The Role of the LLNL Atmospheric Release Advisory Capability in a FRMAC Response to a Nuclear Power Plant Incident

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ABSTRACT

The Federal Radiological Emergency Response Plan (FRERP) can provide several emergency response resources in response to a nuclear power plant (NPP) accident if requested by a state or local agency. The primary FRERP technical resources come from the U. S. Department of Energy's (DOE) Federal Radiological Monitoring and Assessment Center (FRMAC). Most of the FRMAC assets are located at the DOE Remote Sensing Laboratory (RSL) at Nellis Air Force Base, Las Vegas, Nevada. In addition, the primary atmospheric dispersion modeling and dose assessment asset, the Atmospheric Release Advisory Capability (ARAC) is located at Lawrence Livermore National Laboratory (LLNL) in Livermore, California. In the early stages of a response, ARAC relies on its automatic worldwide meteorological data acquisition via the Air Force Global Weather Center (AFGWC). The regional airport data are supplemented with data from on-site towers and sodars and the National Oceanographic & Atmospheric Administration's (NOAA) field-deployable real-time rawinsonde system. ARAC is prepared with three-dimensional regional-scale diagnostic dispersion model to simulate the complex mixed fission product release from a reactor accident. The program has been operational for 18 years and is presently developing its third generation system. The current modernization includes faster central computers, a new site workstation system, improvements in its diagnostic dispersion models, addition of a new hybrid-particle source term, and implementation of a mesoscale prognostic model. As these new capabilities evolve, they will be integrated into the FRMAC's field-deployable assets.

FRMAC ACTIVATION

Established by 44 CFR 351 in 1985, the FRERP and the FRMAC are relatively young organizations with maturing procedures and expanding experience base. Figure 1 shows the process of activating a FRMAC (EG&G 1994). After the determination that a radiological emergency could significantly impact public health and safety, the state or local government, the Lead Federal Agency (LFA) such as the Nuclear Regulatory Commission (NRC) or the Environmental Protection Agency (EPA), or the DOE Regional Assistance Program (RAP) office can request FRMAC resources from the FRMAC Director at DOE/NV in Las Vegas through the DOE Headquarters Operations Emergency Management Team (DOE/HQ-OEMT). The purpose of the FRMAC is to provide technical assistance to the state(s) and local response agencies when their resources are exceeded. This assistance focuses on monitoring and assessing the extent of health effects and contamination from the atmospheric releases of radioactive material. Depending on the magnitude of the incident, the request initiates either a limited or full FRMAC and associated staffing level (from 20 to more than 300).

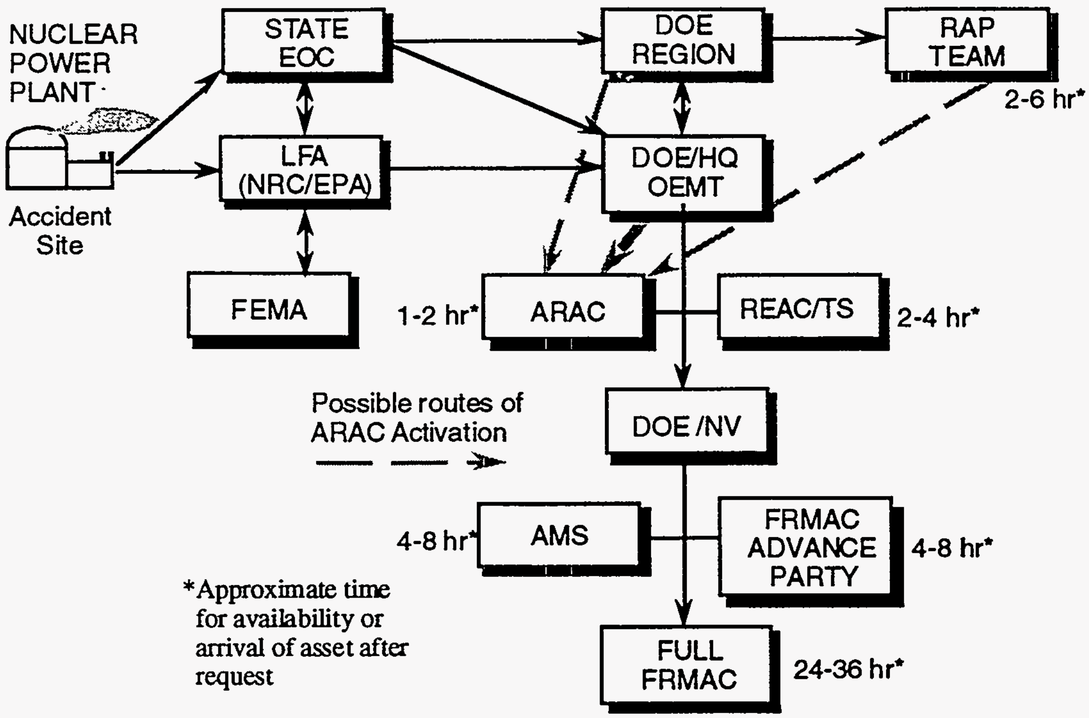

Figure 1. Activation of the DOE FRMAC for a nuclear power plant accident

ARAC ACTIVATION

ARAC may be activated before the FRMAC. Figure 1 shows that ARAC may be contacted by a DOE Regional Office, the DOE/HQ-OEMT, a RAP Team or by a request from a state or LFA through the DOE/HQ-OEMT. Activation of ARAC through the DOE/HQ-OEMT is preferred because the approval process and information flow is automated. OEMT personnel can directly enter incident information into their **ARAC Workstation** at DOE Headquarters EOC in Washington, DC. This information is electronically transmitted to the ARAC Center over a high-speed DOE communication network. In 1995, ARAC Workstations will also be installed at the eight DOE Regional Operations Office on this network and made available to RAP teams.

FRMAC (EG&G 1994) and NRC (McKenna et al. 1993) list the incident information requested for a timely response:

- Type and name of facility
- Location of emergency
- Estimate of the source term, isotopes, and their chemical and physical form
- The time of any release(s) and potential for future releases
- The meteorological conditions at the time of the emergency
- Name and phone number of technical person from the facility who is knowledgeable of the situation.

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As soon as minimal **release information** (time, location, and type of release) are delivered to LLNL, ARAC assessors will model the extent of the dose and deposition from the release or potential releases. ARAC is not manned 24-hours/day but is a 24-hour/day operation via an on-call paging system. The operational duty hours are from 7:15 am to 4:15 pm Pacific time. After duty hours, an emergency call is forwarded to the on-call assessor who will initiate the response from home while a second assessor goes into the ARAC Center. Table 1 lists the response times for the initial plots after ARAC is notified with the minimal information.

Table 1. Response Time for Initial ARAC Plots for NPP Accidents

Time of Day	Response Time (hours)
Duty hours (7:15 am to 4:15 pm Pacific time)	1
Off-duty hours	1.5

Initial ARAC plots will be disseminated to the:

- DOE/HQ-OEMT,
- Regional DOE Office,
- RAP Team,
- DOE/NV FRMAC,
- RSL Aerial Measurements Survey (AMS),
- State,
- LFA, and
- NPP facility/licensee.

The **goal of the ARAC regional models** is to realistically portray the off-site extent of a major release. ARAC typically starts the response on a "local" to "regional" scale (10 to 200 km). As the response evolves, the operations staff can expand or contract the model grid proportional to the extent of the hazard. It is possible that the NPP and or the state may have also already used one or more dispersion models to issue protective actions. ARAC assessors will attempt to resolve any differences between their initial plots and those already prepared by other agencies.

An ARAC assessor will also deploy to the accident site as a part of the FRMAC and work with agencies which are modeling the release. As various model calculations become available, the ARAC assessor in the FRMAC's **Evaluation and Assessment (E&A)** Division will compare the results, model inputs and assumptions, determine errors and resolve differences. The goal is to produce the most realistic estimate of the dose and deposition patterns. The estimates of deposition will be used to direct the initial aerial and ground monitoring surveys. The initial estimates may also be used for early FRMAC recommendations to the state and local agencies for protective actions.

THE ARAC SYSTEM

Over the last 18 years ARAC has developed a **highly-automated system** to supply DOE, nuclear-capable DOD, and Naval Reactor facilities around the country with real-time dispersion model products. The automated system uses a distributed network of ARAC Workstations at the fixed facilities around the country to access a centralized modeling capability in Livermore. The same central system supports off-site consequence analysis for the FRMAC during nuclear power plants incidents. Figure 2 depicts the top-level functions of the ARAC Emergency Response Operating System (AEROS).

The **request for an ARAC response** immediately triggers a paging system that alerts ARAC's staff and sets in motion the acquisition of all available regional and site weather data for input into the model calculations. Within minutes, all model input data are in the central system. ARAC personnel then simulate the release with complex dispersion models that account for the effects of local terrain, and prepare graphical plots of the contamination overlaid on the local geography.

Typically, ARAC's **response time** is equally divided among computer (or voice) communications with the site, automated (or manual) model input preparation, model execution, and human interaction with the system. ARAC currently uses 35 million instructions/second (Mips) Digital Equipment Corporation (DEC) VAX 6610 computers to run the models to communicate with Sun Sparc 10 and DEC PC380 Site Workstations. For training and exercise purposes with supported sites, default source terms are used in conjunction with automated software to produce a "Totally Automated Hands-off Exercise" (TAHOE) calculation in less than 10 min.

The ARAC codes combine real-time **meteorological data** with topographical data to calculate a detailed treatment of atmospheric dispersion that is three-dimensional, terrain-influenced, and spatially and temporally varying. During an ARAC response, hourly surface and twice-daily upper-air meteorological data are automatically acquired from ARAC's dedicated 14,400-baud link to the U.S. Air Force Global Weather Central (AFGWC). In 2 minutes, these data can be received, decoded, and formatted for input to the model. Depending on the situation, meteorological variables, such as atmospheric stability, mixing height, and vertical-wind-power-law profile parameters, can either be determined automatically using on-line algorithms or input manually by the assessment meteorologist who is running the computer codes. On-site **Tower metdata from the NPP** can be crucial in directing the close-in dispersion of a release. Because ARAC does not currently have automated access to this data, on-site met data needs to be transmitted through NRC or FRMAC liaison channels or preferably faxed directly to the ARAC Center. In addition, during the FRMAC response the NOAA Air Resources Laboratory Special Operations and Research Division (ARL/SORD) from Las Vegas will deploy a portable rawinsonde and provide periodic detailed upper-air soundings.

A variety of **source-term** inputs such as release rate, source geometry, particle-size distribution, and deposition velocity are calculated from the Questionnaire information and on-line databases. In lieu of specific nuclide release data from the NPP, ARAC uses the ST-DOSE (Source Term to Dose) code from the Radiologic Assessment System for Consequence Analysis (**RASCAL**) code (Athey et al. 1993) to estimate the initial source terms.

The **geographic databases** provide mapping information on scales ranging from buildings and streets on the local scale to country outlines on the hemispherical scale. For general map coverage of the United States, ARAC uses the U.S. Geological Survey (USGS) 1:2,000,000 Digital Line Graph (DLG) database. ARAC's on-line **topographical** database is derived from the Defense Mapping Agency's Digital Terrain Elevation Data covering much of the world with 0.5-km resolution. DOE's **dose-factor database** provides estimates of dose-conversion factors (DCFs) for internal and external exposure for all nuclides of concern.

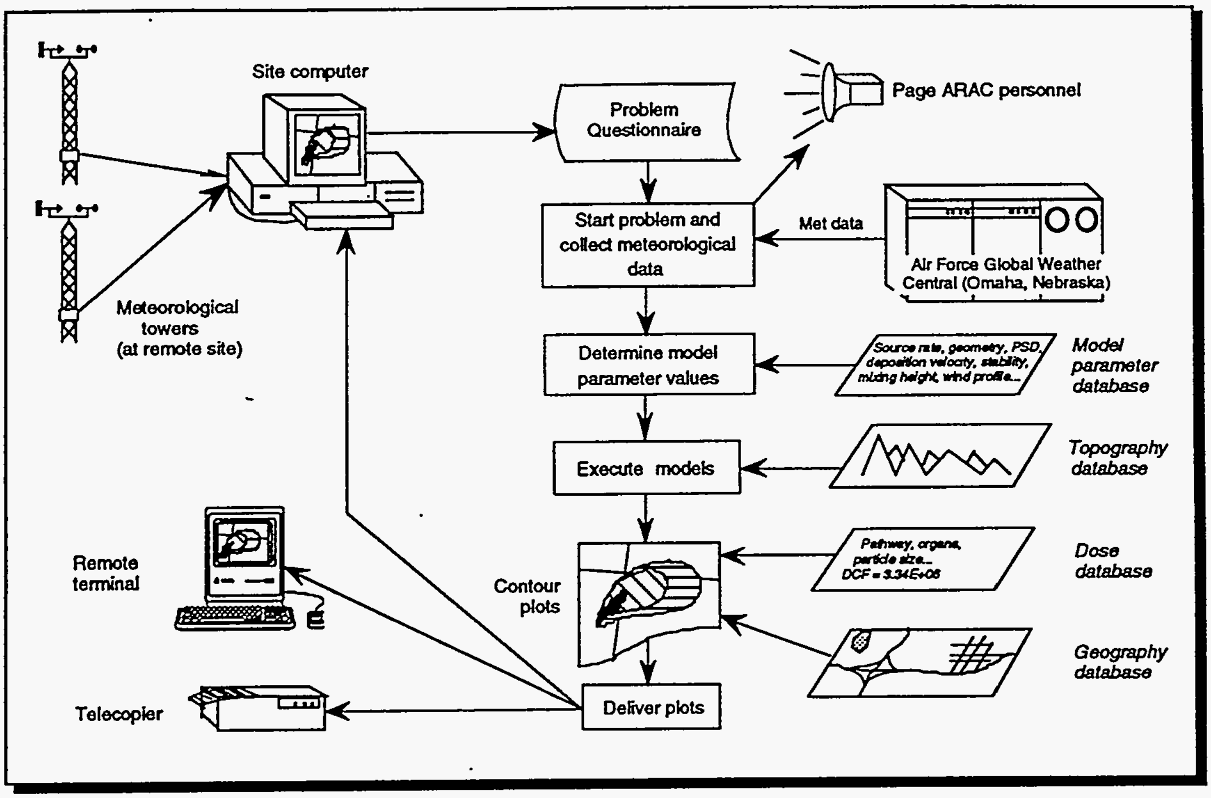


Figure 2. Functions of the ARAC Emergency Response Operating System

ARAC DISPERSION MODELS

At the foundation of the ARAC modeling effort are two three-dimensional, **diagnostic, finite-difference computer codes: MATHEW** (Mass-Adjusted Three-Dimensional Wind Field) (Sherman 1978), and **ADPIC** (Atmospheric Dispersion Particle-In-Cell) (Lange 1978). These codes are used in conjunction with TOPOG (a topographic grid generation code), MEDIC (MEteorological Data Interpolation Code), PLOT CONTOUR (a graphical contour plot generator). Figure 3 illustrates the basic MATHEW/ADPIC run stream that culminates in the hazard-assessment product. The typical run of this system takes about 5 to 10 min of VAX CPU time at 35 Mips to complete, including the automated preparation of the input files.

Topography databases provide information for determining how wind fields are influenced by underlying terrain. In 2 to 5 minutes, ARAC's operations staff can create a terrain file with a resolution 0.5 km x 0.5 km and can display images of the mountains, valleys, seashores, and plains for almost any part of the world. **TOPOG** produces an Eulerian grid with block-form terrain for the lower boundary of the model system. The model domain is typically divided into 35,000 cells with an array of 50 x 50 horizontal cells and 14 evenly-spaced vertical layers.

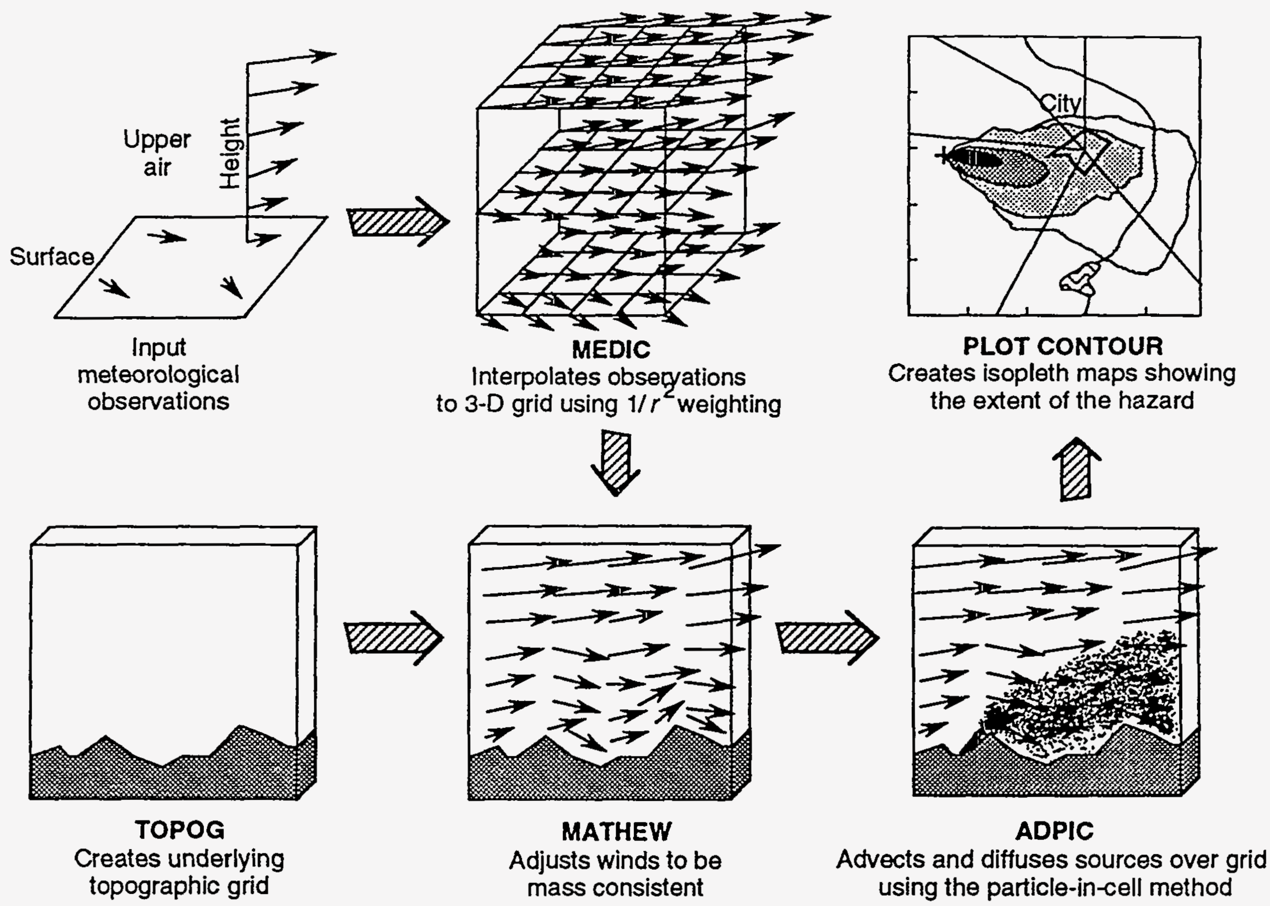


Figure 3. ARAC's diagnostic emergency response dispersion model run stream

MEDIC uses an inverse-distance-squared ($1/r^2$) weighting of wind-speed and direction observations and wind-profile laws to extrapolate horizontal wind vectors to the face of each grid cell. Because this extrapolation does not account for terrain, it can yield winds that blow through instead of around mountains and across rather than along the valleys. To correct such impossible results, each grid cell that is below the terrain (e.g., under a mountain or ridge) is marked to prohibit air from entering it. **MATHEW** then applies a calculus-of-variation technique to create a mass-consistent, nondivergent flow field over the block-form terrain. Vertical velocities are generated by enforcing the mass conservation (or continuity) equation on each grid cell, ensuring that the same amount of air leaves each box as enters it. The relative magnitude of adjustments to the horizontal and vertical wind components are governed by atmospheric stability, calculated from surface observations. The height of the inversion and the stability of the atmosphere can be specified as a function of time, but they are currently uniform over the model domain. Because this is a purely diagnostic model, thermally driven flows such as sea breezes, slope flows, or convection motion are not created in the calculation. Resolving these features relies to a great degree on the representativeness of input wind observations. The wind field calculated by MATHEW provides the three-dimensional mean wind components for ADPIC.

ADPIC is a Lagrangian particle-in-cell code that provides the dispersion physics for a wide range of emissions, such as neutrally buoyant gases, and/or particles, including radioactive and nonradioactive materials. Up to 20,000 marker particles are available to represent as many as **nine different species** or sources in a single model run. For NPP sources, the nine highest contributors to each dose type are analyzed from the complete set of nuclides generated by RASCAL. Experience has shown that the 9 highest contribute to more than 90% of the total dose when compared to the complete nuclide suite.

Sources may be either instantaneous puffs or continuous plumes with time-varying release rates. Each source is simultaneously injected into the wind field with its own release rate, particle-size distribution, deposition velocity, and time-dependent plume rise using stack, fire or explosion algorithms. Radioactive decay, particle-size-dependent gravitational settling, dry deposition, and precipitation scavenging are computed during each time step for each source. Four inner nested grids with 2, 4, 8, and 16 times the resolution of the primary grid cell provide higher resolution near sources.

Dispersion of ADPIC marker particles can be described by two basic processes: transport by the mean wind and diffusion by turbulence. MATHEW provides the mean winds for use by ADPIC. The operational version of ADPIC uses parameterizations for horizontal and vertical eddy diffusivities (K-theory) and solves the advection-diffusion equation using a particle-in-cell technique. The first-order closure parameterizations of the eddy diffusivities are based on Obukhov length, mixed-layer height, surface roughness, and wind speed.

PLOT CONTOUR produces a variety of plots using a geographic map overlay. Dose factors can be applied to the individual organs or the whole body through inhalation, immersion, or ground-exposure pathways. **Typical products** for NPP incidents include:

- Air concentration
- Adult 50-year thyroid dose via inhalation
- Cumulative effective dose equivalent (CEDE) via inhalation
- Air immersion (cloud shine) dose rate
- Effective whole body ground exposure dose (ground shine)
- 4-day total effective dose equivalent (TEDE = CEDE + cloud & ground shine)
- Cumulative deposition.

Plots may be generated for instantaneous dose rates or time-integrated doses (4-day, 1-year, 2-year, 50-year) as needed. The nine highest contributors to each plot are combined and contoured according to requested isopleth values. The plots include legends that describe the release, the species involved, and type, units, and valid time for the contours. After a quality assurance review by an assessment meteorologist, the plots can be transmitted by modem to a computer at ARAC-supported sites or can be faxed to the emergency response teams in the field. Figure 4 shows a sample plot which was created during the FRMAC-93 exercise at the Ft. Calhoun NPP.

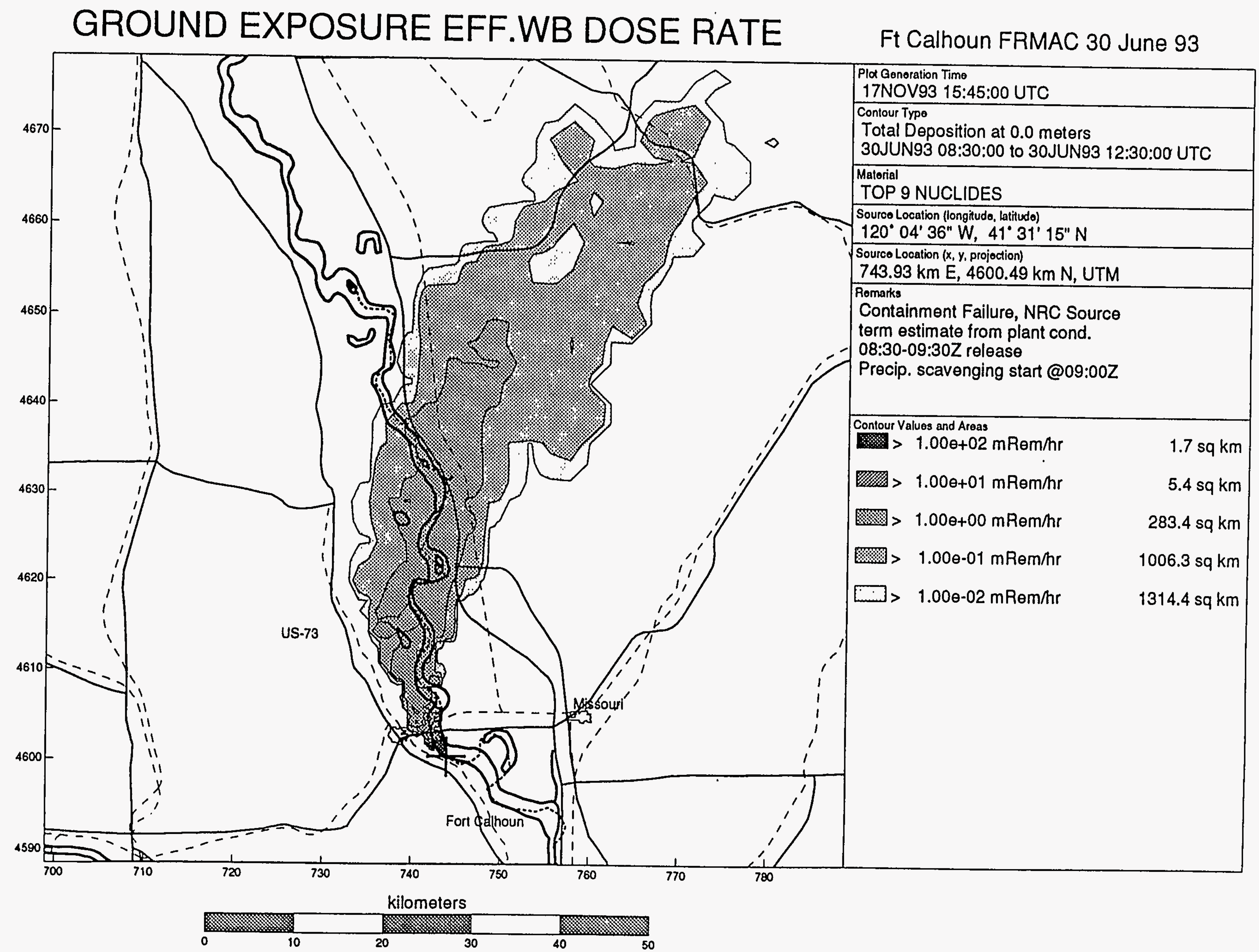


Figure 4. Example ARAC plot from FRMAC-93 exercise at Ft. Calhoun NPP, Nebraska

NUCLEAR POWER PLANT SOURCE TERM UNCERTAINTY

NRC experience with actual NPP events such as the 1979 Three Mile Island accident emphasizes the large uncertainty likely in the magnitude of source term estimates. Table 2 lists the range of possible errors associated with attempting to model NPP releases with the Gaussian-based RASCAL model (Athey et al. 1993). These uncertainty factors are ratios between model projections for a particular accident sequence and the average dose that might be observed. It may be possible to characterize releases through a **monitored pathway**, such as a stack, reasonably well. However, large uncertainties in release rates can occur from **unmonitored pathways** such as containment failures. Consequently, NRC advises that "dose projections should be viewed as only rough estimates." Once the source term is adjusted by an analysis of the radioactive iodine and other particulate measurement data, the adjusted model calculation can be used with greater confidence.

Table 2. Source-term and Dispersion Model Uncertainty Factors for the RASCAL model[a]

COMPONENT	AT BEST	MOST LIKELY	NEAR WORST[b]
Source Term	5	100-1000	1,000,000
Dispersion Model			
Diffusion (concentration)	2	5	10
Transport (direction)	22°	45°	180° (low wind speed)
Transport (speed)	1	2	10
Dosimetry	3	4	10
ALL COMPONENTS	10 22°	100-100,000 45°	1,000,000 180°

[a]Estimates are for average dose (15-30 min) at a location, not for a single monitor reading
[b]Unmonitored release case

During the early phase of the response for an unmonitored release, NRC recommends basing protective-actions decisions only on plant conditions and general meteorological conditions. However, models can still bracket the possible location *and* extent of contamination for a range of *possible* source terms. It is our experience to not attempt to show model uncertainty in a response. Presenting uncertainty on plots is difficult and can lead to confusion. Instead our preference is to show all assumptions and attempt to present the best estimate.

ARAC MODEL UNCERTAINTY

We have conducted more than a dozen **model-evaluation studies** over the years in a variety of settings and scales with the MATHEW/ADPIC models. Figure 5 illustrates results from evaluations on local-to-regional scales (1 to 100 km) over the last 20 years (see Sullivan et al. 1993). Each evaluation used the most stringent statistical comparison, where measurements are paired with model calculations in *both* space and time. Also, all tracer samples were used. The sources include neutrally buoyant tracers released both as surface and elevated point sources. The studies are categorized as "simple", involving flat or rolling terrain with relatively steady meteorology, or "complex", involving rolling to complex terrain or complex meteorology, such as sea breezes, mountain-valley flows or changing winds during the tracer release.

Each study represents hundreds to thousands of 20- to 60-min averaged **ratios** of measured to modeled values of the concentration of the tracer in ground-level air. Using ratios to compare model results with observations gives every data point equal weighting, regardless of the magnitude of the concentration, thus favoring low concentrations at the edges of the plume. This method provides a measure of relative model performance between experiments, but it does not offer any details about the model's bias. (Other statistics have shown that the models do not have a significant bias.).

Results show that the MATHEW/ADPIC models estimated the air concentrations of the tracer to within a **factor of 2 of the measured values 20 to 50% of the time,** and to within a factor of 10 of the measurements 50 to 98% of the time, depending on the complexity of the meteorological conditions, the terrain, and the release height. These values include diffusion and transport direction and speed errors in model inputs and model calculations. Therfore, the majority 3-D diagnostic models concentrations, especially those near the plume centerline, should be within a factor of 10 of the actual values. Our evaluation studies show in most cases that accuracy is most sensitive to correctly determining wind direction. Measurement errors of ±5° in wind direction on towers and ±10° in airport observations are most likely and will be propagated in the wind field model.

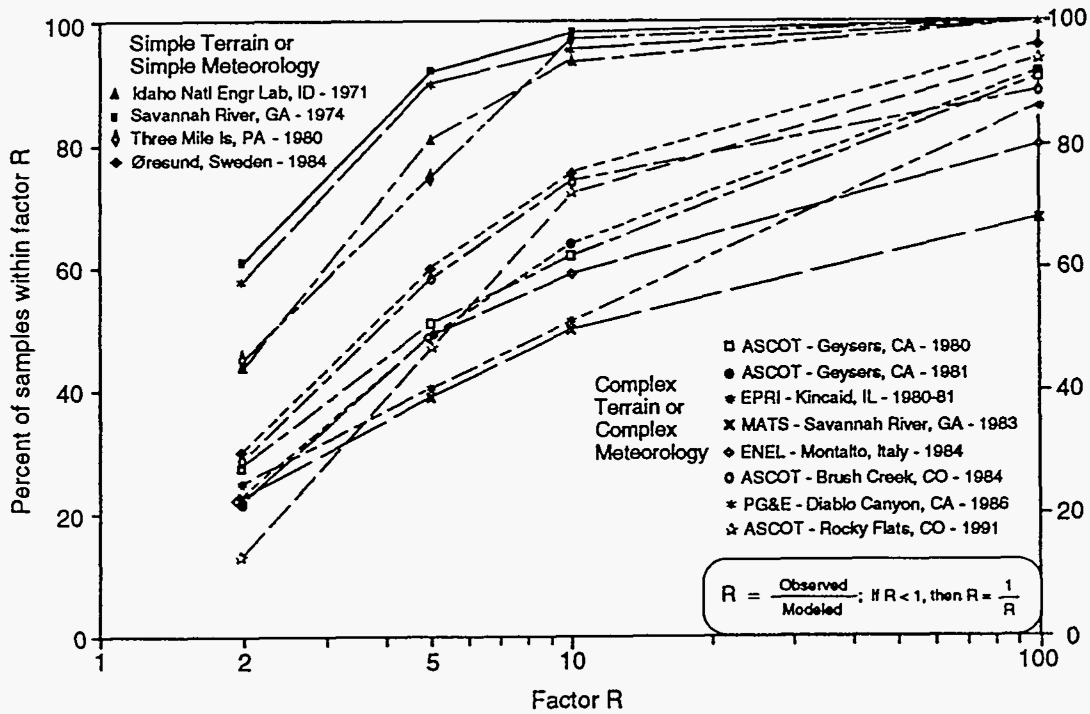


Figure 5. Accuracy of MATHEW/ADPIC models from twelve tracer studies

TRANSITION FROM MODELS TO MEASUREMENTS

Table 2 indicates the greatest improvement for overall model uncertainty is possible by accurately determining the source term. ARAC will use the first radiological measurements received by the FRMAC Data Center from the NPP and state teams and the initial FRMAC aerial survey to adjust the source term and refine the calculation. The assessor uses a real-time field measurement tool to calculate a set of **ratios between individual measurements and model outputs**. Even under simple dispersion conditions, one would not expect complete agreement between field monitors and the model. However, the data are analyzed for a consistent set of ratios which are averaged to estimate source-term multipliers for a refined set of plots. Outlier values are tagged and those locations are recommended for further monitoring. Refined plots can then be used to optimize more comprehensive field surveys.

Later, as **sufficient quality assured measurements** begin to produce a reasonably consistent picture, measurement data will primarily be used for decision making. Interaction between ARAC, the states, and the utility modeling groups, and the FRMAC E&A, Predictions Team, and Monitoring and Analysis Team Leaders is essential to determine the best information at each stage of the process. This is a dynamic and challenging process requiring rapid communication with team members who must be experienced with real-world events and the associated uncertainties in models and monitoring data.

DIAGNOSTIC MODEL IMPROVEMENTS

The current model performance statistics leave room for significant improvement. ARAC has embarked on a multi-year modernization effort to add new capabilities, improve databases, model physics, and speed. Some of these are outlined in the Table 3.

Table 3. Key Improvements Planned for the ARAC System

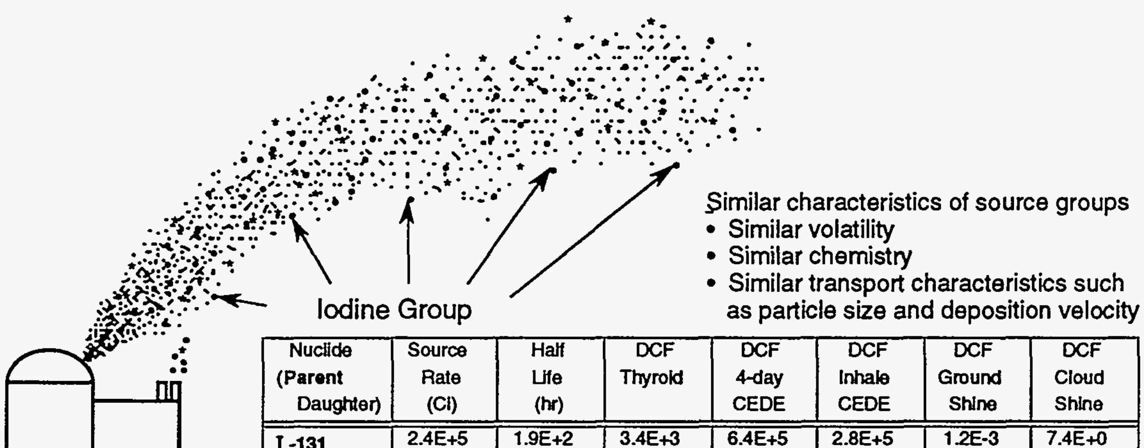
ITEM	CURRENT	PLANNED
Computer speed	35 Mips VAX	2-5 times faster Alpha VAX
Terrain resolution	500 m	100 m
Geography database	1:2,000,000 USGS DLG	1:100,000 USGS DLG Digital Chart of World Arc/Info & TIGER overlay
Sources	Radiological	Toxic and dense gas spills
Number of nuclides	Nine	Unlimited nuclide grouping via "hybrid-particle source"
Real-time metdata	Air Force GWC	Navy FNMOC McIdas
Model terrain grid	Block cell	Continuous terrain
Wind field	$1/r^2$ interpolation	Spatially-weighted inputs with pseudo-dipole method
	Purely diagnostic	Add slope and stability physics
Dispersion	Cell-dependent gradient diffusion	Random displacement model Langevin equation model
	Spatially-homogeneous parameters	Spatially-varying land use, surface roughness, precipitation

After each new capability is developed and tested, the model performance statistics will again be computed using a standardized set of model evaluation field programs to quantify the level of improvement.

Of these planned new capabilities, one of the most useful tools for NPP accidents will be the "**hybrid-particle source.**" Figure 6 shows that by grouping nuclides with similar volatility, chemical properties, and transport characteristics (particle size distribution and deposition velocities), a table of data can be carried with each marker particle rather than single values. Possible NPP hybrid-particle groups could be:

- Noble gases
- Iodines
- Alkali metals
- Noble metals
- Elemental halogens
- Refractory oxides

Built into the table is the generation of daughter product decay chains, weathering, and mitigation factors. This capability will allow an assessor to easily populate the source-term with a complete set of nuclides and not need to determine which are the major contributors to each dose type.



Nuclide (Parent Daughter)	Source Rate (Ci)	Half Life (hr)	DCF Thyroid	DCF 4-day CEDE	DCF Inhale CEDE	DCF Ground Shine	DCF Cloud Shine
I -131	2.4E+5	1.9E+2	3.4E+3	6.4E+5	2.8E+5	1.2E-3	7.4E+0
I -132	2.2E+5	2.3E 0	4.2E+4	7.3E+4	4.2E+4	2.2E-4	4.5E+0
Te-132	1.1E+5	7.8E+1	2.1E+3	8.6E+4	5.2E+5	1.2E-4	6.1E+1
I -132	1.1E+5	2.3E 0	1.5E+3	9.8E+3	6.7E+4	2.6E-3	2.6E-1
I -133	4.3E+5	2.1E+1	1.3E+3	2.9E+5	8.3E+5	5.1E-3	4.3E+0
I- 134	2.1E 0	8.8E-1	5.1E+3	5.0E+3	1.6E+4	7.8E-4	5.7E+1
I -135	5.4E+4	6.6E 0	1.4E+3	3.2E+4	7.4E+5	9.2E-4	3.4E-1
Xe-135m	2.2E+4	5.3E+1	7.2E+4	5.1E+4	2.6E+4	3.3E-3	7.8E-1

Table of time-dependent data carried with each ADPIC marker particle in group

Figure 6. Illustration of an ADPIC hybrid-particle source term

NEW PROGNOSTIC MODEL IMPLEMENTATION

Currently ARAC uses a two-hour persistence forecast or the Assessor's analysis to project plumes beyond the current time. We recognize the need to implement a prognostic model for up to 18 hour forecasted wind and dispersion conditions. This spring the LLNL Regional Atmospheric Science (RAS) Division embarked upon a study to test and evaluate three candidate mesoscale prognostic models to be used as both in ARAC operational emergency response as well as in Division research programs. In late 1994, RAS will select one final model to begin integrating into the ARAC System and use as the Division's basic research tool. Research applications include cloud physics, chemistry and electrification, severe storms, mesoscale and orographic systems, volcanic and smoke plume dynamics, and weather modification and climatic change effects. The basic criteria were that the model be available for cooperative research and have as many of the desired characteristics listed in Table 4 as possible.

From over twenty candidate models, RAS selected the following three to test and evaluate on the LLNL Crays:

- Advanced Regional Prediction System (ARPS)
  Center for the Analysis and Prediction of Storms
  University of Oklahoma

- Regional Atmospheric Modeling System (RAMS)
  Colorado State University

- Naval Operational Regional Atmospheric Prediction System (NORAPS)
  Coupled Ocean-Atmosphere Mesoscale Prediction System (COAMPS)
  Naval Research Laboratory

SUMMARY

ARAC is an integral part of DOE's radiological emergency response assets in support of the FRMAC for accidents at nuclear power plants. Trained meteorologist assessors use a highly-automated modeling system coupled with real-time meteorological data links and communicating with a network of workstations distributed around the country to respond to a variety of atmospheric releases. A well-established suite of diagnostic dispersion models coupled with source-term, topographic, geographic, and dose-conversion databases are currently used to rapidly respond to complex mixed fission releases. A multi-year modernization effort was begun in 1994 to improve many of the capabilities. Key new developments important to the FRMAC are the hybrid-particle source terms and the mesoscale prognostic model.

ACKNOWLEDGMENT

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Table 4. Desired Characteristics for the
LLNL RAS Mesoscale Prognostic Model

FEATURE	DESIRED CHARACTERISTICS
General dynamic framework	Compressible Nonhydrostatic
Code architecture	Modular standardized coding & configuration Parallelizable Hierarchical user levels
Hardware & runtime	Memory and storage within RAS capacity Runtime speed for emergency response
Selectable spatial scales and phenomena treatments	1. Meso-gamma 0.5-10 km cells, up to 200 km domain Plumes, convection, fires, thunderstorms, tornadoes, orographic clouds, local terrain-driven flows 2. Meso-beta 0.5-20 km cells, up to 1000 km domain Mesoscale convection systems, land/sea breezes and coastal dispersion, mountain flow systems 3. Meso-alpha 5-50 km cells, up to 5000 km domain Frontal systems, hurricanes, regional hydrology, continental-scale dispersion
Selectable coordinate systems	Terrain-following coordinates Cartesian, Mercator, Lambert Conformal
Selectable physics modules	Cloud microphysics (liquid and solid phase) Aerosol microphysics Radiative transfer (solar and IR) physics Planetary boundary layer physics Surface energy budget Soil processes
Diagnostic modules	Simulated instrument aircraft module Aerosol mass budget Water mass budget Heat & moisture budgets for cloud processes Radar reflectivity Interactive graphics and visualization
Met data assimilation	3-D initialization from multiple sources Initialization scheme 4-D data assimilation
Support	Stable documented code with User's Guide Troubleshooting assistance by phone Supported by collaborative research team

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