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J. R. Albritton, R. L. Lee, G. Sugiyama,
R. L. Baskett, R. M. Hodur, and C. -S. Liou

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MODELING THE WIND-FIELDS OF ACCIDENTAL RELEASES WITH AN OPERATIONAL REGIONAL FORECAST MODEL

J. R. Albritton*, R. L. Lee, G. Sugiyama and R. L. Baskett
Lawrence Livermore National Laboratory
Livermore, CA 94551

R. M. Hodur and C.-S. Liou
Naval Research Laboratory
Monterey, CA 93943

1. INTRODUCTION

The Atmospheric Release Advisory Capability (ARAC) (Sullivan et al. 1993) is an operational emergency preparedness and response organization supported primarily by the Departments of Energy and Defense. ARAC can provide real-time assessments of atmospheric releases of radioactive materials at any location in the world. ARAC uses robust three-dimensional atmospheric transport and dispersion models, extensive geophysical and dose-factor databases, meteorological data-acquisition systems, and an experienced staff.

Although it was originally conceived and developed as an emergency response and assessment service for nuclear accidents, the ARAC system has been adapted to also simulate non-radiological hazardous releases. For example, in 1991 ARAC responded to three major events: the oil fires in Kuwait, the eruption of Mt. Pinatubo in the Philippines, and the herbicide spill into the upper Sacramento River in California.

ARAC's operational simulation system (Rodriguez et al. 1992), includes two three-dimensional finite-difference models: a *diagnostic* wind-field scheme (MEDIC/MATHEW, Sherman 1978), and a Lagrangian particle-in-cell transport and dispersion scheme (ADPIC, Lange 1978). The meteorological component of ARAC's real-time response system employs models using real-time data from all available stations near the accident site to generate a wind-field for input to the transport and dispersion model. It is well known that the success of this approach is highly dependent on the quantity and quality of observational data which is acquired. Using purely diagnostic models, there are many atmospheric motions which may not be captured by the calculations. Locally-driven flows within spatially-sparse data networks are a prime example. Because of the difficulty in determining the details of local wind-fields objectively, the assessment meteorologist must sometimes modify the input data based on a hand analysis of the winds to produce a reasonably modeled wind-field.

All the foregoing observations suggest that some of ARAC's un-met meteorological data needs could be met by relatively fine scale spatial data from a *simulation* of the atmospheric boundary layer. ARAC is always in the process of improving its meteorological data gathering and modeling capabilities, and has begun to explore the use of an operational limited-area forecast scheme, a *prognostic* model, to complement its diagnostic models for wind-fields in its next generation emergency response system.

Here we report on simulation studies of past and potential release sites to show that even in the absence of local meteorological observational data, readily available gridded analysis and forecast data and a prognostic model, the Navy Operational Regional Atmospheric Prediction System (NORAPS, Liou 1994), applied at an appropriate grid resolution can successfully simulate complex local flows. NORAPS was developed by the Naval Research Laboratory (NRL) in Washington DC and Monterey, California to provide forecasts for Naval Operations. It is a primitive equation model employing a sigma/pressure vertical coordinate, and permits a total of three one-way nested grids in the horizontal. Model physics includes soil and water surface parameterizations, a one-and-one-half order planetary boundary layer turbulence treatment, dry convective adjustment, large scale precipitation, a modified Kuo convective parameterization, and solar and thermal radiation schemes.

* *Corresponding author address*: J. R. Albritton, L-262, ARAC/RAS, LLNL, Livermore, CA 94551

Initial conditions and forecast boundary conditions for NORAPS are obtained from the Navy Operational Global Atmospheric Prediction System (NOGAPS), the US Navy operational global forecast model. The regional model can be located anywhere in the world within a global one degree gridded dataset from the Fleet Numerical Meteorological and Oceanographic Center (FNMOC) in Monterey, California. Observational data can also be incorporated into the forecasts via an incremental update/optimum interpolation procedure.

The locales chosen for our initial wind-field simulation studies are in the San Francisco Bay Area, the site of a toxic oleum release in July 1993, and the Cape Canaveral Kennedy Space Center Area, the site of major rocket launches, including a nuclear power reactor aboard the Cassini mission satellite scheduled to launch in the Fall of 1997. We have made multiply nested simulations which focus on these sites, and intense observational data collection campaigns are in progress to form complete verification cases for our new modeling capability.

2. AN EXAMPLE OF DIAGNOSTIC MODEL LIMITATIONS ON THE LOCAL SCALE

ARAC is located at the Lawrence Livermore National Laboratory (LLNL) in the San Francisco Bay Area (SFBA), and recently provided dispersion simulation products to California state and local emergency and health service agencies during and after the accidental venting of a chemical tank car in nearby Richmond (Baskett et al. 1994). Figure 1(a) is a 3D enhanced terrain view of the SFBA to orient the reader. About 8 tons of oleum, SO_3, were released over about 4 hours beginning at about 7 AM on July 26, 1993. A visible cloud containing sulfuric acid, H_2SO_4, formed in the cool, moist early morning air and was transported and dispersed by the ambient winds over a path almost a kilometer wide and several kilometers long. Thousands of people reported to local hospitals complaining of irritation of their eyes, skin and respiratory tract. Figures 1(b), (c), and (d) are increasingly magnified 2D maps of Fig. 1(a) which display important meteorological stations and data, the associated modeled surface wind-field, and the horizontal extent of the simulated plume.

ARAC's response to the Richmond accident (Baskett et al. 1994 and 1995) shows the importance of *local* meteorological data in producing accurate wind-fields with the

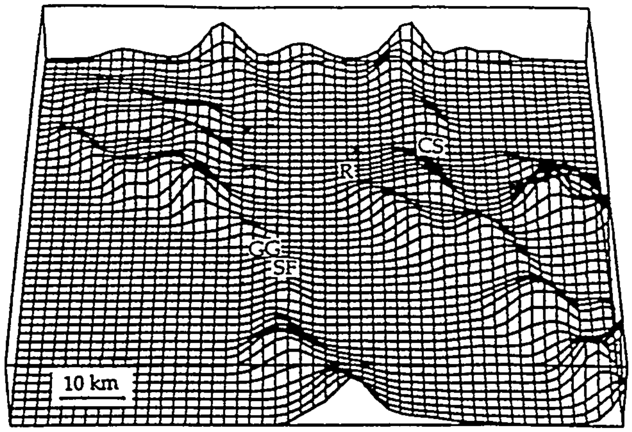
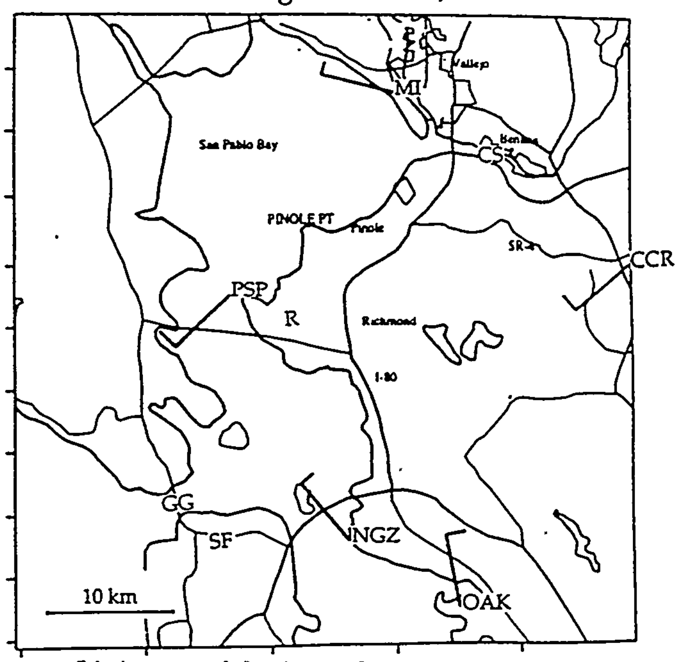


Figure 1. (a) An elevated view of enhanced terrain looking north at the SFBA. Note the Pacific Ocean to the west, the coastal hills, the Golden Gate (GG) pass near San Francisco (SF), the East Bay hills and Richmond (R), and the Sacramento River Delta beyond the Carqueniz Straights (CS) in the northeast region of the map. The map spans 100 km north-south and east-west with 2 km resolution elements. LLNL is located about 20 km to the east, off the mid-lower part of the map. The maximum terrain height is about 1,000 m.



(b) A map of the inner SFBA. The wind-barbs are surface station data near the time of the accident described in the text: Oakland International Airport (OAK 4.1 m s^{-1}), Alameda Naval Air Station (NGZ 3.1 m s^{-1}), Point San Pablo Tower (PSP 4.5 m s^{-1}), Mare Island Naval Shipyard (MI 2.7 m s^{-1}), and Contra County Airport (CCR 4.1 m s^{-1}).

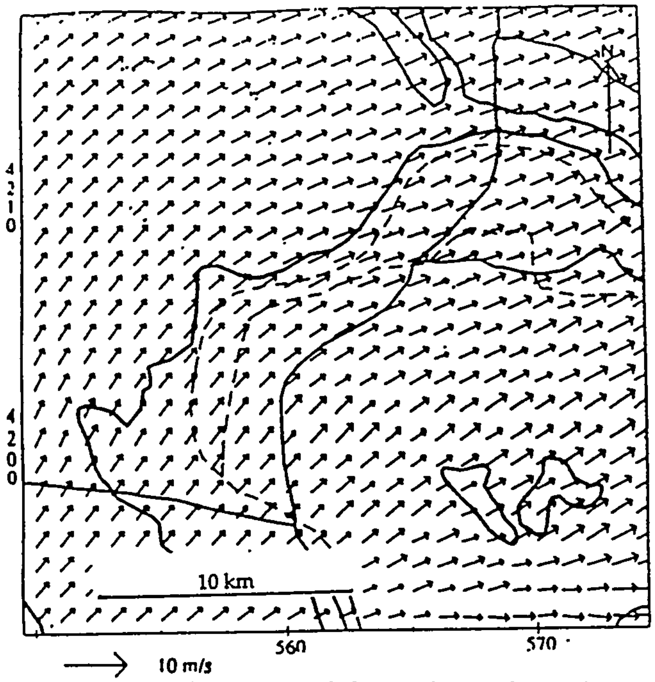
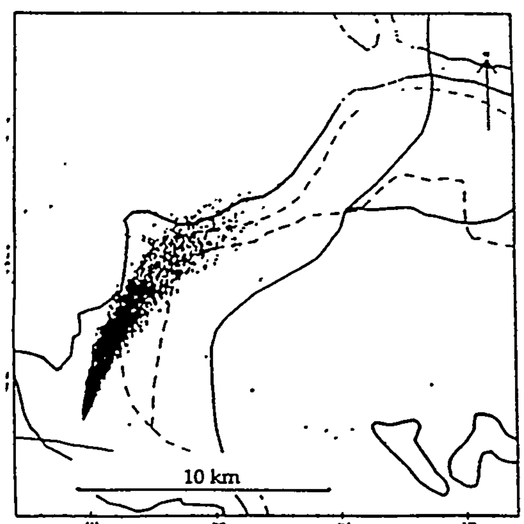


Figure 1. (c) A map of the Richmond accident area at twice the magnification of (b). The MATHEW-modeled wind-field vectors were generated from the station data of (b) and upper air sounding data of Fig. 3.



(d) The ADPIC-simulated dispersion of the near-surface extent of the cloud about an hour after the release began. The dots represent Lagrangian marker particles of material released into the ambient flow.

operational models. Figures 1(b) and (c) show that the Point San Pablo tower (PSP) of the Bay Area Air Quality Management District is closest to the accident site, at less than 5 km away, and is dominant in determining the modeled wind-field, which in turn controls the modeled plume, especially its direction, as shown in Fig. 1(d). The other meteorological stations are about 20 km and further distant and reveal a complex wind pattern typical of mid-summer mornings in the SFBA.

Note that with only the Oakland International Airport (OAK), Alameda Naval Air Station (NGZ) and the Mare Island Naval Ship Yard (MI) data an almost *due* west wind would be *interpolated* at Point San Pablo (PSP), where in fact a *south*west wind exists. The *north*eastward course of the plume as shown in Fig. 1(d) as compared an almost *due* eastward course is a matter of consequence to the emergency response managers.

3. POTENTIAL FOR IMPROVEMENT FROM A PROGNOSTIC MODEL

The situation just described illustrates the vulnerability of modeling data-sparse locales with interpolation-based schemes. Specifically, without the identified *near-source* information, the modeled wind-field could be substantially in error in its direction and strength. Even the fair weather circulations about many of ARAC's fixed supported sites can present a severe challenge to current interpolation-based wind-field models. Such models are often handicapped by sparse input data from meteorological surface stations and soundings. Forecasting by persistence, these models are also often limited in their ability to predict important changes over the diurnal cycle.

For application to the Richmond case, a prognostic model can be used to perform a "now-cast" in a *spatially data-sparse* situation, the time evolution of which is slow and not of primary concern. A second naturally related but distinct application of such a model is of course true forecasting to future local meteorological conditions. In applications to *temporally* data-sparse situations, the *time evolution* of the flow is wanted. Such forecasts are likely to be superior to persistence extrapolation as longer and longer times become of interest.

The Richmond accident then serves to define a meteorological problem of practical interest: modeling the winds in the SFBA given only its terrain and the large-scale atmospheric temperature and wind profiles. This problem represents a proof-of-concept exercise for the implementation of a limited-area forecast model into the ARAC operational system.

We have made two preliminary prognostic simulations of the wind-field of this event with models developed for other purposes here at

LLNL. We applied a primitive equation regional precipitation model (Lee, Soong, and Yin 1995), and also a finite-element planetary boundary layer model (Albritton, Baskett, and Leone 1995) to the incident. Both of these prognostic models produced simulations exhibiting semi-quantitative agreement with the important meteorological data of the incident. These results emerged from only the synoptic flow at the time of the accident, and the SFBA terrain. Thus we captured from first-principles a substantially self-consistent picture of the wind-field of the accident.

This work is very encouraging and further points to the promise of a model using nested grids which is capable of resolving the synoptic flow over a large region and thence the local flow within a still more highly resolved limited area.

4. CONCLUSION

Modeling atmospheric releases even during fair weather can present a severe challenge to ARAC's diagnostic operational models. Such schemes are often handicapped by sparse input data from meteorological surface stations and soundings. Forecasting by persistence is only acceptable for a few hours and cannot predict important changes in the diurnal cycle. Many accident scenarios are data-sparse in space and/or time.

We have shown the potential value of limited-area forecast models for real-time emergency response. A limited-area forecast model promises to overcome some of the major limitations of the diagnostic wind-field model used in our current operational system. ARAC plans to implement such a model into its operational system and to use it to *resolve* and to *forecast* improved wind-fields. The prognostic wind-fields will be passed to ARAC's operational dispersion model to produce improved forecasts of dispersion following accidents.

Not least because of its computational burden, prognostic modeling will likely be applied to preparedness planning and post-accident assessments for some time before it will be applied to real-time response. The present work is an example of such activities which will permit ARAC to gain experience with this new capability while the required increase in computer performance is expected to emerge over the next few years.

REFERENCES

Albritton, J. R., R. L. Baskett, and J. M. Leone 1995: Modeling the wind-field of an accidental release by limited-area forecasting. Lawrence Livermore National Laboratory Report UCRL-JC-

Baskett, R. L., P. J. Vogt, W. W. Schalk III, and B. M. Pobanz 1994: ARAC dispersion modeling of the July 26, 1993 oleum tank car spill in Richmond, California. Lawrence Livermore National Laboratory Report UCRL-ID-116012.

Baskett R. L., P. J. Vogt, W. W. Schalk III, B. M. Pobanz, C. S. Foster, and J. S. Ellis 1995: The challenge of emergency response dispersion models on the meso-gamma urban scale: a case study of the July 26, 1993 oleum tank car spill in Richmond California. *5th Topical Meeting on Emergency Preparedness and Response*, Savannah, Georgia, Apr. 18-21. Lawrence Livermore National Laboratory Preprint Report UCRL-JC-118082.

Lange, R. 1978: A three-dimensional particle-in-cell model for the dispersal of atmospheric pollutants and its comparison to regional tracer studies. *J. Appl. Meteor.* **17**, 320-329.

Lee, R. L., S.-T. Soong, and X. Yin 1993: Simulation of an accidental release over an urban area with a prognostic emergency response model. *5th Topical Meeting on Emergency Preparedness And Response*, Savannah, Georgia, Apr. 18-21.

Liou, C.-S., R. Hodur, and R. Langland: Navy Operational Regional Prediction System (NORAPS): A triple nest mesoscale model. *10th Conference on Numerical Weather Prediction*, Portland, Oregon, July 18-22, 1994, 423-425.

Rodriguez, D. J., G. D. Greenly, P. M. Gresho, R. Lange, B. S. Lawver, L. A. Lawson, and H. Walker 1992: User's guide to the MATHEW/ADPIC models. Lawrence Livermore National Laboratory Report UCRL-MA-103581.

Sherman, C. A. 1978: A mass-consistent model for wind fields over complex terrain. *J. Appl. Meteor.*, 17, 312–319.

Sullivan, T. J., J. S. Ellis, C. S. Foster, K. T. Foster, R. L. Baskett, J. S. Nasstrom, and W. W. Schalk III 1993: Atmospheric Release Advisory Capability: Real-time modeling of airborne hazardous materials. *Bull. Amer. Meteor. Soc.* 74, 2343-2361.

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