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Recent Improvements to an Advanced Atmospheric Transport Modeling System

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Abstract— *The Atmospheric Technologies Group (ATG) has developed an advanced atmospheric modeling capability using the Regional Atmospheric Modeling System (RAMS) and a stochastic Lagrangian particle dispersion model (LPDM) for operational use at the Savannah River Site (SRS). For local simulations concerning releases from the Central Savannah River Area (CSRA), RAMS is run in a nested grid configuration with horizontal grid spacing of 8 and 2 km for each grid, with 6-hr forecasts updated every 3 hours. An interface to allow for easy user access to LPDM had been generated, complete with post-processing results depicting surface concentration, deposition, and a variety of dose quantities.*

A prior weakness in this approach was that observations from the SRS tower network were only incorporated into the three-dimensional modeling effort during the initialization process. Thus, if the forecasted wind fields were in error, the resulting plume predictions would also be erroneous. To overcome this shortcoming, the procedure for generating RAMS wind fields and reading them into LPDM has been modified such that SRS wind measurements are blended with the predicted three-dimensional wind fields from RAMS using the Barnes technique. In particular, the horizontal components in RAMS are replaced with the observed values at a series of 8 towers that exist within the SRS boundary (covering ~300 km^2). Even though LPDM is currently configured to account only for radioactive releases, it was used in a recent chlorine gas release to generate plume concentrations based on unit releases from the site of a train accident in Graniteville, South Carolina. This information was useful to local responders as an indication of potential protective actions downwind of the release.

I. INTRODUCTION

Emergency response capabilities at the Department of Energy's (DOE) Savannah River Site (SRS) are in a continual state of improvement as a result of increased computing speeds. A prior paper[1] discussed the use of a prognostic mesoscale capability as input to a stochastic Lagrangian particle dispersion model in an operational setting at the SRS. In that version, there was no incorporation of observed meteorology available from the local SRS tower network. The current paper details the use of the horizontal winds observed at SRS as blended in the three-dimensional wind fields from the mesoscale model as a means of improving the transport predictions.

II. METHODOLOGY

The Regional Atmospheric Modeling System (RAMS)[2,3] is a three-dimensional finite-difference numerical model used to simulate atmospheric phenomena ranging from global scale down to large-eddy simulations. A Lagrangian particle dispersion model (LPDM)[4] uses the dynamic three-dimensional winds and turbulence fields from RAMS and numerically tracks the position of a large number of particles through solution of the Langevin stochastic differential equation. The model has previously been modified to incorporate deposition (wet and dry) using source-dependent scavenging coefficients and an analog resistance method to determine dry deposition velocity.[5] Although deposition and dose calculations for radioactive releases are calculated in this version of LPDM, they are not discussed in this paper.

A two-grid domain is established using 8 and 2-km grid spacing (Fig. 1) centered on the SRS, initialized with the Rapid Update Cycle (RUC) larger-scale numerical weather predication data. Twelve-hour forecasts are generated with updates every 3 hours. Nominally, only the final 6 hours of the forecast are used for transport calculations in order to allow for 'spinup' of the atmospheric conditions.

In RAMS, there is an option to use Barnes interpolation[6] to incorporate weather observations into gridded data fields. This technique is used to incorporate 61-m tower observations from SRS at 8 locations (A, C, D, F, H, K, L, and P). Because local tower data are updated every 15 minutes, the gridded RAMS fields are saved at this time interval as well. Since the intention is to use this for releases in the vicinity of the SRS (i.e. grid 2 of Fig. 1), the influence of these winds on the three-dimensional wind fields in RAMS are made to be very strong.

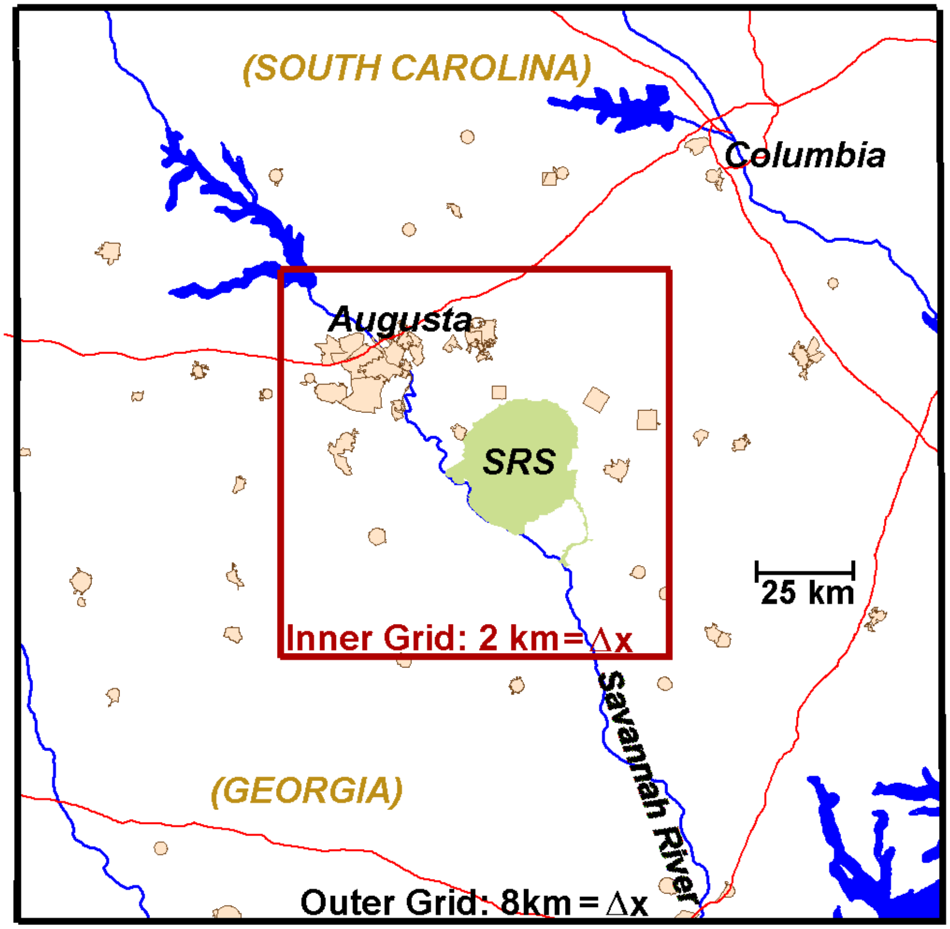

Figure 1: Domain used to generate the meteorology on an operational basis at the SRS. The results are updated every 3 hours. Observations from the SRS are blended into the predicted fields as they become available.

Scripts have been set up to archive RAMS meteorology. At 15-minute intervals, the current RAMS *u-v* wind fields are modified to incorporate the SRS tower observations, and a new "blended" RAMS meteorology file is created. (Note that the turbulence generated in RAMS is not replaced; rather, only the horizontal wind components are substituted). In addition, LPDM has been modified to look for the existence of a blended file. Although dose calculations are restricted to radiological isotopes, the transport model can be used for any type of effluent for examination of time and space-varying concentration fields.

III. APPLICATIONS

There was an accident involving two trains in Graniteville, SC during the early morning of 6 January, 2005. A stationary train sitting on a track 'spur' was impacted by another train carrying a variety of hazardous chemicals, including liquid chlorine (Cl_2). Operators inadvertently left a track switch directed to the 'spur' rather than northward and out of Graniteville. At 2:40 LST (0740 UTC), the train carrying these chemicals collided with the stationary train resulting in train derailment and compromise to one the cars containing the liquid chlorine. Upon contact with the atmosphere, the chlorine vaporized and thus became an airborne threat to the immediate vicinity. Unfortunately, exposure to the chlorine gas in highly concentrated form led to the death of 9 individuals.

The LPDM using blended RAMS winds was used during the event to predict the path of plume migration. A plume showing migration toward the north-northeast is shown in Fig. 2. This information was useful to emergency responders in the area.

Note that use of this technique for a release from Graniteville, SC should be viewed with caution during periods of extremely light and variable winds such as were experienced on the evening of January 6, since the resulting blended wind fields utilize measurements made at the SRS, ~40 km south of Graniteville.

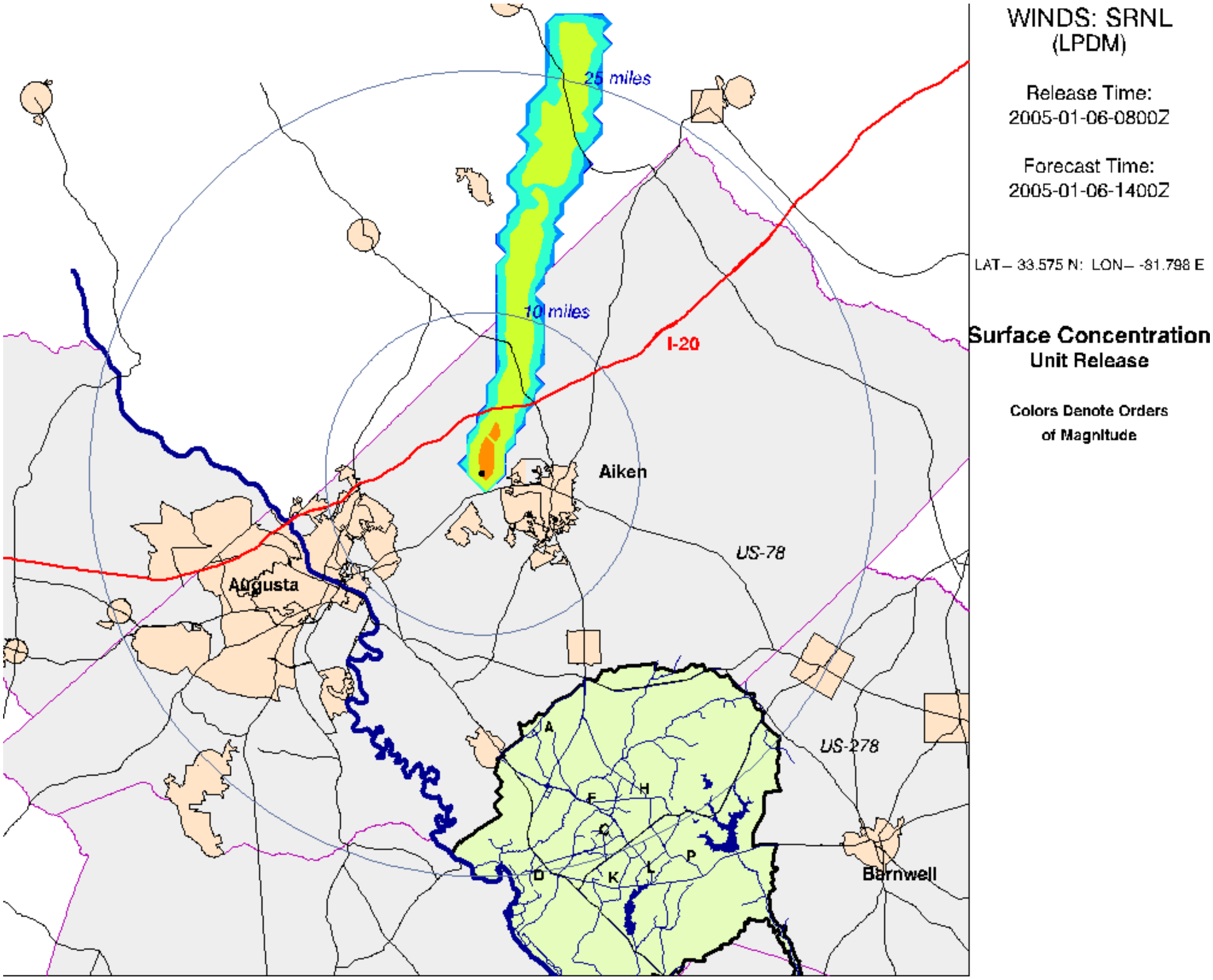

Figure 2: Plot of instantaneous surface concentration at 09:00 LST using the RAMS/LPDM forecasting system. A unit release was assumed due to a lack of knowledge regarding the source term.

The modeling system has also been used during numerous emergency response drills conducted at the SRS. An example of the impact of local winds on the overall transport is seen for an exercise conducted on 30 March, 2004. In this instance, an explosion was simulated from a location very near H-area on site with a release of 1.5×10^{6} [Ci] of tritium oxide (HTO) at 18:03 UTC, 30 March, 2004. An example of the difference in results when incorporating local tower observations into the wind fields is shown in Fig. 3, indicating two separate simulations performed at different times. The contours represent integrated surface deposition from the time of the release at a time of 00:00 UTC, 31 March 2004 (roughly 6 hours after the explosion). The first simulation on the left represents results generated soon after the release and utilizes strictly forecast winds. The figure on the right side was generated using tower data blended with forecast winds over the next 3 hours (18:00 to 21:00 UTC) and forecasts winds for the remainder of the time (21:15 to 00:00 UTC).

The difference in plume footprint location is explained by the fact that the model was predicting winds to be rather steady from the south-southwest throughout the area, whereas local tower winds indicated winds from the south to south-southeast. If this event were real, the difference in wind direction (~30 to 45°) could have a major impact on mitigation strategies for the town of Aiken, South Carolina. This indicates the importance of incorporating meteorological information in the transport and dispersion of effluent atmospheric releases.

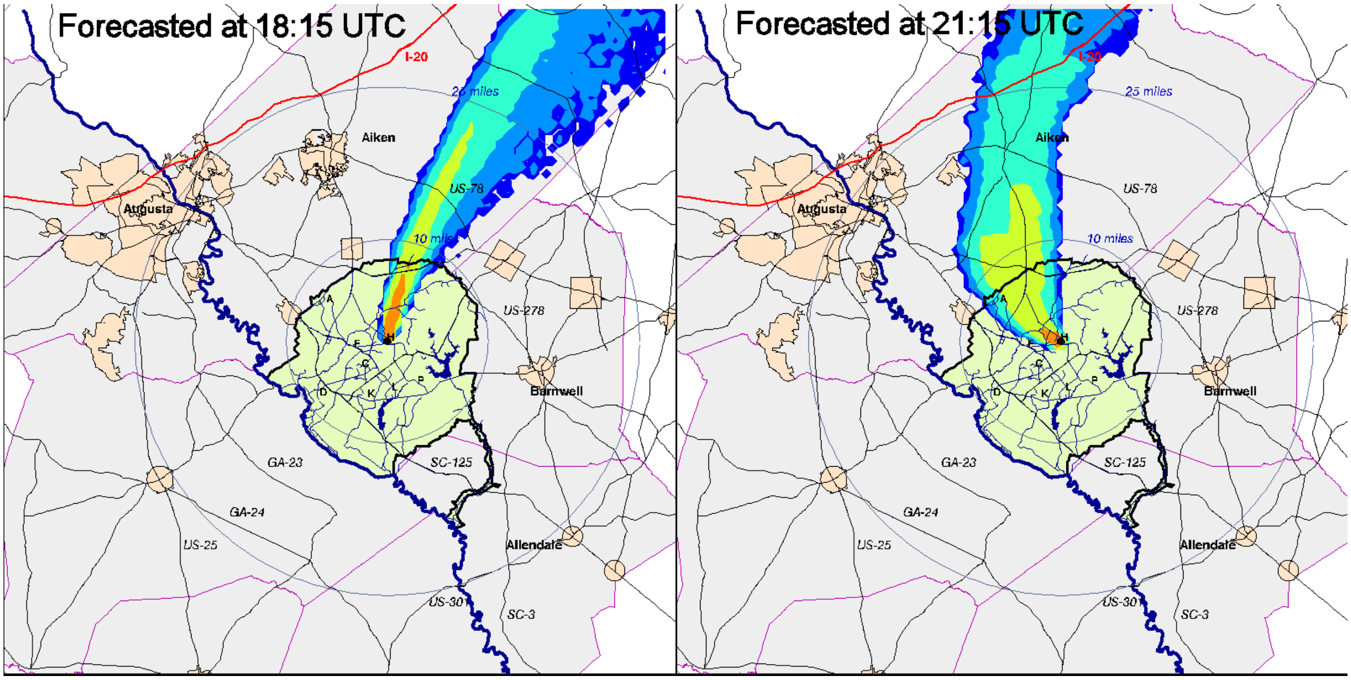

Figure 3: Forecast of integrated total surface deposition (colors denote orders of magnitude differences) as determined at different times. The figure on the right incorporates more observational tower data than the one on the left due to the availability of the data. The release occurred at 18:03 UTC, 30 March, 2004, and results are shown at 00:00 UTC, 31 March.

IV. CONCLUSIONS

Software was designed at SRNL several years ago to allow users to supply input, execute, and display output of results for atmospheric releases on a PC using a stochastic atmospheric Lagrangian particle transport model incorporating three-dimensional forecast winds and turbulence. Recent modifications allow for ingestion of local winds into the forecast fields as the observations become available. Although the computational requirements using this system are greater than simple Gaussian models, there are potential benefits. Use of fully three-dimensional meteorology is very important in capturing frontal changes, slope flows, sea breezes, and other time and space dependent processes not adequately simulated with simple one-dimensional Gaussian models. By having both types of dispersion models available during emergency situations, timely and accurate plume transport predictions for all phases of a response are possible. This has been demonstrated through an accidental release in Graniteville, SC of chlorine gas to the atmosphere in early January, 2005. The benefits of incorporating available meteorological observations into the models as they become available have also been demonstrated during a recent emergency response exercise.

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