WSRC-MS-96-0015

CONF-9606116--60

Forecasting Long-Range Atmospheric Pollutant Transport and Dispersion: Approaches and Issues

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A document prepared for AMERICAN NUCLEAR SOCIETY 1996 ANNUAL MEETING AND EMBEDDED TOPICALS at Reno from 06/16/96 - 06/20/96.

DOE Contract No. DE-AC09-89SR18035

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Introduction

The ability to forecast the transport and diffusion of airborne contaminants over long distances is vital when responding to nuclear emergencies. Increases in computing capabilities and ready access to large-scale model output make it possible to employ advanced three-dimensional prognostic models to forecast the long-range transport of toxic or radioactive gases for emergency response. The Savannah River Technology Center (SRTC) of the U.S. Department of Energy's Savannah River Site demonstrated this during the European Tracer EXperiment[1] (ETEX).

ETEX, conducted in the Fall of 1994, is designed to evaluate the performance of models for long-range atmospheric pollutant transport and dispersion. ETEX involved two tracer experiments as well as a multinational real-time modeling exercise. The real-time modeling component tested the ability of participants to provide timely long-range forecasts of the tracer plume transport and diffusion. Notification of the time, location and amount of tracer occurred after the start of the release. Participants provided 60-hour forecasts of tracer surface concentration within 6 hours of being notified, and updated forecasts every 12 hours thereafter. The two tracer experiments were conducted near Rennes, France on October 23, 1994 and November 14, 1994.

Modeling Approaches

The SRTC employs the Colorado State University Regional Atmospheric Modeling System (RAMS)[3] and a Lagrangian Particle Dispersion Model (LPDM).[4] RAMS is a primitive equation three-dimensional atmospheric model with a terrain-following vertical coordinate system. LPDM simulates dispersion based upon the flow and turbulence fields calculated by RAMS.

The ETEX model domain encompasses most of Western Europe (see Figure 1a). For long-range transport over a large model domain, application of atmospheric prognostic modeling methods within a useful response time requires a system of automatic data acquisition, assimilation, and model execution. SRTC automatically downloads analyzed and forecasted meteorological conditions twice daily. For ETEX, the US National Weather Service Aviation Model (AVN) 72-hour forecast was used to produce the initial and boundary conditions for RAMS. After the data transfer, RAMS executed automatically to interpolate the AVN data to the model grid. The AVN data is available by 4:00 AM and 4:00 PM Eastern Daylight Time (EDT) each day. To produce a 66-hour forecast with RAMS requires approximately 7 hours on a CRAY X-MP supercomputer, so new forecasts were available by 11:00 AM and 11:00 PM each day. The pollutant transport and dispersion prediction could then be executed in approximately one hour on an IBM RS/6000 high-performance workstation.

Results

This paper considers the first ETEX release, for which some SRTC results have been reported previously[5,6]. The first release commenced at 16 UTC (noon EDT); notification was received at 1:24 PM EDT. A 66-hour forecast initialized with AVN output incorporating 00 UTC observations had been automatically generated as described earlier. The LPDM transport and dispersion calculation was then executed and the results provided to ETEX officials by 4:15 PM EDT, less than 3 hours after the notification. Around this time, a second 66-hour forecast was initiated using AVN output incorporating 12 UTC data. This forecast and the subsequent LPDM calculation were finished prior to 1:00 AM on 10-24-94. Updated forecasts incorporating new AVN output were performed every 12 hours through the end of the exercise at 4 UTC on 10-26-94.

Figures 1 and 2 show the surface wind streamlines and ground-level tracer gas concentration predicted with the initial forecast (simulation 1, based on 00 UTC observations) and the second forecast (simulation 2, based on 12 UTC observations) at 24 and 48 hours after the release, respectively. There is a distinct difference between simulations 1 and 2, particularly for the longer times and distances. In simulation 2, the plume was generally predicted to cover more area and to have higher concentration of the tracer. The trajectories are similar at 24 hours, but at 48 hours the simulation 2 plume extends further east and considerably further south. In contrast, the second and subsequent simulations have rather similar predicted surface concentration fields throughout the 60 hours. Preliminary results from the tracer experiment suggest that simulation 2 better represents the actual transport and dispersion of the plume.

The differences seen in Figures 1 and 2 are apparently because simulation 1 was based on data from 00 UTC on 10-23-94, some 16 hours before the release. The second and all subsequent forecasts had the benefit of data from 12 UTC on 10-23-94, only 4 hours before the release. In this case, the most significant impact of including timely data is seen 36 to 60 hours after the release. All the simulations were in reasonable agreement through 24 to 36 hours after the release. Since the results from simulation 2 were available 12 to 13 hours after the release, the simulation 1 predictions beyond 36 hours are not crucial. This illustrates the value of updating the simulations as new data become available and the importance of waiting for the updated results to make decisions requiring reliable long-range predictions.

Acknowledgment

The information contained in this document was developed during the course of work conducted under contract No. DE-AC09-89SR18035 with the U.S. Department of Energy.

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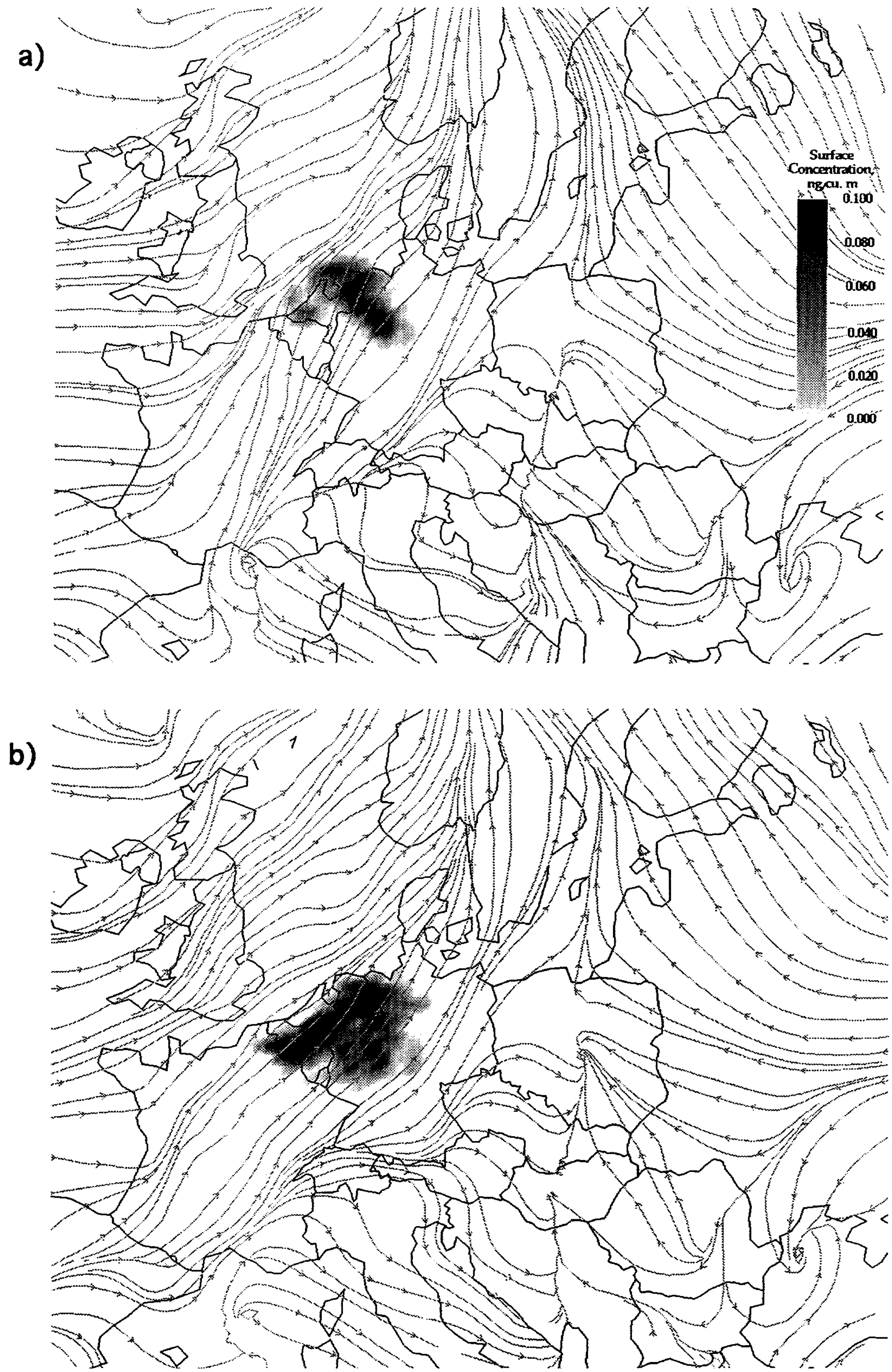

Figure 1. Near-surface streamlines (50 m AGL) and surface concentration for: a) simulation 1 and b) simulation 2 at 24 h after the release (16 UTC, 10-24-94)

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a)

b)

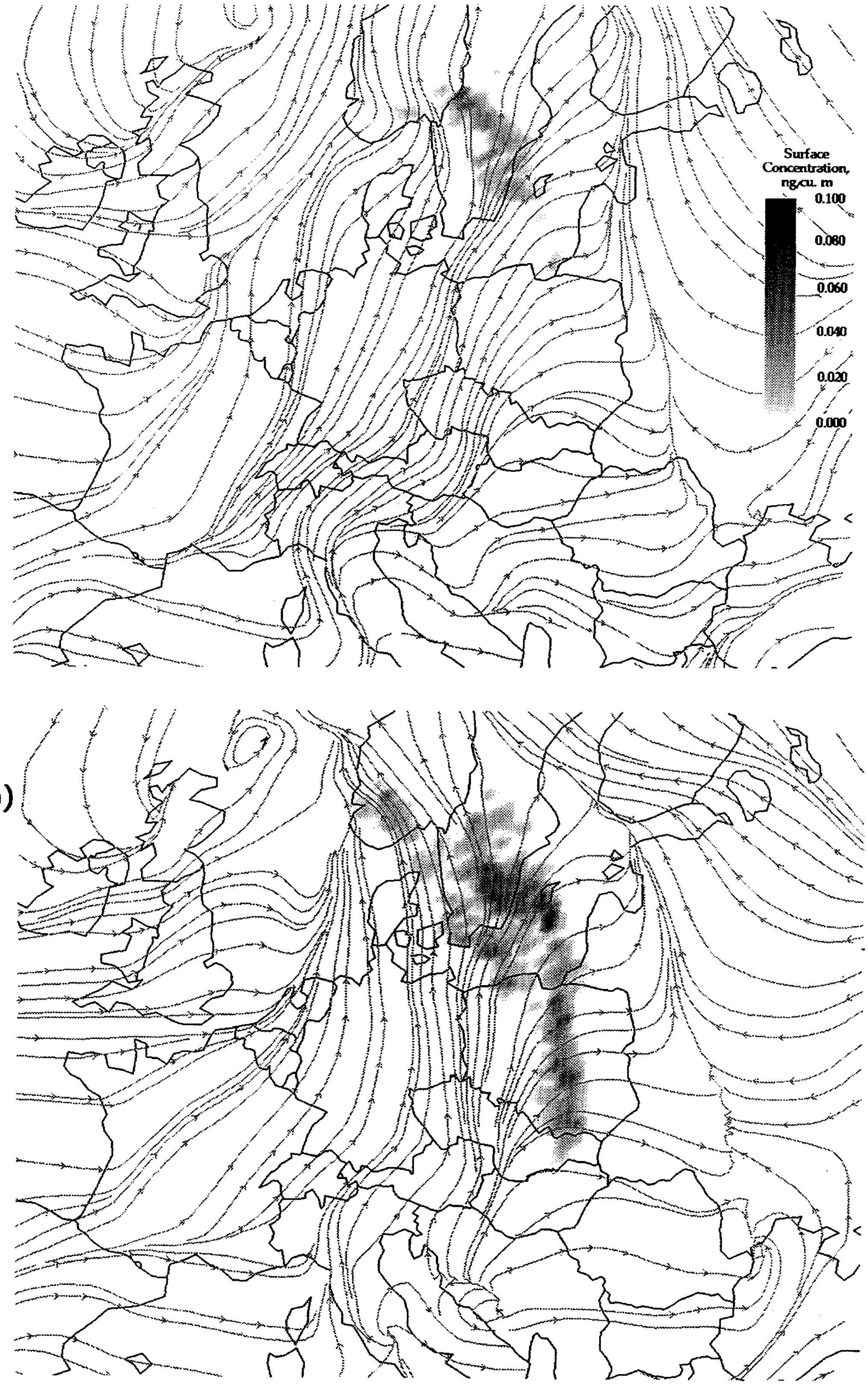

Figure 2. Near-surface streamlines (50 m AGL) and surface concentration for: a) simulation 1 and b) simulation 2 at 48 h after the release (16 UTC, 10-25-94)