8.2 Utilizing Mesoscale Model Output within the SLAM-P model Framework

Michael K. Atchison[1] and Mark Kienzle
ENSCO, Inc., Melbourne, Florida

1. Introduction

With the advent of fast desktop computers, mesoscale models are being run to supply data for all types of air pollution problems. However, key algorithms in many of these transport and diffusion models have not been designed to handle the various types of data that are available from these forecast models. An example of this is found in the SLAM-P (Short-range Layered Atmospheric Model) for particulates model which handles both gaseous and particulate dispersion. Up to recently, SLAM-P has made use of mixing depths as a twice-daily function that takes the mixing depth at a trajectory location at sunrise and sunset and uses these values to control vertical puff splitting and maximum plume growth. This procedure, while easy to implement, does have a couple of major drawbacks. First, the afternoon maximum mixing height is applied throughout daytime. However, we know that the true mixing depth increases slowly after sunrise and then grows rapidly later in the morning reaching a maximum in the afternoon. A second drawback is the assumption that the mixing depth within a puff remains constant relative to puff movement. However, we know that the true mixing depth changes in time through advection over varying surface conditions and through different synoptic weather patterns. Through the use of hourly mixing depths from a mesoscale model such as RAMS (Regional Atmospheric Modeling System) it is hoped that these drawbacks will be eliminated and will produce more realistic transport layer depth calculations and splitting conditions. This paper will describe the implementation of these hourly mixing depths within the SLAM-P modeling framework. In addition, results from the tracer data set ANATEX (Across North America Tracer Experiment) will also be presented.

2. SLAM

SLAM (ENSCO, Inc. 1994) is a multilayer Gaussian puff trajectory and diffusion model which can use a wide variety of weather data such as regular surface and upper-air observations, gridded hemispheric analyses, and mesoscale model output. The trajectory splitting process is controlled by the mixing depth and can take place twice daily for regular surface and upper-air observations as well as hemispheric model output. How the mixing depths are used for mesoscale model output is discussed in the next section.

[1] Corresponding author, address; Michael K. Atchison, ENSCO Inc., Melbourne, FL 32940
atchison.Kevin@ensco.com

3. Incorporation of Hourly Mixing Depths.

Mixing heights from RAMS are input to SLAM-P on an hourly basis. These data are spatially and temporally interpolated to the puff location at each advection time step. The mixing depth limits the puff boundaries for a puff that is below the mixing depth. This limit is adjusted at each model time step (down to 1 minute). During the growth phase of the diurnal cycle as shown in Figure 1, a puff will typically mix up to the mixing depth, a process that is simple to model. During the late afternoon as the mixing depth is declining, modeling the different parts of a puff that have become thoroughly mixed up to the maximum depth of the boundary layer, becomes a more complicated task. Portions of the puff that are now above the declining mixing depth will become separated from the mass of the puff below the mixing depth. Since this process occurs over a several hour period and is not instantaneous, mass at different levels will advect in different directions. A typical puff model will move this puff in a single direction.

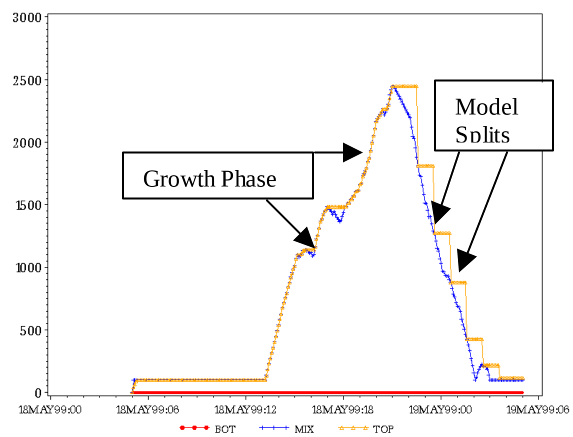

Figure 1. Vertical Plume Growth During Diurnal Cycle.

Through vertical splitting, this process can be modeled in a more realistic manner. The new vertical splitting procedure in SLAM-P gives the modeler control over the degree and frequency of the puff splitting. Figure 1 shows the splitting procedure during the declining afternoon mixing cycle. Each modification of the puff top signifies a puff split with the mass apportioned to each portion of the puff, which is then tracked independently. Splitting can be controlled by a time lag that controls how often a puff can split. The percent drop in the mixing depth as well as the layer thickness can also control the splitting process. Computer resources can become a limiting factor for model runs that are several days in duration as the total number of puffs being tracked can become quite large.

4. RAMS

RAMS (Pielke et al., 1992) is a flexible modeling system capable of simulating atmospheric flows over a wide range of spatial scales. Data input to the model can consist of regular surface and upper -air observations as well as gridded data from hemispheric models (e.g. NOGAPS, MRF, etc.). The model takes these initial conditions and integrates the equations of motion to predict meteorological varia bles. The model outputs gridded wind and MASS fields which are then ingested by SLAM to produce trajectories and concentrations.

Our configuration of RAMS consisted of two nested grids with spacings of 64 and 32 km. The RAMS model was initialized with bo th 10 minute and 30 arc second topographic data. A few of the options employed in these model runs include the use of the non -hydrostatic form of the model equations, full microphysical treatment of water, and use of the Chen and Cotton radiation scheme. C umulus parameterization was employed on both grids. In addition, RAMS was initialized and nudged at 6 hour intervals with gridded data from the NCEP/NCAR Renanalysis Project (Kalnay et al., 1996).

5. ANATEX Experiment

ANATEX was designed to provide an ov erall database for determining the performance of medium and long - range transport and diffusion models. For this experiment two perfluorocarbon tracers (PMCH and PTCH) were released for a 3 -hour duration every 2.5 days from two sites in the north -central p ortions of the United State (Glasgow, Montana and St. Cloud Minnesota). Daily (24 -hour) average ground level concentration measurements were taken at 77 samplers located on pseudo arcs at ranges of 500 to 3000 km from Glasgow. More detailed information abo ut the experiment can be found in Draxler and Heftner (1989).

6. Results.

The RAMS model was run for the period 5 -13 January 1987. The SLAM -P model then used the RAMS data to simulate the 3 -hour releases on 5 January (1700 -2000 UTC) from St. Cloud. Durin g the first sampling day (1400 UTC 5 January to 1400 UTC 6 January) the observed plume went north -northwest into northern Minnesota. During the second plume day (1400 UTC 6 January to 1400 UTC 7 January) the plume shifted to the south into Nebraska, Kansas and Missouri in response to the development of a low -pressure system over the central plains. During this time, the predicted plume from SLAM -P matched the observed plume (see Table 1) over Kansas and Nebraska very well but was a little slow over southern Missouri. During the third plume day (1400 UTC 7 January to 1400 UTC 8 January) the observed plume continued moving south down into Oklahoma and Arkansas. As shown in table 2, the predicted plume from SLAM -P was within a factor of 2 or 3 of the observed p lume. More results will be presented at the conference.

Table 1. Release 1 from St. Cloud, MN (PMCH)

(1400 UTC 6 January to 1400 UTC 7 January)		
Station	Observed*	Predicted*
Kansas City, KN	53	144
Omaha, NE	189	211
Oklahoma City, OK	23	1
Neosho, MO	184	3
Columbia, MO	62	48

*pg m/m ^{3}

Table 2. Release 1 from St. Cloud, MN (PMCH)

(1400 UTC 7 January to 1400 UTC 8 January)		
Station	Observed*	Predicted*
Oklahoma City, OK	111	44
Tulsa, OK	190	307
Neosho, MO	23	1
Little Rock, AR	84	81
Long View, TX	0	16

*pg m/m ^{3}

7. References

ENSCO, Inc., 1994: Software Requirement Specification for the Short -Range Layered Atmospheric Model (SLAM) CSCI of the Integrated RPP Evaluation System. Prepared for the U.S. Air Force Technical Application Center, Patrick AFB, FL, by ENSCO Inc., Melbourne FL.

Pielke, R.A., W.R. Cotton, R.L. Walko, C.J. Tremback, W.A. Lyons, L.D. Grasso, M.E. Nicholls, M.D. Moran, D.A. Wesley, T.J. Lee, and J.H. Copeland, 1992: A Comprehensive Meteorological Modeling System – RAMS. Meteor. Atmos. Phys., 49, 69 -91.

Kalnay, E., and Coauthors, 1996: The NCEP/NCAR 40-year reanalysis project. Bull. Amer. Meteor. Soc., 77, 437 -471.

Draxler, Roland R., and J.L. Heftner, eds., 1989. Across North America Tracer Experiment (ANATEX) Vol I: Description, ground level sampling at primary sites and meteorology. NOAA Technical Memo. ERL ARL -167, 88pp. and appendices. [Available from National Technical Information Service, Springfield, Va.]