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The Explosive Release Atmospheric Dispersion Model

ERAD Overview

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NNSA National Nuclear Security Administration

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Agenda

- ERAD’s Integral Plume Rise Model
- Parameterization of the Boundary Layer
- Validation
- Example Illustrating Usability
- Sandia Hazard Assessment Response Capability (SHARC)

ERAD

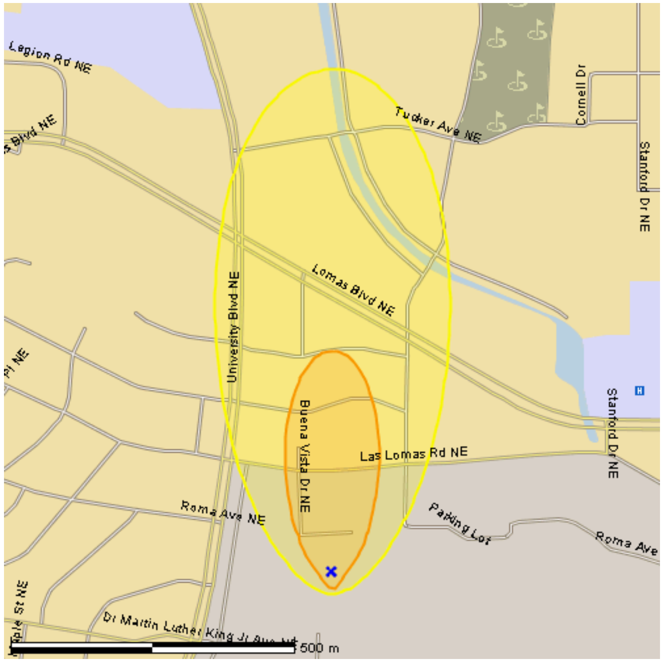
- **Model Description**
  - Three-dimensional numerical simulation of atmospheric transport and diffusion
  - Integral technique for source buoyancy
  - Probabilistic approach for turbulent dispersion
  - Workstation or PC compute platform
  - Execution time ~2 minutes

- **ERAD Model References**

  - Boughton, B.A. and J.M. Delaurentis (1987) "An Integral Model of Plume Rise from High Explosive Detonations," Proceedings of the 24th National Heat Transfer Conference, ASME, 27-32.
  - Boughton, B.A. and J.M. Delaurentis (1992) Description and Validation of ERAD: An Atmospheric Dispersion Model for High Explosive Detonations, Sandia National Laboratories, SAND 92-2069, October, 1992.

ERAD

- **Gaussian-Puff dispersion model used to predict the dispersion associated with a radiological detonation**
- **Fast-running model between Hotspot and NARAC in complexity**
- **PUFF - Prompt Explosively Driven Dynamic Plume Rise**
  - Predicts the dynamic plume rise associated with the prompt detonation effects
- **MCK - Monte Carlo Gaussian Puff Dispersion Model**
  - Adds in the particulate and determines deposition patters



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Plume Rise Background

- **In 1969, Hugh Church (SNL) published a report that provided an empirical formula for two-minute cloud top height versus yield. Most of Church's data was from nuclear clouds and high explosive clouds taken in early morning (stable) conditions.**
  - $H = 76*W^{1/4}$ Where H is the cloud top height in meters at two minutes and W is the TNT equivalent weight in pounds.

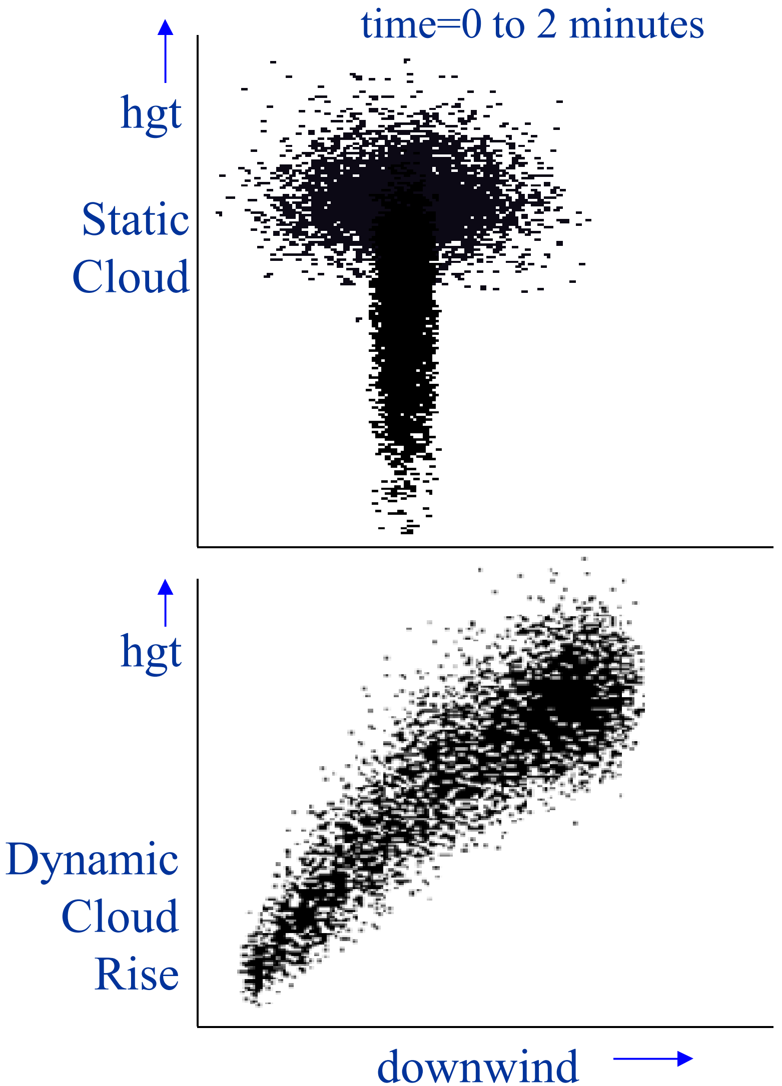
- **The Church height is used as the primary basis for establishing initial particle location in 3D wind field dispersion models (HPAC) and simple models (HOTSPOT).**

- **The ERAD model was developed in the 1980s to assess the time-dependent buoyant rise for different meteorological conditions (different vertical temperature profiles). A recent example of the time-dependent rise for different meteorological conditions is provided later (Church's 2-minute height is included on the plot).**

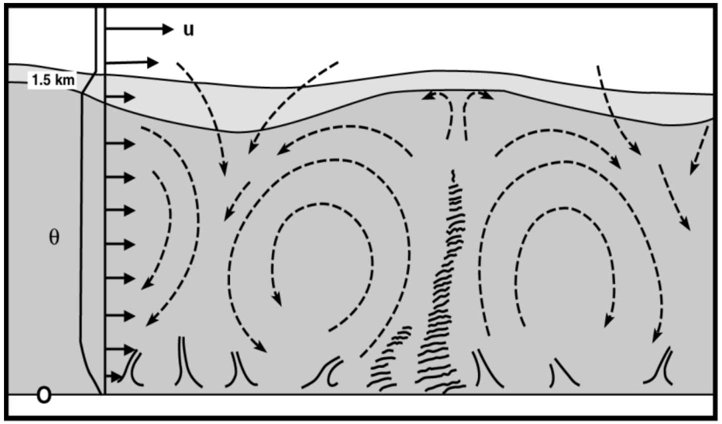
Static vs. Dynamic Plume Height

- **Static Plume Height**
  - Based on Church's cloud height analysis at 2 minutes after detonation
    - Cloud dimensions are a function of explosive weight only
    - No meteorological dependence
    - General under-prediction of surface contamination close to detonation location

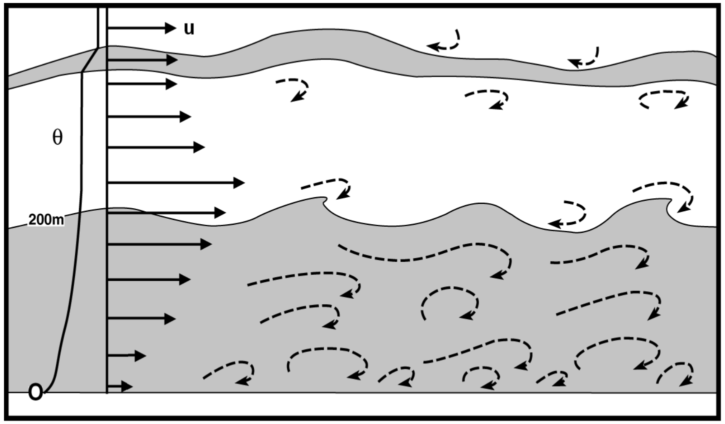
- **Dynamic Plume Rise**
  - Modeled using an integral technique
  - Provides time-dependent rise of buoyant gas cloud
  - Particles couple to buoyant gas cloud



ERAD's Parameterization of Boundary Layer



Convective Boundary Layer



Stable Boundary Layer

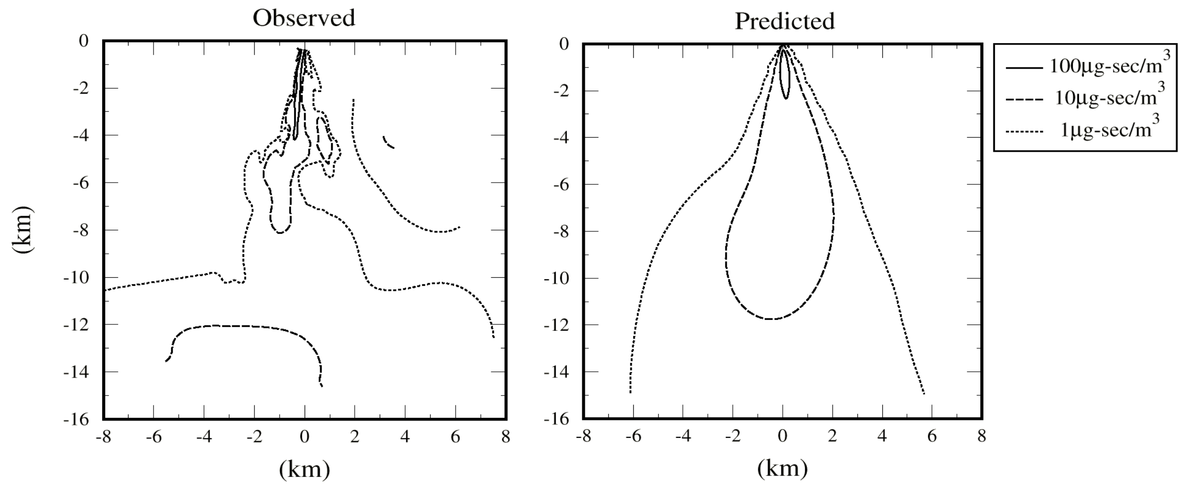
- ERAD models vertical diffusion using Monte Carlo method.
- Mixing height is utilized along with sounding data to generate the turbulent velocity profiles.
- Surface roughness length scales are used to characterize the region and terrain.

ERAD Validation

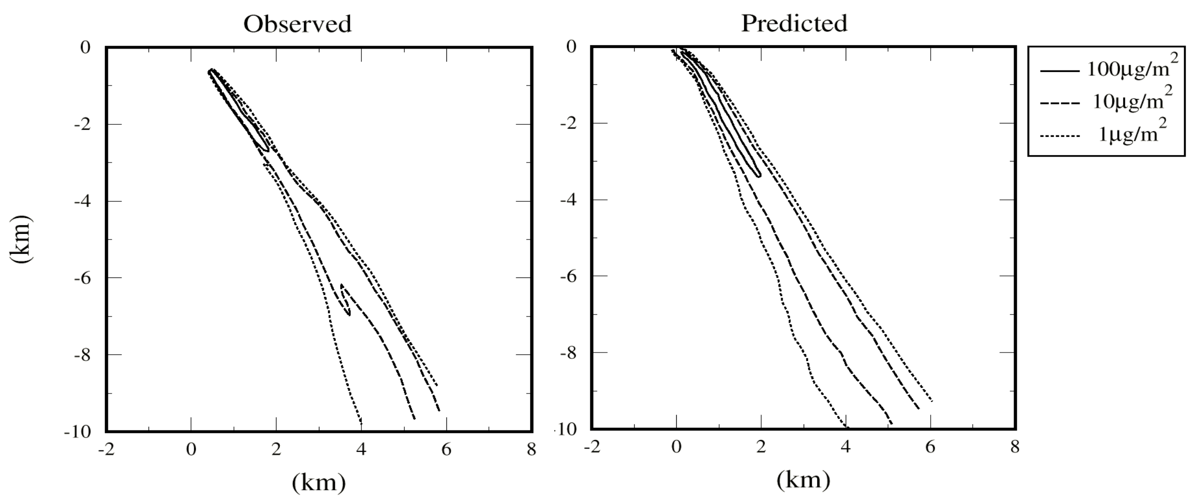
- **Complete model benchmarked against DOUBLE TRACKS and CLEAN SLATE 1 events of Operation ROLLER COASTER**
  - Double Tracks ~48 kg HE, Clean Slate ~428 kg HE
  - Truncated lognormal particle size distribution used fit to measurements
  - Three wind profiles, one temperature sounding per event
  - Dose and deposition contour area predictions average within about 50% of observations; within uncertainty of measurements

ERAD Validation

- **Double Tracks Respirable Dosage**



- **Clean Slate 1 Deposition**



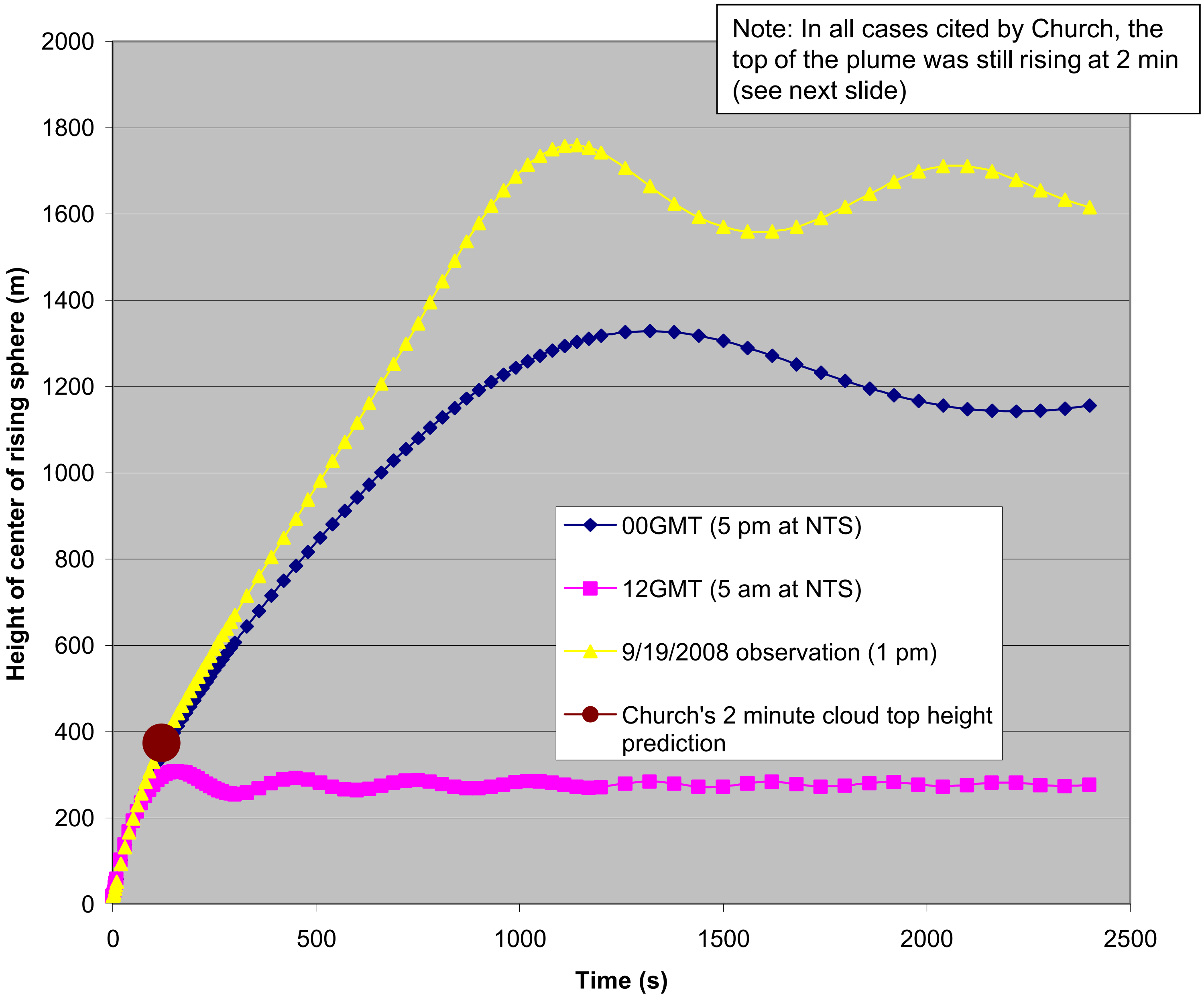
Plume Trajectory Calculations using ERAD

- **ERAD used to predict the position and size of rising sphere of gas generated from an explosive event**
- **Selected cases provide a feel for potential variability (shown on next slide)**
- **Used to make tentative flight plan**
- **Vertical readings taken prior to the shot were implemented and relayed to the flight crew**

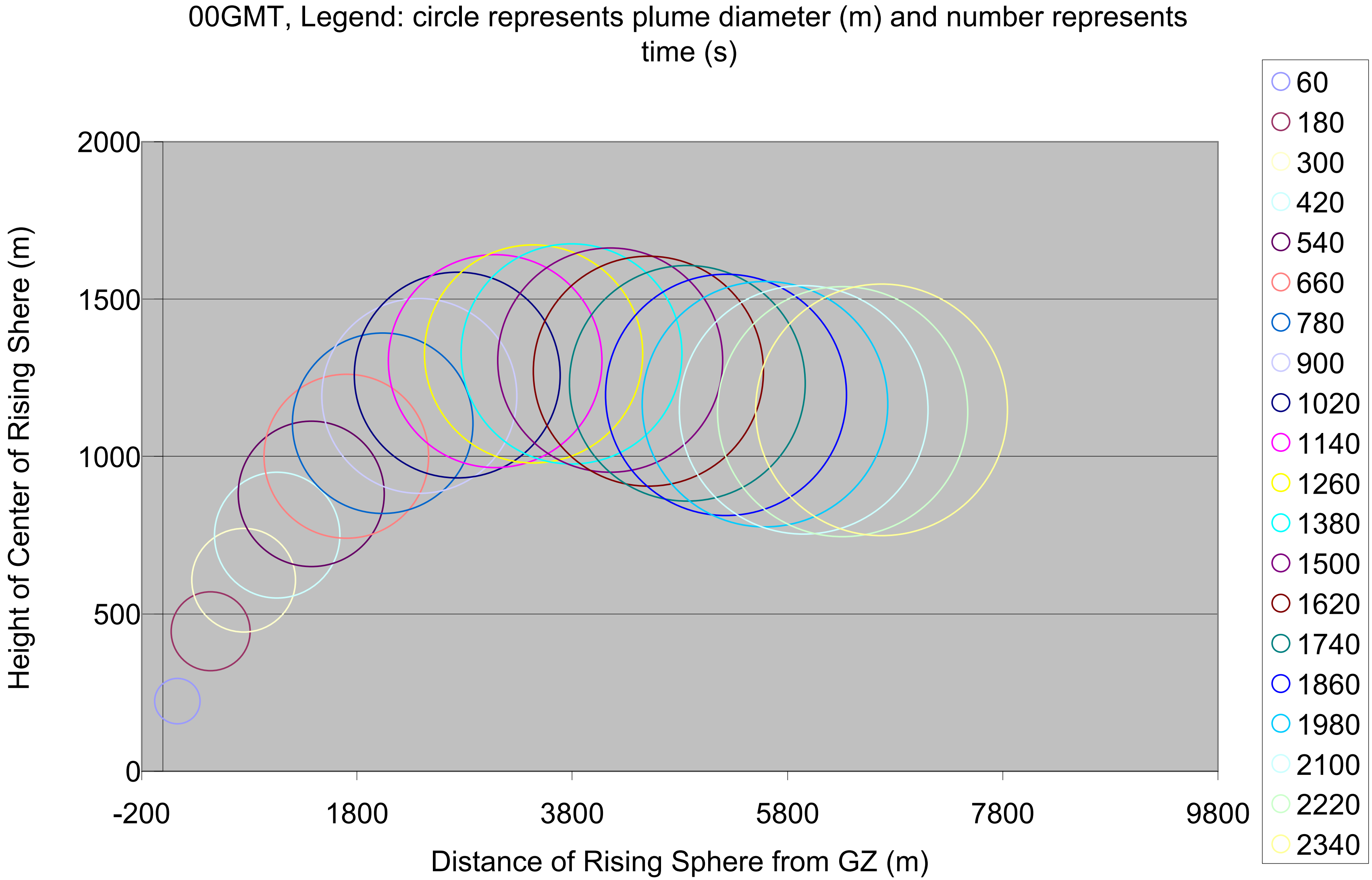
Cases

- **00GMT – Average 5 pm October meteorology from mean upper air sounding from 1978 to 2002 for Desert Rock (closest sounding station to NTS)**
  - Probably typical of afternoon profile (after ground heating has warmed the lower atmosphere)
  - Plumes go higher because of constant vertical potential temperature profile
- **12GMT – Average 5 am October meteorology from mean upper air sounding from 1978 to 2002 for Desert Rock (closest sounding station to NTS)**
  - Probably typical of meteorological conditions before ground heating has warmed the lower atmosphere
  - Plume will not go as high as previous case because vertical potential temperature profile has positive slope, meaning potential temperature increases with altitude, which inhibits the buoyancy of the plume
- **Sep 19 Observation – vertical profile for Sep 19 at about 1 pm**
  - Example of a trajectory based on the observed vertical wind and temperature profiles at Desert Rock

Height of center of rising gas sphere (m) vs time



Position and Size of Rising Sphere of Gas



Plume diameter is represented realistically here and is shown explicitly in later v-graph

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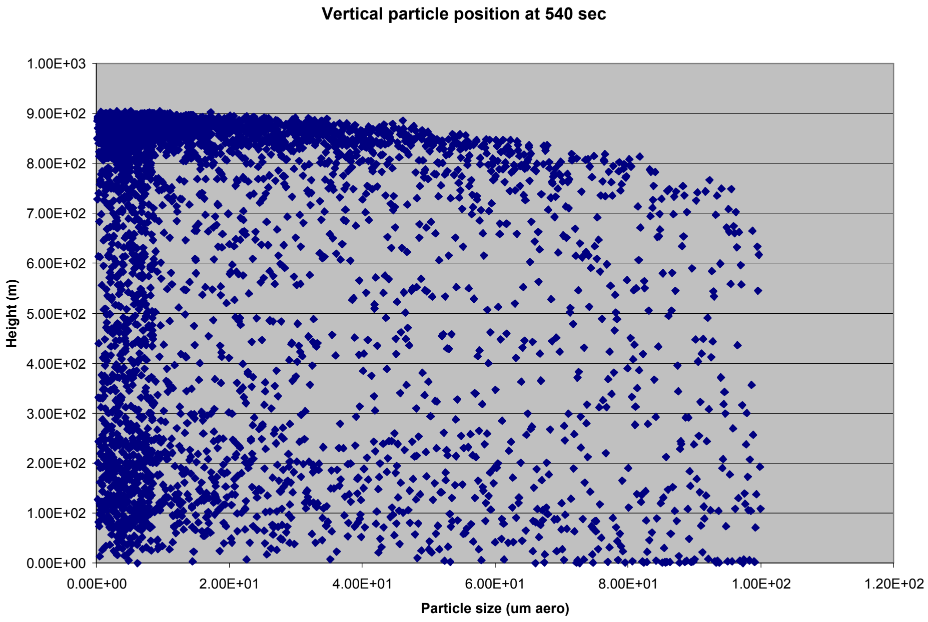
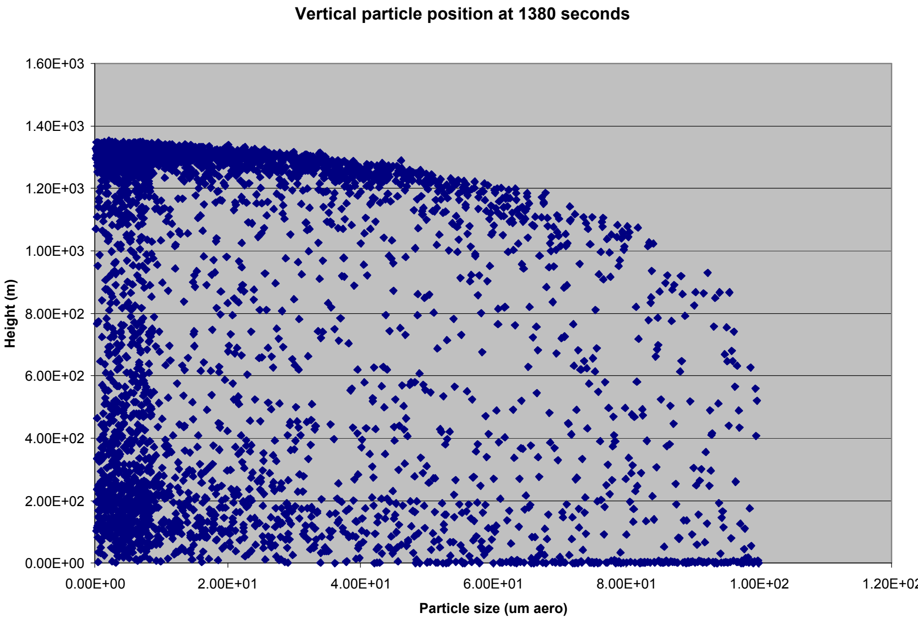
Vertical Position of the Particles

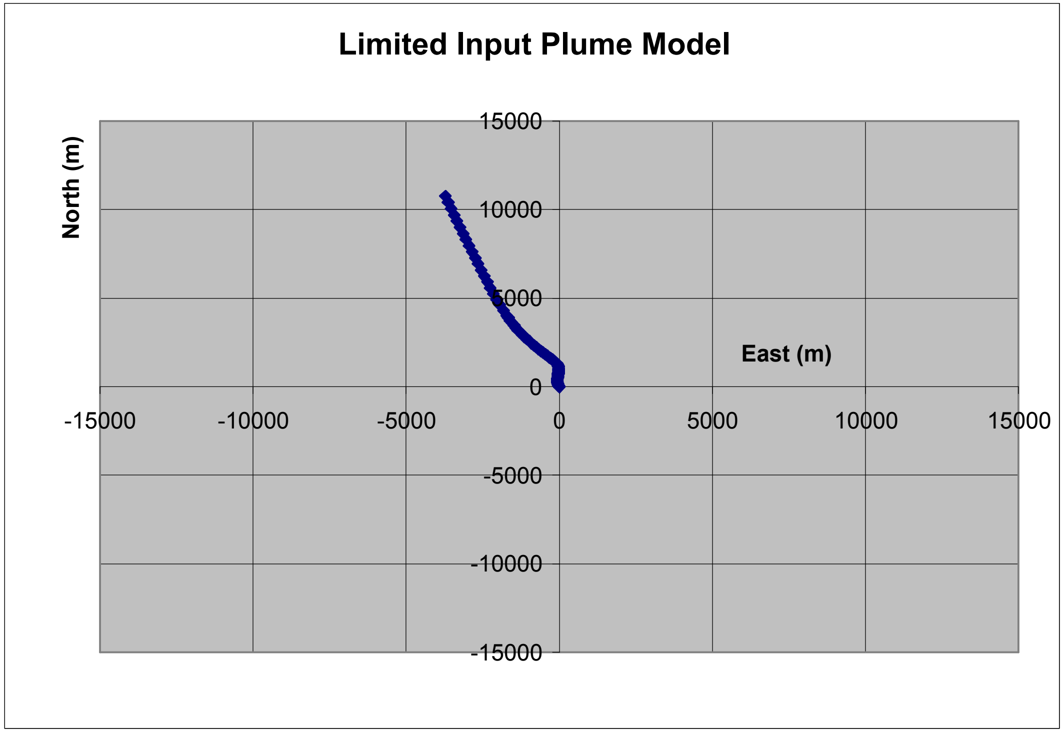
- Vertical distribution of particulate frequently appears bimodal
- It appears that the best strategy would be to base flight plans on the height of the center of the buoyant plume (or rising sphere of gas)





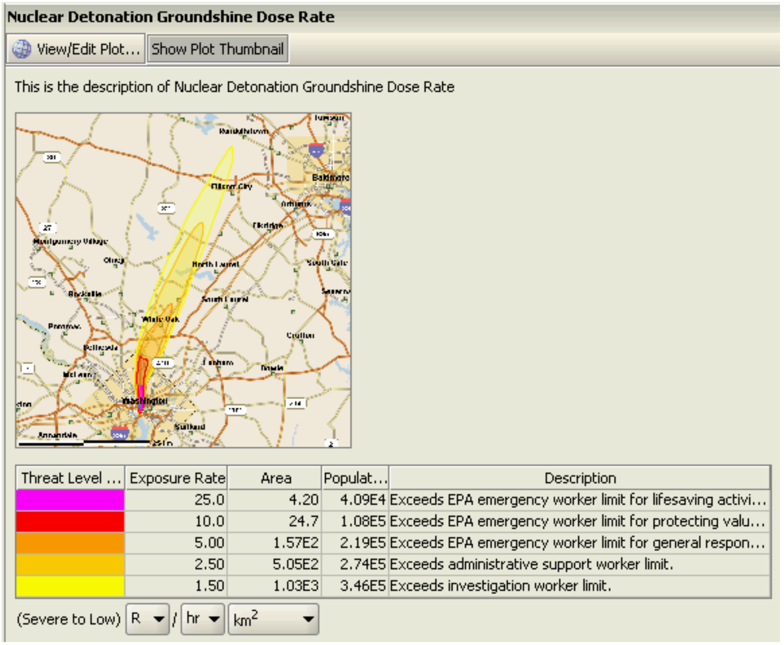
Aircraft Intercepted the Plume

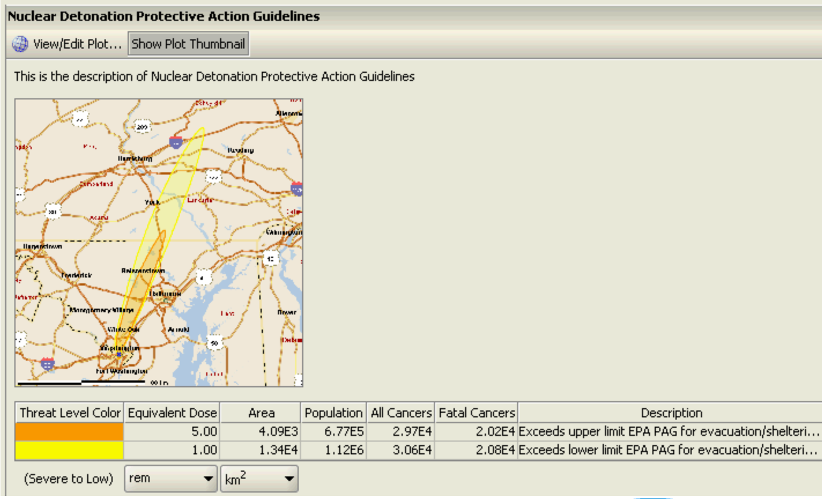
- **Information to Aircraft: time, height, latitude, longitude, and diameter of the buoyant plume**



SHARC - Overview

- **Developed at SNL to support JTOT**
- **Consists of five models:**
  - Nuke – Prompt Nuclear Effects
  - AIRRAD – Fallout
  - Blast – Prompt Explosive Effects
  - ERAD
    - PUFF – Prompt Explosively Driven Dynamic Plume Rise
    - MCK – Monte Carlo Gaussian Puff Dispersion Model
- **Some capabilities predicted fallout patterns that indicate areas in excess of federal PAG guidance for:**
  - Short-term evacuation
  - Long-term relocation





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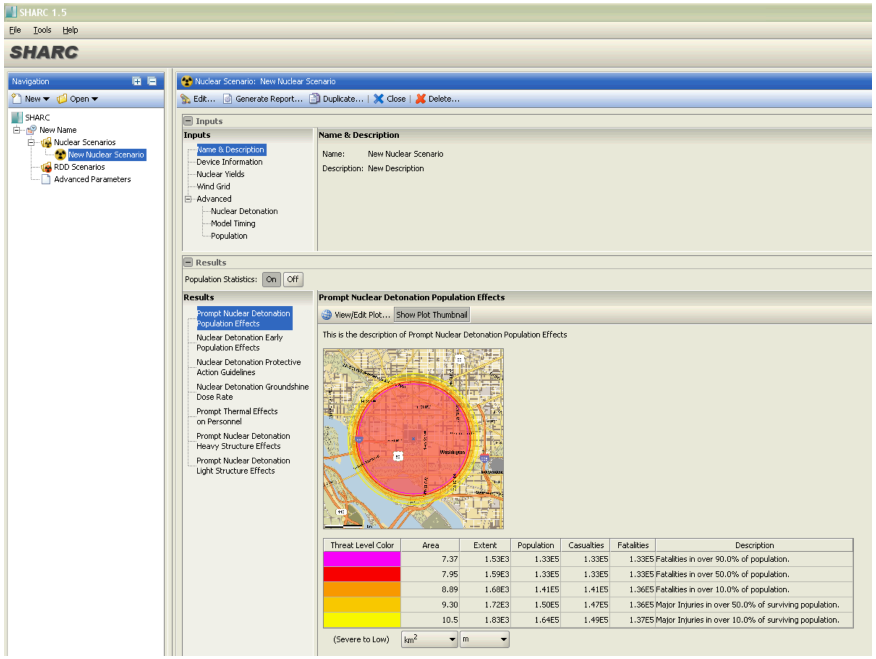
SHARC

- **Two scenarios available**
  - Nuclear Scenario
  - RDD Scenario
    - Buoyant (explosively driven)
    - Non-buoyant
- **Automated calculation of fatality and casualty estimates using population databases**
  - Landscan 2006
  - U.S. Census 2009
- **Integrated with Turbo FRMAC for health physics calculations**
- **Fully automated report generation**



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Questions