check for processing of input parameters. ZZZZZ signals the end of TOPIN input to be read. Comments may be placed after these two lines.

IRESTART

Integer flag (0 or 1) indicating that an existing GRIDIN file is to be opened and read. This allows a previous grid to be modified interactively without rerunning all of TOPOG.
(Default: IRESTART = 0 -› start from scratch and create new GRIDIN)

JUSTTOPO

Integer flag (0 or 1) indicating that no cell descriptions are to be generated and no GRIDIN file to be produced. This allows numerous grids to be examined via graphics without running all of TOPOG, and may be helpful in choosing the best grid in a crucial assessment.
(Default: JUSTTOPO = 0 -› cell descriptions and GRIDIN are generated)

JUSTMAT

Integer flag (0 or 1) indicating that ADPIC will not be run. Therefore, no ADPIC model terrain is generated and MATHEW does not produce a VEL file. When this flag is set, a MATHEW grid origin (specified via UTMXMAT and UTMYMAT) must be given rather than an ADPIC grid origin.
(Default: JUSTMAT = 0 -› ADPIC will be run)

SCTOP

The scaling parameter for the plotting package.
(Default: SCTOP = 1.0)
Warning errors: none
Fatal errors: SCTOP ‹= 0.0
SCTOP › 100.0 (M/A)

UTMXCENTER

The UTM easting coordinate of the center of the ADPIC grid, input in kilometers. Note: It is important to use the same UTM band throughout the model input files.
Note: UTMXCENTER and UTMYCENTER may be used instead of UTMXPIC and UTMYPIC.
Special note for HM/A: UTMXCENTER = 8763., and the coordinates are really hemispheric coordinates, not universal transverse mercator coordinates.

UTMYCENTER

The UTM northing coordinate of the center of the ADPIC grid, input in kilometers. Note: It is important to use the same UTM band throughout the model input files.
Note: UTMXCENTER and UTMYCENTER may be used instead of UTMXPIC and UTMYPIC.
Special note for HM/A: UTMYCENTER = 9525., and the coordinates are really hemispheric coordinates, not universal transverse mercator coordinates.

UTMXMAT

The UTM easting coordinate of the lower left-hand corner of the MATHEW grid in kilometers. This variable must be assigned a value if JUSTMAT = 1. It may also be used to override TOPOG's choice of a MATHEW grid origin derived from the origin of the ADPIC grid.

Warning errors: UTMXMAT › 1000.0 (M/A)
Fatal errors: UTMXMAT ‹= 0.0
UTMXMAT › 1500.0 (M/A)

UTMYMAT

The UTM northing coordinate of the lower left-hand corner of the MATHEW grid in kilometers. This variable must be assigned a value if JUSTMAT = 1. It may also be used to override TOPOG's choice of a MATHEW grid origin derived from the origin of the ADPIC grid.

Warning errors: UTMYMAT › 8500.0 (M/A)
Fatal errors: UTMYMAT ‹= 0.0
UTMYMAT › 10000.0 (M/A)

UTMXPIC

The UTM easting coordinate of the lower left-hand corner of the ADPIC grid in kilometers. Note: It is important to use the same UTM band throughout the model input files.

Note: UTMXPIC and UTMYPIC may be used instead of UTMXCENTER and UTMYCENTER.

Warning errors: UTMXPIC › 1000.0 (M/A)
Fatal errors: UTMXPIC ‹= 0.0
UTMXPIC › 1500.0 (M/A)

UTMYPIC

The UTM northing coordinate of the lower left-hand corner of the ADPIC grid in kilometers. Note: It is important to use the same UTM band throughout the model input files.

Note: UTMXPIC and UTMYPIC may be used instead of UTMXCENTER and UTMYCENTER.

Warning errors: UTMYPIC › 8500.0 (M/A)
Fatal errors: UTMYPIC ‹= 0.0
UTMYPIC › 10000.0 (M/A)

XRANGE

ADPIC grid extent along the x-axis in kilometers. XRANGE may be used instead of DELX -- also see notes for DELX.

YRANGE

ADPIC grid extent along the y-axis in kilometers. YRANGE may be used instead of DELY -- also see notes for DELY.

ZRANGE

ADPIC grid extent along the z-axis in meters. ZRANGE may be used instead of DELZ -- also see notes for DELZ.

TOPIN INPUT FILE FORM

(Coordinates of the lower left-hand corner of the grid)

UTM X coordinates of ADPIC–km

UTMXPIC= .

UTM Y coordinates of ADPIC–km

UTMYPIC= .

X-direction cell size –km

DELX= .

Y-direction cell size –km

DELY= .

Z-direction cell size –m

DELZ= .

Alphanumeric string of up to six characters to identify the site, e.g., 'TMI', 'TOKYO'

SITE= ' '

Number of sampling cells per advection cell in x, y, and z directions

NDELX=

NDELY=

NDELZ=

IGOOF=1

ZZZZZ

Variables for special cases (see TOPIN write-up for explanations):

JUSTMAT
UTMXMAT

UTMYMAT
IFLATTOPO
JUSTTOPOG
IRESTART
CTDEL
SCTOP

III.B.2. Geography

The geography file contains location and classification information about geographic features (e.g. roads, lakes, rivers, political boundaries). This information is used to plot a base map for some of the model graphics products. These files are normally not provided with the models.

III.B.3. Terrain

The TERRAIN file is the local terrain data base for a site. It is composed of a header which describes the grid being used, followed by a two-dimensional array of cell heights, one for each grid cell. In the ARAC system this data is extracted from a terrain data base covering the continental U.S. which has been designed for ARAC problems. This data base has been generated, in turn, from high resolution Defense Mapping Agency terrain tapes obtained from the National Cartographic Information Center in Reston, Virginia.

The terrain file is a binary file consisting of the following data:

Variable	Dimension	Type	Description
NAMMTP	1	INTEGER*4	Site name (8 characters)
NAMXVTP	15	INTEGER*4	Averaged terrain file used (10 character sets)
DELXMTP, DELYMTP	1	REAL*4	Terrain data base grid cell size
IMAXMTP, JMAXMTP	1 1	REAL*4	Terrain data base grid dimension
LSTATTP	1	INTEGER*4	Status of data base
CENLNTP	1	REAL*4	UTM band central longitude
UTMXSWT, UTMYSWT	1 1	REAL*4	UTM location of southwest corner of data base grid
UTMXNWT, UTMYNWT	1 1	REAL*4	UTM location of northwest corner of data base grid
UTMXNET, UTMYNET	1 1	REAL*4	UTM location of northeast corner of data base grid
UTMXSET, UTMYSET	1 1	REAL*4	UTM location of southeast corner of data base grid
LATACC, LONGACC	1 1	INTEGER*4	Geographic location of accident
UTMXACC,	1	REAL*4	UTM location of accident

UTMYACC	1		
LEFTTOP	74	INTEGER*4	Header pad
MSTRTOP	IMAXMTP JMAXMTP	INTEGER*4	Terrain data base elevations

NAMMTP

NAMMTP is the site name. This is a string of up to eight characters. To allow this data to be stored in a common block with other header variables, it is maintained in the file as an integer array with each array element storing the integer representation of one character. Utility routines (FORM_STRING, DECOMP_STRING) are available to create strings from this data or to decompose strings into this format. All strings in any ARAC binary file are stored in this fashion.

NAMAVTP

NAMAVTP is a list of the names of the ARAC averaged data base files used to generate this TERRAIN file. Each name is a character string of up to ten characters, stored as an array of integers. Up to fifteen file names may appear in this list.

DELXMTP

DELXMTP is the size of a terrain data base grid cell along the x-direction in kilometers. For a standard ARAC terrain data base, DELXMTP is 0.500 km.

DELYMTP

DELYMTP is the size of a terrain data base grid cell along the y-direction in kilometers. For a standard ARAC terrain data base, DELYMTP is 0.500 km.

IMAXMTP

IMAXMTP is the number of grid cells along the x-axis of a terrain data base grid. For a standard ARAC terrain data base, IMAXMTP is 400.

JMAXMTP

JMAXMTP is the number of grid cells along the y-axis of a terrain data base grid. For a standard ARAC terrain data base, JMAXMTP is 400.

LSTATTP

LSTATTP is a flag describing the completeness and quality of the terrain data base file.

CENLNTP

CENLNTP is the central longitude of the UTM band being used in the terrain data base in degrees. The western hemisphere is indicated by positive values, the eastern hemisphere by negative values.

UTMXSWT

UTMXSWT is the UTM easting coordinate of the southwest corner of the terrain data base grid in kilometers.

UTMYSWT

UTMYSWT is the UTM northing coordinate of the southwest corner of the terrain data base grid in kilometers.

UTMXNWT

UTMXNWT is the UTM easting coordinate of the northwest corner of the terrain data base grid in kilometers.

UTMYNWT

UTMYNWT is the UTM northing coordinate of the northwest corner of the terrain data base grid in kilometers.

UTMXNET

UTMXNET is the UTM easting coordinate of the northeast corner of the terrain data base grid in kilometers.

UTMYNET

UTMYNET is the UTM northing coordinate of the northeast corner of the terrain data base grid in kilometers.

UTMXSET

UTMXSET is the UTM easting coordinate of the southeast corner of the terrain data base grid in kilometers.

UTMYSET

UTMYSET is the UTM northing coordinate of the southeast corner of the terrain data base grid in kilometers.

LATACC

LATACC is the latitude of the accident site in seconds. The northern hemisphere is indicated by positive values, the southern hemisphere by negative values. The accident site is normally in the center of the terrain data base grid.

LONGACC

LONGACC is the longitude of the accident site in seconds. The western hemisphere is indicated by negative values, the eastern hemisphere by positive values.

UTMXACC

UTMXACC is the UTM easting coordinate of the accident site in kilometers.

UTMYACC

UTMYACC is the UTM northing coordinate of the accident site in kilometers.

LEFTTOP

LEFTTOP pads the header out to 250 words. This allows extra information to be added to the header while maintaining compatibility with existing data bases and codes.

MSTRTOP

The array of terrain heights is based on the grid defined in the header. Each grid cell is associated with an array index pair (i,j) with the pair (1,1) indicating the grid cell at the southwest corner of the grid. The value of an array element is the average height in meters above sea level of the corresponding grid cell. An array value of -9999 indicates that no valid data was available to generate a value for this grid cell. TOPOG treats these missing data flags as sea level (0) heights. The standard ARAC terrain data base is a 400 by 400 array; thus, there are 160,000 height values stored in a typical TERRAIN file.

III.B.4. Site

The Site file is an input file for the MEDIC code when the Problem Station Library and Problem Metdata files are not used (i.e., when the variable "DST" is not used in the WINDY file). It specifies meteorological measurement stations, both surface and upper air, by name, location, and measurement height (only for the surface stations). Each meteorological measurement station referenced in the WINDY data file must have been assigned a location in the site file. While the site file normally is left unchanged for a well characterized site, it can be changed at any time between MEDIC runs to provide locations for additional meteorological stations that have become available during an accident response.

The following variables must be assigned a value in the Site file.

NUPR

The number of vertical wind profiles and/or upper air stations (UPRSTN). A maximum of fifteen stations is permitted.

Warning errors:	None
Fatal errors:	NUPR $<$ 1
	NUPR $>$ 15

UPRSTN

This item consists of a sequence of upper air station location records, with one record identifying and locating one upper air station. Each record consists of three items:

1. The station identifier, which is a character string of up to eight (8) characters delimited by apostrophes.
2. The UTM easting of the upper air station location in kilometers. The array for this value in the code is UPRSTX.
3. The UTM northing of the upper air station location in kilometers. The array for this value in the code is UPRSTY.

Warning errors:	UPRSTX $\geq$ 1000.0
	UPRSTY $\geq$ 8500.0
Fatal errors:	UPRSTX $<$ 0.0
	UPRSTY $<$ 0.0
	UPRSTX $\geq$ 2000.0
	UPRSTY $\geq$ 10000.0

NSFC

The number of surface wind measurement stations (SFCSTN). A maximum of 50 stations is permitted.

Warning errors:	None
Fatal errors:	NSFC $<$ 1
	NSFC $>$ 50

SFCSTN

This item consists of a sequence of surface station location records with one record identifying and locating one surface instrument. Each record consists of four items.

1. The station identifier, which is a character string of up to eight (8) characters delimited by apostrophes.
2. The UTM easting of the surface station location in kilometers. The array for this value in the code is SFCSTX.
3. The UTM northing of the surface station location in kilometers. The array for this value in the code is SFCSTY.
4. The height of the instrument above ground level in meters. The array for this value in the code is SFCHGT.

Warning errors:	SFCSTX $\geq$ 1000.0
	SFCSTY $\geq$ 8500.0

	SFCHGT $\geq$ 100.0
Fatal errors:	SFCSTX $<$ 0.0
	SFCSTY $<$ 0.0
	SFCHGT $\leq$ 0.0
	SFCSTX $\geq$ 2000.0
	SFCSTY $\geq$ 10000.0
	SFCHGT $\geq$ 10000.0

IGOOF

IGOOF is a flag to check for improper inputs of data. It must always be set to one (1) as the last variable in the namelist file. After any input through a name list, if IGOOF remains zero, a mistake in spelling or an omission has been made in preparing the input. The ECHOMEDIC file should then be examined because the last line of the site file written to ECHOMEDIC contains the erroneous input.

ZZZZZ

This string of Z's should be the *last* entry of the input file. It is a signal to the code that all parameters are entered.

There is one optional variable in the Site file:

IPRINT

IPRINT is a flag which, if set to one (1), indicates that the reference level, upper level, and extrapolated wind fields are to be printed in ECHOMEDIC. The default is zero (0).

Warning errors:	None
Fatal errors:	IPRINT $<$ 0
	IPRINT $>$ 1

SITE INPUT FILE FORM

Specifies meteorological measurement stations by name and location. File name is given by the variable SITE in TOPIN.

Number of vertical wind profiles and/or upper air stations (max number = 15)

NUPR=

Names of vertical wind profile measurement stations (up to eight characters)	X-coordinates of vertical wind profile measurement stations—UTM—km	Y-coordinates of vertical wind profile measurement stations—UTM—km
UPRSTN= ' '*	.	.
UPRSTN= ' '	.	.
	•	
	•	
	•	
UPRSTN= ' '	.	.
UPRSTN= ' '	.	.

*First upper station in the site file is used to define the σ_θ profile if σ_θ data exists.

Number of surface wind measurement stations (max number = 50)

NSFC=

Names of surface measurement stations (up to eight) characters)	X-coordinates of surface wind stations UTM—km	Y-coordinates of surface wind stations UTM—km	Heights of surface wind stations above terrain (tower height)—m
SFCSTN= ' '			
SFCSTN= ' '			
•			
•			
•			
SFCSTN= ' '			
SFCSTN= ' '			

IGOOF=1

ZZZZZ

Variables for special cases (see SITE file description for explanations):
IPRINT

III.B.5. WINDY

WINDY is an input file for the MEDIC code. It provides MEDIC with surface and upper air meteorological data, as well as numerous parameters controlling the wind field extrapolation procedure. Each WINDY data set is used to create a snapshot of the atmospheric winds throughout a gridded volume. These winds, after adjustment for mass-consistency, are assumed to persist in ADPIC until the next WINDY data set. Most of the meteorological variables in WINDY are subject to change from data set to data set, so a WINDY file is usually constructed each hour.

Because MATHEW does a minimal wind field adjustment and because the advection winds in ADPIC persist for extended periods, it is very important that the analyst provide the best possible set of extrapolated winds. The extrapolated winds are sensitive to relatively small changes in the WINDY parameter values, and the effects on the wind field are often complex and hard to visualize. It is therefore essential that the assessor (a meteorologist) carefully examines the plots of the extrapolated winds which MEDIC produces to determine the validity of the wind field. If the wind field fits the assessor's concept of the state of the atmosphere, then MATHEW may be run with the data set. Otherwise, several of the variables in WINDY may have to be changed and MEDIC run again. It may also be necessary to omit meteorological data if it is obviously erroneous, e.g., several hours of unchanged direction readings from a station may indicate a "frozen" wind vane. This process is iterative, and is continued until the assessor is satisfied that the best extrapolation (consistent with the data) has been produced.

The following is a list of variables which must be assigned a value in WINDY.

DST

DST is the Data Set Time of the Problem Metdata Files (surface, tower, and upper air). It is given in GMT and is expressed as a nine-digit character string in the format yymmddhhq, where q is the quartile of the hour. For example, "780503141" represents 3-May-78, 1415 GMT.

NDATE

NDATE is the date for which the WINDY dataset is to start being used by ADPIC. This date is given in GMT and is expressed as a six-digit integer with the first two digits specifying the year, the second two digits the month, and the last two digits the day (i.e., yymmdd). For example, 780501 represents 1 May 1978. NOTE: NDATE and NTIME may be omitted from the WINDY file if DST is specified, in which case a default value will be assigned: NDATE, NTIME = DST – AVTIME/2.0

Warning errors:	None
Fatal errors:	NDATE < 101
	NDATE > 991231

NTIME

NTIME is the time for which the WINDY dataset is to start being used by ADPIC. This time is given in GMT and is expressed as a four-digit integer with the first two digits specifying the hour, and the last two digits the minute (i.e., hhmm). For example, 1400 represents 1400 GMT. NOTE: NDATE and NTIME may be omitted from the WINDY file if DST is specified, in which case a default value will be assigned: NDATE, NTIME = DST - AVTIME/2.0

Warning errors:	None
Fatal errors:	NTIME < 0
	NTIME > 2400

NRUN

NRUN is the numerical data set sequence number. It numbers a WINDY data set as it is being processed and then appends the same number on the corresponding output (MVELnnn). Thus, the first data set of a problem, normally run with NRUN=1, will produce MVEL001. The next data set, with NRUN=2, will produce MVEL002, and so on. The ECHOMEDIC and graphics files are also numbered in this fashion.

Warning errors:	None
Fatal errors:	NRUN < 1
	NRUN > 594

AVTIME

AVTIME is only used when DST has been specified. AVTIME is used to compute NDATE and NTIME when these two parameters are not specified in WINDY: NDATE, NTIME = DST - AVTIME/2.0, where AVTIME is in integer minutes.

Warning errors:	AVTIME > 180.0
Fatal errors:	AVTIME ≤ 0.0
	AVTIME > 1440.0

SRH

SRH is the surface roughness height in meters. The surface roughness height is approximately the average height of most land-based features (e.g., grass, trees, buildings) divided by 30. The analyst should consider features over the entire gridded area before entering a value. This is a subjective parameter since we are usually dealing with very diverse geographical areas. On page 2 of the WINDY input form, a graph of "Modeling the Planetary Boundary Layer" and a general guide to surface roughness heights are provided. TOPBL as used by the model is the height at which the extrapolated upper air profile matches the observed upper air profile. The wind speed and direction above TOPBL matches the observed upper air profile if IPROFIL = 1, but remains constant if IPROFIL = 0.

Warning errors:	SRH ≥ 2.0
Fatal errors:	SRH ≤ 0.0
	SRH > 5.0

PWRSL

PWRSL is the power law exponent for the surface layer. It can be calculated directly from surface-layer wind observations in the vertical using the power law formula given by Eq. (C.1). Alternatively (and more generally), it is a tabular look-up with the selection based on atmospheric stability (see page 2 of the WINDY input form). PWRSL is used within the code to extrapolate: (1) wind speeds from their measured height to REF (see below), (2) wind speeds from the SRH to the top of the surface layer above terrain in the parameterized extrapolation procedure (see TOPSL below), and (3) wind speeds from the SRH to REF in the profile extrapolation procedure (see Section II.C.3.b. for details).

Warning errors:	PWRSL $>$ 0.5
Fatal errors:	PWRSL $<$ 0.0
	PWRSL $>$ 10.0

PWRBL

PWRBL is the interpolation exponent for the boundary layer. It is used to interpolate winds within the boundary layer, and is valid between the top of the surface layer (TOPSL) and the top of the boundary layer (TOPBL). A more complete discussion of this very important parameter is contained in Section II.C.3.b.

Warning errors:	PWRBL $>$ 10.0
Fatal errors:	PWRBL $<$ 0.0
	PWRBL $>$ 50.0

REF

REF is the level (above terrain) in meters to which the surface wind observations are adjusted using the surface power law (PWRSL). Adjustments of the measurements to a common height, usually the typical height of the surface instruments, permits the extrapolation of winds in the horizontal direction.

Warning errors:	REF $\leq$ 2.0
	REF $\geq$ 100.0
Fatal errors:	REF $\leq$ 0.0
	REF $\geq$ 500.0

TOPSL

TOPSL is the height (in meters) of the surface layer above terrain. The surface boundary layer is defined as that part of the atmosphere boundary layer where momentum, heat, and energy fluxes are constant. While the height of this layer is typically about 10% of the boundary layer height (TOPBL), it is more useful to consider TOPSL as the level at which the wind direction begins to turn with height.

Warning errors:	TOPSL $\leq$ 2.0
	TOPSL $\geq$ 100.0
Fatal errors:	TOPSL $\leq$ 0.0
	TOPSL $\geq$ 500.0

TOPBL

TOPBL is the height (in meters) of the boundary layer above terrain. The height of the boundary layer is the level at which the wind speed and direction become nearly geostrophic, i.e., change little with height because of the negligible effects of surface drag. Upper air soundings (RAWINS or PIBALS) are the best data source for determining TOPBL. If no soundings are available, an alternative procedure to obtain TOPBL is to use the graph "Modeling the Planetary Boundary Layer" on page 1b of the WINDY input file. TOPBL as used by the model is the height at which the extrapolated upper air profile matches the observed upper air profile. The wind speed and direction above TOPBL matches the observed upper air profile if IPROFIL=1, but remains constant if IPROFIL=0.

Warning errors:	TOPBL $\leq$ 50.0
	TOPBL $\geq$ 3000.0
Fatal errors:	TOPBL $\leq$ 0.0
	TOPBL $\geq$ 5000.0

TOPML

TOPML is the height (in meters) of the mixed layer above terrain. The height of the mixed layer is that demarcation between well mixed, turbid air below, and relatively clear air above. The mixed layer, typically ranging from 300 to 3000 m above terrain, basically indicates the height of the temperature inversion base. TOPML is usually obtained from the radiosonde nearest the source (or area of interest). In the absence of a temperature profile, observations have often shown that the wind will shear rapidly in direction and be accompanied by a speed minima as the sonde passes through the inversion layer.

Warning errors:	TOPML $\leq$ 50.0
	TOPML $\geq$ 6000.0
Fatal errors:	TOPML $<$ DELZ
	TOPML $\geq$ 10000.0

SMOLI

SMOLI is the inverse of the Monin-Obukhov length. The Monin-Obukhov length (usually referred to as L) is the height above the surface at which mechanical and thermal turbulence are of equal importance. From an estimate of SRH and the atmospheric stability, SMOLI can be found from the nomogram on page 2b of the WINDY input forms.

Warning errors:	SMOLI $<$ $-$ 0.15
	SMOLI $>$ 0.15
Fatal errors:	SMOLI $<$ $-$ 1.00
	SMOLI $>$ 1.00
	SMOLI $>$ 0.0 and ISTAB $<$ 4
	SMOLI $<$ 0.0 and ISTAB $>$ 4

ISTAB

ISTAB is the Pasquill-Gifford stability category for vertical diffusion. It also defines horizontal diffusion if σ_θ is absent. Finally, it is used to assign a value to the SIGV parameter in MATHEW. There are many ways to determine atmospheric stability. One is the Pasquill-Turner method, which incorporates insolation assessments based on hourly cloud

observations. The heat flux at the earth's surface is qualitatively estimated from these cloud observations, and then related to stability on the basis of the station wind speed. This method is similar to the method used to define the stability categories during the original development of the Pasquill-Gifford curves. Another method is to use a table, such as the "Relation of Turbulence Types to Weather Conditions" included on page 2 of the WINDY input form. A consistent stability for each surface observation is generally made, so the number of values can be quite sizable. Since ISTAB must represent a composite of the grid-wide stability, the individual stabilities are averaged with a greater weight given to those estimates nearest the source location.

Warning errors:	None
Fatal errors:	ISTAB < 1
	ISTAB > 6

UPR

This item consists of a sequence of upper air records, with each record identifying a measurement station along with all of its upper air data and is to be used only when not using the Problem Metdata files. Each record is composed of:

1. The station identifier, which is a string of up to eight (8) characters delimited by apostrophes. The location of this station must be defined in the site file.
2. A series of measurement records, one for each level in the upper air profile. Each measurement record consists of four data items:
   a. The height of the data level in meters above ground. The array for this value in the code is UPRHGT.
   b. The direction measurement for this level. This is the direction the wind is coming from, in degrees, measured from north. The array for this value in the code is UPRDIR.
   c. The speed measurement for this level in meters/second. The array for this value in the code is UPRSPD.
   d. The σ_θ measurement (i.e., the standard deviation of wind direction) for this level in degrees. The array for this variable in the code is UPRSIG.

Each measurement record must contain all four entries. If no data is available for a given field, then a -1.0 should be entered to signify missing data. If speed or direction is available at a given level but not both, the value should still be entered since MEDIC extrapolates speed and direction separately. At least one upper air speed and one upper air direction measurement is required (not necessarily at the same station). Each upper air station record can contain up to twenty measurement records, i.e., twenty upper air levels. There can be up to fifteen upper air stations.

The first upper air station record will be used to generate a σ_θ profile for ADPIC (assuming the availability of σ_θ).

Warning errors:	UPRHGT < 2.0
	UPRHGT > 10000.0
	UPRSPD > 100.0
	UPRSIG > 90.0
Fatal errors:	UPRHGT > 50000.0
	UPRDIR > 360.0

UPRSPD > 200.0	
UPRSIG > 180.0	
UPRHGT < 0.0 and	UPRDIR $\geq$ 0.0 or
	UPRSPD $\geq$ 0.0 or
	UPRSIG $\geq$ 0.0

SFC

This item consists of a sequence of surface station records with one record identifying a measurement station followed by its surface observations and is to be used only when not using the Problem Metdata files. Each record is composed of three items:

1. The station identifier which is a string of up to eight (8) characters delimited by apostrophes. The location of all stations must be defined in the site file.
2. A direction measurement. This is the direction the wind is coming from, in degrees, measured from north. The array for this value in the code is SFCDIR.
3. A speed measurement in meters/second. The array for this value in the code is SFCSPD.

Each surface station record must contain all three entries. If no data is available for a given field, then a -1.0 should be entered to signify missing data. If speed or direction is available, but not both, the value should still be entered since MEDIC extrapolates speed and direction separately. At least one surface speed and one surface direction measurement is required (not necessarily at the same station). As many as fifty surface station records are allowed.

Warning errors:	SFCSPD > 35.0
Fatal errors:	SFCSPD > 100.0
	SFCDIR > 360.0

IGOOF

IGOOF is a flag to check for improper inputs of data. It must always be set to one (1) as the last variable in the WINDY data set. After any input through a namelist, if IGOOF remains zero (the value given IGOOF prior to the WINDY input), a mistake in spelling or an omission has been made in preparing the input. The ECHOMEDIC file should then be examined because the last line of the WINDY file written to ECHOMEDIC will contain the erroneous input.

ZZZZZ

This string of Z's should be the *last* entry of the WINDY data. It is a signal to the code that all the input values have been read. Several WINDY data sets can be stacked in one WINDY file. The namelist for each data set (except for the first one) begins on the line following the ZZZZZ symbol terminating the previous data set. Termination of a sequence of data sets is marked by the two entries IGOOF=999999 and another ZZZZZ, both placed after the ZZZZZ completing the last data set.

There are a number of optional variables which may be used to handle special extrapolation problems, to pass time-varying data to ADPIC, and to control graphics. The variables are:

IPROFIL

IPROFIL allows the user to select one of two vertical extrapolation schemes. If IPROFIL is one (1), upper air profiles are used to perform the vertical extrapolation. If IPROFIL is zero (0), only the extrapolation parameters are used to generate three-dimensional gridded winds from two-dimensional grids of winds. (Also see TOPBL for note concerning the relationship between IPROFIL and TOPBL.) The default is one (1).

Warning errors:	None
Fatal errors:	IPROFIL < 0
	IPROFIL > 1

IROTHORZ

IROTHORZ controls the sense of how upper air and surface direction discrepancies are resolved at the top of the surface layer, and is only used when IPROFIL = 1 (the profile extrapolation). The default is 180.

Warning errors:	None
Fatal errors:	IROTHORZ < 0
	IROTHORZ > 360

IROTVERT

IROTVERT controls the sense of the vertical direction extrapolation in the boundary layer, and is only used when IPROFIL = 0 (the parameterized extrapolation). It is the largest angle, measured in degrees, which will be resolved by veering (i.e., the winds rotate in a clockwise direction with height) rather than by backing. The default is 240.

Warning errors:	None
Fatal errors:	IROTVERT < 0
	IROTVERT > 360

BMOLI

BMOLI is the boundary layer inverse Monin-Obukhov length. Normally, there is insufficient information to differentiate the surface layer and boundary layer Monin-Obukhov lengths. Therefore, SMOLI is the only value set in WINDY. When this is the case, BMOLI is set equal to the value of SMOLI in ADPIC. If both variables are assigned values in WINDY, then ADPIC will use SMOLI between TOPSL and BMOLI above TOPSL.

Warning errors:	BMOLI < -0.15
	BMOLI > 0.15
Fatal errors:	BMOLI < -1.0
	BMOLI > 1.0
	ISTAB < 4 and BMOLI > 0.0

ISTAB > 4 and BMOLI < 0.0

IPRO

IPRO is a list of the i indices of the sample profiles to be plotted. Up to ten sample profiles are allowed. The first value in IPRO is matched with the first value in JPRO to give the horizontal grid indices of the first profile. Succeeding indices from each list are matched in a similar fashion. The default for IPRO with a standard 51 by 51 by 15 MATHEW grid is: 14 26 38 14 26 38 14 26 38. This gives the normal nine sample profiles.

JPRO

JPRO is a list of the j indices of the sample profiles to be plotted. Up to ten sample profiles are allowed. The first value in JPRO is matched with the first value in IPRO to give the horizontal grid indices of the first profile. Succeeding values from each list are matched in a similar fashion. The default for JPRO with a standard 51 by 51 by 15 MATHEW grid is: 14 14 14 26 26 26 38 38 38. This gives the normal nine sample profiles.

KPLOT

KPLOT is a list of k levels above terrain at which horizontal vector plots are to be produced. For a standard 51 by 51 by 15 MATHEW grid, up to fifteen levels can be plotted. The default is two (2), giving a plot located 1*DELZ above terrain.

NVCTFQ

NVCTFQ allows the user to increase or decrease the density of vectors on the vector plots. A value of one (1) indicates that a vector is plotted at every horizontal grid point. A value of two (2) indicates that a vector is plotted at every other grid point, etc. The default is two (2).

Warning errors:	None
Fatal errors:	NVCTFQ $\leq$ 0

SCLX

SCLX scales the size of the vectors on the vector plots in the x direction. The default value is 0.5.

Warning errors:	None
Fatal errors:	SCLX $\leq$ 0.0

SCLY

SCLY scales the size of the vectors on the vector plots in the y direction. The default value is 0.5.

Warning errors:	None
Fatal errors:	SCLY $\leq$ 0.0

WINDY INPUT FILE FORM

Observation time (hhmm)	Observation date (yymmdd)	Data set number
NTIME=	NDATE=	NRUN=

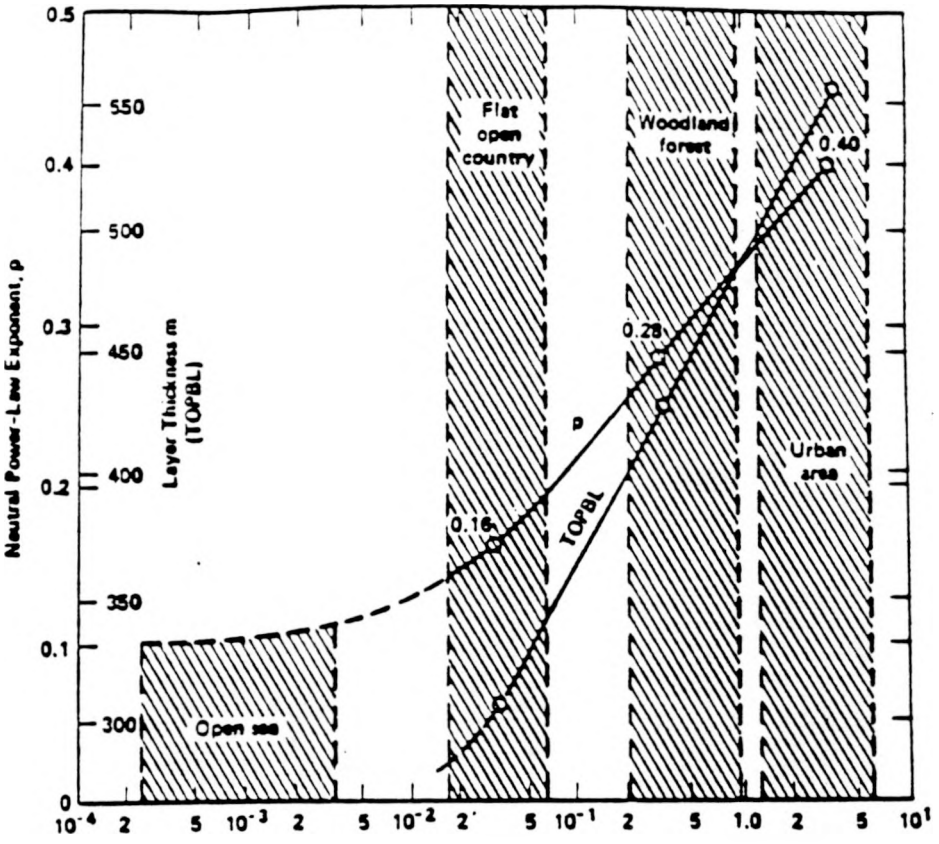
Averaging time for wind set—minutes	Surface roughness height—m
AVTIME= .	SRH= .

Power law exponent for surface layer	Interpolation parameter for boundary layer
PWRSL= .	PWRBL= .

Surface observation interpolation level above terrain—m	Height of surface layer above terrain—m	Height of boundary layer above terrain—m	Height of mixed layer above terrain—m
REF= .	TOPSL= .	TOPBL= .	TOPML= .

Inverse of the Monin-Obukhov length 1/m

SMOLI= .



Surface roughness height (Z_0) – m.

The exponent in the power law and the height of the boundary layer as functions of the roughness height and the type of terrain. From Davenport (1965).

Estimated stability correction for p:

Stable:	add 0.1
Neutral:	as is
Unstable:	subtract 0.1

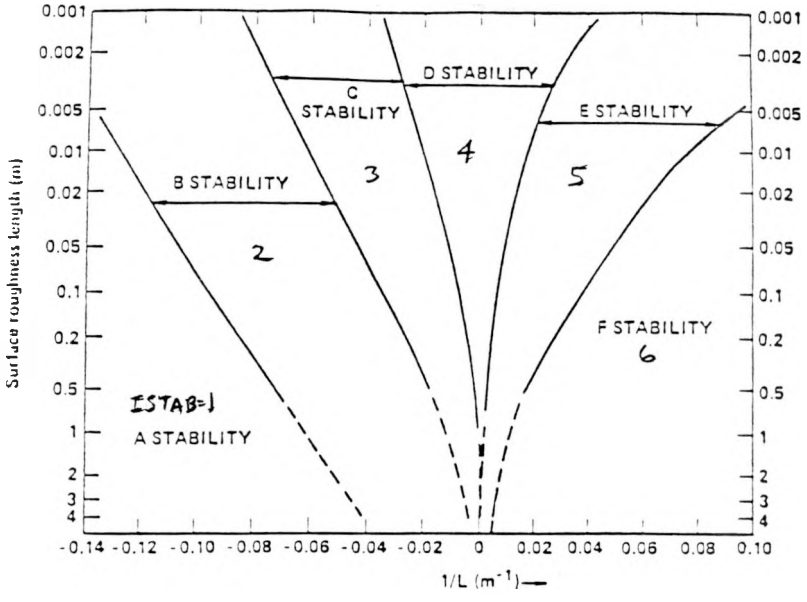
h_o =average height of terrain features (e.g., buildings, trees, grass)

Z_o =surface roughness height (m) $\simeq h_o/30$

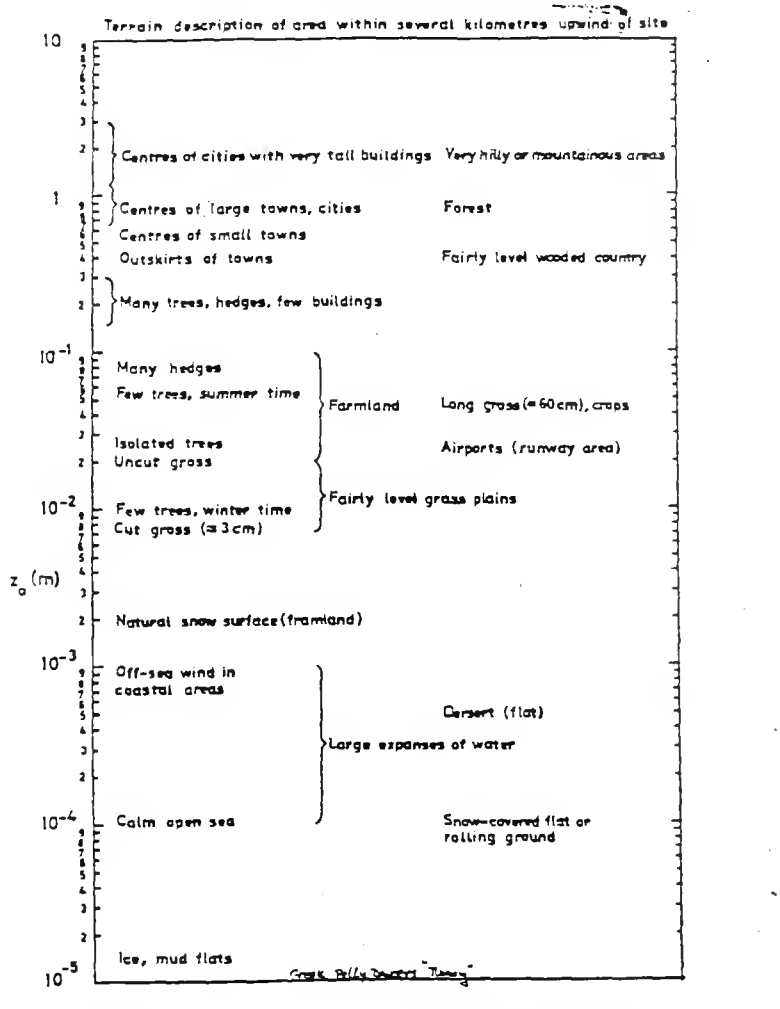
TOPSL =.1 TOPBL

The power-law exponents are functions of Z_o; PWRSL is obtained from graph using appropriate Z_o and correction for stability (if necessary).

Relation of Monin-Obukhov L to Pasquill class and roughness length.



z_0 Values for Typical Terrain Types (After ESDU 72026, 1972)



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Davenport, A. G., 1967: The dependence of wind loads on meteorological parameters. *Proc. Int. Res. Seminar, Wind Effects on Buildings and Structures*, Ottawa, University of Toronto Press, 19–82.

ESDU 72026, 1972: Characteristics of wind speed in the lowest

UPPER AIR DATA

This is a sample form for entering data from a single upper air station. (Additional station data can be entered on this same form, but the '$UPR =$' symbol should be omitted.)

(−1. denotes missing or questionable data.)

Maximum number of levels = 20
Maximum number of upper air stations = 15

Station name (up to 8 char.)	Measurement height above terrain—m	Wind direction at measurement height —degrees	Wind speed at measurement height—m/s	σ_θ-degrees (enter −1. if unknown)
UPR= ' '	.	.	.	.
	.	.	.	.
		•		
		•		
		•		
	.	.	.	.
	.	.	.	.

SURFACE DATA

(−1.0 denotes missing or questionable data.)

Maximum number of surface stations = 50

Station name (up to 8 char.)	Wind direction—degrees	Wind speed— m/s
SFC= ' '	.	.
' '	.	.
	•	
	•	
	•	
' '	.	.
' '	.	.

IGOOF=1

ZZZZZ

After the last full data set, IGOOF=999999 and ZZZZZ must be input (i.e., if you are running hourly, each data set must end with these two lines, but if you are stacking data sets, the last set must end with IGOOF= 1, ZZZZZ, IGOOF= 999999, ZZZZZ).

Optional Inputs for WINDY

Optional WINDY inputs (see WINDY write-up for explanations):

IPROFIL
IROT
ZSCH
NVCTFQ
SCLX
SCLY
IPRO
JPRO
KPLOT

III.B.5B. HWINDY

HWINDY is an input file for the HMEDIC code. It provides HMEDIC with the dates of the AFGWC gridded metdata files to be used as well as other meteorological parameters. Some of the parameters are the same as those used in TOPIN and WINDY, and this fact is indicated in the parameter description.

The namelist format of the HWINDY file is similar to that of the RSUSIN, which is different that all of the rest of the M/A input files. The guts of defining the parameter values is the same for both of the namelist formats: parameter_name = parameter_value. The same style of "free formating" applies to both namelist formats. The difference is in the initiation and termination of the namelist as a whole.

HWINDY contains three namelists:

1) cml - miscellaneous info
2) topinpt - grid info
3) windyf - met info

Each of the three namelists must begin with a dollar sign in the 2nd column of the first line followed by the name of the namelist. The following lines contain the parameters and their values. A second dollar sign signals the end of the namelist input to be read. The word "end" is also usually added, although not needed. For example an empty CML namelist would look like this:

```
$CML
 IGOOF =1
$END
```

(with the "$" in the 2nd column).

The following is a list of the parameters for HWINDY with the associated namelist indicated beside the parameter name.

DELX (TOPINPT namelist parameter)

See same TOPIN parameter for description.
(Default: DELX = value specified in TOPIN.)

DELY (TOPINPT namelist parameter)

See same TOPIN parameter for description.
(Default: DELY = value specified in TOPIN.)

DELZ (TOPINPT namelist parameter)

See same TOPIN parameter for description.
(Default: DELZ = value specified in TOPIN.)

FINAL (WINDYF namelist parameter)

10-character string (hhZddmmmyy) specifying the time of the last met dataset (AFGWC gridded metdata file) to be read.
(Default: none? - required parameter?)

FIRST (WINDYF namelist parameter)

10-character string (hhZddmmmyy) specifying the time of the last met dataset (AFGWC gridded metdata file) to be read.
(Default: none? - required parameter?)

FORECAST_HOUR (WINDYF namelist parameter)

Integer (0 to 99) which must match the number of hours forecast in the met dataset filename (AFGWC gridded forecast filename). This parameter is to be used only if forecast data (rather than analysis) data is to be used.
(Default: parameter omitted -› analysis data is to be used.)

HSITE (WINDYF namelist parameter)

3-character lowercase string ('nhe' for Northern Hemisphere, 'she' for Southern Hemisphere) used to select the hemisphere for the met dataset filenames.
(Default: HSITE = none? required parameter)

IAVTIMEO (WINDYF namelist parameter)

Integer number of hours of the smallest time interval between input met datasets. The interval between any 2 successive datasets must be an integer multiple of IAVTIMEO.
(Default: IAVTIMEO = 12?)

IOOOF = 1 (CML, TOPINPT, and WINDYF namelist parameter)

Signals end of the namelist.
(Default: none - this is a required parameter.)

IMAXTRY (WINDYF namelist parameter)

Integer maximum number of IAVTIMEO intervals the code will search ahead for the next met dataset.
(Default: IMAXTRY = 3?)

ISTAB (WINDYF namelist parameter)

See same WINDY parameter for description.
(Default: ISTAB = 4?)

LAT_PROFILE (WINDYF namelist parameter)

Real number representing latitude in degrees (+ for north, - for south) of the location of the vertical wind profile to be written to the ECHOHMEDIC file. Profile is not constructed if this parameter is omitted.
(Default: parameter omitted -› profile not constructed.)

LON_PROFILE (WINDYF namelist parameter)

Real number representing longitude in degrees (+ for east, - for west) of the location of the vertical wind profile to be written to the ECHOHMEDIC file. Profile is not constructed if this parameter is omitted.
(Default: parameter omitted -› profile not constructed.)

NNLAST (WINDYF namelist parameter)

Integer which is used to calculate the sequence number for the first VEL file to be created: sequence number = NNLAST + 1.
For example, if VEL.01 and VEL.02 exist and new data is to be appended starting with VEL.03, set NNLAST = 2.
(Default: NNLAST = 0?)

NSETS (CML namelist parameter)

Integer maximum number (1 to 6) of met datasets per VEL file.
(Default: NSETS = 6)

READ_GRIDIN (CML namelist parameter)

Boolean flag (.TRUE. or .FALSE.) controlling whether or not to use an existing GRIDIN file. This allows for running HMEDIC without first running HTOPOG for flat terrain. If "READ_GRIDIN = .FALSE." then DELX, DELY, and DELZ must be specified in HWINDY.
(Default: READ_GRIDIN = .TRUE. -› GRIDIN already exists from an HTOPOG run or a previous HMEDIC run.)

SRH (WINDYF namelist parameter)

See same WINDY parameter for description.
(Default: none? required parameter?)

TOPBL (WINDYF namelist parameter)

See same WINDY parameter for description.
(Default: none? required parameter?)

TOPML (WINDYF namelist parameter)

See same WINDY parameter for description.
(Default: none? required parameter?)

TOPSL (WINDYF namelist parameter)

See same WINDY parameter for description.
(Default: none? required parameter?)

ZBOT (CML namelist parameter)

Height above ground of the bottom pressure level of the computational grid in meters.
(Default: ZBOT = 0.)

ZMOLI (WINDYF namelist parameter)

See same WINDY parameter for description.
(Default: ZMOLI = 0.0?)

III.B.6. MINV

MINV is the input file that controls a MATHEW or HMATHEW run. A basic MINV file is a list of the met datasets which MATHEW or HMATHEW is to process. The MEDIC code produces a default minimal MINV file; HMEDIC currently does not create a MINV file.

If more than one met dataset is to be processed, then the MINV file will be stacked, with the "IGOOF = 1" and "ZZZZZ" lines separating the stacks.

The following variables are required in each MINV data set.

NRUNNOW

Integer number of the met dataset to be processed.
For MATHEW: If MVEL.003 and MVEL.004 are to be processed, then there will be 2 "stacks" with NRUNNOW's of 3 and 4.
For HMATHEW: If the number of datasets per VEL file is 6, and all of the datasets in VEL.03 and the first two in VEL.04 are to be processed, then there will be 8 "stacks" with NRUNNOW's of 13 through 20.
(Default: none? required parameter?)
Warning errors: None
Fatal errors: NRUNNOW < 1
NRUNNOW > 594

IGOOF = 1
ZZZZZ

IGOOF is a flag to check for processing of input parameters in the current stack. ZZZZZ signals the end of the current stack. Comments may be placed after these two lines.
(Default: none - this is a required parameter.)

IGOOF = 999999
ZZZZZ

IGOOF is a flag to check for processing of input parameters in the current stack (a value of 999999 indicates this is the last stack). ZZZZZ signals the end of the current stack. Comments may be placed after these two lines.
(Default: none - this is a required parameter.)

There are a number of optional variables which may be changed from their default values to handle special problems. These variables are:

SIGH

SIGH is used with SIGV to control how much mass-adjustment takes place in the horizontal as opposed to the vertical direction. Since the ratio of SIGV to SIGH controls MATHEW's behavior, SIGH is normally set to 1.0 and only SIGV is changed. The default value is 1.0.

Warning errors:	SIGH $>$ 5.0
Fatal errors:	SIGH $\leq$ 0.0
	SIGH $\leq$ 100.0

SIGV

SIGV is used with SIGH to control how much mass-adjustment takes place in the vertical as opposed to the horizontal direction. The choice of SIGV is a function of the grid cell geometry and the atmospheric stability as defined by the Pasquill categories. The default for SIGV is scaled by stability as follows:

ISTAB	SIGV
1	3.3*(2*DELZ/DELX)
2	2.4*(2*DELZ/DELX)
3	1.6*(2*DELZ/DELX)
4	1.0*(2*DELZ/DELX)
5	0.7*(2*DELZ/DELX)
6	0.33*(2*DELZ/DELX)

The assessor may override the default to give a better picture of atmospheric flow conditions.

Warning errors:	SIGV $>$ 2.0
Fatal errors:	SIGV $\leq$ 0.0
	SIGV $>$ 100.0

Note for HMATHEW: A value of 0.0010499 is recommended.

BETAH

For future use.

BETAV

For future use.

RCERR

RCERR is the relative convergence error. When LAM (Lagrangian multiplier) values from successive iterations change by less than RCERR for all grid points, the adjustment is complete. The default is 0.01.

Warning errors:	RCERR $<$ 0.0001
	RCERR $>$ 1.0
Fatal errors:	RCERR $\leq$ 0.0
	RCERR $>$ 10.0

OMEGA

OMEGA is the over-relaxation parameter in the MATHEW iteration procedure. The default is 1.78.

Warning errors:	None
Fatal errors:	OMEGA < 1
	OMEGA ≥ 2

ITEROMG

After ITEROMG iterations, the over-relaxation parameter is changed to 1.0 in an attempt to speed convergence. The default is 600.

Warning errors:	ITEROMG > ITERHLT
Fatal errors:	ITEROMG < 1

ITERHLT

After ITERHLT iterations, the code is stopped. The default is 1500.

Warning errors:	None
Fatal errors:	ITERHLT < 1
	ITERHLT > 5000

ITERPNT

A status message is sent to the terminal after every ITERPNT iterations. The message gives the number of iterations and the number of "cells" that must still converge. The default is 50.

Warning errors:	None
Fatal errors:	ITERPNT < 0

ICLOSETOP

ICLOSETOP is a flag which, if set to one (1), indicates that a "no flow through" boundary is to be placed one k-level below the top of the grid. The default is zero (0).

Warning errors:	None
Fatal errors:	ICLOSETOP < 0
	ICLOSETOP > 1

NOVARY

NOVARY is a flag which, if set to one (1), indicates that the extrapolated gridded winds from MEDIC are to be passed directly to ADPIC without adjustment for mass-consistency. The default is zero (0).

Warning errors:	None
Fatal errors:	NOVARY < 0
	NOVARY > 1

IWIND0GRID

IWIND0GRID is a flag which, if set to one (1), indicates that the grid point extrapolated winds are to be printed in the ECHOMAT file. The default is zero (0).

Warning errors:	None
Fatal errors:	IWIND0GRID < 0
	IWIND0GRID > 1

IWIND0FACE

IWIND0FACE is a flag which, if set to one (1), indicates that the face-centered extrapolated winds are to be printed in the ECHOMAT file. The default is zero (0).

Warning errors:	None
Fatal errors:	IWIND0FACE < 0
	IWIND0FACE > 1

IWIND0DIVG

IWIND0DIVG is a flag which, if set to one (1), indicates that the divergence of the extrapolated winds is to be printed in the ECHOMAT file. The default is zero (0).

Warning errors:	None
Fatal errors:	IWIND0DIVG < 0
	IWIND0DIVG > 1

ILAMBDAS

ILAMBDAS is a flag which, if set to one (1), indicates that the Lagrangian multipliers are to be printed in the ECHOMAT file. The default is zero (0).

Warning errors:	None
Fatal errors:	ILAMBDAS < 0
	ILAMBDAS > 1

IWINDSADJU

IWINDSADJU is a flag which, if set to one (1), indicates that the adjusted face-centered winds are to be printed in the ECHOMAT file. The default is zero (0).

Warning errors:	None
Fatal errors:	IWINDSADJU < 0
	IWINDSADJU > 1

IWINDSGRID

IWINDSGRID is a flag which, if set to one (1), indicates that the grid point adjusted winds are to be printed in the ECHOMAT file. The default is zero (0).

Warning errors:	None
Fatal errors:	IWINDSGRID < 0
	IWINDSGRID > 1

IWINDSADPI

IWINDSADPI is a flag which, if set to one (1), indicates that the ADPIC winds are to be printed in the ECHOMAT file. The default is zero (0).

Warning errors:	None
Fatal errors:	IWINDSADPI < 0
	IWINDSADPI > 1

IPR

IPR is a list of the i indices of the sample profiles of the adjusted winds to be plotted. Up to ten sample profiles are allowed. The first value in IPR is matched with the first value in JPR to give the horizontal grid indices of the first profile. Succeeding indices from each list are matched in a similar fashion. The default for IPR with a standard 51 by 51 by 15 MATHEW grid is: 14 26 38 14 26 38 14 26 38. This gives the normal nine sample profiles.

JPR

JPR is a list of the j indices of the sample profiles of the adjusted winds to be plotted. Up to ten sample profiles are allowed. The first value in JPR is matched with the first value in IPR to give the horizontal grid indices of the first profile. Succeeding indices from each list are matched in a similar fashion. The default for JPR with a standard 51 by 51 by 15 MATHEW grid is: 14 14 14 26 26 26 38 38 38. This gives the normal nine sample profiles.

KABOVETOPO

KABOVETOPO is a list of k levels above terrain at which horizontal vector plots are to be produced. For a standard 51 by 51 by 15 MATHEW grid, up to fifteen levels may be plotted. The default value is two (2), giving a vector plot located 1*DELZ above terrain.

ISLICE

ISLICE is a list of i-indices at which vector plots of v-w component winds are to be produced. For a standard MATHEW grid having 51 by 51 by 15 points, up to 51 slices can be plotted. The default value is zero (0).

JSLICE

JSLICE is a list of j-indices at which vector plots of u-w component winds are to be produced. For a standard MATHEW grid having 51 by 51 by 15 points, up to 51 slices can be plotted. The default value is zero (0).

NVCTFQ

NVCTFQ allows the user to increase or decrease the density of vectors on the vector plots. A value of one (1) indicates that a vector is plotted at every horizontal grid point. A value of two indicates that a vector is to be plotted every other grid point, etc. The default is two (2).

Warning errors:	None
Fatal errors:	NVCTFQ < 0

SCLX

SCLX scales the size of the vectors on the vector plots in the x direction. The default value is 0.5.

Warning errors:	SCLX ≥ 25.0
Fatal errors:	SCLX ≤ 0.0

SCLY

SCLY scales the size of the vectors on the vector plots in the y direction. The default value is 0.5.

Warning errors:	SCLY ≥ 25.0
Fatal errors:	SCLY ≤ 0.0

SCLZ

SCLZ scales the size of the vectors on the vector plots in the z direction. The default value is 25.0.

Warning errors:	SCLZ $\geq$ 200.0
Fatal errors:	SCLZ $\leq$ 0.0

A MINV file of the following form is produced by a successful MEDIC run:

Data set number

NRUNNOW=

IGOOF=1

ZZZZZ

•
•
•

NRUNNOW=

IGOOF=1

ZZZZZ

NRUNNOW=

IGOOF=1 Last data set

ZZZZZ

IGOOF=999999

ZZZZZ

II.B.7. PICIN

PICIN is an input file to the ADPIC code which contains the source and editing information for an ARAC problem. Before ADPIC is run, either initially or as a restart, a PICIN file must be prepared.

Descriptions of all of the individual PICIN parameters follows:

Problem Title

70-character string which will appear as the title on the particle plots and in the echo file. This is not a namelist parameter and therefore has no parameter name, equal sign, or quotes; the contents of the first line of the PICIN file are simply assigned to a string. Do NOT omit this first line of the PICIN file.

BUZZ

Fraction that the time step may vary on gradient diffusion. When the advection component of the velocity is much less than the diffusion component, the particles will try to line up on grid lines. This is particularly true in the vertical. To help break up this alignment we have introduced "buzzing" (Busting Up Zee Zilly Incompetent Nonmovement Game). To accomplish this a small random movement is applied to the particle. BUZZ controls the amount of this small random movement.
(Default: BUZZ = 0.01)

DELTO

Floating point value specifying the value for the initial time step (seconds) for ADPIC; all succeeding time steps will be calculated by the code. ADPIC calculates the succeeding time steps such that a particle should not move more than one cell in that time step. DELTO is also used to generate a warning error ("Time step has decreased to x.xxxExx") whenever code-calculated time steps are less than DELTO/10.

DROP

Factor used to determine whether or not an ADPIC particle should be eliminated due to decreased mass or activity: If mass or activity is less than DROP times the original mass or activity of the ADPIC particle, then the particle is eliminated.
(Default: DROP = 0.001)

FRACT

The fraction of a cell a particle moving at the mean velocity is allowed to travel during one time step.
(Default: FRACT = 1.0)

FRSAMSZ

Vertical height of the sampling cell expressed as a fraction of DELZ.
(Default: FRSAMSZ = 1.0)

GGGG

Floating point value representing the acceleration of gravity used in Stokes Law. (Also see Section II.B.3.d for more information)

HALF

Array (dimension = number of ADPIC sources) of floating point values specifying the radioactive half-life (hours) of each ADPIC source.
Use HALF = 0 for all non-radioactive substances.

HINVSRCi

ADPIC source-specific (i = 1 to 9) time-varying arrays (1 to 50 different times, specified by IDATSRC and ITIMSRC parameters) of height (m) of strong inversion affecting plume rise. This is an optional parameter; if a value is input, plume rise for source will be limited by this height, but only in cases involving buoyancy plume rise and neutral/unstable stability classes. If a value is not input, the TOPML value serves this function, but only for cases of vertical plumes in neutral/unstable stability classes.

IDATMET

Array (1 to 50) of 6-digit integers (yymmdd) specifying the dates at which new values of the time-varying met parameters (ITIDIF, ITISTAB, TBMOLI, TSMOLI, TTOPML, TSIGTHFACT, TRRATE, and TQLAM) take effect.
Also see ITIMMET, which specifies the times.

IDATSRC

Array (1 to 50) of 6-digit integers (yymmdd) specifying the dates at which new values of the time-varying source parameters (TSRATEi and TZSCHi) take effect. Also see ITIMSRC, which specifies the times.

IDIF

Integer (1 to 6) specifying the type of diffusion scheme to be used in ADPIC. Values and the corresponding diffusion scheme are listed below:

IDIF = 1 -› presently not available

IDIF = 2 -› Idaho Falls MESODIF model (Gaussian).
Diffusion parameters Kz and Kh are bassed on Pasquill-Gifford sigma-z(x) and sigma-y(x) curves and stability categories. This IDIF is suitable for plumes on flat or nearly flat surfaces, or where no better diffusion data are available.
The stability category (ISTAB in WINDY) is the only information needed by ADPIC to specify the diffusion parameters. The horizontal diffusion parameter Kh reflects modification by INEL, Idaho Falls, to give larger horizontal diffusion (in a time-averaged sense) under stable conditions due to plume meander.

IDIF = 3 -› presently not available

The following statements apply to both IDIF's 4 and 5:
Generalized diffusion parameters are computed for the entire atmospheric boundary layer as a function of wind profile, stability, surface roughness, and mixing layer thickness. The following input parameters must be available from WINDY: stability category (ISTAB), inverse Monin-Obukhov length (SMOLI), top of mixing layer (TOPML), power law exponent in surface layer (PWRSL), and surface roughness height (SRH). The vertical diffusion coefficient Kz is based on Monin-Obukihov theory in the surface layer and on similarity theory in the outer mixing layer.

IDIF = 4 -› Gradient diffusion with with sigma-theta available.
The generalized diffusion parameters are also a function of the horizontal fluctuation of the wind direction (sigma-theta), input via the UPR parameter in the WINDY file. The horizontal diffusion coefficient Kh is based on Taylor's theory. This diffusion scheme is suitable for continuous and moderately elevated releases within the mixed layer where data are available.

IDIF = 5 -› Gradient diffusion without sigma-theta available.
The generalized diffusion parameters are also a function of the energy dissipation rate. The horizontal diffusion parameter Kh is based on scale-dependent diffusion. This diffusion scheme is suitable for continuous and instantaneous surface and elevated releases where horizontal diffusion is based on the atmospheric energy dissipation rate (epsilon).

IDIF = 6 -› presently not available

IDUMP

6-digit integer time interval (hhhhmm) at which data is output from ADPIC into a restart dump file (ADUMP.DAT). It therefore determines the times at which a problem can be restarted since the dump file contains all of the necessary information, i.e., coordinates of all of the particles. When a restart is initiated, each particle will begin to move from its last location. Since dumps are costly and create immense files, only three dumps are allowed per run. No dump (IDUMP = 0000) is usually made for an Initial calculation.

IEDIT

6-digit integer (hhhhmm) specifying the edit interval at which particle status information lines are written to the screen and to the echo file.
(Default: IEDIT = 0100 -› 1-hour edit interval)

IGOOF = 1
ZZZZZ

IGOOF is a flag to check for the end of the input parameters. ZZZZZ signals the end of PICIN input to be read. Comments may be placed after these two lines.

IOUT

6-digit integer (hhhhmm) specifying the output interval at which particle information is written to the DPOUTnn file.
(Default: IOUT = 0100 -› 1-hour dumps to the DPOUTnn file)

IOPT

Array (dimension = number of ADPIC output bins, maximum of 10) of integers representing the type of concentration output desired for the ADPIC output bins:

IOPT = 1 -› integrated air concentration
IOPT = 2 -› instantaneous air concentration
IOPT = 3 -› total ground deposition

IPLRIS

Array (dimension = number of ADPIC sources) of integer flags (0 or 1) indicating whether plume rise should be calculated for a specific source. If other plume rise parameters are present, but IPLRIS = 0, then the other parameters will be ignored.
(Default: IPLRIS = 0 -› no plume rise)

IPLT

6-digit integer (hhhhmm) specifying the time interval at which particle plots are written to the graphics file.
(Default: IPLT = 0100 -› 1-hour plot interval)

IRSRT

4-digit integer (hhmm) specifying the time relative to the problem start time (ISTRTTIM) when the rain is to start. This is used in conjunction with IRSTP (rain stop time) and QLAM (washout coefficient).

IRSTDAT

6-digit integer (yymmdd) specifying the restart date of the ADPIC calculation. This restart date/time MUST have a corresponding dump in the ADUMP file (see IDUMP description). Also see IRSTTIM, which specifies the time.
(IRSTDAT = 000000 for a non-restart run)

IRSTP

4-digit integer (hhmm) specifying the time relative to the problem start time (ISTRTTIM) when the rain is to stop. This is used in conjunction with IRSRT (rain start time) and QLAM (washout coefficient).

IRSTTIM

4-digit integer (hhmm) specifying the restart time of the ADPIC calculation. This restart date/time MUST have a corresponding dump in the ADUMP file (see IDUMP description). Also see IRSTDAT, which specifies the date.
(IRSTTIM = 0000 for a non-restart run)

IRUNTIM

6-digit integer (hhhhmm) specifying the time interval for the current ADPIC run. It is relative to ISTRTDAT & ISTRTTIM if it is not a restart run, and from IRSTDAT & IRSTTIM if it is a restart run. If the run time extends beyond the last WINDY met dataset, ADPIC will assume meteorological persistence for that period.

ISPEC

Array (dimension = number of ADPIC output bins, maximum of 10) of integer digit (1 to 9) strings. Each integer digit string represents a combination of ADPIC sources to be grouped into a single bin. For example if ISPEC = 12 13 123 2, four output bins would be produced for:

a) ADPIC sources 1 and 2 combined
b) ADPIC sources 1 and 3 combined
c) ADPIC sources 1, 2, and 3 combined
d) ADPIC source 2

ISSRT (******* recommend using IDATSRC and ITIMSRC instead *******)

Array (dimension = number of ADPIC sources) of integers (hhhhmm) specifying the release start time relative to the run start time (ISTRTDAT & ISTRTTIM for non-restart, IRSTDAT & IRSTTIM for restart) for each ADPIC source. Use of IDATSRC and ITIMSRC will override use of ISSRT. Use of IDATSRC and ITIMSRC instead of ISSRT is recommended because they are absolute times and allow for time-varying source rates.

ISSTP (******* recommend using IDATSRC and ITIMSRC instead *******)

Array (dimension = number of ADPIC sources) of integers (hhhhmm) specifying the release stop time relative to the run start time (ISTRTDAT & ISTRTTIM for non-restart, IRSTDAT & IRSTTIM for restart) for each ADPIC source. Use of IDATSRC and ITIMSRC will override use of ISSTP. Use of IDATSRC and ITIMSRC instead of ISSTP is recommended because they are absolute times and allow for time-varying source rates.

ISTRTDAT

6-digit integer (yymmdd) specifying the start date of the ADPIC calculation. Note that this value remains unchanged from the original run to a restart run.

ISTRTTIM

4-digit integer (hhmm) specifying the start time of the ADPIC calculation. Note that this value remains unchanged from the original run to a restart run.

ITIDIF

Time-varying array (1 to 50 different times, specified by IDATMET and ITIMMET parameters) of integers (1 to 6) representing the diffusion scheme to be used (see IDIF description). ITIDIF will override IDIF.

ITIMMET

Array (1 to 50) of 6-digit integers (hhhhmm) specifying the times at which new values of the time-varying met parameters (ITIDIF, ITISTAB, TBMOLI, TSMOLI, TTOPML, TSIGTHFACT, TRRATE, and TQLAM) take effect. Also see IDATMET, which specifies the dates.

ITIMSRC

Array (1 to 50) of 6-digit integers (hhhhmm) specifying the times at which new values of the time-varying source parameters (TSRATEi and TZSCHi) take effect. Also see IDATSRC, which specifies the dates.

ITISTAB

Time-varying array (1 to 50 different times, specified by IDATMET and ITIMMET parameters) of integers (1 to 6) representing the Pasquill-Gifford stability category to be used (see the ISTAB parameter description in the WINDY input file section). ITISTAB will override ISTAB.

ITOT

Array (dimension = number of ADPIC sources) of integers specifying the total number of particles to be generated for each ADPIC source. ITOT is used to calculate the particle release rate. Although ADPIC allows a total maximum of 20,000 particles from all sources at any given time, a continuous release with particle depletion (via deposition, advection, and upward diffusion) can easily release more than 20,000 particles without exceeding this limit at any one time. However, if this maximum is exceeded, ADPIC will redistribute the mass or activity evenly among the 20,000 particles. Particles will be removed from the grid via deposition, advection, or upward diffusion. (Recommended values: ITOT = 3000 for multi-species, ITOT = 5000 for single species)

KLEAK

Integer flag (1 or 0) which determines whether or not particles will be allowed to "leak" through the top of the mixed layer instead of being reflected. (Default: KLEAK = 0 -› no leakage, i.e., particles are reflected back into the mixed layer)

NPOP

Integer representing the maximum number of cells that a particle can pop up. There is a tendency for particles to impact with topography in complex terrain. In order to help alleviate this problem we have introduced "pop up" (Proceeding Over Places of Unfortunate Placement) to get the particles back out into the flow field. Pop up involves moving the particle up one cell at a time in the vertical until the particle has either cleared topography or has reached the limit of vertical movement. If this limit has been reached, the particle is moved only with the velocity component parallel to the topography. This change will allow the particle to either move over or around the topography. NPOP specifies the limit of cells a particle is allowed to pop up.
(Default: NPOP = 1)

NVEL

Array (dimension = number of VEL files, maximum = 10) of integers, each integer specifying the number of met datasets (1 to 6) contained in each VEL file. Persistence will be used if the run extends beyond the last met dataset specified.

OQNSH

Used as a multiplier to QNSH, which determines how long an ADPIC particle remains a source particle.
(Also see OQNSV.)
(Default: OQNSH = 1.0)

OQNSV

Used as a multiplier to QNSV, which determines how long an ADPIC particle remains a source particle.
(Also see OQNSH.)
(Default: OQNSV = 1.0)

PADV

Flag (1.0 or 0.0) which controls the printing of advection velocities in echo file as they are read from the VELnn file.
(Default: PADV = 0.0 -› don't print advection velocities)

PBINS

Flag (1.0 or 0.0) which controls the printing of sampling bin concentrations to the echo file at each IEDIT interval.
(Default: PBINS = 0.0 -› don't print sampling bin concentrations)

PCORD

Flag (1.0 or 0.0) which controls the printing of particle coordinates in echo file at each IEDIT interval.
(Default: PCORD = 0.0 -› don't print particle coordinates)

PCONC

Flag (1.0 or 0.0) which controls the printing of cell concentrations in echo file at each IEDIT interval.
(Default: PCONC = 1.0 -› print cell concentrations)

PFRTNVEL

Flag (1.0 or 0.0) which controls the printing of friction velocities in the echo file at each IEDIT interval.
(Default: PRFRTNVEL = 0.0 -› don't print friction velocities)

PKYKZ

Flag (1.0 or 0.0) which controls the printing (to the echo file) of horizontal and vertical diffusion coeffients (Kh and Kz) at each grid point over the portion of the grid that contains particles.
(Default: PKYKZ = 0.0 -› don't print Kh and Kz)

PRHO

Array (dimension = number of ADPIC sources, maximum of 9) of floating point values specifying the particle density (kg/m3) for each ADPIC source. PRHO is usually a value that has been normalized to 1 g/cc = 1000 kg/m3, but the actual particle density may also be used. Note that the PRHO chosen should be consistent with the values for SAVE, SMIN, and SMAX. (Default: PRHO = 1000. -› 1 g/cc)

PTOP

Flag (1.0 or 0.0) which controls the printing of topography in echo file at beginning of problem.
(Default: PTOP = 1.0 -› print topography)

PVEL

Flag (1.0 or 0.0) which controls the printing of all velocities in echo file at each IEDIT interval.
(Default: PVEL = 0.0 -› don't print velocities)

QLAM

Washout coefficient for rainout calculations. QLAM must be accompanied by entries for IRSRT and IRSTP. Also see description for TQLAM for time-varying washout coefficients.

QSRC

Array (dimension = number of ADPIC sources) of floating point values specifying the sensible heat emission rate (MW) for each ADPIC source. This is an optional parameter used (only if TSRC is not input) to calculate buoyancy flux in plume rise calculations. Typical values might be 0.01 to 100 MW.

RRATE

Floating point value specifying the rain rate (mm/hr) to be used. (Note: this parameter is not currently available.)

RSRC

Array (dimension = number of ADPIC sources) of floating point values specifying the internal stack radius (m) for each ADPIC source. This is used to calculate buoyancy flux and momentum flux for plume rise calculations. It is NOT used to specify the initial source geometry. The parmeters ZT, ZB, XR, XL, YR, YL, SIGX, SIGY, and SIGZ are always used for this and should be consistent with RSRC. Typical values are 1 to 5 m.

SAMHGT

Array (dimension = number of ADPIC output bins, maximum of 10) of floating point values specifying the heights (m) above ground at which the output bin contents (determined by ISPEC and IOPT) are to be calculated. For example: a) if inhalation doses or concentrations are desired, a SAMHGT value of 1.5m (breathing height) would be used; b) if concentrations at stack heights or flight levels are desired, a SAMHGT equal to the height of interest would be used; c) for ground deposition, a SAMHGT of 0.0m would be used.

SAVE

Array (dimension = number of ADPIC sources) of floating point values specifying the effluent particle size median radius (um) for each ADPIC source. If there is no particular range of particle sizes, use SAVE of zero, which will result in a zero gravitational settling velocity.
Typical values are:

SAVE = 20.0 -› Pu HE detonation, based upon CS-I data
SAVE = 0.3 -› Pu fire, based upon Rocky Flats data
SAVE = 0.0 -› passive pollutant (gases, smoke,...)

SGD

Array (dimension = number of ADPIC sources) of floating point values specifying the standard geometric deviation of the log-normal particle size distribution for each ADPIC source, and is defined as the following ratio:

$$\frac{\text{radius at 50\%}}{\text{radius at 16\%}} \quad \text{or} \quad \frac{\text{radius at 84\%}}{\text{radius at 50\%}}$$

on a log-normal frequency distribution plot. If SAVE is set to zero, no entry is required for SGD.
Typical values are:

SGD = 5.71 -› Pu HE detonation, based upon CS-I data
SGD = 3.0 -› Pu fire, based upon Rocky Flats data

SIGX

Array (dimension = number of ADPIC sources, maximum of 9) of floating point values specifying the horizontal standard deviation (m) in the X-direction (East-West) of the initial stabilized source geometry for each ADPIC source.

SIGY

Array (dimension = number of ADPIC sources, maximum of 9) of floating point values specifying the horizontal standard deviation (m) in the Y-direction (North-South) of the initial stabilized source geometry for each ADPIC source.

SIGZ

Array (dimension = number of ADPIC sources, maximum of 9) of floating point values specifying the vertical standard deviation (m) of the initial stabilized source geometry for each ADPIC source.

SMAX

Array (dimension = number of ADPIC sources) of floating point values specifying the largest particle radius (um) of the effluent. It is usually taked to be two orders of magnitude greater than SAVE. (Note: The terminal fall velocities for those particles falling outside the realm of validity of Stoke's Law, i.e., Reynolds number greater than one, are calculated using an algorithm derived from McDonald's computational aid for the terminal fall velocity of spheres. See Section II.B.3.d for more information.)
If SAVE is set to zero, no entry is required for SMAX.
Typical values are:
SMAX = 100.0 -› Pu HE detonation, based upon CS-I data
SMAX = 100.0 -› Pu fire, based upon Rocky Flats data

SMIN

Array (dimension = number of ADPIC sources) of floating point values specifying the smallest particle radius (um) of the effluent. It is usually taked to be two orders of magnitude less than SAVE. If SAVE is set to zero, no entry is required for SMIN.
Typical values are:
SMIN = 0.1 -› Pu HE detonation, based upon CS-I data
SMIN = 0.1 -› Pu fire, based upon Rocky Flats data

SPECIES

Array (dimension = number of ADPIC sources, maximum of 9) of 10-character strings specifying the name of the effluent for each ADPIC source.

SRATE (******* Use of TSRATEi is recommended *******)

Array (dimension = number of ADPIC sources, maximum of 9) of floating point values specifying the source rate for each ADPIC source. The actual units of the bin contents to be plotted by PLCNT are determined by a combination of SRATE, DCON (a CPLIN parameter), and the ADPIC model units. See the description for DCON in the CPLIN section of this User's Guide for a more complete discussion of the interrelation of these parameters.
Use of TSRATEi will override SRATE, and is recommended because it allows for time-varying source rates.

TAMBSRCi

ADPIC source-specific (i = 1 to 9) time-varying arrays (1 to 50 different times, specified by IDATSRC and ITIMSRC parameters) of ambient air temperature (K).
(Default: TAMBSRCi = 288.)

TBMOLI

Time-varying array (1 to 50 different times, specified by IDATMET and ITIMMET parameters) of floating point values specifying the boundary layer inverse Monin-Obukhov length to be used (see the BMOLI parameter description in the WINDY input file section). TBMOLI will override BMOLI.

TQLAM

Time-varying array (1 to 50 different times, specified by IDATMET and ITIMMET parameters) of floating point values specifying the washout coefficients to be used for rainout calculations (see the QLAM parameter description). TQLAM will override QLAM values.

TRRATE

Time-varying array (1 to 50 different times, specified by IDATMET and ITIMMET parameters) of floating point values specifying the rain rate (mm/hr) to be used (see the RRATE parameter description). TRRATE will override RRATE. (Note: this parameter is not currently used by ADPIC.)

TSIGTHFACT

Time-varying array (1 to 50 different times, specified by IDATMET and ITIMMET parameters) of floating point values specifying the multiplier used to scale the sigma theta values (see the UPR parameter description in the WINDY input file section, and also the IDIF parameter).

TSMOLI

Time-varying array (1 to 50 different times, specified by IDATMET and ITIMMET parameters) of floating point values specifying the surface layer inverse Monin-Obukhov length to be used (see the SMOLI parameter description in the WINDY input file section). TSMOLI will override SMOLI.

TSRATEi

ADPIC source-specific (i = 1 to 9) time-varying arrays (1 to 50 different times, specified by IDATSRC and ITIMSRC parameters) of floating point values specifying the source rate. The actual units of the bin contents to be plotted by PLCNT are determined by a combination of TSRATEi, DCON (a CPLIN parameter), and the ADPIC internal units. See the description for DCON in the CPLIN section of this User's Guide for a more complete discussion of the interrelation of these parameters. Use of TSRATEi will override SRATE, and is recommended because it allows for time-varying source rates.

TSRC

Array (dimension = number of ADPIC sources) of values specifying the temperature (degrees K) of the gas emitted from the stack of each ADPIC source. Used to calculate buoyancy flux for plume rise calcualtions.

TTOPML

Time-varying array (1 to 50 different times, specified by IDATMET and ITIMMET parameters) of floating point values specifying the height (m) above ground of the mixed layer to be used (see the TOPML parameter description in the WINDY input file section). TTOPML will override TOPML specified in the WINDY file.

TZSCHi

ADPIC source-specific (i = 1 to 9) time-varying arrays (1 to 50 different times, specified by IDATSRC and ITIMSRC parameters) of floating point values specifying the height (m) above terrain of the source center. TZSCHi entries will override any ZSCH entries.

UCLM

Floating point value representing the minimum value (m/s) for calm winds in friction velocity calculations.
The friction velocity is computed at every grid point, and is dependent on the advection at each of these grid points. An advection velocity of zero will produce a similar friction velocity, which in turn causes the diffusion to go to zero. In order to be able to simulate calm conditions, UCLM is used to compute the diffusion whenever the advection has a lower value than UCLM.
(Default: UCLM = 0.2)

VGRDSRCi

ADPIC source-specific (i = 1 to 9) time-varying arrays (1 to 50 different times, specified by IDATSRC and ITIMSRC parameters) of vertical temperature gradient (K/m) for use in plume rise calculations. Used to calculate the Brunt-Vaisalla frequency. Defaults are provided in ADPIC for each stability class if a value is not input. (Note: The adiabatic, neutral temperature gradient is -0.0098 K/m. The standard atmosphere temperature gradient is -0.0065 K/m)

VDEP

Array (dimension = number of ADPIC sources) of floating point values specifying the surface deposition velocity (m/s) of the effluent. This is not a gravitational settling velocity, but rather a measure of the affinity of the material for the ground. VDEP is a function of particle size, atmospheric stability, and surface roughness height. VDEP is only used in the bottom grid cell to deposit particles onto the ground, and is weighted according to the distance from the bottom of the cell (i.e., zero at the top of the cell to full value at the bottom). The only mechanisms by which particles or a portion of the particle activity can be removed from the atmosphere and deposited on the ground are via VDEP, rainout, and gravitational settling. Experimental data have shown that VDEP usually lies between 0.001 and 0.05 m/s:

Particulate Effluent	VDEP (m/s)
Pu-238, Pu-239	0.001 - 0.01
SO2, Ru	0.01 - 0.03 (0.028)
Cs-137, Sr-90	0.001 - 0.002
I-131	0.003
Inert particles	0.001 - 0.002
HTO	0.005 - 0.008

VISC

Floating point value representing the dynamic viscosity used in Stokes Law. (Also see Section II.B.3.d for more information)

WSRC

Array (dimension = number of ADPIC sources) of floating point values specifying the vertical exit velocity (m/s) of the gas emitted from the stack of each ADPIC source. Used in the plume rise calculation of buoyancy flux and momentum flux. Normal range of values are 3 to 50 m/sec. Any value less than or equal to 2 m/sec is treated as zero. The ratio of horizontal wind velocity at the source location to the vertical exit velocity is used to determine if vertical plume equations or bent-over plume equations are used. If that ratio is less than 0.1, then vertical plume equations are used.

WVEL

Flag (1.0 or 0.0) which primarily determines whether regional-scale or hemispheric-scale diffusion coefficients are to be used. This flag also controls some other micellaneous things concerning the plot appearance, such as the existence of the north arrow.
are used. (Note: WVEL = 0.0 required for HADPIC for hemispheric-scale diffusion coefficients)
(Default: WVEL = 1.0 -› use regional-scale diffusion coefficients)

XL
--

Array (dimension = number of ADPIC sources, maximum of 9) of floating point values specifying the radial cutoff of the initial stabilized source geometry in the negative X-direction (i.e., to the West or "left"), referenced to the source center (XSC) for each ADPIC source.
(Note: since this is distance is reference to the source center, XL should have a negative value.)

XR
--

Array (dimension = number of ADPIC sources, maximum of 9) of floating point values specifying the radial cutoff of the initial stabilized source geometry in the positive X-direction (i.e., to the East or "right"), referenced to the source center (XSC) for each ADPIC source.

XSC

Array (dimension = number of ADPIC sources, maximum of 9) of floating point values specifying the UTM easting coordinate (km) of the source center. Note: Both XSC and YSC must be no closer than 3 grid cells from the edges of the ADPIC grid.

YL
--

Array (dimension = number of ADPIC sources, maximum of 9) of floating point values specifying the radial cutoff of the initial stabilized source geometry in the negative Y-direction (i.e., to the South or "left"), referenced to the source center (YSC) for each ADPIC source.
(Note: since this is distance is reference to the source center, YL should have a negative value.)

YR
--

Array (dimension = number of ADPIC sources, maximum of 9) of floating point values specifying the radial cutoff of the initial stabilized source geometry in the positive Y-direction (i.e., to the North or "right"), referenced to the source center (YSC) for each ADPIC source.

YSC

Array (dimension = number of ADPIC sources, maximum of 9) of floating point values specifying the UTM northing coordinate (km) of the source center. Note: Both XSC and YSC must be no closer than 3 grid cells from the edges of the ADPIC grid.

ZB
--

Array (dimension = number of ADPIC sources, maximum of 9) of floating point values specifying the radial cutoff of the initial stabilized source geometry in the negative Z-direction (i.e., downward or to the "bottom"), referenced to the source center height (ZSCH) for each ADPIC source. (Note: since this is distance is reference to the source center height, ZB should have a negative value.)

ZSCH

Array (dimension = number of ADPIC sources, maximum of 9) of floating point values specifying the height (m) above terrain of the source center. If a time-varying ZSCH is required, then TZSCHn should be used instead of ZSCH in PICIN, or it may be entered in the WINDY file. The time-varying entries will override any ZSCH entries.

ZT
--

Array (dimension = number of ADPIC sources, maximum of 9) of floating point values specifying the radial cutoff of the initial stabilized source geometry in the positive Z-direction (i.e., upward or to the "top"), referenced to the source center height (ZSCH) for each ADPIC source.

ZUB

Height (m) of mean wind used to compute friction velocity. (Default: ZUB = 10.0)

PICIN INPUT FILE FORM

Hollerith title for this run (max=70 characters)

Starting Time — Length of running time

yymmdd — hhmm — hhmm

ISTRTDAT= ISTRTTIM= IRUNTIM=

Dump interval — Time of restart — Initial time

hhmm — yymmdd — hhmm — step—s

IDUMP= IRSTDAT= IRSTTIM= DELT0=

Type of diffusion parameter — Number of data sets in each VELnn file

IDIF= NVEL=

Source species name (up to 10 characters)

SPECIES= ' ' ' ' ' ' ' ' ' '

Source σ_x—m

SIGX=

Source σ_y—m

SIGY=

Source σ_z—m

SIGZ=

Source X-right cutoff—m

XR=

Source X-left cutoff—m

XL=

Source Y-right cutoff—m

YR=

Source Y-left cutoff—m

YL=

Source Z-top cutoff—m

ZT=

Source Z-bottom cutoff—m

ZB=

Source center height above terrain—m

ZSCH=

UTM easting coordinate of source center—km

XSC=

UTM northing coordinate of source center—km

YSC=

Source start time—hhmm

ISSRT=

Source stop time—hhmm
ISSTP=
Source rate
SRATE=
Total number of particles assigned to each source
ITOT=
Activity descriptor—hr
HALF=
Surface deposition velocity—m/s
VDEP=
Particle size median radius—μm
(for no particle size distribution SAVE=0)
SAVE=
Standard geometric deviation of particle (if SAVE=0., input 0.)
SGD=
Largest particle radius—μm (if SAVE=0., input 0.)
SMAX=
Smallest particle radius—μm (if SAVE=0., input 0.)
SMIN=

Output options for PICIN

ISPEC= Species number (1-9) using source specification order
IOPT= Output type
SAMHGT= Height above terrain at which output is to be calculated—m

IGOOF=1

ZZZZZ
IOPT: 1. integrated air concentrations
2. instantaneous air concentrations
3. total deposition

II.B.8. CPLIN

CPLIN is the input file that directs a PLCNT run. It contains timing information on when (and over what interval) to produce a set of concentration isopleths. Re-expression or factoring of a result through the parameter DCON may also be done. The basic format of the contour plot is determined by the parameters LDESCRFMTn and XYTICKLBL, with CIRCL2000, NOTESBANR, and TITLEGEOG also contributing.

CPLIN is currently also the input file for a TIMHIS run. In addition to SLOTn, UNITSn, ADPTODOSE, DOSETOCON, and the DCON parameters which are also used by PLCNT, the time-history-specific parameters for a TIMHIS run are listed at the end of this section.

Problem Title

The first line of the CPLIN file no longer appears on the plots. However, it is still in the CPLIN file and read by PLCNT and written to the first line of the ECHOPLOT file. It also currently appears in the title field in the expanded plot description on the Site System.
(Default: none -- required to be first line in CPLIN file.)

ADPTODOSE

Array (array dimension = number of dose bins, maximum of 30) of integers (values = ADPIC bin numbers) specifying which ADPIC bin (1 to 10) goes into which dose bin, i.e., the "ADPic TO DOSE" bin mapping.
For example, if the same ADPIC bin were put into three different dose bins, different dose conversion factors (DCON's) could be applied to each dose bin (for example: whole body dose, child thyroid dose, and air concentration) without having to have separate ADPIC bins. (Also see DOSETOCON.)
(Default: ADPTODOSE = 1 2 3 4 5 6 7 8 9 10 -› one dose bin for each ADPIC bin, with the dose bins in the same order as the ADPIC bins)

AREAMAX

Real number representing minimum area in sq-km that will be plotted and shown in the legend. This will eliminate any contour levels specified by CONTRLVLSn which do not meet the AREAMAX requirement. (Also see CONTRLVLSn)
(Default = 0.1% of grid area)

BLOWUPSRC

An integer (1 to 9) specifying the number of the ADPIC source whose location is to be placed as indicated by SRCOCTANT.

CIRCL2000

Boolean flag ('Y' or 'N') specifying whether or not the 2000ft blast effects circle will be plotted at the release location.
(CIRCL2000 = 'Y' is required for DOD plots.)

CONTRLVLSn

Array (maximum size = 5) of specific contour levels to be plotted for each specified contour bin (n = 1 to 30).
The CONTRLVLSn parameter is required for DOD and AWE plots:

```
CONTRLVLSn = 150.  25.  5.  0.5   (DOD CEWBDE)
CONTRLVLSn = 600.  60.  6.        (DOD depostition)
CONTRLVLSn = 4.7   0.94 0.78 0.15 (AWE 50yr CEWBDE)
CONTRLVLSn = 20.0  2.0  0.2  0.03 (AWE depostition)
```

Contour levels specified by CONTRLVLSn that do not meet the AREAMAX requirement will not be plotted. If none of the levels specified for a contour bin meet the AREAMAX requirement, then PLCNT will pick its own levels.
(If CONTRLVLSn is not specified, PLCNT will pick its own contour levels, based upon the AREAMAX requirement.

DCON

Array of values, each of which act as a numerical multiplier to the concentrations calculated by ADPIC for a dose bin. The size of the array is required to be equal to the number of dose bins (maximum of 30) specified in ADPTODOSE.
The DCON parameter must either be specified completely or be omitted, in which case the concentrations in the dose bins remain unchanged.
The actual units of the bin contents to be plotted by PLCNT are determined by a combination of SRATE (a PICIN parameter), DCON, and the ADPIC model units:

actual units = (SRATE) * (DCON) * (ADPIC model units)

There are several possible combinations involving SRATE and DCON; below are four of the most common:

1) SRATE = actual source rate (e.g., g/s or Ci/s),
   DCON = dose conversion factor (dcf)
2) SRATE = unit source rate in 1/s,
   DCON = dcf and the actual amount (e.g., g or Ci)
3) SRATE = unit amount (instead of a rate),
   DCON = dcf * actual source rate (e.g., g/s or Ci/s)
4) SRATE = dcf * actual source rate (e.g., g/s or Ci/s)
   DCON = 1

Combination #3 is the one used by the model parameters system. Combination #4 is currently necessary when dose plots for multi-nuclides are desired.

DOSETOCONn

Array (maximum size = 30) of integers (values = dose bin numbers) specifying which dose bin numbers will be combined into contour bin "n", i.e., the "DOSE TO CONtour" bin correlation. This allows for specification of the combination of dose bins to be delayed until PLCNT, as well as allowing for the re-use of the dose bins. (Also see ADPTODOSE.)

GENTIME

13-character string (ddMMMyyyyhhmm) labelled as the generation time of a set of plots in the second or third line of the plot legend.
Note that this time is not currently the same as the generation time in the product description record.
(Default: GENTIME = current system time if the parameter is missing or blank.)

GEOGNEW

Flag (0. or 1.) for forcing a new geography file to be produced for overlaying with the contour plot.
(Default: GEOGNEW = 0. -› do not create a new geography file if one exists that covers the same area.)

IGOOF = 1
ZZZZZ

IGOOF is a flag to check for processing of input parameters. ZZZZZ signals the end of CPLIN input to be read. Comments may be placed after these two lines.

INITIAL

Flag used to indicated an initial calculation. The fact that this is an Initial calculation will be part of the plot description record. (Note: the sending of the description and graphics files is now controlled interactively in Show_Site_Plot.)

LDESCRFMTn

Contour bin-specific (n = 1 to 30) 5-character string specifying the format to be used in displaying the cross-hatching and area information in the plot legend. Current values and meanings are:

'3LINE' -› use 3-line DOD action level format
'CODED' -› use 2-character coded format which does not include the isopleth value (used for AWE)
'NONE ' -› no coding or action level descriptions

LDESCRHDRnt

This is a 2-line (t = A to B) header which is contour bin-specific (n = 1 to 30). This 2-line header (each line consists a 32-character string) appears on lines 11 and 12 in the plot legend, which is immediately above the cross-hatching section of the legend.
(Usual values: LDESCRHDRnA = 'Exposure Action Levels: ' for DOD sites and LDESCRHDRnA = 'Contours: ' for other sites; LDESCRHDRnB = '(Level and Area Covered) ' for all sites.

LEGTITLEn

32-character string for a specific contour bin (n = 1 to 30), which appears on first line of legend on right side of plot. Alternately, one legend title can be used for all contour bins/plots by omitting the contour bin number in the parameter name.
(Default: LEGTITLE = ' '.)

LEVnDESCRit

Character strings describing emergency or protective actions associated with a given contour level (specified by CONTRLVLn). There are a maximum of three (t = A, B and C) 32-character strings each for each of 5 contour levels (i = 1 to 5) for each of 30 contour bins (n = 1 to 30). The maximum combination of character strings may be used for LDESCRFMTn = '3LINE', while only the first two characters of the LEVnDESCRiA strings are used for LDESCRFMTn = 'CODED'. LEVnDESCRit is not used for LDESCRFMTn = 'NONE '. Below is an example for LDESCRFMTn = '3LINE':

```
LEV1DESCR1A =  'Immediate respiratory protection'
LEV1DESCR1B =  'and evacuation recommended.      '
LEV1DESCR1C =  '                                 '

LEV1DESCR2A =  'Prompt action required;          '
LEV1DESCR2B =  'respiratory protection required;'
LEV1DESCR2C =  'consider shelter or evacuation.  '

LEV1DESCR3A =  'Respiratory protection required,'
LEV1DESCR3B =  'recommend sheltering,            '
LEV1DESCR3C =  'consider evacuation.             '

LEV1DESCR4A =  'Consider sheltering.             '
LEV1DESCR4B =  '                                 '
LEV1DESCR4C =  '                                 '

LEV1DESCR5A =  '                                 '
LEV1DESCR5B =  '                                 '
LEV1DESCR5C =  '                                 '
```

MAPSCALE

A two-element integer array specifying the map scale to be used. The first element represents a unit of actual distance on the map and the second element is the corresponding actual physical distance. For example a map scale of 1:50,000 means that 1 inch on the map represents 50,000 inches of actual physical distance, and MAPSCALE = 1 50000. This parameter is is ignored if MAPSCLFLGn = 'N' for all contour bins.

MAPSCLFLGn

Contour bin-specific (n=1 to 30) flag ('Y' or 'N') indicates whether or not the specified map scale is to be applied to this bin (n). (Default: MAPSCLFLGn = 'N')

MATERIALn

22-character string specifying the material or species for a specified contour bin (n = 1 to 30) that is to appear in the 10th line of plot legend. (Note: the bin number is required.)

MAXCONTRSn

Contour bin-specific (n = 1 to 30) integer maximum number (1 to 5) of contour levels to be plotted and shown in legend.

NESTCNTRS

Boolean flag ('Y' or 'N') which determines whether the nested grid or the coarse sampling grid is to be used for contouring.
(Default: NESTCNTRS = 'Y' -› used nested grid.)

NESTTYPE

10-character string which specifies if and how the nested grids are shown on the contour plots. Current values and meanings are:
'NONE ' -› no nesting stuff drawn
'BOUNDARIES' -› boundaries of nested grids drawn
'CELLS ' -› grid cells and boundaries of nested grids drawn

NOCONT

Flag (0 or 1) for plotting contour plots. This parameter was used before the days of TIMHIS when only time history plots were desired.
(Default: NOCONT = 0 -› plot contours.)

NOPRINT

Flag (0 or 1) for writing cell concentrations to the echo file.
(Default: NOPRINT = 0 -› none written.)

NOTESBANR

Boolean flag ('Y' or 'N') specifying whether or not the "SEE NOTES" banner is written diagonally across the graphics portion of the plot.
(NOTESBANR = 'Y' is required for DOD plots.)

PCONC

Flag (0. or 1.) which controls the printing of the input concentrations to the echo file.
(Default: PCONC = 0. -› none are written.)

PLOTDESCn

32-Character contour bin-specific (n = 1 to 30) string which will appear in the "one-line plot description" in the scrolling regions used to select plots in VAXDSPLAY and also on the Site System.
(Defaults: PLOTDESCn = PLOTTITLEn.)

PLTSIZCM

A real number specifying the size (cm) of the resulting plot as it would appear on the hardcopy device. Values of PLTSIZCM for various hardcopy devices are listed below:

```
PLTSIZCM = 15.2  for LASER1 (ARAC Center QMS)
PLTSIZCM = 15.2  for LTA21 (T1735 Talaris 1500)
PLTSIZCM = 15.3  for LaserWriterII (VTerm-Pro)
PLTSIZCM = 8.5   for LA50 - Print Screen
PLTSIZCM = 12.6  for LA50 - Print Graphics
PLTSIZCM = 13.0  for Tek 4693 RGB
```

PLOTTITLEn

32-character string for a specified contour bin (n = 1 to 30) which will appear in the 2nd line of the plot legend. This string will also appear across the top of the graphics section if TITLEGEOG = 'Y'.
(Default = blank string for 'DOD ', following hardwired strings for ACTGUIDE = 'NONE': 'INTEGRATED CONCENTRATION', 'INSTANTANEOUS CONCENTRATION', 'CUMULATIVE DEPOSITION' will be assigned.)

REMARKSnt

For each contour bin (n = 1 to 30) there can be up to 4 lines (t = A to D) of remarks. Each line consists of a 32-character string. Alternately, the same remarks line can be used for all contour bins/plots by omitting the bin number in the parameter name. The first line (t = A) usually begins with the characters 'REMARKS:'

RESPEND

Flag (0. or 1.) which controls whether a single deposition contour (whose value = 10% of maximum concentration) is computed for representing the resuspension source area, and the RSUSGEO file is created in preparation for a resuspension calculation.
(Default: RESPEND = 0. -› neither the resuspension contour is drawn, nor is the RSUSGEO file created.)

SLOTn

An array of 3 (or multiples of 3 up to 15) real numbers which specifies when contours are to be plotted for the specified contour bin (n = 1 to 30). The 3 numbers are a date (yymmdd.), a time (hhmm.), and a time interval in hours. The first date and time specifies the time of the first plot to be made, and the first interval specifies the plot interval (and also the integration or deposition time if applicable) for the first plot. A positive interval represents a cumulative integration or deposition, while a negative interval represents a integration or deposition only over the interval. (The sign of the interval does not affect instantaneous plots.) Plots will continue to be generated at the interval specified unless an additional set of date-time-interval is specified (which must be chronologically later than its predecessor).

Example #1 (cumulative integration):

SLOT1 = 890501. 1247. 0.5

Plots would be generated for 1247z and every half hour thereafter for all plot types (integrated, instantaneous, and deposition). If the type of plot were integrated, the first plot would be integrated from 1217z to 1247z, the second plot from 1217z to 1317z, the third plot from 1217z to 1347z, etc.

Example #2 (interval integration):

SLOT1 = 890501. 1247. -0.5

Plots would be generated for 1247z and every half hour thereafter for all plot types. If the type of plot were integrated, the first plot would be integrated from 1217z to 1247z, the second plot from 1247z to 1317z, the third plot from 1317z to 1347z, etc.

Example #3 (changing intervals):

SLOT1 = 890501. 1447. 2.5 890501. 1517. 0.5

Plots would be generated for the first time specified (1447z) and every 2.5 hours thereafter until the second time and interval is reached. Plots would be generated for 1447z (if applicable, integrated from 1217z to 1447z), 1517z (if applicable, integrated from 1217z to 1517z), 1547 (if applicable, integrated from 1217z to 1547z), etc.

SRCLOCNUM

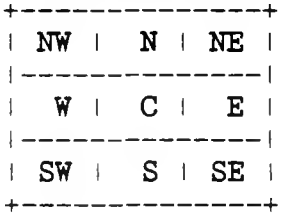
Integer (0 to 9) representing the ADPIC source number for which the location of the source should be displayed in the plot legend.
For example, "SRCLOCNUM = 1" will result in location of ADPIC source number 1 being written in legend. (Also see SRCLOCTYP.)
(Default: SRCLOCNUM = 0 -› no location is written in the legend.)

SRCLOCTYP

6-character string ('XY ' or 'LATLON') indicating whether the source location is to be displayed as UTM's or latitude/longitude. (Also see SRCLOCNUM.)
(Default: SRCLOCTYP = 'LATLON' --› latitude/longitude location)

SRCOCTANT

2-character string ('NW','N ','NE','W ','C ','E ','SW','S ','SE') specifying the desired placement of the source within the first subplot when scaling maps (MAPSCLFLGn = 'Y'). The following diagram indicates the two character codes corresponding to the allowed locations:



TITLEGEOG

Boolean flag ('Y' or 'N') specifying whether or not the PLOTTITLEn string is to appear at the top of the graphics portion (left side) of the plot.
(TITLEGEOG = 'Y' is required for DOD plots.)

UNITSn

10-character string specifying the units of the concentrations of the specified contour bin (n = 1 to 30) that appear on the plots.
(Default: UNITSn = ' '.)

XXMAX

Real number specifying the maximum UTM Easting of the area to be windowed. Used in conjunction with XXMIN, YYMIN, and YYMAX.
(Default: none, i.e., no windowing.)

XXMIN

Real number specifying the minimum UTM Easting of the area to be windowed. Used in conjunction with XXMAX, YYMIN, and YYMAX.
(Default: none, i.e., no windowing.)

XYTICKLBL

Boolean flag ('Y' or 'N') specifying whether or not UTM tick marks and labels are to appear on the bottom and left sides of the plot at the time of screen display on the Central System and on hardcopies produced by the Central System; i.e., the tick marks are not part of the graphics file, but are generated separately by VAXDSPLAY and are never sent to a Site System. This parameter is only used by PLCNT to pass on to VAXDSPLAY.
(XYTICKLBL = 'N' is the usual value.)

YYMAX

Real number specifying the maximum UTM Northing of the area to be windowed. Used in conjunction with XXMIN, XXMAN, and YYMIN.
(Default: none, i.e., no windowing.)

YYMIN

Real number specifying the minimum UTM Northing of the area to be windowed. Used in conjunction with XXMIN, XXMAN, and YYMAX.
(Default: none, i.e., no windowing.)

Additional parameters for use with TIMHIS:

NRPERPLT

Integer number (maximum of 50) of data points (corresponding to IOUT dumps) to be plotted on each frame of the time history plots.

SAMINFO

2-D array of real numbers used to specify the sampler info (sampler number, contour bin number, sampler UTME location, sampler UTMN location, date of measurement, time of measurement, and measurement value) for a maximum of 65 samplers. Only one bin number can be specified for each sampler listed in SAMNAM. Although "-1." may be specified for missing measurement values, the measurement date and time must always be specified.
For example:

```
SAMNAM = '#1' '#2' '#3'
SAMINFO = 1.  1.  405. 2345. 890501. 1200. -1.
          2.  1.  406. 2349. 890501. 1200. -1.
          3.  1.  407. 2352. 890501. 1200. -1.
```

SAMNAM

Array (maximum size = 60) of 10-character strings representing the names/id's of samplers.

CPLIN INPUT FILE FORM

ARAC problem title (60 character maximum including spaces)

Contour intervals* for integrated air concentrations
PLTHINT= . . . . .

Contour intervals* for instantaneous air concentrations
PLTHIST= . . . . .

Contour intervals* for deposition
PLTHDEP= . . . . .

Dose conversion factors
DCON= . . . . .

. . . . .

*Code chooses contours when values are missing

Hollerith label for plotting units (10 characters maximum)

UNITS1= ' '
UNITS2= ' '

•
•
•

UNITS9= ' '
UNITS10= ' '

Plotting default units for a unit rate release as a plume.

Integration:	UNITSn='s**2 /m**3'
Instantaneous:	UNITSn='s/m**3'
Deposition:	UNITSn='s/m**2'

If problem involves a puff release, the appropriate units must be entered, e.g.,

Integration:	UNITSn='s/m**3'
Instantaneous:	UNITSn='1/m**3'
Deposition:	UNITSn='1/m**2'

Hollerith label for individual contour plots (60 characters maximum)

DCONNAM1= ' '

DCONNAM2= ' '

•
•
•

DCONNAM9= ' '

DCONNAM10= ' '

yymmdd hhmm hr yymmdd hhmm hr yymmdd hhmm hr

SLOT1= . . . . . .

SLOT2= . . . . . .

•
•
•

SLOT9= . . . . . .

SLOT10= . . . . . .

IGOOF=1

ZZZZZ

II.B.9. RSUSIN

RSUSIN is an input file to RSUS containing the user-specified parameters needed to determine the resuspension source term and to construct the input files (SITE, TOPIN, WINDY, PICIN, and CPLIN) for the resuspension MATHEW/ADPIC calculation.

IMPORTANT: All lines in RSUSIN must begin in column 2. Also, the "$CML" line must be the first line, and "$END" must be the last line of the file.

The following variables must be assigned a value in RSUSIN:

$CML

This signifies the beginning of a VAX namelist.

TITLE

50-character string which will be used for the Title parameter in the PICIN and CPLIN namelist files created by RSUS.

SPD

Floating point value representing the surface wind speed (m/s) at the resuspension source site.

DIR

Floating point value representing the surface wind direction (deg) at the resuspension source site.

ISTRT

10-character string (yymmddhhmm) representing the starting time for the resuspension calculation, and will appear in WINDY, PICIN, and CPLIN.

IGOOF = 1
ZZZZZ = 0.
$END

IGOOF is a flag to check for processing of input parameters. ZZZZZ signals the end of RSUSIN input to be read, and must be set equal to some real number. $END signifies the end of the VAX namelist. Comments may be placed after this line.

The following parameters have default values, and need only be specified if you do not wish to use the defaults:

NSURF

Integer (1,2,or 3) representing the soil surface type within the resuspension source term area: 1 => sandy, 2 => loam, 3 => clay or snow.
(Default: NSURF = 1)

CD
--

Floating point value representing the drag coefficient. More information about the drag coefficient can be found in Priestly (1954).
(Default: CD = 0.0028)

DELTX

Floating point value representing the horizontal ADPIC grid cell size (km) to appear in TOPIN.
(Default: DELTX = 0.75 => 30km grid)

DELZ

Floating point value representing the vertical ADPIC grid cell size (m) to appear in TOPIN.
(Default: DELZ = 50.0 => 700m grid depth)

IFLATTOPO

Integer flag (1 or 0) indicating whether or not flat terrain will be used.
(Default: IFLATTOPO = 1 => flat terrain)

Beginning of namelist indicator:

```
$CML
```

Title to appear on resuspension dot plots and contour plots (50 char max):

```
TITLE ='                                                    '
```

Surface type: 1=sandy, 2=loam, 3=clay or snow, (default = 1)

```
NSURF     =
```

Drag coefficient: (default = 0.0028)

```
CD        =    .
```

Surface wind speed (m/sec) at resuspension source site:

```
SPD       =         .
```

Surface wind direction (deg) at resuspension source site:

```
DIR       =    .
```

Starting GMT time (yymmddhhmm) for resuspension run:

```
ISTRT     = '          '
```

Horizontal ADPIC grid cell size (km): (default = 0.75)

```
DELTX     =    .
```

Vertical ADPIC grid cell size (m): (default = 50.0)

```
DELZ      =    .
```

Flat topography option: 1=use flat topography, 0=use TF---file (default=1)

```
IFLATTOPO =
```

End of namelist indicators:

```
IGOOF     = 1
```

```
ZZZZZ     = 0.
```

```
$END
```

(this page intentionally blank)

III.C. Output Files

III.C.1. GRIDIN

The GRIDIN file is generated by TOPOG and supplies the model grid definitions and model terrain for all subsequent codes in the ARAC code stream. MEDIC, MATHEW, and ADPIC read all or part of the GRIDIN file. GRIDIN is a binary file used to pass data between codes and is not normally examined by a user. The GRIDIN file is a binary file composed of four sections:

Variable	Dimension	Type	Description
ID block			Problem parameters
KPICTOP	IPICMXP,JPICMXP	INTEGER*4	ADPIC topography
KMATTPC	IMATMXP,JMATMXP	INTEGER*4	MATHEW topography
ICELLDS	IMATMXP,JMATMXP, KMATMXP	INTEGER*4	MATHEW cell descriptors

IDBlock

The ID block is a section found at the beginning of all ARAC binary files. It contains all the parameters and data which affect the solution of a problem. As a problem evolves through the stream of codes, the appropriate values in the ID block are filled in by each code. TOPOG assigns values to the ID block variables describing the MATHEW and ADPIC grids. This information is used by the two codes to define their grids. The ID block is 3500 four-byte words long. (See the ID block data dictionary for a complete description.)

KPICTOP

ADPIC topography is represented by an integer array with each array element corresponding to an ADPIC horizontal grid cell. The value of each array element is the height of the model block topography entered as the number of k levels above the grid bottom, i.e., the bottom of the grid is indicated by zero (0). The array is dimensioned IPICMXP by JPICMXP, which for the normal ADPIC grid is 41 by 41.

KMATTPC

MATHEW topography is represented by an integer array with each array element corresponding to a MATHEW horizontal grid cell. The value of each array element is entered as the number of k levels above the grid bottom plus one, i.e., the bottom of the grid is indicated by one (1). The array is dimensioned IMATMXP by JMATMXP which, for the typical MATHEW grid, is 51 by 51.

ICELLDS

The MATHEW cell descriptors are a way of describing which faces of a six-sided divergence cell are open or closed to wind (and hence mass) flow. Each cell in the grid volume is assigned a cell descriptor. Thus the descriptors are stored as integers in a three-dimensional array. (See the theoretical discussions of TOPOG and MATHEW for a description of the format and function of the cell descriptors.) The descriptor array is dimensioned IMATMXP by JMATMXP by KMATMXP, which for a typical MATHEW grid is 51 by 51 by 15.

III.C.2. ECHOTOPOG

ECHOTOPOG is the BCD output file for TOPOG. It is used to examine and verify the results of, or to debug, a TOPOG run. It is not used by other computer codes. During normal execution of the ARAC code stream, this file would rarely be examined, but in the event of difficulty, the information is available. There are seven sections in an ECHOTOPOG file:

1. TOPIN echo
2. Grid parameter display
3. Cell heights
4. Model levels
5. ADPIC model terrain
6. MATHEW model terrain
7. Cell descriptors

Each of these sections is discussed below.

TOPIN Echo

The entire TOPIN file is written exactly as it appears in the input file if the TOPIN data are read correctly. Otherwise the last line will contain the error.

Grid Parameter Display

The various grid parameters are written exactly as they are displayed on the user's terminal during a TOPOG run. These parameters include the minimum and maximum extent of the terrain data base in UTM coordinates, the MATHEW and ADPIC model grid dimensions, the grid cell sizes, and the sampling cell description. If errors are found in defining the model grids, then the error messages are printed before the parameter display as they are on the user's terminal.

Cell Heights

The averaged cell height in meters for each MATHEW cell is printed. This is stored in a real array dimensioned IMATMXP by JMATMXP.

Model Levels

The MATHEW model level (k-levels) for each cell is printed. This is stored in an integer array dimensioned IMATMXP by JMATMXP.

ADPIC Model Terrain

The ADPIC model terrain is printed as an integer array of model levels (k-levels) dimensioned IPICMXP by JPICMXP (41 by 41 for a typical ADPIC grid).

MATHEW Model Terrain

The MATHEW model terrain is printed as an integer array of model levels (k-levels) dimensioned IMATMXP by JMATMXP (51 by 51 for a typical MATHEW grid).

Cell Descriptors

A cell descriptor for each cell in the MATHEW grid volume is printed as a series of two-dimensional integer arrays, one for each vertical grid level. Thus for a typical MATHEW grid, 15 two-dimensional arrays will be printed, each dimensioned 51 by 51.

III.C.3. GRAFTOPOG

GRAFTOPOG is the graphics output file for TOPOG. It is composed of two plots:

1. Topography contours,
2. MATHEW cell heights. These are described as follows:

Topography Contours

The topography contours are isolines of model terrain height. The MATHEW block topography is converted to heights in meters above sea level at each of the horizontal grid points. The height at a model grid point is equal to the highest of the grid cells (usually four) adjacent to it. The resulting array of values is contoured and the contour lines are labeled in meters above sea level. The default contour interval is 1*DELZ but this can be overridden by giving a value to CTDEL in TOPIN (see TOPIN description for details). The contours are displayed on the MATHEW grid; the ADPIC grid is indicated by a square drawn within the grid. To avoid confusion with the contour lines, no line elements of geography are drawn, but the point elements (location names, character data) are displayed.

MATHEW Cell Heights

The MATHEW cell height along each column of grid cells is the number of model levels below the terrain with one (1) indicating the lowest terrain level in the MATHEW grid.

III.C.4. MVELnnn

The MVELnnn files are generated by MEDIC and are used to pass the extrapolated wind fields to MATHEW. One MVELnnn file is produced for each WINDY data set. The three digit number appended to the MVEL prefix indicates the data set number (NRUN). Thus a MEDIC run of three WINDY data sets with NRUN sequentially set to 1, 2, and 3 will produce three MVELnnn files: MVEL001, MVEL002, and MVEL003. Since WINDY data sets usually correspond to hourly meteorological data, an individual MVELnnn file is produced each hour. The MVELnnn file is a binary file used to pass data between codes and is not normally examined by a user. The MVELnnn is a binary file composed of three sections:

Variable	Dimension	Type	Description
ID block			Problem parameters
U0REF,V0REF	IMATMXP,JMATMXP	REAL*4	Reference level winds
U0,V0	IMATMXP,JMATMXP, KMATMXP	REAL*4	Extrapolated winds

These sections are described as follows:

ID Block

The ID block contains all parameters and data which affect the solution of a MATHEW/ADPIC problem. MEDIC assigns values to all the ID block variables related to the three-dimensional wind field extrapolation procedure. The ID block is 3500 four-byte words long. See the ID block data dictionary for a complete description of the ID block.

U0REF, V0REF

The reference level winds are winds extrapolated to a two-dimensional grid from the surface wind observations. These winds are stored in separate u- and v-component arrays as floating point numbers in meters/second. These wind vectors exist at the reference level along each column of grid points in the MATHEW grid; therefore each array is dimensioned IMATMXP by JMATMXP. For the typical MATHEW grid the arrays are 51 by 51. The component arrays follow each other (v after u) in the MVELnnn file.

U0, V0

These are winds extrapolated to a three-dimensional grid from both surface and upper air data. These winds are stored in separate u- and v-component arrays as the floating point

numbers in meters/second. Wind vectors exist at each grid point in the MATHEW grid volume. Therefore, each array is dimensioned IMATMXP by JMATMXP by KMATMXP. For the typical MATHEW grid the arrays are 51 by 51 by 15. The grid volume includes terrain. The component arrays follow each other (v after u) in the MVELnnn file.

III.C.5. ECHOMEDIC

ECHOMEDIC is the BCD output file from MEDIC. One ECHOMEDIC file is produced for each WINDY data set, i.e., one file for each new value of NRUN. This file is used to examine and verify the results of, or to debug, a MEDIC run. It is not used by other computer codes. During normal execution of the ARAC code stream, this file would rarely be examined, but if problems arise the information is available as an aid in locating the difficulty.

There are as many as five sections in each ECHOMEDIC file:

1. Site file echo
2. WINDY echo
3. Grid descriptions
4. Reference level winds
5. Extrapolated winds

Each of these sections is discussed below:

Site File Echo

The site file is written exactly as it appears in the input file if the site file data is read correctly. Otherwise the last line will contain the error. The site file echo will appear only in the first ECHOMEDIC file produced by a MEDIC run.

WINDY Echo

The WINDY data set is written exactly as it appears in the input file if the WINDY data is read correctly. Otherwise the last line will contain the error. The WINDY file echo will appear in all ECHOMEDIC files.

Grid Descriptions

The model grid parameters are listed under a 'TOPIN:' heading. This includes values describing the terrain data base, ADPIC, and MATHEW grids.

Reference Level Winds

The reference level wind vectors are printed as separate u- and v-component arrays of real numbers in meters/second. A reference level wind vector exists at each grid point in the horizontal direction, so the arrays are dimensioned IMATMXP by JMATMXP (51 by 51 for a typical MATHEW grid). The u-component array is printed first, followed by the v-component array. This section will appear only if IPRINT is set to one (1) in the site file.

Extrapolated Winds

The extrapolated wind vectors are printed as separate u- and v-component arrays of real numbers in meters/second. These arrays are printed as a series of two-dimensional arrays, one for each vertical model level. Thus for a typical MATHEW grid, 15 arrays, each dimensioned 51 by 51, will be printed to define one component. The u-component arrays are written first, followed by the v-component arrays. This section will appear only if IPRINT is set to one (1) in the site file.

III.C.6. GRAFMEDIC

GRAFMEDIC is the graphics output file for MEDIC. It is composed of seven types of plots:

1. Surface data
2. Horizontal plane vector plots
3. Sample profile locations
4. Sample profiles
5. Measured profiles
6. sigma theta profile
7. Input data

These plots are described below:

Surface Data

The surface wind observations, adjusted to the reference height (REF), are plotted on the MATHEW grid border as wind barbs. The adjustment to the reference height is done according to the surface layer power law using the exponent PWRSL provided in WINDY.

Wind barbs, as used on ARAC graphics products, present a slight variation on the standard meteorological wind bard convention for representing wind observations. In the standard convention, wind direction is represented by a line segment, or stem, with one end, the origin, located at the observation point and the other end located exactly upwind from the origin. Thus the stem represents the direction from which the wind is blowing. Speed ranges are represented by the number of flags and short line segments, i.e., barbs, attached to the stem. The first flag or barb is attached to the stem at the distal end with additional flags and barbs being placed closer to the origin. Flags are added first, at the distal end, followed by barbs. Each flag represents a wind speed of 50 knots and each barb represents 10 knots. The last barb, i.e., closest to the origin, may be half the length of a normal barb, thereby indicting a 5 knot wind. Thus a stem with one flag, one barb, and one half barb indicates a wind of at least $50 + 10 + 5 = 65$ knots, but less than 70 knots (see Fig. B.1a.). With ARAC's convention, because many of the surface wind speeds are low, the 5 knot ($\sim$2.5 m/s) resolution of this scheme is limiting. Therefore the last barb is scaled exactly to the reported speed, e.g., a 12 knot wind would be represented as one barb at the end of the stem (10 knots) and one short barb one-fifth as long as a standard barb somewhat closer to the origin (see Fig. III.C.1b.).

In plotting the surface observations, the origin of the stem is placed at the observing location and the station name is printed adjacent to the origin. If the speed data is missing from an observation, then only the stem is plotted, indicating the direction. If the direction data is missing from an observation, a barb indicating a north wind is plotted with the measured speed. An 'S' is printed following the station name to indicate that only the speed is valid, and that the *direction of the wind barb must be ignored.*

Horizontal Plane Vector Plots

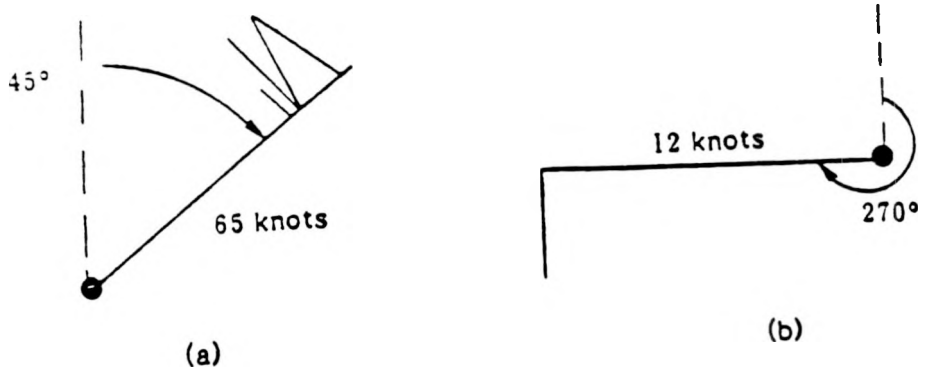


FIGURE III.C.1.

Examples of wind barbs showing (a) 65 knot winds from 45°N and (b) 12 knot winds from 270°N.

Horizontal grids of extrapolated wind vectors are plotted at constant heights above terrain. Since wind vectors crossing the outer boundary of the MATHEW grid are clipped, vectors are plotted only at internal grid points (1<I<IMAX and 1<J<JMAX). This offers some protection against clipping. The density of the vectors can be controlled by giving a value to NVCTFQ in WINDY. The default is two (2), which causes vectors to be plotted at every other grid point (see WINDY description for details). The size of the vectors can be scaled by giving values to SCLX and SCLY in WINDY (see WINDY description for details). The levels plotted by default are the reference level, 1*DELZ, and the upper level winds. All these levels are at constant heights above terrain. The upper level winds are the winds at 14*DELZ above terrain, unless the parameterized extrapolation is being used and the top of the boundary layer (TOPBL) is greater than 14*DELZ. In this case the upper level winds are the winds at the top of the boundary layer. Other model level wind vectors can be plotted by assigning values to KPLOT in WINDY (see WINDY description for details).

Sample Profile Locations

The positions of the sample profiles are indicated by asterisks (*) within the MATHEW grid outline. The asterisks are followed by numbers used to identify the profiles.

Sample Profiles

The extrapolated winds along a column of MATHEW grid points are displayed as a function of height. Three different profiles are plotted with the vertical extent of each representing the vertical dimension of the grid, (14*DELZ), above the local terrain. The first display is a profile of speed as a function of height and the second is a profile of direction as a function of height; both profiles are plotted as solid lines. The last display is a vertical line with wind barbs attached. The origins of the wind barbs are placed at various model levels and indicate the extrapolated winds at that level. (See the discussion

on "surface data" for a description of wind barbs.) Every other k-level is shown, as well as the wind at the reference height (REF), the top of the surface layer (TOPSL), and the top of the boundary layer (TOPBL). The speeds and directions at the model grid levels are printed below the displays. If the profile extrapolation procedure is being used, additional information on the speed and direction profile is shown. The speed and direction profiles synthesized from the upper air data are shown on the corresponding profile displays as dotted lines. These profiles were used to generate the extrapolated winds along this column of grid points and are helpful in understanding the effects of some of the extrapolation parameters. (See the MEDIC model description for details of the extrapolation process.) If default values are used, plots will be generated for nine columns of grid points spaced evenly over the MATHEW grid area. The user may select different columns by assigning values to IPRO and JPRO in WINDY (see WINDY description for details).

Measured Profiles

The upper air station observations are plotted in a format very similar to the sample profile, i.e., a speed profile, a direction profile, and a column of wind barbs are displayed for each station. The wind barbs are shown only at alternate model k levels, and not at the reference height, etc. If all the speed data for a station is missing, then the speed profile does not appear. The same is true for the direction profile.

Sigma Theta Profile

The standard deviation of the horizontal wind direction (sigma theta data) from the first upper air station listed in the site file is plotted as a function of height. A least squares cubic fit to the data is listed below the display, as well as the functional values of this fit at all the MATHEW k levels.

Input Data

All the input data used in TOPOG and MEDIC is listed where appropriate under the three headings:

1. TOPIN
2. WINDY
3. Site file

III.C.7. VELnn

VELnn files are generated by MATHEW and contain the advection (mass-balanced) winds used by ADPIC. Each VELnn file can contain up to six data sets (i.e., adjusted wind fields created from six WINDY data sets). The location of a data set within a VELnn file (as well as the particular VELnn file in which it resides) is determined by the value of NRUN in the ID block. Wind fields with data set numbers 1 to 6 are stored sequentially in VEL01, wind fields with data set numbers 7 to 12 are stored in VEL02, etc. VEL99 is the last VELnn file allowed. Missing data sets do not cause a shift in the locations of any subsequent data sets. Therefore a VELnn file may contain 'holes', i.e., slots for data sets where no data exists. Any 'holes' of this nature must be filled before ADPIC is run. The VELnn is a binary file used to pass data between codes and is not normally examined by a user. VELnn file data sets are composed of three data sections:

Variable	Dimension	Type	Description
ID block			Problem parameters
HMIXPIC	IPICMXP,JPICMXP	REAL*4	ADPIC mixing level
UPIC,VPIC,WPIC	IPICMXP,JPICMXP, KPICMXP	REAL*4	ADPIC advection winds

Each of these sections is described below:

ID Block

The ID block contains all parameters and data which affect the solution of a MATHEW/ADPIC problem. MATHEW assigns values to several ID block variables which describe the iteration process. The ID block is 3500 four-byte words long. See the ID block data dictionary for a complete description.

HMIXPIC

The mixing height is passed to ADPIC as a two-dimensional array of floating point numbers. The value of each element in the array is the mixing height along a column of grid points in the ADPIC grid. The array is therefore dimensioned IPICMXP by JPICMXP, which for a typical ADPIC grid is 41 by 41. As the codes currently exist, each element in the array is set to the height of the model grid k-level closest to the top of the mixing layer (TOPML) in meters. Terrain is not used in assigning values to this array so each element is equal to all the others.

UPIC, VPIC, WPIC

The advection winds are a subset of the MATHEW grid point adjusted winds chosen to cover the ADPIC grid. These winds are stored in three arrays, one for the u-components, one for the v-components, and one for the w-components of the wind vectors which are expressed as real floating point numbers in m/s. These wind vectors exist at each ADPIC grid point, so each array is dimensioned IPICMXP by JPICMXP by KPICMXP which, for a typical ADPIC grid, is 41 by 41 by 15. These component arrays are stored one after the other (u, v, w) in the VELnn file data set.

III.C.8. ECHOMAT

ECHOMAT is the BCD output file for MATHEW. One ECHOMAT file is produced for each data set number, i.e., for each new value of NRUN. This file is used to examine and verify the results of, or to debug, a MATHEW run. It is not used by other computer codes. During normal execution of the ARAC code stream, this file would rarely be examined, but if problems arise, the information is available as an aid in locating the difficulty. There are as many as nine sections in an ECHOMAT file:

1. MINV echo
2. Problem data description
3. Grid point extrapolated winds
4. Face-centered extrapolated winds
5. Extrapolated wind divergence
6. Lagrangian multipliers
7. Face-centered adjusted winds
8. Grid point adjusted winds
9. ADPIC adjusted winds

Each of the sections is discussed below:

MINV Echo

The MINV data set is written exactly as it appears in the input file if the MINV data was read correctly. Otherwise the line containing the error will be the last to appear.

Problem Data Description

All parameters and data affecting the problem solution to this point are printed under four headings which indicate the source of the parameters. The subsections are:

'TOPIN:' - which includes data defined by the terrain data base as well as by TOPIN.
'WINDY:' - which includes all the WINDY data and parameters.
Site file - which lists the observation locations.
'MINV:' - which lists the MATHEW parameters, including any default values.

Grid Point Extrapolated Winds

The grid point extrapolated winds are printed as u- and v- component arrays of real numbers in m/s. These arrays are printed as a series of two-dimensional arrays, one for each vertical model level. Thus for a typical ARAC grid, 15 arrays, each dimensioned 51 by 51, will be written to define one component. The u-component arrays are written first, followed by the v-component arrays. This section will appear only if IWIND0GRID is set to one (1) in the MINV file.

Face – Centered Extrapolated Winds

The face-centered extrapolated wind components are printed in the same format as the grid point extrapolated winds (see 3 above). This section will appear only if IWIND0FACE is set to one (1) in the MINV file.

Extrapolated Wind Divergence

The extrapolated wind divergences are printed in the same format as the grid point extrapolated winds. This section will appear only if IWIND0DIVG is set to one (1) in the MINV file.

Lagrangian Multipliers

The Lagrangian multipliers are printed, after convergence, in the same format as the extrapolated wind divergence. This section will appear only if ILAMBDAS is set to one (1) in the MINV file.

Face – Centered Adjusted Wind

The face-centered adjusted wind components are printed in the same format as the grid point extrapolated winds, except that an additional array must be written for the w-components after writing the other two arrays. This section will appear only if IWIND-SADJU is set to one (1) in the MINV file.

Grid Point Adjusted Winds

The grid point adjusted wind vectors are printed in the same format as the grid point extrapolated winds, except that an additional array must be written for the w-components after writing the other two arrays. This section will appear only if IWINDSGRID is set to one (1) in the MINV file.

ADPIC Adjusted Winds

The ADPIC wind vectors are printed in the same format as the grid point extrapolated winds, except that an additional array must be written for the w-components. Also each array is dimensioned IPICMXP by JPICMXP by KPICMXP (41 by 41 by 15 for a typical ADPIC grid). This section will appear only if IWINDSADPI is set to one (1) in the MINV file.

III.C.9. GRAFMAT

GRAFMAT is the graphics output file for MATHEW. It is composed of four types of plots:

1. Horizontal plane vector plots
2. Vertical profile locations
3. Vertical wind profiles
4. Input data

These plots are described as follows:

Horizontal Plane Vector Plots

Horizontal grids of adjusted MATHEW wind vectors are plotted at constant heights above terrain. These vectors are plotted within the MATHEW grid borders. Since wind vectors crossing the outer boundary of the MATHEW grid are clipped, vectors are plotted only at internal grid points (1<I<IMAX and 1<J<JMAX). The density of the vectors can be controlled by setting a value to NVCTFQ in MINV. The default is two (2), which causes vectors to be plotted at every other grid point (see MINV description for details). By default only the MATHEW winds 1*DELZ above terrain are shown. By selecting model levels through KPLOT in MINV, the user can view as many or as few model levels as desired.

Vertical Profile Locations

The position of the vertical profiles are indicated by asterisks (*) within the MATHEW grid boundary. The asterisks are followed by numbers used to identify the profiles.

Vertical Wind Profiles

The adjusted wind vectors along a column of MATHEW grid points are displayed as a function of height. Three different displays are plotted, each with the vertical extent representing the vertical range of the MATHEW grid so terrain is included in the plots. The first display is a profile of speed as a function of height and the second is a profile of direction as a function of height. The last display is a vertical line representing the vertical extent of the grid with wind barbs attached at every other model *k* level. These barbs represent the adjusted wind at the various levels (see Section 1 of GRAFMEDIC for a discussion of wind barbs). The wind speeds and directions at the model k levels are printed below the displays. If the default value is used, plots are generated for nine columns of grid points spaced evenly over the MATHEW grid area. The user may select different columns by assigning values to IPR and JPR in MINV (see MINV description for details).

Input Data

All the input data used by TOPOG, MEDIC, and MATHEW is listed where appropriate under four headings:

1. TOPIN
2. WINDY
3. Site file
4. MINV

III.C.10. DPOUTnn

DPOUT.nn files are generated by ADPIC and contain deposition and instantaneous and integrated air concentration information used by PLCNT in plotting the contours. Each DPOUT.nn file can hold up to six data sets, each of which contains five two-dimensional arrays of concentration for each level, up to 10 levels. An individual set is written at each output time. The two-digit number (nn) appended to the DPOUT name is used for sequencing the files. For example, after filling DPOUT.01 with the maximum number of data sets, ADPIC will then close the file and automatically create a new one, DPOUT.02. DPOUT.nn is a binary file which is rarely examined by the user. It consists of the following data:

Variable	Dimension	Type	Description
ID Block			Problem parameters
RNRM	IMAXPIC, JMAXPIC, NUMBERBIN	REAL*4	Concentration arrays
RNRMNST	IMAXPIC JMAXPIC NUMBERBIN KSG	REAL*4	Nested grid concentration arrays
NRNESTS	1.	INTEGER*4	Number of nested grids
ITMDAT, ITMTIM	1, 1	INTEGER*4	Time at which concentrations are valid
XX	IMAXPIC	REAL*4	UTM easting coordinates of RNRM array
YY	JMAXPIC	REAL*4	UTM northing coordinates of RNRM array
SXX	KIS KSG	REAL*4	UTM easting coordinates of RNRMNST arrays
SYY	KJS KSG	REAL*4	UTM northing coordinates of RNRMNST arrays
OUEND		REAL*4	Last word

This variable information is described as follows.

ID Block

The ID block contains all of the parameters and data that have contributed to a MATHEW/ADPIC solution. A complete reconstruction of the current problem is possible with the recovery of data from this section of the file.

RNRM

These are a series of two-dimensional concentration arrays, where the type of concentration, species sampled, and sampling height have been specified by the user in PICIN. Up to 10 (the current value of NUMBERBIN) combinations of IOPT, ISPEC, and SAMHGT can be specified in any given run.

RNRMNST

These are a series of four two-dimensional nested grid arrays of concentration that correspond to the RNRM arrays (see Section II.B.3.e. for a detailed explanation).

NRNESTS

This is the number of nested grids used by ADPIC.

ITMDAT, ITMTIM

ITMDAT is the year, month, and day (yymmdd), and ITMTIM is the hour and minute (hhmm) at which the cell-centered concentrations in RNRM are valid. These times are appended to each contour plot produced by PLCNT.

XX

XX values are the UTM easting coordinates of the cell centers whose concentrations are given in the RNRM array.

YY

YY values are the UTM northing coordinates of the cell centers whose concentrations are given in the RNRM array. When the elements in YY are matched with those in XX, the spatial coordinates of the cell centers are completely specified.

SXX

SXX values are the UTM easting coordinates of the cell centers whose concentrations are given in the RNRMNST array.

SYY

SYY values are the UTM northing coordinates of the cell centers whose concentrations are given in the RNRMNST array. When the elements in SYY are matched with those in SXX, the spatial coordinates of the cell centers are completely specified.

OUEND

OUEND is the last word to be buffered out in the DPOUT.nn file. While it is used to compute the length of the buffer-out in some versions of ADPIC, OUEND otherwise contains no useful information.

III.C.11. ECHOADPIC

ECHOADPIC is a BCD output file from ADPIC. This file is not used by other codes and it is rarely examined by the user. However, it can serve as a diagnostic aid by helping the user locate the source of a fatal error, when such an error occurs during an ADPIC run. There can be up to six sections in an ECHOADPIC file:

1. PICIN Echo
2. New Source Rates
3. ID Block
4. Particle Budget
5. Particle Summary
6. Optional Output

Each section is discussed below.

PICIN Echo

The PICIN data set is written exactly as it appears in the input file, assuming that PICIN has been read correctly. If not, the line containing the error will be the last to be printed.

New Source Rates

New source rates can be incorporated into an ADPIC calculation by using TSRATE in PICIN. When this option is selected, a line will be added to the ECHOADPIC file; this gives the value of the new rate and the time it is valid.

ID Block

The ID block contains all of the parameters and data from the TOPIN, WINDY, Site, MINV, and PICIN input files. Additionally, a section with the heading MAX VELOCITIES WITH LOCATION INDICES is provided. This section gives the maximum interpolated u- and v-component winds with their i, j, and k indices and the maximum adjusted u-, v-, and w-components with their indices. If the particles appear to be moving too fast, a check in this section should indicate whether the problem is caused by advection or diffusion velocities. The next entries are entitled ITER LIMIT and ITER ACTUAL; they define the maximum number of iterations that are allowed for a MATHEW convergence and the actual number of iterations required to adjust the winds for mass consistency.

Particle Budget

At the end of each cycle (Δt), ADPIC writes the following information to ECHOADPIC:

NCYC - Number of the current cycle

DELT - Time step for this cycle
TIME - Total time since ISTRTDAT,ISTRTTIM
NTOT - Total number of active particles
MGEN - Number of particles generated this cycle
MTOT - Number of particles generated for entire problem
LCYC - Number of particles lost this cycle
LTOT - Total number of particles lost for entire problem
NOCL - Number of times particles moved more than one cell in any direction
AVOCL - Average number of cells that NOCL particles moved

If NOCL becomes significantly larger than one, the diffusion velocity algorithm leads to instabilities. The time step can become erratic under these conditions and the particle plots may show a very uneven distribution, especially in the vertical. If this happens, FRACT should be reduced, resulting in a smaller time step, and the problem rerun. FRACT is input through PICIN; it has a default value of one (1).

Particle Summary

At the end of each edit (IEDIT) interval, a partial summary of the particle budget for each source is written to ECHOADPIC. The elements in this list are NTOT, MGEN, and LTOT, and either the particle mass (QSNC) or activity (TACT).

Optional Output

If optional parameters have been selected in PICIN, they are written to ECHOADPIC at the end of each edit interval.

ADUMP is a binary file which contains all of the information necessary to restart the ADPIC code. The number of data sets (dumps) has been limited to three because of the appreciable size of each set. The output times (and the permissible restart times) are controlled by IDUMP in the PICIN file. More specifically, IDUMP indicates the output interval in hours and minutes (hhmm) relative to ISTRTDAT and ISTRTTIM on the first restart, and IRSTDAT and IRSTTIM on subsequent restarts; the interval is based on the running time (IRUNTIM) of the code. As an example, if ISTRTDAT equals 820930 (30 September 1982) and ISTRTTIM equals 1200 (the problem start time in hours and minutes), then for an ADPIC calculation lasting six hours, the maximum interval for IDUMP would be 0200, or every two hours. This means that the user can restart the problem at 1400, 1600, or 1800 hours.

The following information can be found in an ADUMP file.

Variable	Dimension	Type	Description
PX,PY,PZ	IPRT	REAL*4	Easting and northing UTM coordinates and the vertical height of all active ADPIC particles.
PP	IPRT	REAL*4	Mass or activity of each particle.
PT	IPRT	REAL*4	Age of each particle since the generation of the parent puff.
PS	IPRT	REAL*4	Stokes' fall velocity for those particles which have been assigned a particle size.
NSPC	IPRT	INTEGER*4	Number of the source to which each particle belongs.
IPX,JPY,KPZ	IPRT	INTEGER*4	The i, j, k index of the cell enclosing each particle.
SSPX,SSPY,SSPZ	IPRT	REAL*4	Distance that a source particle has diffused in the x, y, and z directions since the generation of the parent puff.
NVELCT	1	INTEGER*4	Number of data sets that have been read from VELnn files.
HECT	1	REAL*4	Time of the next edit.
HPLCT	1	REAL*4	Time of the next plot.

NDI	1	INTEGER.4	Number of data sets in each DPOUTnn file
ND	1	INTEGER.4	Number of the current DPOUTnn file.
NNDI	100	INTEGER.4	Number of data sets written to each DPOUTnn file.
NTOT(NDU1)*	1	INTEGER.4	Total number of active particles.
MTOT(NDU2)*	1	INTEGER.4	Number of particles generated during the last cycle.
NTOTI(NDU3)*	MAXSOURCE	INTEGER.4	Number of active particles for each source.
LTOTI(NDU4)*	MAXSOURCE	INTEGER.4	Number of particles lost for each source.
NCYC(NDU5)*	1	INTEGER.4	Number of completed cycles.
LTOT(NDU6)*	1	INTEGER.4	Total number of particles lost.
DELT(DU1)*	1	REAL.4	Current time step.
TIME(DU2)*	1	REAL.4	Total running time up to this point.
HDPOUT(DU3)*	1	REAL.4	Time of the next write to DPOUTnn.
TMCT(DU4)*	1	REAL.4	Time of the next read from VELnn.
HDMP(DU5)*	1	REAL.4	Time of the next write to ADUMP.
XY(DU6)*	1	REAL.4	Random number generator seed.
TIH.TIV	MAXSOURCE	REAL.4	Time required for a puff to grow from a point source to the size specified in PICIN.
QNSH.QNSV	MAXSOURCE	REAL.4	Time required for the standard deviation of a puff to grow to the size of one cell.
RNRM	IMAXPIC, JMAXPIC, NUMBERBIN	REAL.4	Series of two-dimensional concentration arrays.
RNRMNST	IMAXPIC JMAXPIC NUMBERBIN KSG	REAL.4	Nested grid concentration arrays
NRNESTS	1.	INTEGER.4	Number of nested grids

ITMDAT,	1	INTEGER*4	The date (yymmdd) and time (hhmm)
ITMTIM	1	INTEGER*4	at which the concentrations in RNRM are valid.

* The variables in parentheses are used only for writing to or reading from an ADUMP file.

III.C.13. GRAFADPIC

GRAFADPIC provides three different views of the Lagrangian particle positions as computed by ADPIC at each IPLT time. The first plot represents a full projection of the particles onto an x,z plane, with the plane situated over the UTM northing coordinate of the source point (the observer looks from south to north). The second plot represents a projection of the particles onto a y,z plane positioned over the UTM easting coordinate of the source (the observer looks from east to west). Topography is transparent in these displays, but individual boundary cells are frequently outlined, in part, when there are numerous particles in the grid volume. The two plots appear on the same page. Since the aspect ratio of the horizontal and vertical grid dimensions is quite large, the two scales in the vertical have been exaggerated to better view the particle distributions.

The display on the subsequent page of GRAFADPIC shows the particles projected onto a horizontal plane; in this case, the observer is looking downward. (Since the frame sizes of the horizontal particle plots and the contour plots are identical, they can be overlayed.) Two pieces of timing information are included with each display: the actual time (yymmddhhmm) at which the plot is valid (written in the upper right-hand corner of the frame), and below this value, the time, in hours and minutes, since the beginning of the problem. A title supplied by PICIN appears at the bottom of each page.

III.C.14. GRAFPLOT

GRAFPLOT shows families of concentration isopleths about a selected release point. Since PLCNT allows numerous options, the amount of information attached to each plot must be commensurately large to uniquely identify the plots. Two lines of information are written above each plot. The first line is the problem title as it appears in CPLIN; the second line gives the time at which the plot is valid, and the time of the latest meteorological data used in obtaining the results.

The species under consideration is identified below the plotting frame. This is followed by the type of concentration (integrated, instantaneous, or deposition) requested by the user. The interval over which sampling occurs is also printed on this line if the user has asked for integrated air concentration or deposition. The next line contains the name from DCONNAMn in CPLIN. If DCONNAMn has been omitted, the code supplies a default name based on the type of sampling. The last line at the bottom of the plot identifies the start time of the problem (ISTRTDAT and ISTRTTIM from PICIN), and the maximum concentration in the two-dimensional array. This maximum value should be used only after careful deliberation since it represents a concentration over a cell volume, rather than an actual maximum concentration at some point in space, i.e., the reported value will always be conservative (too small). The extent to which it agrees with the actual maximum depends on the steepness of the concentration gradient within the cell volume and on the extent of the coverage by the puff or plume. Following this value, the code prints out the sampling height and the sampling units. The height (SAMHGT) is a variable in PICIN and the units can be specified in CPLIN via UNITSn. The remaining information appearing on the plot is the list of contour levels and the area enclosed by each contour. Following the plot, PLCNT prints the two-dimensional arrays of concentration values from which the contours were generated.

III.C.15. ECHOPLOT

ECHOPLOT is a BCD output file from PLCNT. This file is not used by other codes, and it is rarely examined by the user. However, if PLCNT fails to run because of an improper input, then ECHOPLOT can be helpful in locating the source of the fatal error. There can be up to four sections in the ECHOPLOT file:

1. CPLIN Echo
2. ID Block
3. Concentrations
4. Samplers

Each section is described below:

CPLIN Echo

These data are written exactly as they appear in the CPLIN file, provided CPLIN has been read correctly. If not, the last line will contain the error.

ID Block

The ID block contains a complete list of the parameters and data used to arrive at a MATHEW/ADPIC solution. The ID block is printed only once at the beginning of an ECHOPLOT file. (See Section III.C.11. for further details.)

Concentrations

The two-dimensional arrays of grid point concentrations which are used by PLCNT in providing the contour plots are written to ECHOPLOT. Each array is preceded by all of the descriptor information that appears on the corresponding plot. (See Section III.C.14. for further details.)

Samplers

If the user decides to place samplers within the ADPIC grid, then the sampler names and their values are printed after the corresponding concentration array. After writing the final set of concentrations to ECHOPLOT, PLCNT will then output a list of the sampler values.

APPENDIX A. BIBLIOGRAPHY

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