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Prognostic Modeling of Long- Range Atmospheric Pollutant Transport for ETEX (U)

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PROGNOSTIC MODELING OF LONG-RANGE ATMOSPHERIC POLLUTANT TRANSPORT FOR ETEX

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1. INTRODUCTION

The ability to forecast the transport and diffusion of airborne contaminants over long distances is vital when responding to nuclear emergencies. Atmospheric models used in such emergency response applications must be able to include the effects of the evolving synoptic weather systems in a timely manner. The European Tracer EXperiment (ETEX), conducted in October and November, 1994, is designed to evaluate the performance of such models [Klug, *et al.*, 1993]. In addition to the tracer experiments, concurrent real-time modeling exercises were conducted by some twenty-four organizations world-wide, including the Savannah River Technology Center (SRTC) of the U.S. Department of Energy's Savannah River Site.

This paper describes the forecast results obtained by atmospheric modelers at SRTC in applying an advanced three-dimensional modeling system to forecast tracer transport and diffusion during ETEX. Forecast results from the first of two tracer experiments are presented in this preprint paper. Data for the tracer gas concentrations is not yet available; however, surface and sounding data are available from the time periods of the releases. This paper will focus on the evaluation of the forecasts in light of the surface wind data, and relate the forecast evaluations to the differences in the tracer gas dispersion predicted using these forecasts. Plume transport and diffusion results were reported previously [Addis, Griggs, and Fast, 1995].

2. BACKGROUND ON ETEX

The Commission of European Communities, the World Meteorological Organization, and the International Atomic Energy Agency jointly organized the European Tracer EXperiment (ETEX). ETEX involves two tracer experiments, each comprised of three distinct parts: (a) long range atmospheric tracer release, sampling and analysis; (b) real-time atmospheric model forecasting 60 hours into the future, with a subsequent model evaluation study; and (c) a post release model operation and subsequent model evaluation study.

An atmospheric perfluorocarbon tracer gas was released on 10/23/94 and again on 11/14/94, from a location near Rennes, in northeastern France [Girardi, 1995]. Meteorological conditions were chosen to maximize the likelihood of transport of the tracer over the surface sampling network. Twenty-four consecutive 3-hour samples were taken at each sampler location. Twenty-four institutions from 20 countries participated in the real-time modeling exercise, including the SRTC. The real-time modeling component of ETEX tests the ability of participants to provide 60-hour forecasts of the tracer plume in real-time.

3. MODELING SYSTEM

SRTC employs the Colorado State University Regional Atmospheric Modeling System (RAMS) [Pielke, *et al.*, 1992] and a Lagrangian Particle Dispersion Model [McNider, Moran, and Pielke, 1988]. RAMS is a primitive equation three-dimensional atmospheric model with a terrain-following vertical coordinate system. The nonhydrostatic option of RAMS with cumulus and second-order turbulence parameterization was used. The domain encompasses most of Western Europe (see Figure 2). The model grid had a uniform spacing of 75 km and a stretched vertical coordinate with the first grid point at 50 m above the ground level (AGL) and a grid spacing of 1250 m near the model top at approximately 19.7 km AGL. A time step of 60 s was used. The US National Weather Service Aviation (AVN) model was used to produce the initial and boundary conditions for RAMS. The 60-hour forecasts were then performed on a CRAY X-MP supercomputer and the dispersion calculations were performed on an IBM RS/6000 high performance workstation.

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4. RESULTS FOR THE FIRST ETEX TRACER GAS RELEASE

The first ETEX tracer gas experiment began on October 23, 1994. The basic information about the release (i.e., location: Rennes, France; release time: 16 UTC; duration: 12 hours; amount of tracer released: 7.9 g/s) was transmitted to participants by facsimile. After the completion of the first simulation (S-1), an additional five simulations (forecast and plume transport) were performed, including updated forecasts beginning at 12, 24, 36, and 48 h after the specified release time, as well as one 60-hour simulation from the time of the release using analyzed (rather than forecast) meteorological data (S-6).

4.1 Review of Plume Transport Results

As previously reported [Addis, Griggs, and Fast, 1995], differences were observed in the plume transport predicted using the initial forecast (S-1) versus the analysis (S-6). The simulated tracer gas transport results for S-1 are as follows. Initially the plume was transported from Rennes, France in a northeasterly direction; 24 hours after the release, the predicted plume location was over Germany, Belgium, and the Netherlands. After 48 hours, the plume was further to the northeast and spread out somewhat, located over southern Norway, Sweden, and the Baltic Sea.

The tracer gas transport results from S-6 (the analysis) are somewhat different. In general, the plume was predicted to cover more area and to have higher surface concentration. The plume location at 24 hours is the same in both simulations, but after 48 hours the plume extends further east and considerably further south in S-6 than in S-1. The plume at 48 hours is located over southern Norway, Sweden and the Baltic Sea (same as in forecast S-1), but additionally affecting Denmark and extending southward into Poland, the former Czechoslovakia, Hungary, and the former Yugoslavia.

4.2 Evaluation of Forecast Results

Figure 1 shows surface wind data from 171 stations at 18 UTC on 10/23/94, two hours after the initiation of the ETEX release. Figure 2 shows the forecast results for surface winds at that time. The RAMS results clearly show the effect of a low pressure system present over the Atlantic Ocean northwest of the British Isles at the time. Overall, the agreement between the data and the forecast is quite good, though the model tends to overpredict the wind speed. The model and the data show very good agreement in the wind direction in France, where the plume was located. Looking east to north-central Germany and the Netherlands, one can see that RAMS predicts a southerly wind, whereas the measured winds are from the south-southeast.

The RAMS results for wind speed were interpolated from the model grid to the locations of the weather data shown in Fig. 1 and the model error at each location and an overall root mean square error were calculated. These results show that at two-thirds of the locations the model predicted higher wind speeds than were measured; the root mean squared error is 2.6 m/s. However, the wind speed data have a nominal uncertainty of ±0.5 m/s because the reported values are rounded to the nearest meter per second. Taking this into account, 53% of the predicted wind speeds exceed the data, 28% are below the data, and 19% are within the data uncertainty.

Figure 3 shows surface winds from 218 stations at 18 UTC on 10/25/94, 50 hours after the initiation of the ETEX tracer gas release. At this point, the highest concentrations of the plume were predicted to be over Norway, Sweden, and the Baltic Sea. Figure 4 shows the forecast results for the surface winds at that time. The overall agreement in the data and the predicted wind pattern is still very good. Some disparities are evident, however, such as in eastern Germany and western Poland, where the data show winds from the southeast (or south-southeast) and the predicted winds are largely southerly. Perhaps more significant to the plume transport is the Baltic Sea region, where measured winds are from the southeast but predicted winds are from the south or southwest.

The comparison of measured and predicted surface wind speeds for 18 UTC on 10/25/94 is similar to that for the same time two days earlier. As before, the forecast wind speeds are, on the whole, higher than the data. Here, the interpolated model results exceed the nominal measured wind speeds at 80% of the stations. When the nominal data uncertainty is considered, the model results exceed the data for 74% of the stations, are below for 16%, and within the uncertainty for 10%. In addition, the root mean square error is 3.0 m/s. Thus, the bias toward overpredicting the wind speed data and the overall error in the forecast for 10/25/94 increased compared to the forecast for 10/25/94.

The S-6 surface wind field results were also compared to the data from 18 UTC on 10/23/94 and 10/25/94. The predicted wind field for 10/23/94 is quite close to that shown in Fig. 2. At this

relatively early time in the forecast, the only difference in the two simulations is the inclusion in S-6 of AVN model results for 12 UTC on 10/23/94. This makes little impact on the forecast of the horizontal wind field. Looking at the wind speed comparison, the similarities between S-1 and S-6 continue. The root mean square wind speed error is effectively unchanged at 2.6 m/s. Accounting for the nominal uncertainty in the wind speed data, the interpolated model results exceed the data at 50% of the stations, are below the data at 34%, and are within the uncertainty at 16% of the stations. Thus, S-6 also tends to predict higher winds than were measured, and in about the fraction of locations.

The forecast wind field from S-6 for 10/25/94 is similar to that shown in Fig. 4, but shows significant differences in eastern Europe and over the United Kingdom and the North Sea. The wind direction in eastern Poland and over the Baltic Sea is forecast to be more westerly (or even northwesterly) than shown in Fig. 4. This is consistent with the differences in plume position described earlier. Figure 3 shows a few stations in eastern Poland with winds from the northwest, but does not show any westerly winds over the Baltic. The predicted winds over Great Britain are more southwesterly than in Fig. 4, and thus in better agreement with the data. Despite these local differences between S-1 and S-6, the overall comparison of measured and interpolated model wind speeds is quite similar. The root mean square wind speed error is effectively unchanged at 3.1 m/s. Accounting for the nominal uncertainty in the wind speed data, the interpolated model results exceed the data at 69% of the stations, are below the data at 19%, and are within the uncertainty at 12% of the stations. Thus, S-6 also tends to predict higher winds than were measured, and in about the same fraction of locations. As in S-1, some degradation of the forecast results with forecast time is observed.

5. CONCLUSIONS

Both the initial forecast (S-1) and the analysis (S-6) gave a good prediction of the horizontal surface wind field. Early in the forecast (12 hours), the two are very similar. Some significant local differences appear later (60 hours), though the gross features still similar. When the forecast wind speeds are interpolated to the data locations, both simulations show a tendency to higher speeds than were measured. Both simulations have a root mean square wind speed error of about 2.5 m/s and 3.0 m/s at 12 and 60 hours of forecast time, respectively. The similarity of the forecasts at 12 hours is consistent with the observed similarity of plume transport early on. Though more differences between the predicted wind fields are evident at 60 hours, they do not seem sufficient to account for differences in predicted plume transport at that time. Furthermore, though a case can be made that the analysis agrees with the surface wind data better than the initial forecast, detailed comparisons do not strongly favor one forecast over the other. Pending the availability of tracer gas concentration data, additional insights into the plume transport differences will require further evaluations of forecast results.

6. ACKNOWLEDGEMENT

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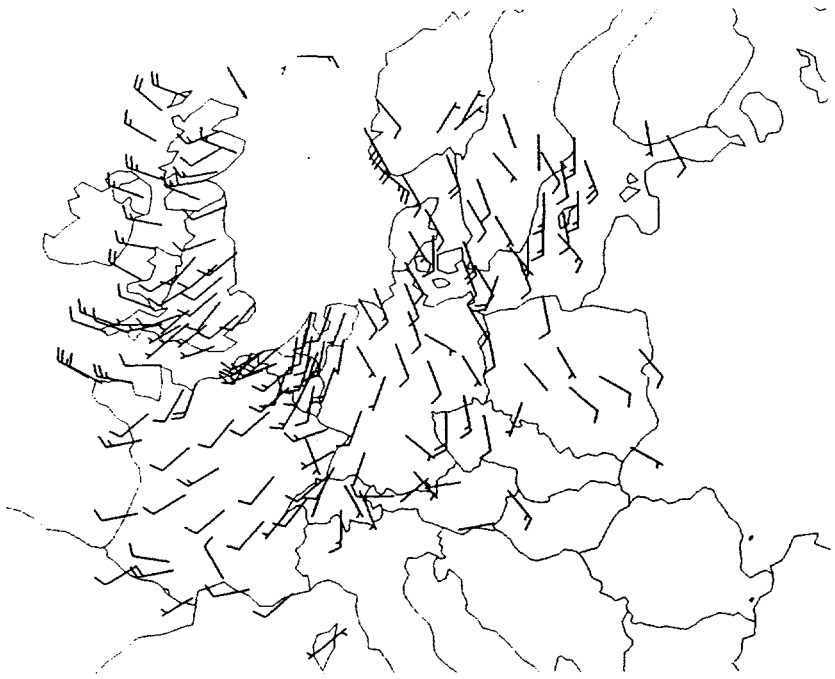

Figure 1. Measured surface winds for 18 UTC on 10-23-94

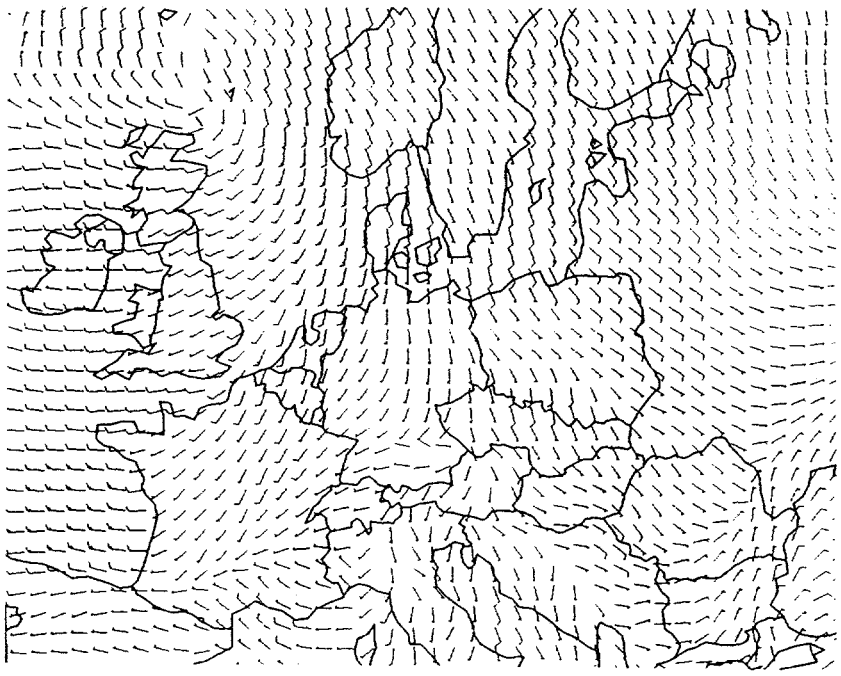

Figure 2. Forecast surface winds for 18 UTC on 10-23-94

Figure 3. Measured surface winds for 18 UTC on 10-25-94

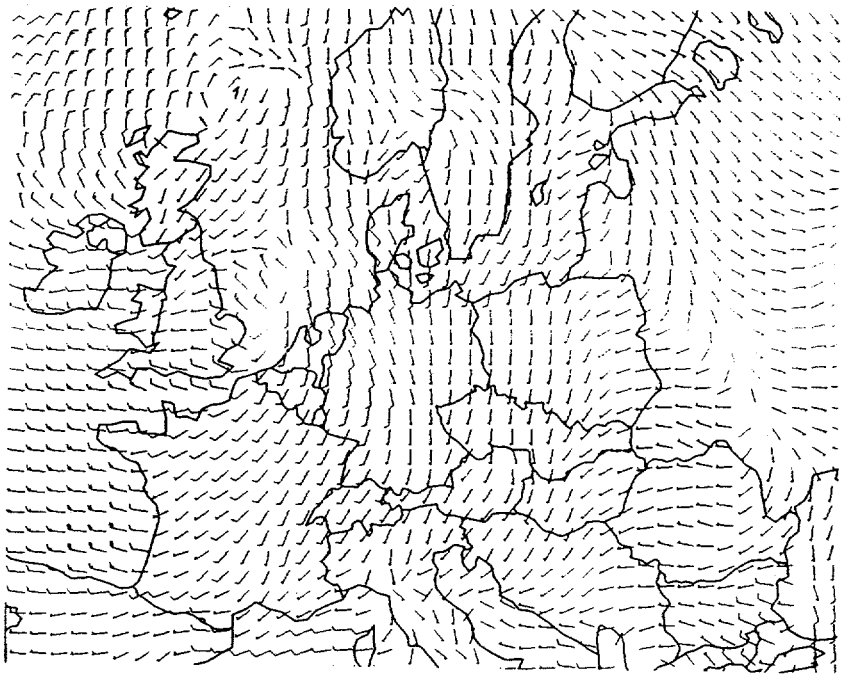

Figure 4. Forecast surface winds for 18 UTC on 10-25-94