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Numerical Simulations of the Mountain Iron Tracer Data

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Extensive field experiments were conducted during 1965 and 1966 near Vandenberg Air Force Base. The experiments included wind speed and wind direction measurements at several towers, upper air soundings by radiosondes, and fluorescent particle releases to characterize the diffusion processes.

The data provide a unique opportunity to test numerical models under realistic boundary conditions: land-sea contrast and complex topography. We used HOTMAC (High Order Turbulence Model for Air Circulations), a three-dimensional mesoscale model based on simplified turbulence-closure equations to simulate temporal and spatial variations of wind, temperature, mixing ratio of water vapor, and turbulence distributions.

Surface concentrations were computed by using a three-dimensional transport and diffusion model RAPTAD (Random Puff Transport and Diffusion). RAPTAD is a Lagrangian puff code based on the Monte Carlo statistical diffusion process. The center location and standard deviation of concentration distribution for each puff are computed by using wind and turbulence modeled by HOTMAC. Then, the concentration at any location is computed by summing concentrations contributed by all the puffs.

Introduction

The purpose of this study is to simulate the transport and dispersion of atmospheric pollutants in the complex terrain surroundings at Vandenberg Air Force Base (VAFB) by using the Los Alamos National Laboratory (LANL) atmospheric models HOTMAC and RAPTAD.[1]

HOTMAC is a prognostic model and solves a set of time-dependent physical equations such as conservation equations of momentum, internal energy, and mixing ratio of water vapor. Prognostic models can forecast three-dimensional distributions of wind speed, wind direction, temperature, mixing ratio of water vapor, and turbulence variables.

HOTMAC provides RAPTAD both mean and turbulence variables to simulate transport and diffusion processes of airborne materials. Only a few mesoscale atmospheric models can forecast three-dimensional variations of atmospheric turbulence. Therefore, HOTMAC and RAPTAD offer a considerable improvement over the current emergency response management models at VAFB that are extremely simple.

The Mountain Iron Diffusion Experiments

The Mountain Iron (MI) diffusion experiments[2] were conducted at VAFB during 1965 and 1966 to establish quantitative diffusion predictions for use as range safety tools in the "South Vandenberg" (SV) ballistic and space vehicle operations.

The experimental site, SV, is located along the California coast approximately 160 km west-northwest of Los Angeles. The coastline is oriented in approximately a north-south direction along the western side of SV, but changes abruptly at Point Arguello to an east-west direction. The coastline gradually changes to a north-south direction down to Point Conception and then changes again to an east-west direction. The Santa Ynez Mountains form an east-west barrier along the coastline far south of SV.

Fluorescent pigment zinc sulfide particles with a geometric mean of 2.5 microns in diameter were released to understand transport and diffusion processes and derive an empirical formula for the pollutant concentration distribution in the SV area. The effective release height was 2 to 6 meters above ground. The primary sampler used was a membrane filter inserted in a disposable polyethylene holder. The bulk samples from the field were assayed by use of the Rankin counter, which uses an alpha emitter to activate the fluorescent pigment deposited on the membrane filter.[3]

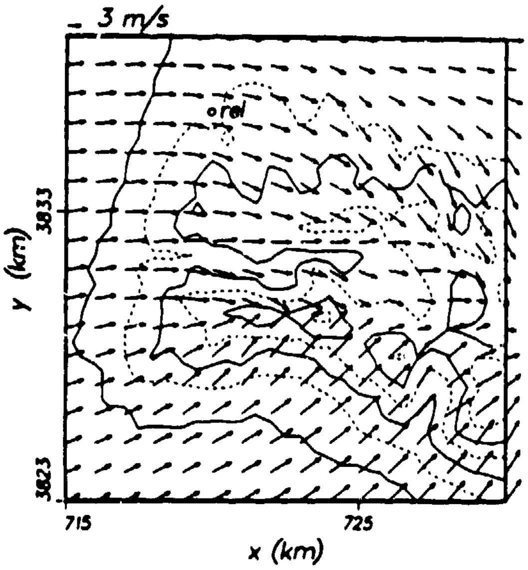

Figure 1. Modeled horizontal wind vectors at 6m above the ground at 1300 lst, June 13, 1966. Terrain is contoured by solid lines with an increment of 200 m. Dashed lines indicate contours halfway between the solid contours.

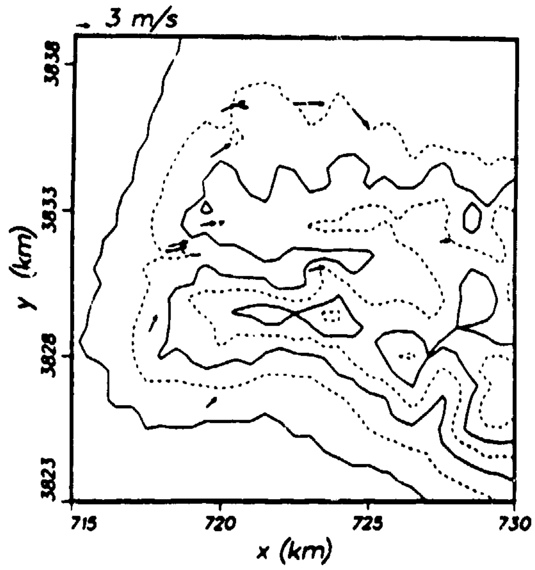

Figure 2. Same as in Figure 1 except observed wind vectors in the surface layer are shown.

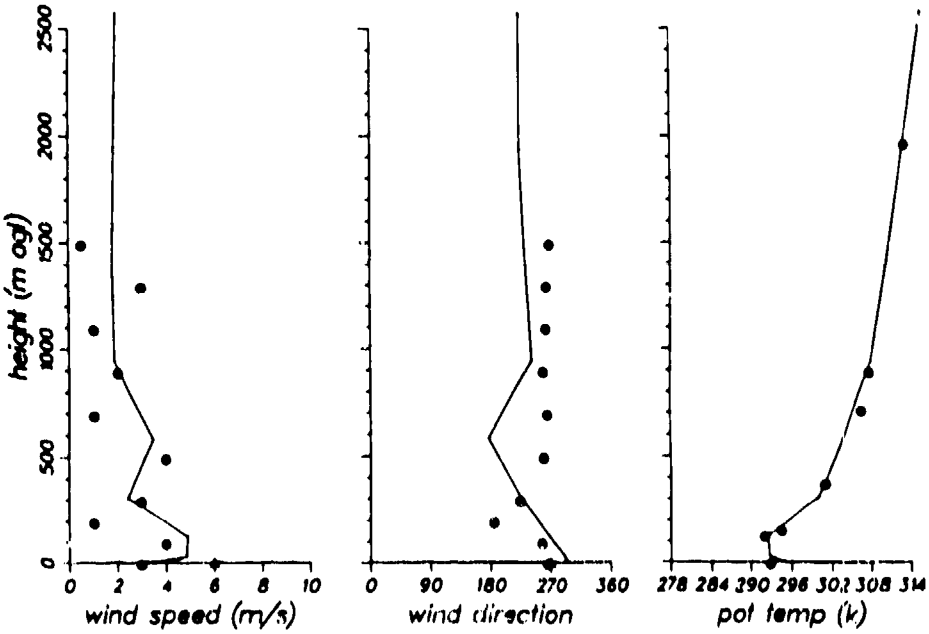

Figure 3. Vertical profiles of the modeled wind speed, direction, and potential temperature at 1300 lst, June 13, 1966 at B22. Solid circles indicate observations.

Results and Discussions

A total of 113 tracer releases was made from which we selected the MI87, MI90 and MI91 cases to evaluate the performance of HOTMAC and RAPTAD. Only the results from the MI87 simulations are reported here.

The initial potential temperature profile was determined by averaging the four upper air soundings at 1300 local standard time (lst) in SV. The potential temperature lapse rate was approximately 0.044° C/m from the sea surface to 460 m mean sea level (msl), 0.0142° C/m between 460 m and 960 m, and 0.0045° C/m above 960 m msl. Wind speed and direction were determined by examining five upper air soundings (four locations mentioned above plus VIP-1) at 1300 lst. Intial upper air wind speed and wind direction were estimated to be 2 m/s and 225 degrees, respectively.

The computational domain is 40 x 48 km^2 with a horizontal grid spacing of 1 km. To resolve the details of topography in the vicinity of the release site, we decided to nest a fine resolution grid 15 x 16 km^2 with horizontal grid spacing of 0.5 km.

Integration started at 0500 lst, June 13, 1966 and continued for over 12 hours. The plume was released at 1310 lst for 30 minutes as was done in the experiment. The plume was followed for 4 hours in the model computation. By that time the plume was transported far away from the sampling areas.

Figure 1 shows the modeled horizontal wind vectors in the inner computational grid at 6 m above the ground at 1300 lst, June 13 (Julian day 164). Although the upper air wind direction is 225 degrees (southwest), upslope flows develop in the surface layer due to heating at the sloped surfaces.

The modeled wind distribution (Figure 1) is in good agreement with the observation (Figure 2). The observed winds show much more variations in space than the modeled winds. Observations adjacent to each other show considerable variations in direction and magnitude. On the other hand, the modeled wind field varies more slowly in space than the observed since the model neglects subgrid scale variations of the surface (the grid resolution is 500 m). Nevertheless the simulation successfully reproduced many features observed.

Less satisfactory results are obtained in comparison of the vertical profiles of the modeled wind speed and wind direction with observations (Figure 3). Wind speed and wind direction become highly variable in space and time when the prevailing wind speed is small. It is noted that the observations were instantaneous values whereas the modeled results are ensemble averages. On the other hand, potential temperature is relatively stationary unless synoptic scale disturbance such as fronts pass through the measurement area.

Significant changes in the modeled wind direction occurred at around 600 m above the ground. This is caused by the mass conservation constraint to compensate the divergence and convergence of the wind distributions in the boundary layer

(Figure 3). Observed wind direction profiles appear to support such variations but the changes appear to occur at heights much closer to the ground than those modeled.

Figure 4 shows the modeled ground level concentration contours and Figure 5 shows the corresponding observation. Figure 5 also shows the observed wind speeds and wind directions at the ground stations. The observed wind direction close to the release site is west-southwesterly, but changes to westerly at the station slightly north of the release site. Our simulation (Figure 1) indicates that the wind direction is close to westerly at the release site. The observed plume apparently transported to the east-northeast direction despite the fact that wind directions measured at the ground stations suggest the plume should be transported to the east-southeast which is the case for the modeled plume.

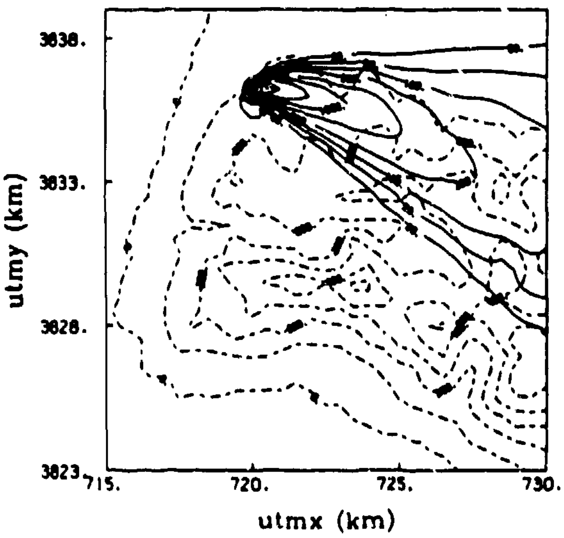

Figure 4. Modeled ground level concentration (accumulated).

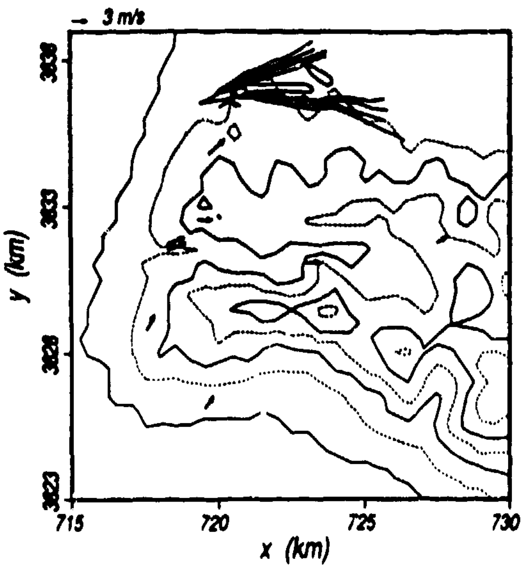

Figure 5. Observed ground level concentration (accumulated).

Although the modeled plume direction did not match the observed one, the modeled ground level concentration along the plume axis are in good agreement with observations as shown in Table I. It is not known why the observation at 3310 m from the source shows the largest value among the observations.

Table I: Normalized Concentrations

Modeled		Observed	
Distance from the source (m)	Concentration	Distances from the Source (m)	Concentration
716	8.04×10^{-6}	720	3.97×10^{-6}
1253	2.55×10^{-6}	1260	1.08×10^{-6}
3312	9.06×10^{-7}	3310	5.39×10^{-6}
4403	7.08×10^{-7}	4400	3.02×10^{-7}

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