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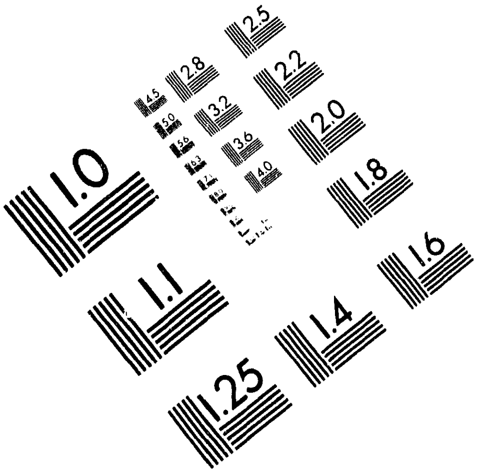

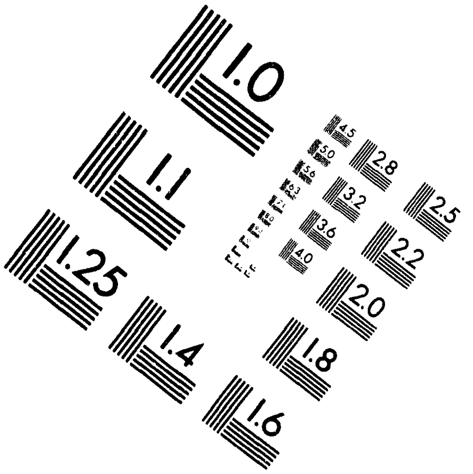

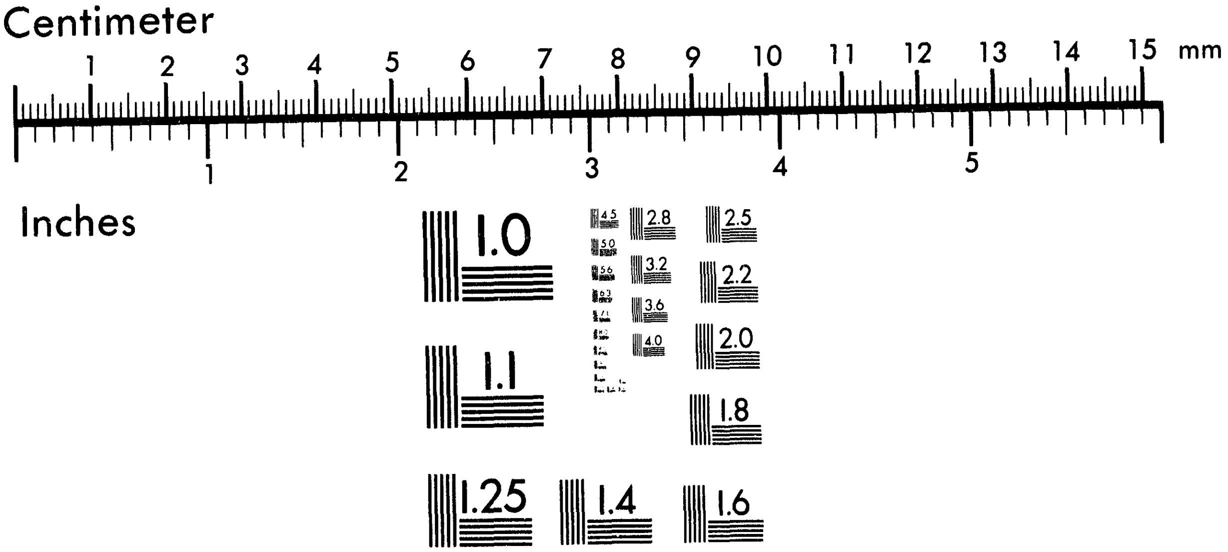

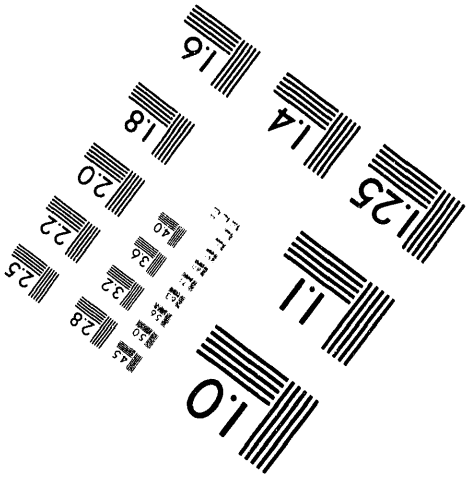

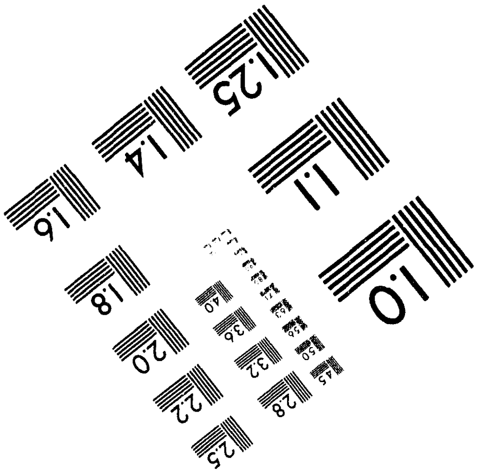

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LONG-RANGE MESOSCALE MODELING OF POLLUTANT TRANSPORT FOR THE EUROPEAN TRACER EXPERIMENT (ETEX)

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LONG-RANGE MESOSCALE MODELING OF POLLUTANT TRANSPORT FOR THE EUROPEAN TRACER EXPERIMENT (ETEX)

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1. INTRODUCTION

The Commission of European Communities (CEC), the World Meteorological Organization (WMO), and the International Atomic Energy Agency (IAEA) are jointly organizing the European Tracer EXperiment (ETEX) (Klug et al. 1993). The ETEX program involves two tracer experiments, each comprising three distinct elements: (a) long-range atmospheric tracer release, sampling, and analysis; (b) real-time model operation and evaluation; and (c) post-release model operation and evaluation. The experiments consist of the release of a non-buoyant tracer from a location in western Europe and sampling of the atmospheric concentration by a network of about 200 stations located in 17 countries.

Twenty-three institutions from 19 countries are expected to participate in the real-time modeling program, including the Savannah River Technology Center (SRTC) of the U. S. Department of Energy's Savannah River Site (SRS). The real-time modeling program tests the participants' current Emergency Response (ER) dispersion capabilities. Notification of the time, location, and amount of the release will occur only after the initiation of the release. Participants will be required to provide 60-h concentration predictions as quickly as possible (within 6 h of being notified) and updated predictions every 12 h after the notification.

With recent advances in both computer hardware and numerical techniques, it has become feasible to employ complex prognostic mesoscale models in ER applications. For instance, mesoscale models are currently being developed and tested for operational ER and environmental applications at the SRS (Fast et al. 1994). A necessary condition for greater use of such methods is the demonstration of their accuracy and dependability for the spectrum of ER situations that may arise; hence, it is important to test their capabilities for a variety of transport situations.

In 1993 two "dry runs" for the real-time modeling component of the program were conducted; the actual tracer release experiment is scheduled for the fall of 1994. This paper describes the modeling approach employed by SRTC and presents some of the results of the second ETEX real-time dry run.

2. MODELING SYSTEM

The modeling system employed by SRTC consists of the Regional Atmospheric Modeling System (RAMS) and a Lagrangian particle dispersion model. RAMS is a three-dimensional primitive equation atmospheric model that employs a terrain-following vertical coordinate system (Pielke et al. 1992). The nonhydrostatic version of RAMS with cumulus and second-order turbulent closure parameterizations is employed for ETEX. The domain encompasses most of western Europe, as shown in Fig. 1a. The model grid has a uniform horizontal spacing of 100 km and a stretched vertical coordinate with the first grid point 48 m above ground level (AGL) and a grid spacing of 1250 m near the model top at approximately 16 km AGL. A time step of 45 s is required for the model to remain stable for this grid configuration. The locations of the samplers are also shown in Fig. 1a.

The Lagrangian particle dispersion model (McNider et al. 1988) simulates dispersion based on the flow and turbulence fields generated by RAMS. The sub-grid scale turbulent velocities are determined from a finite-difference analog to the Langevin stochastic differential equation and depend on the turbulent velocities at the previous time-step and a random component. The turbulent velocity statistics are consistent with the second-order closure applied in RAMS and the effect of vertical inhomogeneity in the second-order moments (drift corrections) have been included in all the random velocity components.

A successful application of mesoscale prognostic methods within the allotted response time requires a system of data acquisition and assimilation, code execution, and post-processing. SRTC automatically downloads analyzed and forecasted meteorological conditions over Europe twice a day. The Medium Range Forecast (MRF) model is used to produce the initial and lateral boundary conditions for RAMS. After the data is transferred, RAMS is executed automatically to interpolate the MRF data to the model grid. With the data acquisition and model initialization performed in this manner, a set of input files incorporating the most recent European weather conditions is available at all times, permitting a rapid response to notification of an ETEX exercise.

In addition to the data acquisition system, RAMS was executed automatically once a day using the 00 UTC MRF model output to produce 69-h forecasts over

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Europe. This was done each day for a week prior to the dry run. Although a 60-h dispersion forecast is required for ETEX, an additional 9 h of forecast time was been added so that a realistic boundary layer would develop by the anticipated time of the release.

During an ETEX exercise, RAMS forecasts can be run on both the SRS Cray XMP/EA supercomputer and on an IBM RS/6000 workstation at the same time. This redundant approach produces the forecast as soon as possible while protecting against an unanticipated code or hardware problem. For the current configuration, RAMS takes about 7.5 h to complete on a IBM model 550 workstation and 4 h to complete on the Cray.

Since the second dry-run, several IBM model 580 and 590 workstations have become available, so that the required computational time is reduced by as much as 50%. A parallel version of RAMS employing domain-decomposition techniques has also been recently developed (Tremback et al. 1994) that significantly reduces the computational time even further. This increase in efficiency will permit a smaller horizontal grid spacing for the actual ETEX exercise this fall. It is anticipated that an additional nested grid (boundaries shown in Fig. 1a) with a 33 km grid spacing may be feasible so that smaller-scale flows can be resolved.

3. DESCRIPTION OF SECOND DRY RUN

The second ETEX dry run for real-time modelers was conducted on December 7, 1993. Information about the release location (Nancy, France), time (15 UTC), duration (6 h), and size (10 g s^{-1}) was transmitted to SRTC by facsimile.

After the completion of the first simulation, an additional five simulations (forecasts and dispersion analyses) were performed, including updated forecasts beginning at 12, 24, 36, and 48 h after the specified release time, as well as one 60 h forecast from the time of release using analyzed meteorological data from the entire 60 hour period. These additional forecasts, designated simulations 2 - 6, differ from the simulation 1 only in the type of data employed at the lateral boundaries. In simulation 1, only forecasts from the MRF model are used at the boundary of the domain. In simulations 2 - 6, a combination of analyzed and forecasted wind fields from the MRF model are used.

4. NUMERICAL RESULTS

The surface winds and plume location 24 and 48 h after the release for simulation 1 is shown in Fig. 1. Initially, the plume is transported from Nancy in a northeasterly direction into Germany. 24 hours after the release, the predicted plume location is over Germany, Poland, and the former Czechoslovakia (Fig. 1a). After 48 hours (Fig. 1b), the plume spreads out as it is advected counter-clockwise in a developing low-pressure system in the Baltic Sea.

Although the surface wind field forecasts from simulation 6 are similar to those produced by simulation 1, a significantly different plume trajectory is produced as seen in Fig. 2. A slightly more westerly component of the wind in southern Germany forces the plume to ultimately travel in a southeasterly direction into eastern Europe before being advected into the low-pressure system in the Baltic Sea.

The predicted wind speed and direction compared to observed values for Stuttgart Germany is shown in Fig. 3. This location was chosen because it was in the path of the plume shortly after the release. Both simulations 1 and 6 forecasted winds that are too westerly after the release, indicating that the plume would have moved in more of a northeasterly direction. The westerly winds

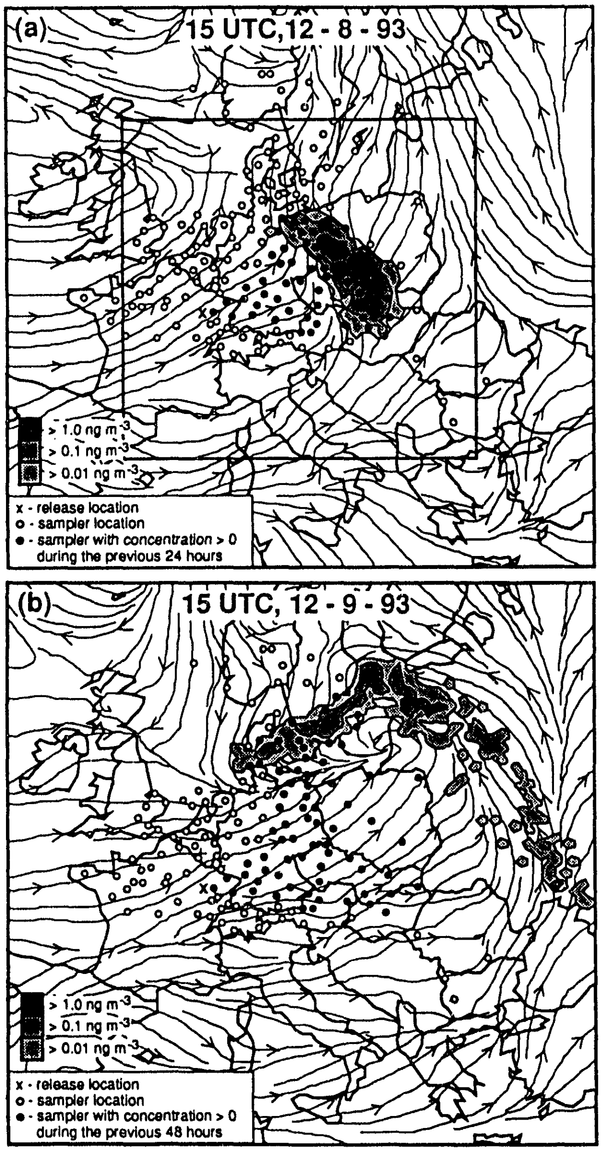

Figure 1. Near-surface streamlines (48 m AGL) and surface concentration (a) 24 h and (b) 48 h after the release time for simulation 1

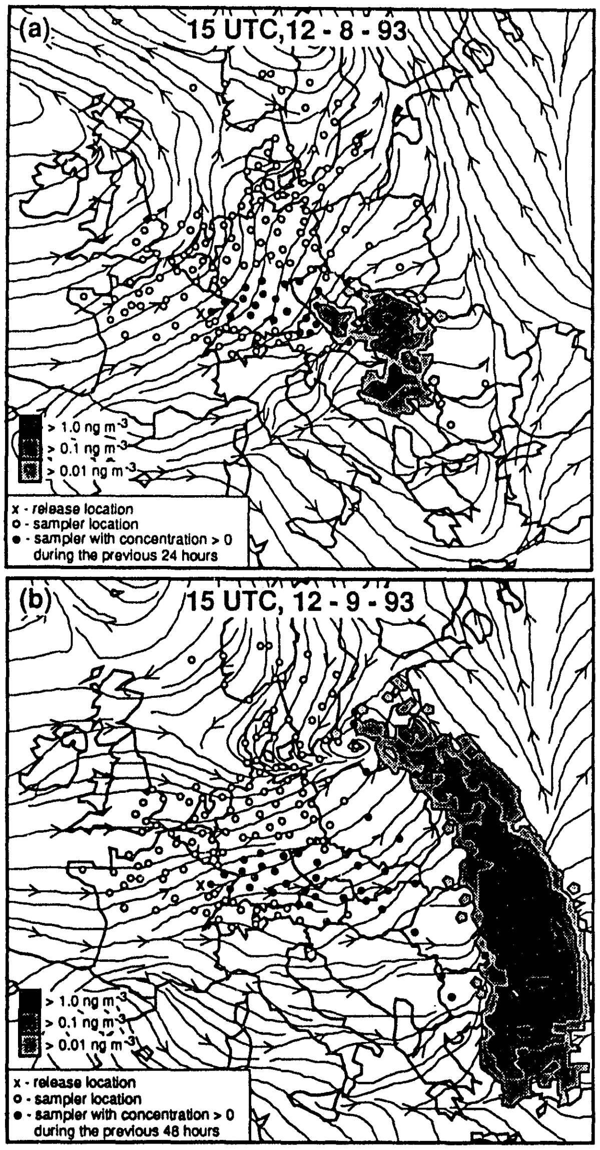

Figure 2. Same as Fig. 1, except for simulation 6

persist longer in simulation 6; therefore, the plume remains in southern Germany and is ultimately advected around the Alps into southeastern Europe.

Preliminary results from nested-grid simulations with a grid spacing of 33 km indicated that the surface winds were slightly more accurate than those produced by simulations 1 and 6. However, the predicted plumes were very similar to those shown in Figs. 1 and 2. The lateral boundary conditions had a larger impact on the model solution than the horizontal resolution.

5. CONCLUSIONS

These simulations demonstrate the impact of boundary conditions on mesoscale models and the potentially large differences in real-time plume forecasts that can occur. Simulations 2 - 6 are updated forecasts that could have included four-dimensional data assimilation (FDDA). FDDA would have increased the accuracy of the wind field produced by RAMS by incorporating the available surface and upper-air observations; however, it may be employed for the actual ETEX exercise this fall. It is hoped that this capability will improve the wind field and subsequently leading to a more accurate plume trajectory. The result of this research is a more efficient, and robust ER dispersion modeling system.

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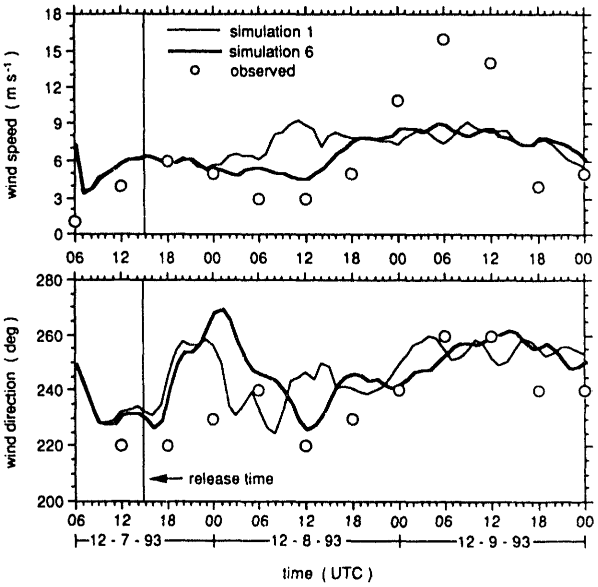

Figure 3. Wind speed and direction predicted by RAMS at Stuttgart, Germany

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