

Title: NUMERICAL PREDICTIONS OF THE ATMOSPHERIC CIRCULATIONS AND DISPERSION OF TOXIC RELEASES IN COMPLEX TERRAIN.

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## 1. INTRODUCTION

The South Area of Tooele Army Depot is one of the U.S. Army's storage facilities for its stockpile of chemical weapon agents. The Department of Defense is preparing to destroy the aging stockpiles of lethal chemical munitions, which have existed since the end of World War II. Although the danger is slight, accurate predictions of the wind fields in the valley and accurate dispersion calculations are important in the event of an accident involving toxic chemicals at the depot.

The Tooele Army Depot South Area is located in the high, broad Rush Valley of North-Central Utah where the local circulations are strongly influenced by slope and valley flows and lake breezes associated with the surrounding mountainous topography and lakes (Stone et al., 1989; Yamada, Williams, and Stone, 1989). The valley is approximately 1560 m above sea level and roughly 20 km across from East to West and 45 km long from North to South. It is surrounded on the west, south, and east sides by mountain ranges. These mountain ranges include peaks from about 2400 m to 3350 m MSL. A somewhat shorter barrier (2000 m) exists on the North end of the valley and the lowest passes are on the north and east sides. Further to the North lies Tooele Valley and the Great Salt Lake. Another significant lake is in the adjacent Cedar valley to the east of Rush Valley and the small Rush Lake is at the North end of Rush Valley. There are several small communities in Rush, Tooele, and Cedar valleys and Salt Lake City is located 65 km to the Northeast of Tooele Army Depot South Area, at 1300 m MSL and beyond the Oquirrh Mountains.

In order to prepare for an emergency which might involve a release of toxic agents to the atmosphere, the Higher Order Turbulence Model for Atmospheric Circulations (HOTMAC) and its companion code Random Particle And Diffusion (RAPTAD) have been adapted

for use in predicting where dangerous amounts of these chemicals may travel. Both codes have been applied to a number of air quality studies in the past, including previous dispersion studies at Tooele (Yamada, Williams, and Stone, 1989).

## 2. THE MODELS

HOTMAC is a mesoscale numerical model which predicts the wind, temperature, humidity, and turbulence fields in three dimensions and time. The basic equations are reported by Yamada and Bunker (1989) and Yamada (1985) and are integrated using the Alternating Direction Implicit method. The model assumes hydrostatic equilibrium and uses the Boussinesq approximation. A terrain following coordinate system, grid nesting in the horizontal, and a stretched vertical grid are employed. The Mellor and Yamada (1982) level 2.5 model is used to predict the turbulent transport of momentum, energy, and water vapor through use of equations that include the turbulent kinetic energy and the turbulent length scale.

Previously, the model incorporated the ability to nudge the predictions toward steady, geostrophic winds at upper levels. The HOTMAC code has been adapted for this application by improving its four-dimensional data assimilation capabilities. The model now incorporates meteorological data from a number of upper air soundings and surface observation sites at variable time intervals. This allows us to take advantage of an extensive network of local observations. At the depot there are eight surface observing stations and a 30 m tower, which collect wind, temperature, and humidity data. Also, Tooele County has recently installed a network of about 25 additional surface stations throughout Rush and Tooele Valleys and on some of the surrounding higher terrain.

RAPTAD is a Lagrangian puff code which uses the Monte Carlo statistical diffusion process (Kao and Yamada, 1988; Yamada, Kao, and Bunker, 1989; Williams and Yamada, 1990). The predicted winds and turbulence from HOTMAC are used to compute the puff

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trajectories and the standard deviation of concentration for each puff. The concentrations at points in the area of a release are computed by summing the concentrations contributed by all the puffs. Dosages are also calculated. The characterization of the release source in RAPTAD has been improved for this application, based on the source characteristics used by the Army in their D2PC model (Whitacre, et al., 1987) for the possible agents and munitions involved.

These improvements to the HOTMAC and RAPTAD codes were made so that they can run operationally at Tooele Army Depot. The data assimilation approach, described below, is used to provide a better initialization to HOTMAC by incorporating the previously forecasted fields at the start time and nudging the model predicted fields for a specified time period, for which the observations are available. Once the model simulation reaches the end of the assimilation period (the time of the last recorded data), it continues the simulation in a purely prognostic mode. A number of HOTMAC simulations can be run each day to continually provide updated forecasts. RAPTAD can then use the HOTMAC output to predict dispersion of possible releases specified by the user. The codes can be used in planning decisions for the weapons destruction program and, because the HOTMAC forecasts will be available throughout the day and RAPTAD runs quickly, they can be used for emergency response in the event of an accident.

### 3. THE DATA ASSIMILATION APPROACH

In order to optimally utilize the local meteorological observations, we have modified HOTMAC to incorporate Newtonian relaxation in a manner similar to the "obs" nudging technique employed by Stauffer and Seaman (1994). In this method, the model state is continuously nudged toward the observed state by adding additional terms to the prognostic equations based on the difference between the two states. The "obs" nudging approach nudges directly toward individual observations distributed non-uniformly in space and time.

To accomplish this relaxation in HOTMAC, an additional term is added to the fields of wind, temperature, and moisture at each grid point in the domain (Costigan et al., 1995). With every timestep of the large grid, each field variable  $\phi$  is modified at each gridpoint by adding the term

$$G \cdot \Delta t \cdot \frac{\left[ \sum_{l=1}^N W_l^2 \cdot (\phi_o - \phi_m)_l \right]}{\sum_{l=1}^N W_l}$$

where the subscript  $l$  denotes the  $l$ -th observation,  $G$  is the nudging factor that determines the relative magnitude of the nudging, and  $\Delta t$  is the large grid timestep. The four-dimensional weighting factor  $W_l$  is determined by the spacial and temporal separation of each of the  $N$  observations from the grid point at the nudging time. The term  $(\phi_o - \phi_m)_l$  is the difference between the locally-observed value of the variable  $\phi_o$  and the model predicted value interpolated to the observation location  $\phi_m$ .

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