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Modeling the Wind-fields of Accidental Releases by Mesoscale Forecasting

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SUMMARY

Modeling atmospheric releases even during fair weather can present a severe challenge to diagnostic, observed-data-driven, 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 or from synoptic evolution. Many accident scenarios are data-sparse in space and/or time. Here we describe the potential value of limited-area, mesoscale, forecast models for real-time emergency response. Simulated wind-fields will be passed to ARAC's operational models to produce improved forecasts of dispersion following accidents.

I. 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 (Sherman 1978, Lange 1978, Rodriguez et al. 1992), extensive geophysical and dose-factor databases, meteorological data-acquisition systems, and an experienced staff.

The meteorological component of ARAC's operational modeling system employs real-time observed data from all available sources near the accident site to generate a wind-field for input to the transport and dispersion model. 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 and future conditions beyond the range of persistence forecasting are prime examples. These considerations 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.

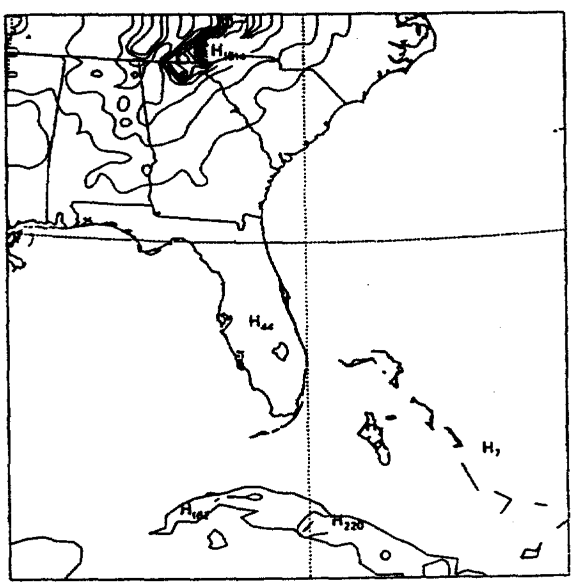
Here we report on simulation studies of past (Lee, Soong, and Yin 1993, Basket et al. 1994 and 1995, Albritton et al. 1995) and potential release sites to show that even in the absence of local meteorological observational data, readily available gridded analysis and forecast data and a prognostic model, the Navy Operational Regional Atmospheric Prediction System (NORAPS, Liou, Hodur, and Langland 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.

Gridded data for initial conditions and future boundary conditions for NORAPS forecasts are obtained from NCEP's NIC web site and/or the Fleet Numerical Meteorological and Oceanographic Center (FNMOC) in Monterey, California. For example, the regional model can be located anywhere in the world within a global one degree gridded data set from the US Navy operational global forecast model, the Navy Operational Global Atmospheric Prediction System (NOGAPS).

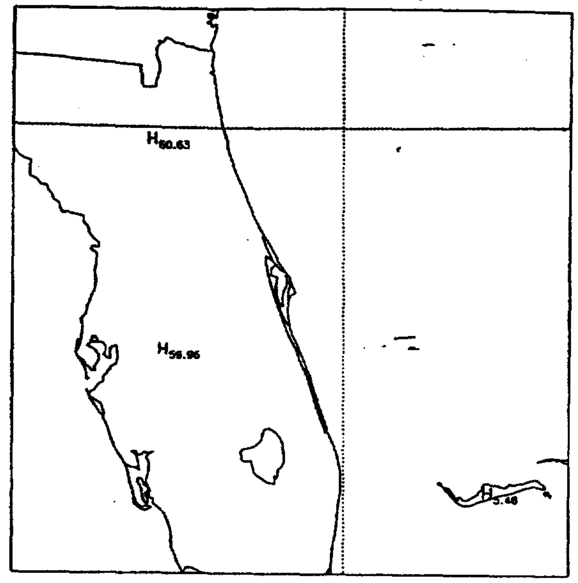
II. MODELING THE WIND-FIELD AT KENNEDY SPACE CENTER ON JANUARY 17, 1997

A Delta II rocket exploded during launch from Cape Canaveral at 1628Z on January 17, 1997. The incident occurred over water, but near the launch pad. A strong vertical variation of the wind direction was present through the low level of the explosion, and caused the resulting plume to evolve into a complicated shape in both the vertical and horizontal. The plume dissipated within a few hours, with some higher parts moving back over land.

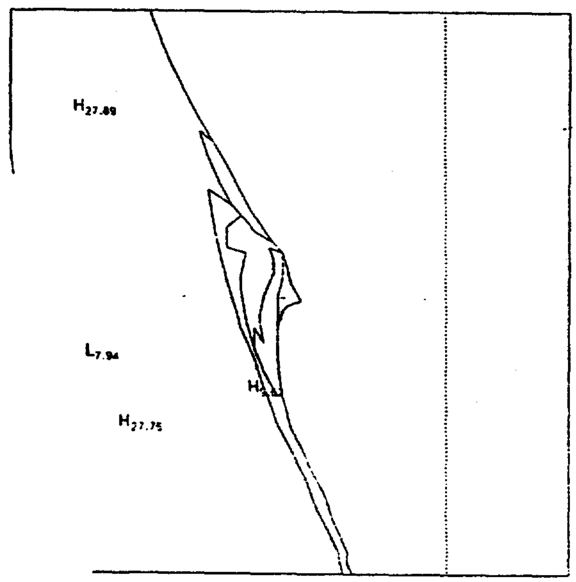
This case serves as a test-case for our forecasting of the site. It will be seen that NORAPS performed well in an "after-the-fact" "operational" simulation of the incident. Figure 1 shows the three nested grids on which the forecast model was run using NCEP's AVN gridded data sets to initialize the atmospheric state, and to provide boundary forcing at 6 hour intervals for a 24 hour forecast from 19970117 00Z to 19970117 24Z/19970118 00Z.



(a)



(b)



(c)

Figure 1. Centered on KSC. (a) Grid 1. a 49x49 grid with Dx = 36 km. (b) Grid 2. a 49x49 grid with Dx = 12 km nested within grid 1. and (c) Grid 3. a 49x49 grid with Dx = 4 km nested within grid 2.

While our inner nested grids can resolve complex local flows, the present case is already well simulated on the first grid. Wind-field data for use in our operational dispersion model is always taken from the third. finest. grid. where weak variations in wind speed and direction are present over the site. Figure 2 shows the 500 mb and surface. 10 m. wind patterns at 00Z and 18Z.

The forecast exhibits different evolutions aloft and near the surface. A trough at 500 mb centered over Hudson's Bay moved slowly Eastward during the forecast period. resulting in nearly steady Westerly winds aloft over the Florida peninsula. On the other hand. high surface pressure. initially in the Northwestern states moved rapidly Southeast to the central US. shifting the surface winds from the West to North along the Florida peninsula. Figure 3 shows the evolution of the surface wind at KSC over the course of the simulation, while almost no shift occurred above about 1500 m.

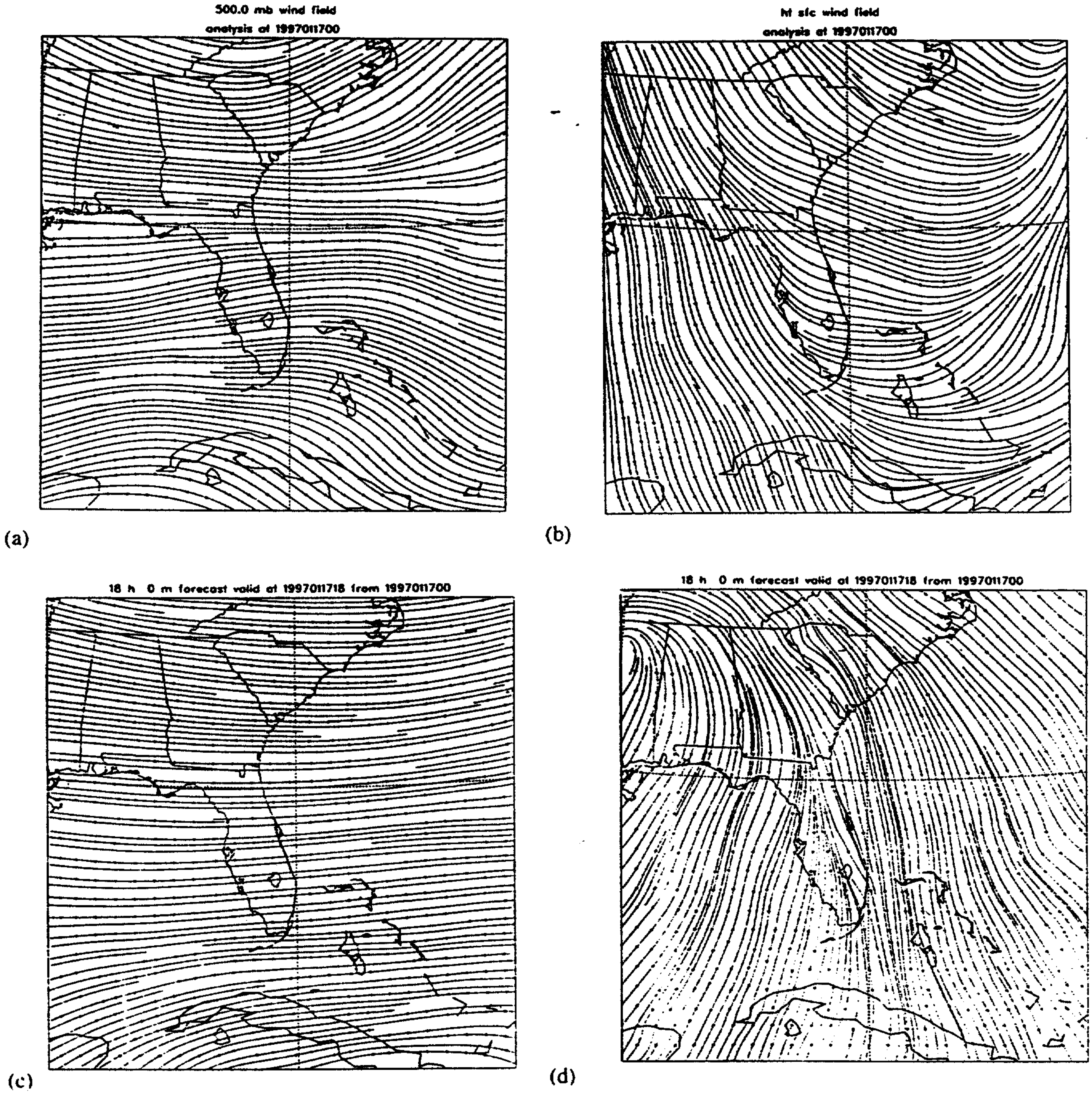


Figure 2. (a) The initial 500 mb wind stream lines at 19970117 00Z. (b) The initial surface, 10 m, wind stream lines at 19970117 00Z. (c) The forecast 500 mb wind stream lines at 19970117 18Z. and (c) The forecast surface, 10 m, wind stream lines at 19970117 18Z.

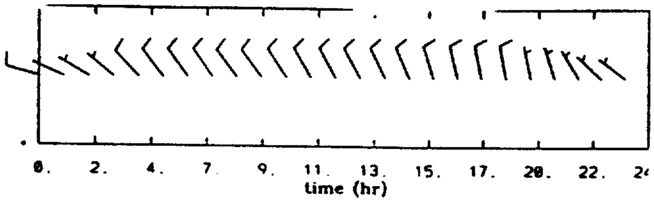
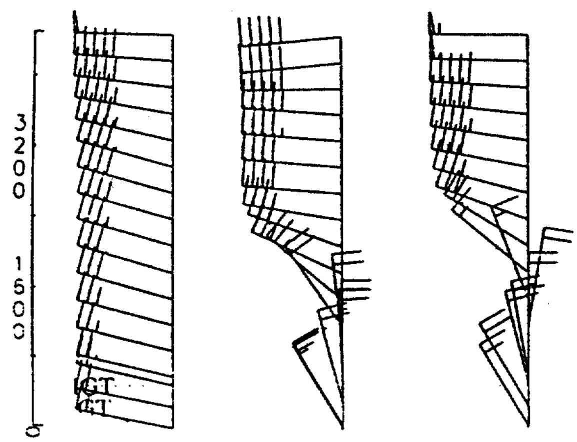


Figure 3 The evolution of the surface, 10 m, wind at KSC from 19970117 00Z to 19970117 24Z/19970118 00Z.

The meteorological situation for the explosion was characterized by the wind-profiles shown in Fig. 4. The observed data consisted of surface stations, towers and a single upper-air sounding. The good agreement between the observed and forecast winds is evident; quite similar dispersion plumes result from the two wind-fields.



(a) (b) (c)
Figure 4. From ARAC's operational modeling system. (a) Vertical winds from a purely diagnostic, observational data driven, simulation of the incident; valid at 00Z, (b) 1630Z, and (c) Vertical winds from a purely prognostic, NORAPS forecast, simulation of the incident, valid at 16630Z.

III. 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 or from synoptic evolution. 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 models to produce improved forecasts of dispersion following accidents.

Not least because of its computational burden, prognostic modeling is being applied to preparedness planning and post-accident assessments 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.

ACKNOWLEDGMENT

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