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APPLICATION OF A MESOSCALE MODEL WITH 4DDA TO THE
COMPLEX TERRAIN NEAR TOOELE, UTAH

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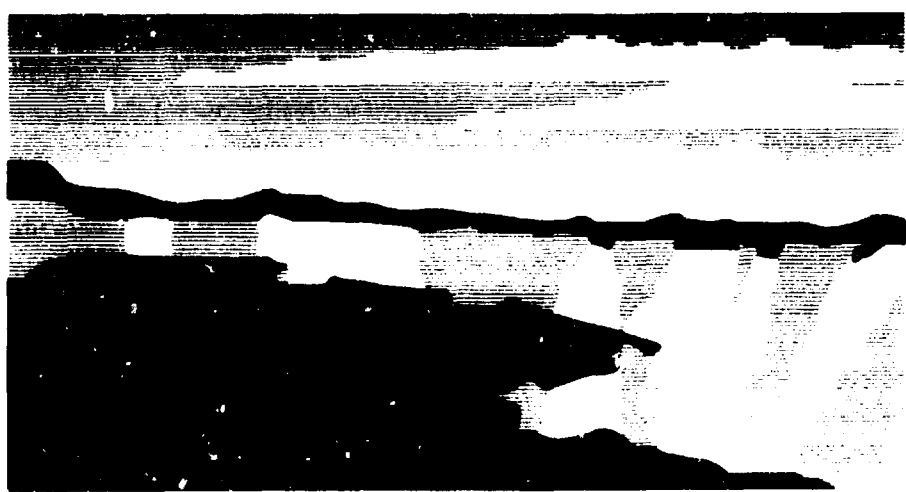
Author(s):

K. R. Costigan, D. G. Flicker, J. T. Lee

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Keeley R. Costigan*, Dawn G. Flicker, and J. T. Lee

Los Alamos National Laboratory
Los Alamos, New Mexico

1. INTRODUCTION

The Tooele Army Depot South Area is located in the high, broad Rush Valley of North-Central Utah. 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 three sides by mountain ranges with the Oquirrh Mountains to the East, the Stansbury and Onaqui Mountains to the West, and the Sheep Rock and East Tintic Mountains to the South (Figure 1). These mountain ranges include peaks from about 2400 m to 3350 m MSL. A somewhat shorter barrier (2000 m South Mountain) 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 valley to the east of Rush Valley and the small Rush Lake is at the North end of Rush Valley. The combination of the topography and the lakes leads to interesting local meteorology affected by slope and valley flows and lake breezes (Stone et al., 1989; Yamada et al., 1989).

The South Area of Tooele Army Depot is one of the U.S. Army's storage facilities for its stockpile of chemical weapon agents. Congress has directed the Department of Defense to eliminate the aging stockpiles, which have existed since the end of World War II, and the U. S. Army is beginning to destroy these lethal chemical munitions. Although the danger is slight, accurate predictions of the wind fields in the valley are necessary for dispersion calculations in the event of an accident involving toxic chemicals at the depot. There are several small communities in Rush and Tooele valleys and Salt Lake City is located 65 km to the North-east of Tooele Army Depot South Area, at 1300 m MSL and beyond the Oquirrh Mountains.

This paper describes how Newtonian Nudging is applied to HOTMAC (Higher Order Turbulence Model

for Atmospheric Circulations) for operational use in this area. The nudging scheme takes advantage of an extensive network of local observations in the valley. At the depot there are seven surface observing stations and a 30 m tower, which collect wind, temperature, and humidity data, and 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.

2. THE MODEL

HOTMAC is a three-dimensional, numerical model that has been applied to a number of mesoscale studies, including previous dispersion studies at Tooele (Yamada et al., 1989). The basic equations for predicting the mean wind, potential temperature, and water vapor are reported by Yamada and Bunker (1989) and Yamada (1985). The model assumes hydrostatic equilibrium and uses the Boussinesq approximation. The equations are then integrated using the Alternating Direction Implicit method. A staggered grid and a terrain following coordinate system are employed. Grid nesting in the horizontal is available, depending on the application, with a stretched grid in the vertical. 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. For this current work, we have changed the nudging procedure to also use information from time-varying, surface observations and upper air soundings.

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

* Corresponding author address: Keeley R. Costigan,
EES-5 Mailstop D401, Los Alamos National Laboratory,
Los Alamos, NM 87545. Email: krc@vega.tlan.gov



Figure 1 Representation of the topography near Tooele, UT. Darker shading indicates higher terrain

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. With every timestep of the large grid, each field variable ϕ is modified at each gridpoint by adding the term

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

where the subscript l denotes the l -th observation. G is the nudging factor that determines the relative magnitude of the nudging, and Δt 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 ϕ_o and the model

predicted value interpolated to the observation location ϕ_m .

The observed vertical soundings are first interpolated to the model grid levels. Specifying $W_l = w_x w_t$ (after Stauffer and Seaman, 1990), the horizontal component of the weighting function is given by

$$w_{xy} = \begin{cases} \frac{R^2 - D^2}{R^2 + D^2}, & D \leq R \\ 0, & D > R \end{cases}$$

where R is a horizontal radius of influence and D is the distance of the l -th observation from the grid point. Surface and upper level values of R are set by the user, with R linearly interpolated at heights in between. When using surface data in complex terrain, we have modified D in a manner similar to Stauffer and Seaman (1994) so that $D = D^* + R C^{-1} |z_o - z_m|$ where C is a constant, z_o is the height of the observation and z_m is the model grid point height. D^* is the horizontal distance between the observation and the grid point. Thus the effective distance is increased and w_{xy} reduced when the height dif-

ference between the observations and the grid points is large, minimizing the influence of valley observations on the model fields over a nearby peak.

The time component of the weighting function w_t is specified to be equal to 1.0 during the center half of a preset time window, centered about the observation time. Further in time from the observation, it decreases linearly from 1.0 to a value of 0.0 outside the time window. The time window is specified to be larger for observations at higher levels than those taken at the surface.

The model, with this data assimilation method, will run operationally at Tooele. The data assimilation approach described here will be 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.

4. ACKNOWLEDGMENTS

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