CONF-960127--5

UCRL-JC-121780
PREPRINT

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This paper was prepared for submittal to the
9th Joint Conference on Applications of Air Pollution
Met. Air & Waste Management Association
Atlanta, GA
January 28–February 2, 1996

September 7, 1995

Lawrence Livermore National Laboratory

DIAGNOSTIC MODELING FOR REAL-TIME EMERGENCY RESPONSE

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1. INTRODUCTION

The Atmospheric Release Advisory Capability (ARAC) provides real-time dose assessments for airborne pollutant releases. ARAC is currently in the process of developing an entirely new suite of models and system infrastructure. Diagnostic and dispersion algorithms are being created in-house and a prognostic model NORAPS (Liou, 1995), imported from the Naval Research Laboratory, Monterey, is currently being adapted to ARAC's needs.

Diagnostic models are essential for an emergency response capability since they provide the ability to rapidly assimilate available meteorological data and generate the mass-consistent three-dimensional wind fields required by dispersion models. The resulting wind fields may also serve to initialize and validate prognostic models. In general, the performance of diagnostic models strongly correlates with the density and distribution of measurements in the area of interest and the resolution of the terrain.

2. METEOROLOGICAL DATA EXTRACTION AND PREPROCESSING

The ARAC system provides global coverage with automated procedures for acquiring and archiving meteorological data, including local surface observations, upper air profiles, and model-generated gridded data. For a given problem, data can be extracted from user-specified databases within a region defined by a metdata grid. Typically the data collection region will cover a geographic domain significantly larger than the area involved in the dispersion simulation in order to provide the most complete set of meteorological information relevant to the problem. This also permits the user to redefine the problem grid size and location, within limits, without reaccessing the meteorological data extraction system.

After the data has been collected, an associated meteorological preprocessor places it in a standard form for further processing. The preprocessor does *not* alter or interpolate wind values; it only performs reversible transformations to convert the data to a standard unambiguous form, e.g. latitude, longitude, height, wind speed and direction. This allows the diagnostic models to use a generalized data ingest routine, not dependent on the form or format of the meteorological data source or database.

3. DIAGNOSTIC MODELS

Our current diagnostic effort focuses on the creation of both a wind-field generator and a mass-consistent adjustment algorithm with improved boundary conditions. These models create wind fields consistent with improvements currently being implemented in the new dispersion model. They are based on a continuous terrain grid with variable vertical resolution (x, y, σ_z) and include a selection of empirically-derived mechanisms to customize wind fields de-

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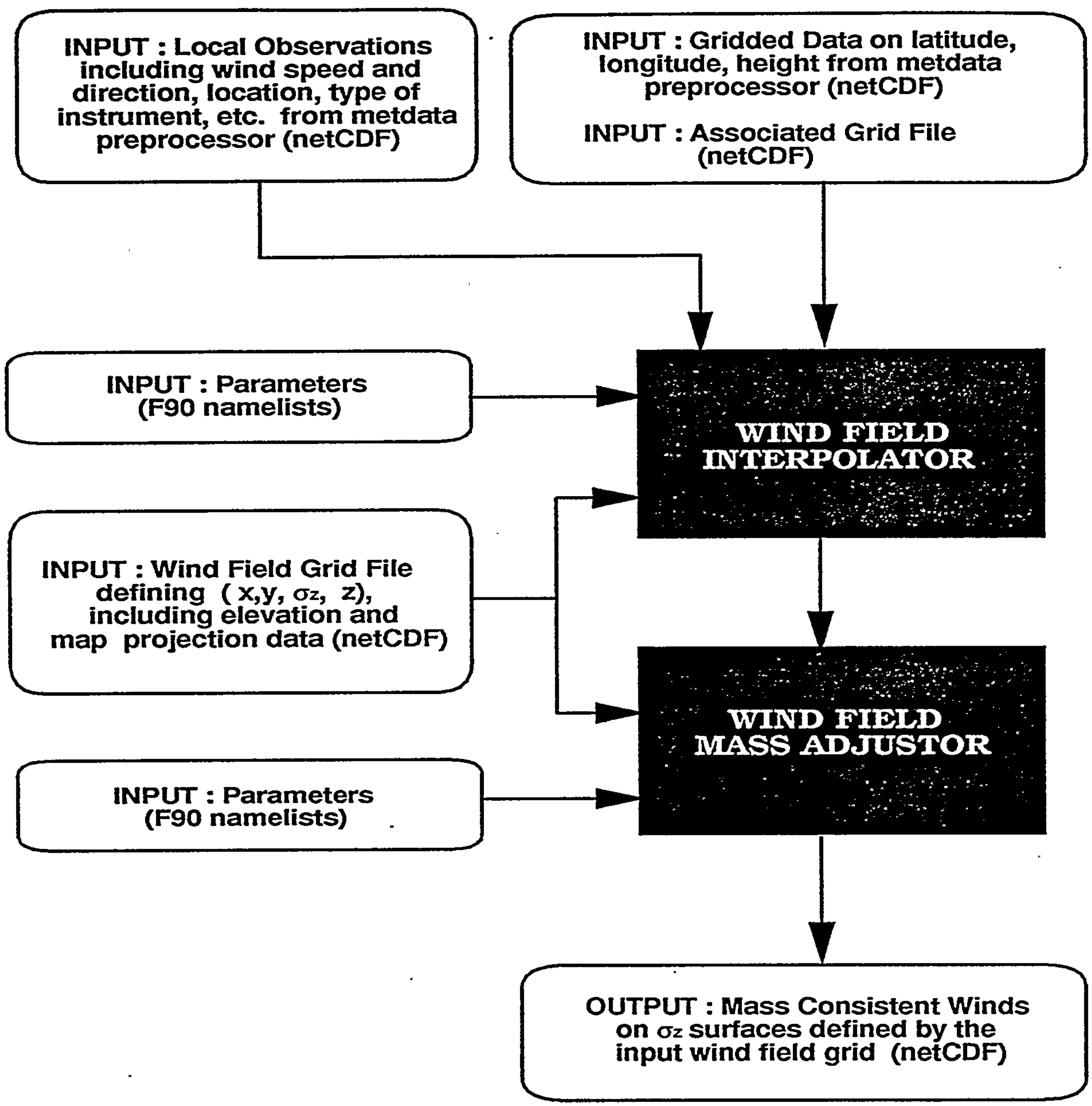

Figure 1: Design flow chart of diagnostic models showing user input, grid files, and meteorological data required to generate a non-divergent wind field that may be passed to a dispersion model. The continuous terrain grid is (x, y, σ_z). Meteorological data is passed in standardized format netCDF files.

pending on topographical and atmospheric conditions. Incorporation of map projections allows maximal flexibility of locations and scales. Figure 1 depicts the data flow through the diagnostic models.

The codes are being written in Fortran-90 for enhanced modularity and efficiency. Model input is performed through Fortran-90 namelists and run-time selection of grid dimensions and resolution is provided. Meteorological data is passed in a platform- and compiler-independent fashion through the use of netCDF files with a standardized format.

4. METEOROLOGICAL DATA ASSIMILATION AND INTERPOLATION

The first priority of ARAC diagnostic model development is the creation of a wind-field generation model based on a straightforward spatial interpolation. More sophisticated methodologies (Daley, 1994), such as Barnes, Cressman, and optimal interpolation, are not robust for typical ARAC applications since they are not ideal for 1) treating relatively sparse observational data sets, 2) providing the necessary computational efficiency for an initial real-time response, and 3) implementing a requirement based on ARAC operational experience for maintenance of locally observed values, particularly near the site of the release. Upon completion of the sparse data interpolation algorithm, we will investigate more sophisticated techniques for interpolating denser data sets and for combining gridded fields and local observations.

The new sparse data wind-field generator uses a weighted inverse-distance squared interpolation of observations. The code assimilates available surface and upper air data as well as gridded analyses in standard preprocessor format. These data are sorted into sets of surface and upper air values. Synthesized vertical profiles are then built at selected surface locations and the resulting profile values on the $x - y$ grid layers are interpolated to create a three-dimensional gridded wind field using an observation-weighted algorithm. As a final step, appropriate adjustments of speed and direction are applied to place the wind field on a user specified map projection.

The new interpolation model possesses a number of features that represent significant improvements of the current ARAC modeling capabilities. Due to the standardized preprocessor format for meteorological data, the diagnostic codes will not need to be altered to ingest databases acquired by ARAC in the future. The model uses a continuous terrain grid with variable resolution in the vertical, which provides improved representation of the wind fields particularly near the surface — a region of the atmosphere which is critical in most ARAC applications. Slip velocities will be made consistent with their use in the dispersion model. The latter features are expected to eliminate much of the reduction of speed problems associated with the block terrain currently used in ARAC models.

Our philosophy is to provide the user with options for the interpolation and adjustment of wind fields via input control parameters, a selection of vertical wind profiling functions (e.g. power law, log, similarity theory), interpolation weights, and quantitative control parameters reflecting atmospheric stability and boundary conditions. As much as possible the control features and their associated variable names will reflect physical phenomena, but it should be recognized that they are simply user-controlled knobs or switches in the diagnostic wind-field models. Until better understanding develops, defaults will be set so as *not* to add unsubstantiated structure or complexity to the wind field, e.g. uniform weighting of observations will be used unless information about topographic or atmospheric forcing is available. However, the user will have the option of choosing other approaches or input parameters to customize the wind field based on an empirical understanding of the problem.

5. NON-DIVERGENCE ADJUSTMENT

The interpolated three-dimensional gridded wind fields of (u, v) or (u, v, w) components must be adjusted for non-divergence as required by the dispersion model. Constrained variational relaxation (Sasaki, 1970; Sherman, 1978) has successfully been used to minimally adjust wind fields.

For rectangular grids and block terrain, a conjugate gradient algorithm has been shown to provide a robust and generally more efficient method of solving the minimization problem than successive over-relaxation techniques. Generalized symmetric MIXED boundary conditions (Gresho, 1975) were also implemented to provide user control of the boundary conditions at the top, lateral, and terrain surfaces, by controlling the degree of normal and tangential adjustment via input parameters. The optimal value of the MIXED boundary condition parameter was shown to be on the order of the characteristic inverse length scale of obstacles to the flow. Significant improvement was demonstrated in potential flow cases (Figure 2) and proper use of the boundary conditions prevented speed reductions and flow artifacts in cases of real complex terrain without drastic slow down in the convergence time (Sugiyama, 1994).

We are currently building a continuous terrain version of this variational relaxation algorithm. Input parameters are invoked to weight the relative adjustment in the vertical and horizontal wind components in order to influence the steerage of winds around topographic features. The variable vertical resolution and non-rectangular nature of the grid result in a substantial increase in the complexity of the finite-difference stencils and Poisson equation solution algorithms. The irregular grid also requires the incorporation of map projections in the non-divergence constraint.

This work was performed under the auspices of the U.S. Department of Energy Lawrence Livermore National Laboratory Contract No. W-7405-ENG-48.

6. REFERENCES

R. Daley, *Atmospheric Data Analysis*, Cambridge University Press (1991) and references cited therein

P. Gresho, UASG 75-22 (1975), private communication

C.-S. Liou, R. Hodur, R. Langland, Navy Operational Regional Atmospheric Prediction System (NORAPS) : A Triple Nest Mesoscale Model, 10th Conference on Numerical Weather Prediction, July 18-22, 1994, 423-425

Y. Sasaki, *Mon. Wea. Rev.* 98, 875-898 (1970)

C. Sherman, *J. App. Met.* 17, 312-319 (1978)

G. Sugiyama, R. L. Lee, and H. Walker, Conjugate Gradient MATHEW, UCRL-ID-118629, LLNL, 1994

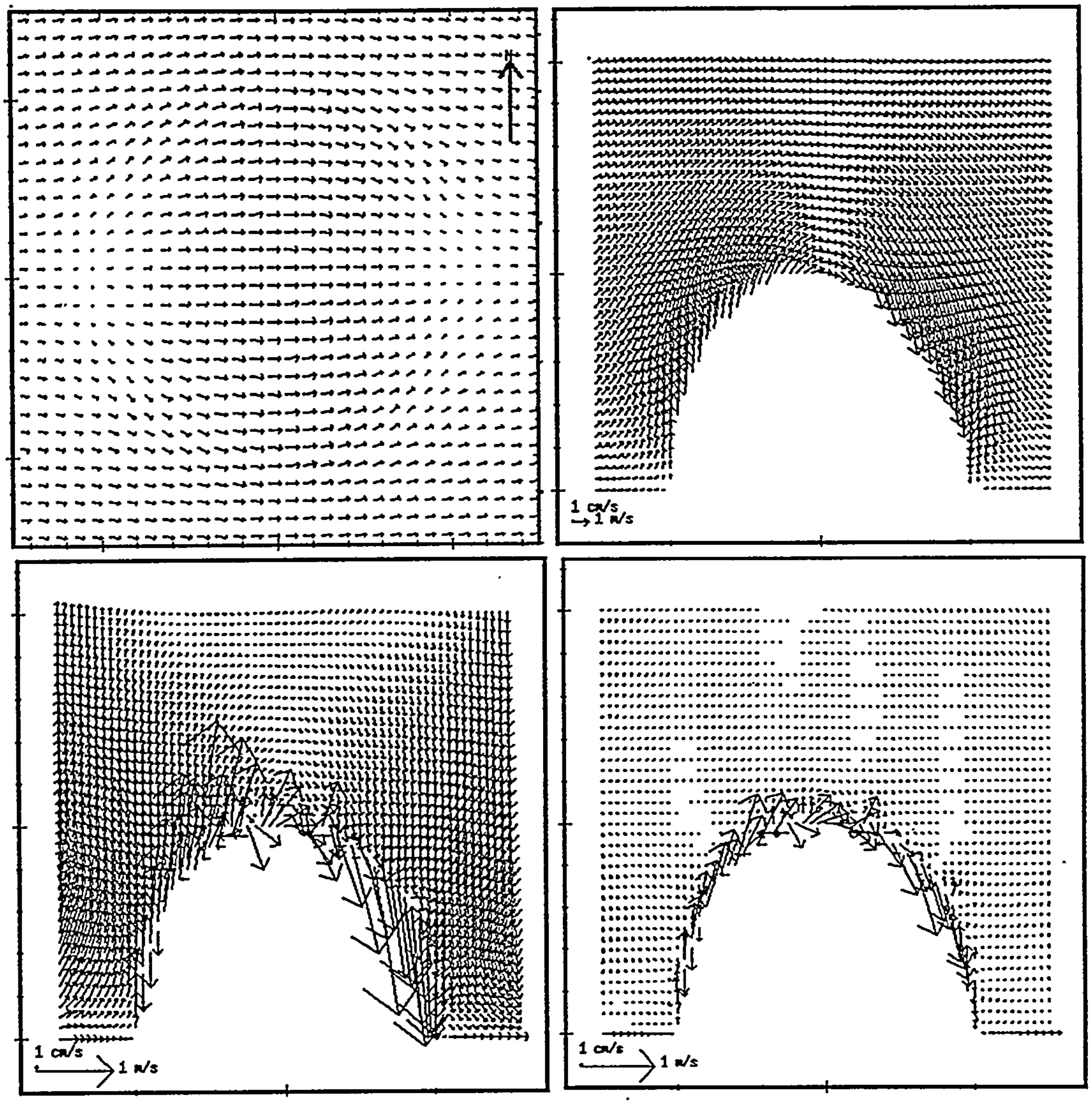

Figure 2: The top panels show the three-dimensional potential flow solution for a hemispheric hill with uniform horizontal input winds flowing from left to right. The top left panel shows the vector field at one grid level above the surface while the top right panel shows an $x - z$ slice through the center of the hill. Differences between the potential flow solution and the adjustment solutions are shown in the bottom panels for the $x - z$ slice. The bottom left hand panel shows the difference for simple boundary conditions which allow only tangential adjustment, while the bottom right hand panel shows the significantly reduced differences when optimal MIXED boundary conditions are used. The vertical components are scaled by a factor of 2.5 and the difference vector lengths are exaggerated by a factor of five. The discrepancies at the terrain surface are due to the block terrain representation. (Sugiyama, 1994)

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