ARAC Results from Phase II of the European Tracer Experiment

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SUMMARY

This paper compares the results of calculations by the Atmospheric Release Advisory Capability (ARAC) during two phases of the European Tracer Experiment (ETEX). In Phase I of ETEX, participants generated predictions in real time of the concentration of inert tracer gases released from a site in western France. Each participating group based their predictions on the meteorological data they had available. In Phase II, all participants were required to recalculate predictions based on the same meteorological data which was generated and supplied by the European Centre for Medium-Range Weather Forecasts (ECMWF). ARAC used ECMWF data and also made additional changes to its model configuration, with the result that ARAC's accuracy during Phase II was much better than for Phase I. Experiments described in this paper examine the effect of each of these changes, and show that each change contributed to the improvement.

II. METEOROLOGICAL DATA

In Phase I, ARAC based its calculations solely on analysis and forecast gridded data from the Navy Operational Global Atmospheric Prediction System (NOGAPS) model, while our Phase II calculations were based solely on higher-resolution ECMWF gridded analysis data. NOGAPS is a T59 spectral model with 18 vertical levels through the entire atmosphere, while the ECMWF model is a T213 spectral model with 31 vertical levels between the surface and 30 km.

We received NOGAPS data at 2.5-deg horizontal resolution, at the standard pressure levels, at 12-hr intervals. The ECMWF data used in the second phase of ETEX were provided at 0.5-deg horizontal resolution, at the 14 vertical levels below 500 mb, at 6-hr intervals.

For Phase I we used a 3000 m deep grid, so the 1000-mb, 925-mb, 850-mb, and 700-mb data were used in our calculations. For Phase II, our model domain was 2100 m deep, so the lowest seven ECMWF layers (at roughly 30, 150, 350, 640, 950, 1380, 1750, and 2200 m above terrain) affected our calculations.

The greater temporal resolution of the ECMWF data allowed better resolution of evolving wind patterns. Our Phase I calculations were based on wind fields which changed every 12 hrs, possibly missing some wind changes. The 6-hr wind fields used in Phase II represented rapidly-changing processes.

III. IMPROVED MODEL PARAMETER VALUES

In addition to wind data, the ECMWF supplied other data types including temperature data. We
analyzed vertical profiles of the temperature and wind data in Phase II to estimate boundary layer height and stability parameters. We were unable to do this in Phase I, instead assigning values we considered reasonable for autumn in Europe. The Phase I mixing layer height values we assigned were higher than those resulting from our Phase II analysis. The released gas in Phase II was therefore more likely to be constrained to the lower levels of the model domain, where different wind velocities were observed.

IV. MODEL ADVANCES

For Phase I, ARAC used an older version of its ADPIC dispersion model, referred to as Gradient ADPIC, which solves the advection-diffusion equation using a hybrid Eulerian-Lagrangian particle-in-cell method. For the second phase we used the newer Random Displacement Method (RDM)\textsuperscript{2} for the diffusion calculation within the ADPIC model framework. RDM ADPIC solves the advection-diffusion equation with a Lagrangian, Monte-Carlo method.

V. RESULTS

Plots of the Phase I ARAC-calculated region with average surface air concentrations greater than 0.05 ng/m\textsuperscript{3} for 3 hr periods ending at 24, 36, and 48 hr after the beginning of the release are shown in Fig 1. Our Phase II results for the same intervals are shown in Fig 2. Fig 3 shows plots of the measured values, taken from the ETEx first experiment draft report. (Note that Figs. 1 through 3 cover somewhat different areas.) Clearly our Phase II results are a better match to the measured values.

To evaluate how much each of the differences in system configuration contributed to the improvement from Phase I to Phase II, we performed a series of tests in which we denied the system various input data, or used older model versions. The results of these tests are presented in this section, both visually, as a sample of plots valid 48 hrs after the release, and statistically, as the percent of predictions within factors of 2, 5, and 10 of the measured values. (A prediction within a factor of 2 of the measured value means the predicted value fell in the range between one-half and twice the measured value.) The results of the statistical evaluation are summarized in Table 1.

In Test 1, we eliminated most of the vertical levels of the ECMWF data, using only the second, fourth, sixth, and tenth levels, to approximate the standard pressure levels available in the NOGAPS data. No other changes to the operational configuration were made. The resulting reduction in accuracy, compared to using all vertical levels, was not large. Test 2 used ECMWF files valid only at 12-hr intervals (00Z and 12Z), as we did with NOGAPS in Phase I. In this test, we used all the available levels of the ECMWF data. As seen in Table 1, the impact of the changes was not large. In Test 3 we combined the first two effects, using only the four vertical levels as in Test 1, and using only 12-hr interval ECMWF data files as in Test 2. The combination of these two effects had a noticeable effect on model accuracy, but the accuracy was still much better than that of ARAC's Phase I calculations.

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Table 1. Percentage of measured concentration values within factors of 2, 5, and 10 of model-calculated values for ARAC Phase I and Phase II results, and each of the ten tests referred to in the text.
Fig. 1. Phase I predictions of area with 3-hr avg. air concentration greater than 0.05 ng/m$^3$ valid 24 hr (top), 36 hr (middle), and 48 hr (bottom) following release.

Fig. 2. Phase II predictions of area with 3-hr avg. air concentration greater than 0.05 ng/m$^3$ valid 24 hr (top), 36 hr (middle), and 48 hr (bottom) following release.

Fig. 3. Measurements of area with 3-hr avg. air concentration greater than 0.05 ng/m$^3$ at 24 hr (top), 36 hr (middle), and 48 hr (bottom) following release.

The fourth test simulated the effect of reducing the horizontal resolution of the ECMWF data file from 0.5 deg to 2.5 deg, by using only every fifth point in both horizontal directions. In this test we used all the available vertical levels and all the available data files. The results show that increasing the horizontal spacing of the input data had only a very minor effect on our accuracy. Of course, use of only part of the ECMWF data did not reduce the basic resolution of the forecast model. In Test 5, we combined the effects of Tests 1, 2, and 4, using fewer levels at fewer times with fewer gridpoints. The statistical change due to the combination of effects exceeded the sum of the changes due to each effect alone. However, Fig. 4 shows the predicted pattern 48 hrs after release was still very much like our Phase II results (Fig. 2, bottom).
Test 6 used the older Gradient ADPIC, with all the available ECMWF data. Model accuracy was noticeably reduced, indicating the newer RDM ADPIC is an improvement over Gradient ADPIC. Test 7 used Gradient ADPIC, as in Test 6, with the reduced meteorological data used in Test 5. Model accuracy was decreased more than the sum of the decreases noted in those two tests (Fig. 5).

In Test 8 we used the model parameter values from Phase I, including greater mixing layer depths. We used RDM ADPIC and all the available ECMWF data. This test had the largest decrease in accuracy of those in which we changed only one variable from our Phase II configuration. Test 9 combined Tests 1, 2, 4, 6, and 8, using less data, Gradient ADPIC, and old model parameter values. This was the worst configuration of any test, with very large statistical decreases in accuracy.

Our tenth test used all the elements of Test 9, but with the deeper model domain used in Phase I (3000 m, rather than 2100 m). This change actually slightly improved the results over those in Test 9. This configuration nearly duplicated the configuration used in Phase I. Although the statistical results are about the same (Table 1), the graphical results (Fig. 6) are still noticeably better than those of Phase I (Fig. 1).

VI. CONCLUSIONS

There is no single dominant reason why ARAC's Phase II calculations were so much better than those from Phase I. All the improvements in meteorological data resolution, model parameters, and model advances played a role, although the use of refined model parameter values seems to have had the largest impact on our Phase II improvement. However, even the accumulated effect of removing all these improvements did not result in performance degradation sufficient to match our Phase I calculations. We conclude that the remaining improvement resulted from use of the higher-resolution ECMWF model.

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REFERENCES

