FIRESTORM FORMATION AND ENVIRONMENT

CHARACTERISTICS AFTER A LARGE-YIELD NUCLEAR BURST

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1. INTRODUCTION

The ignition and propagation of fires after a large-yield HOB detonation represent a potentially important nuclear weapons effect. Urban areas, with many ignition sources, are particularly susceptible to fires and to the rapid spread and possible coalescence of individual fires distributed over a large area. Under some circumstances, a firestorm may develop.

The objectives of this study are to numerically simulate:

1. the physical conditions leading to a firestorm, and

2. the velocity and pressure fields inside and outside a "representative" firestorm.

2. METHODOLOGY

The development of a firestorm involves mutual interactions between the fire combustion/propagation and the atmosphere winds/temperatures. In view of the many uncertainties in the distribution of ignition points and available fuel, the mutual interactions will be analyzed using the DICE code (1) with simple combustion/propagation models.

DICE is an Eulerian code which solves the dynamic two-dimensional (2-D) axisymmetric atmospheric equations of motion using an implicit finite difference technique. The code can accept a general model detailing the the release of chemical energy due to combustion. For the numerical simulations described in this study, a simple model which adds combustion energy at a constant rate of $q_b = 0.25\ MJ/m^2/s$ uniformly along the ground is assumed. The combustion region is assumed circular with a radius of 10 km. Heat loss due to thermal radiation from hot gas and smoke is simulated in some of the calculations.

3. RESULTS

In order to gain some understanding into the phenomenology of a large mass fire, several coarsely zoned numerical simulations were performed. Table 1 lists the cases along with the relevant parameters which were varied.

The objective of these calculations was to provide some understanding of the effects of varying initial and boundary conditions.

Table 1. Numerical Simulation Cases of a Large Mass Fire

Case	Thermal Loss	Atmosphere	Rigid Boundary Upper	Rigid Boundary Radial	Zoning
125	< 1%	standard	no	no	coarse
126	< 1%	standard	yes	no	coarse
127	< 1%	adiabatic	yes	no	coarse
128	< 1%	adiabatic	yes	yes	coarse
129	~45%	adiabatic	yes	no	coarse
301	30%	standard	no	no	fine

The coarsely zoned Cases F-125 to F-129 consisted of 1 km wide cells in the radial direction to a radius of 13 km. Each cell beyond 13 km was larger than the previous one by 9%, to a maximum radius of at least 100 km for the rigid boundary case. The vertical dimension of the first six cells is 100 m, with an increase of 9% for each additional cell upward. A rigid upper boundary occurs at 20 km altitude; Case F-125 has a transmissive upper boundary at 49 km altitude. Rigid boundaries were used for comparisons with prior work (2) and for computational simplicity.

The most pronounced difference is seen between Case F-126, which used a U.S. Standard Atmosphere (-6.5 K/km tropospheric lapse rate) and Case F-127, which had a constant dry adiabatic lapse rate (-9.8 K/km) atmosphere. Figure 1 compares the vertical temperature profiles of each atmosphere. Figure 2 compares the velocity fields at t = 15 min after the start of combustion. Note the formation of a much stronger vortex flow field for Case F-127 centered above and beyond the edge of the fire region. The tropopause tends to confine the vortex below 12 km altitude for Case F-126.

Figure 3 compares the velocity fields at t = 15 min for Case F-126 (rigid upper boundary at 20 km altitude) and Case F-125 (transmissive upper boundary at 49 km altitude). Note that the rigid upper boundary in Case F-126 causes a strong outward flow from the axis at 20 km altitude. However, below 15 km altitude the velocity fields appear identical.

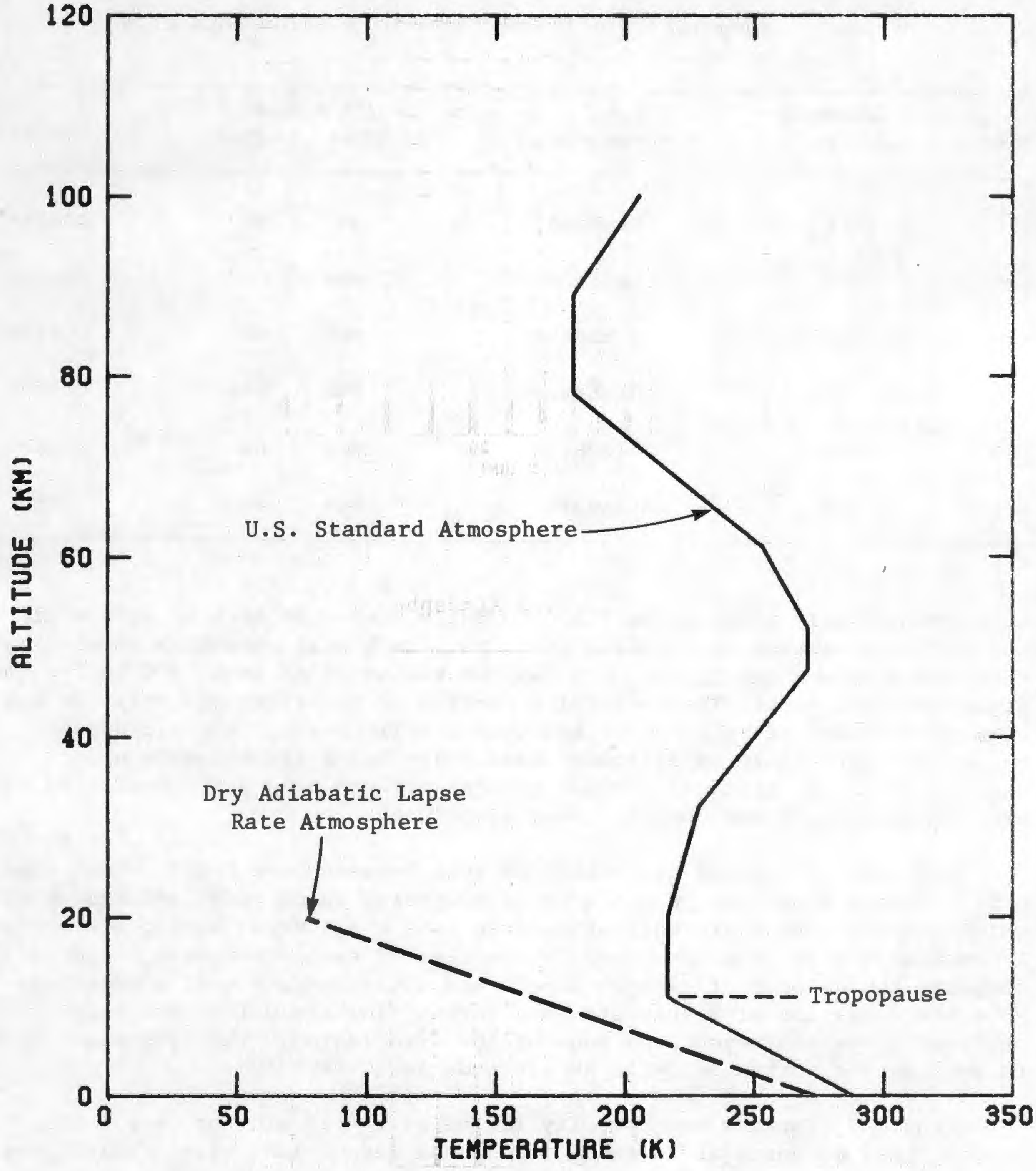
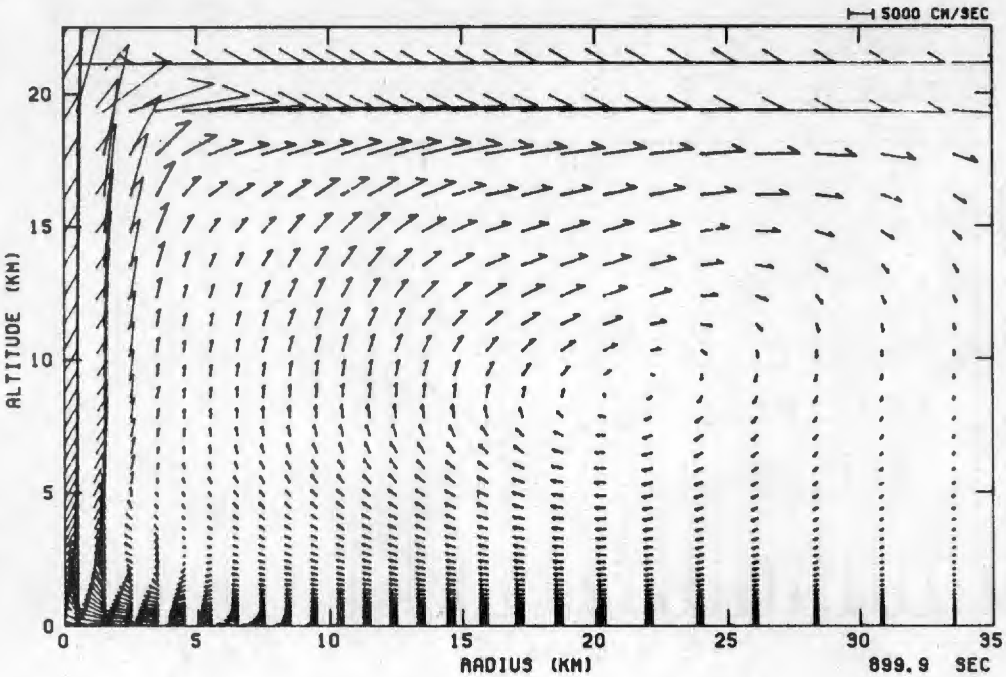


Figure 1. Vertical Temperature Profile Comparison for a U.S. Standard Atmosphere and a Dry Adiabatic Lapse Rate Atmosphere.

(a) Case F-127 (adiabatic atmosphere)



(b) Case F-126 (U.S. Standard Atmosphere)

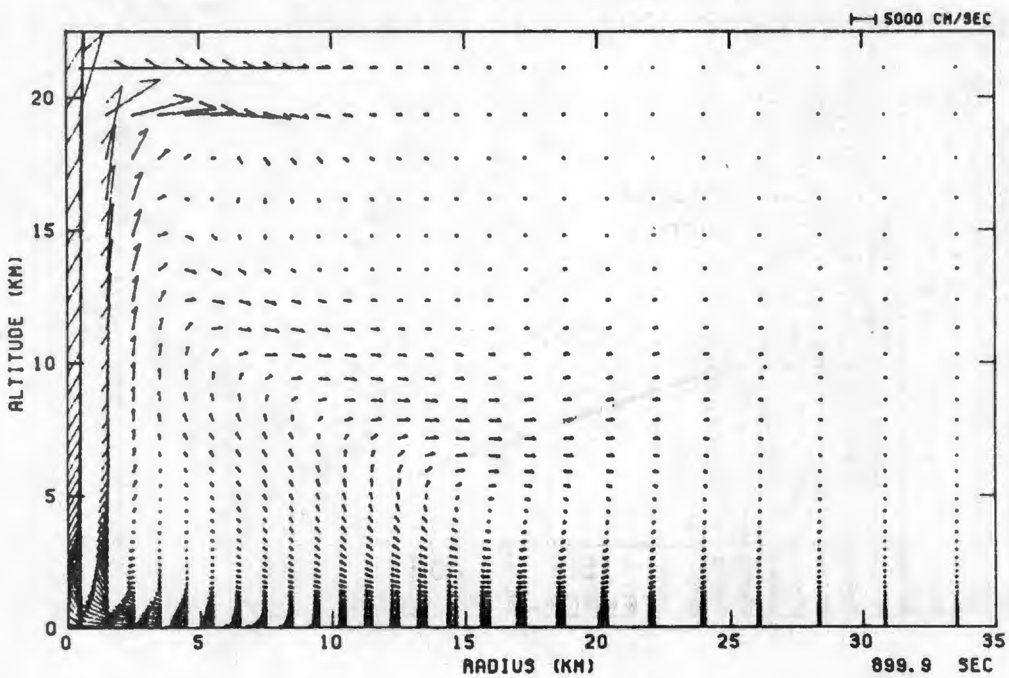
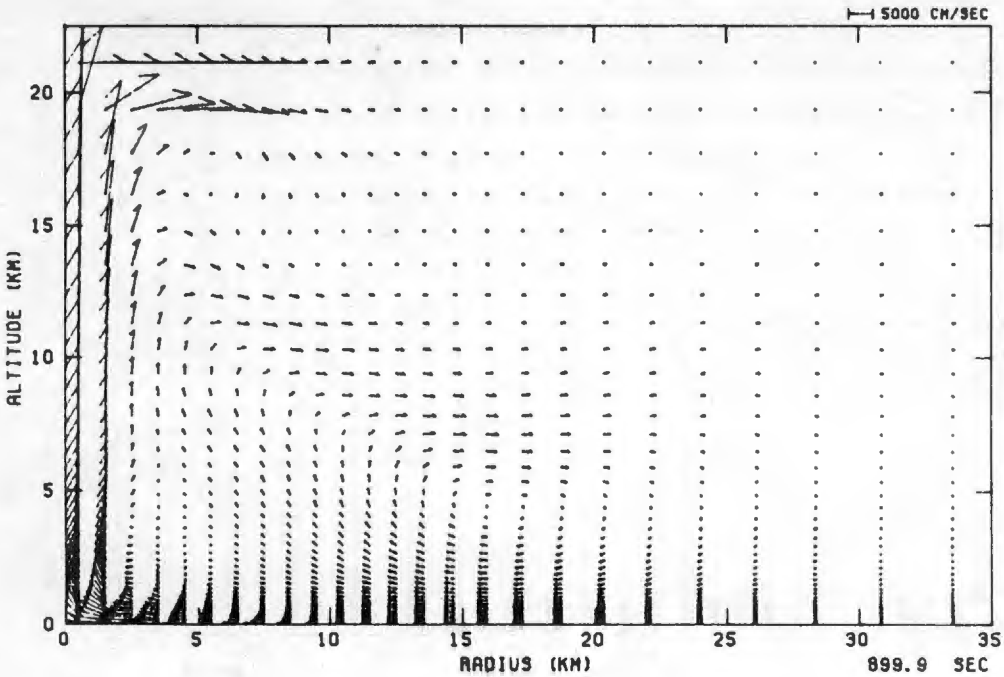


Figure 2. Particle Velocity Field at t = 15 min for
(a) Case F-127 (adiabatic atmosphere) and
(b) Case F-126 (U.S. Standard Atmosphere).

(a) Case F-126 (rigid upper boundary at 20 km altitude)



(b) Case F-125 (transmissive upper boundary at 49 km altitude)

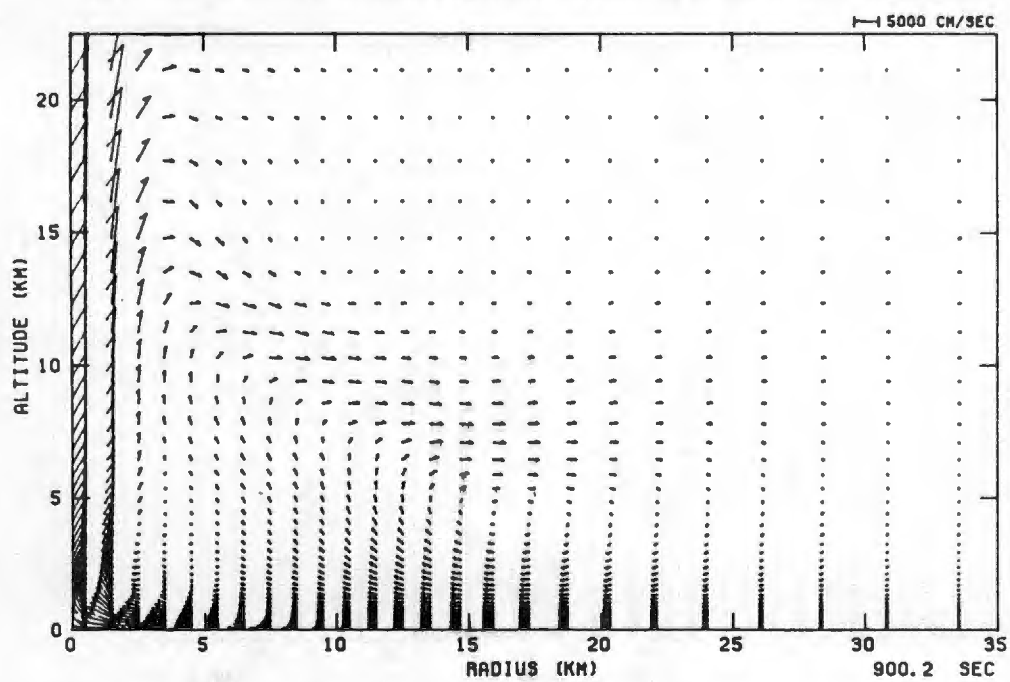


Figure 3. Particle Velocity Field at t = 15 min for

(a) Case F-126 (rigid upper boundary at 20 km altitude) and
(b) Case F-125 (transmissive upper boundary at 49 km altitude).

Figure 4 shows the horizontal velocity versus radius along the ground at t = 15 min for Case F-125. Peak inward velocities of nearly 100 m/s occur at 2 km radius. At the edge of the fire region -20 m/s velocities are evident, and extend to over 15 km radius. The shape of this velocity profile along the ground is maintained to t = 25 min, with variations on the order of 10 m/s.

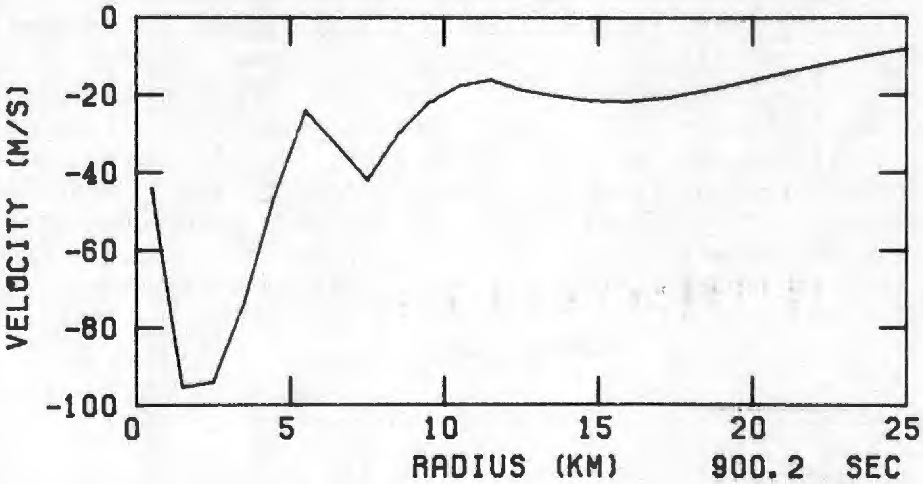


Figure 4. Radial Velocity vs. Range Along the Ground at t = 15 min for Case F-125

A more finely zoned numerical simulation is currently in progress, the results of which will be presented at the conference. Initial conditions include the U.S. Standard Atmosphere, and a linear build-up in time of the combustion rate to its full value (q_b = 0.25 $MJ/m^2/s$) between t = 0 and t = 15 min. The simulation will be carried out to t = 120 min.

REFERENCES

1. Rosenblatt, M., G.E. Eggum, P.J. Hassig, and R.J. Schlamp, DICE Code developed under U.S. Government contracts, California Research & Technology, Inc., 1972-1983.

2. Brode, H.L., D.I. Larson, and R.D. Small: Time-Dependent Model of Flows Generated by Large Area Fires, Pacific-Sierra Research Corporation, Note 483, July 1982.