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Air Force Institute of Technology Dust Cloud Model Vertical Dispersion

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Air Force Institute of Technology
Dust Cloud Model Vertical Dispersion

John W St. Ledger

Abstract

The Air Force Institute of Technology (AFIT) has developed and refined a nuclear dust cloud model for modeling nuclear fallout, and the dust mass and radiation encountered by aircraft flying through a nuclear dust cloud. Recently, a question was raised requesting an explanation of why the vertical mass and activity distributions had an anomalous shape for yields above 1 Mt. This report explains that the anomalous shape occurs because the dust cloud model is a discrete numeric model, and not a continuous model.

Air Force Institute of Technology
Dust Cloud Model Vertical Dispersion

Introduction

The Air Force Institute of Technology (AFIT) has developed and refined a nuclear dust cloud model for modeling nuclear fallout, and the dust mass and radiation encountered by aircraft flying through a nuclear dust cloud. The dust cloud model is based on the Weapon Systems Evaluation Group (WSEG10) model, and curve fits to Defense Land Fallout Interpretive Code (DELFIC) calculations. (Pugh, Bridgman, Clements, Conners, Hopkins)

Recently, a concern was raised over why the vertical mass and activity distributions had an anomalous shape for yields above 1 Mt. This report explains that the anomalous shape occurs because the dust cloud model is a discrete numeric model, and not a continuous model.

Anomalous Shape

Figure 1 shows the particle size distributions from DELFIC. There are 100 particle sizes in each line, which represent 1% of the activity, mass, or number of particles in the dust cloud. The larger particles are spaced farther apart in size, but they are the center particle in the particle size bin for each distribution.

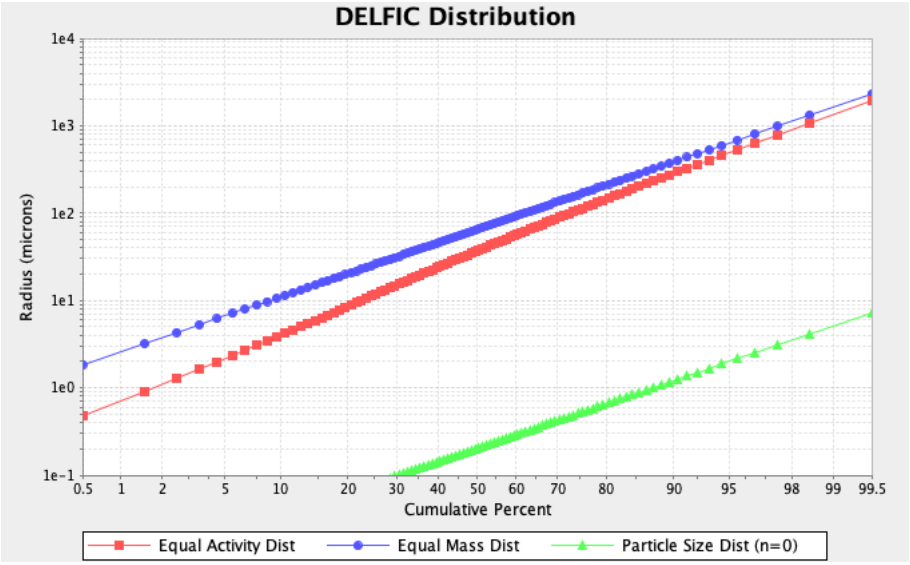

Figure 1—DELFIC Particle Size Distributions

Figures 2 and 3 show the vertical distribution of activity and mass for a 1Mt detonation at the surface. This dust cloud uses the DELFIC dust size distributions from Figure 1. Figures 4 and 5 show the same vertical distributions for a 10 Mt detonation.

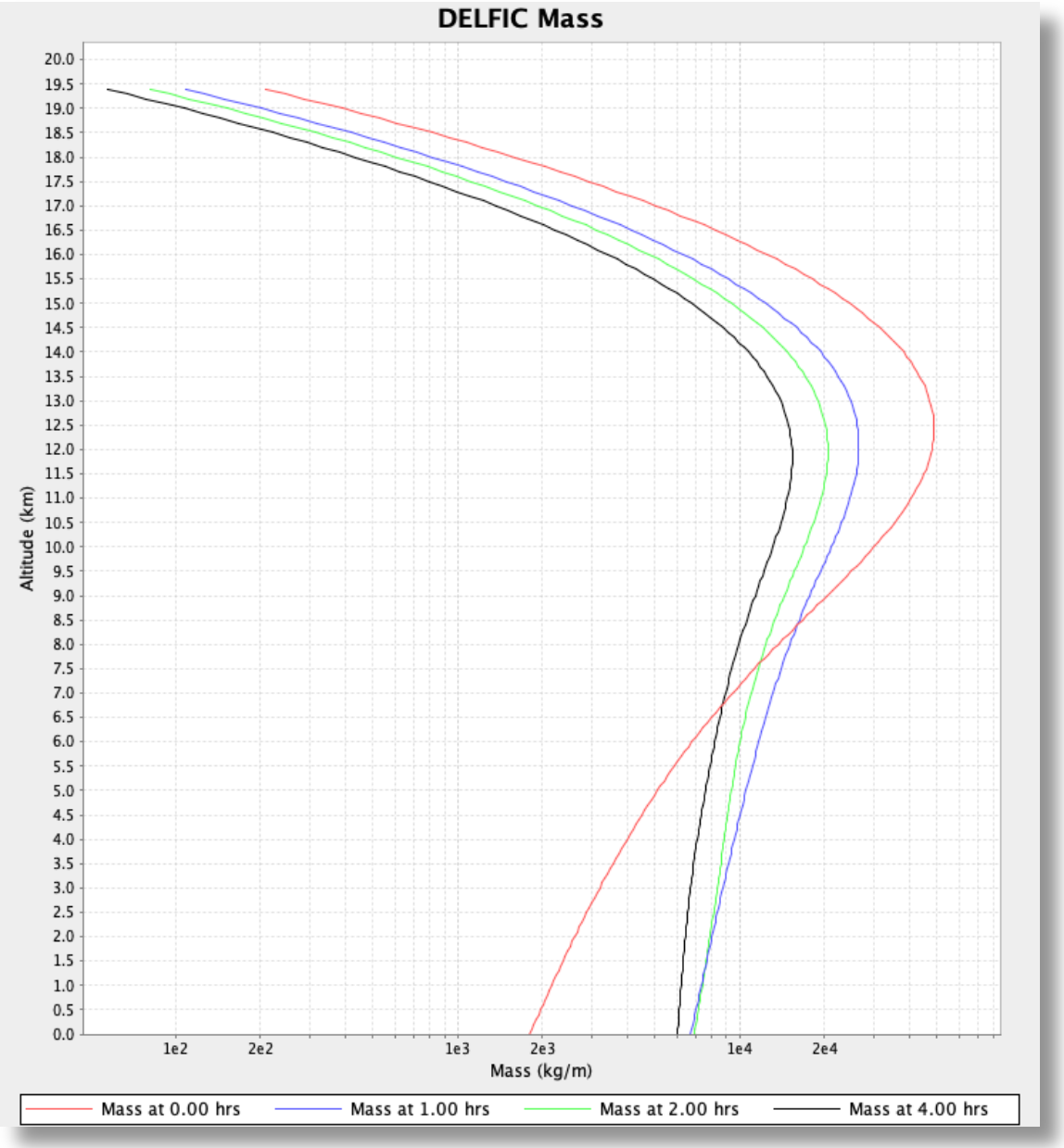

Figure 2—DELFIC 100 Particle Bin 1 Mt Vertical Mass Distribution

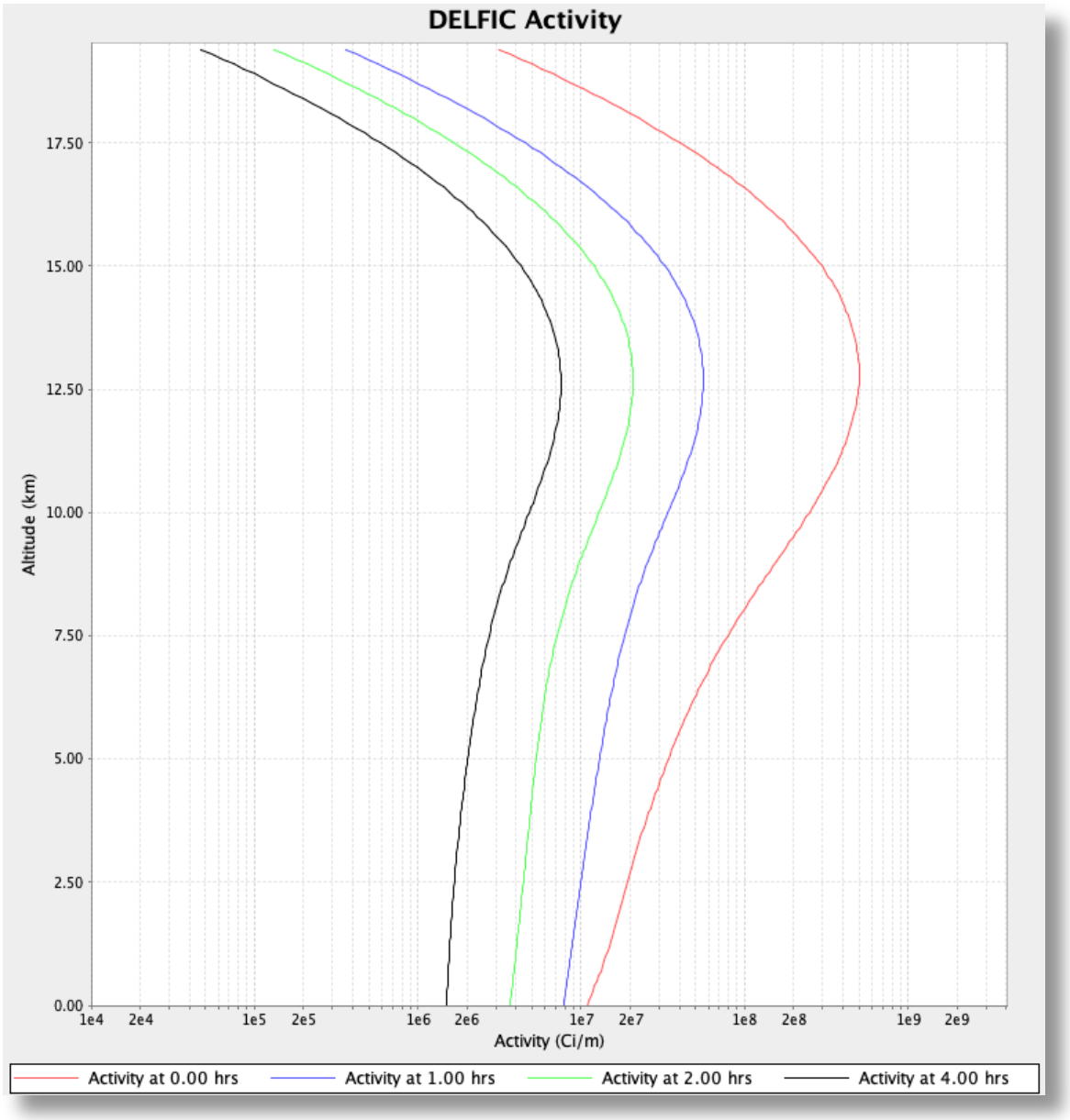

Figure 3—DELFIC 100 Particle Bin 1 Mt Vertical Activity Distribution

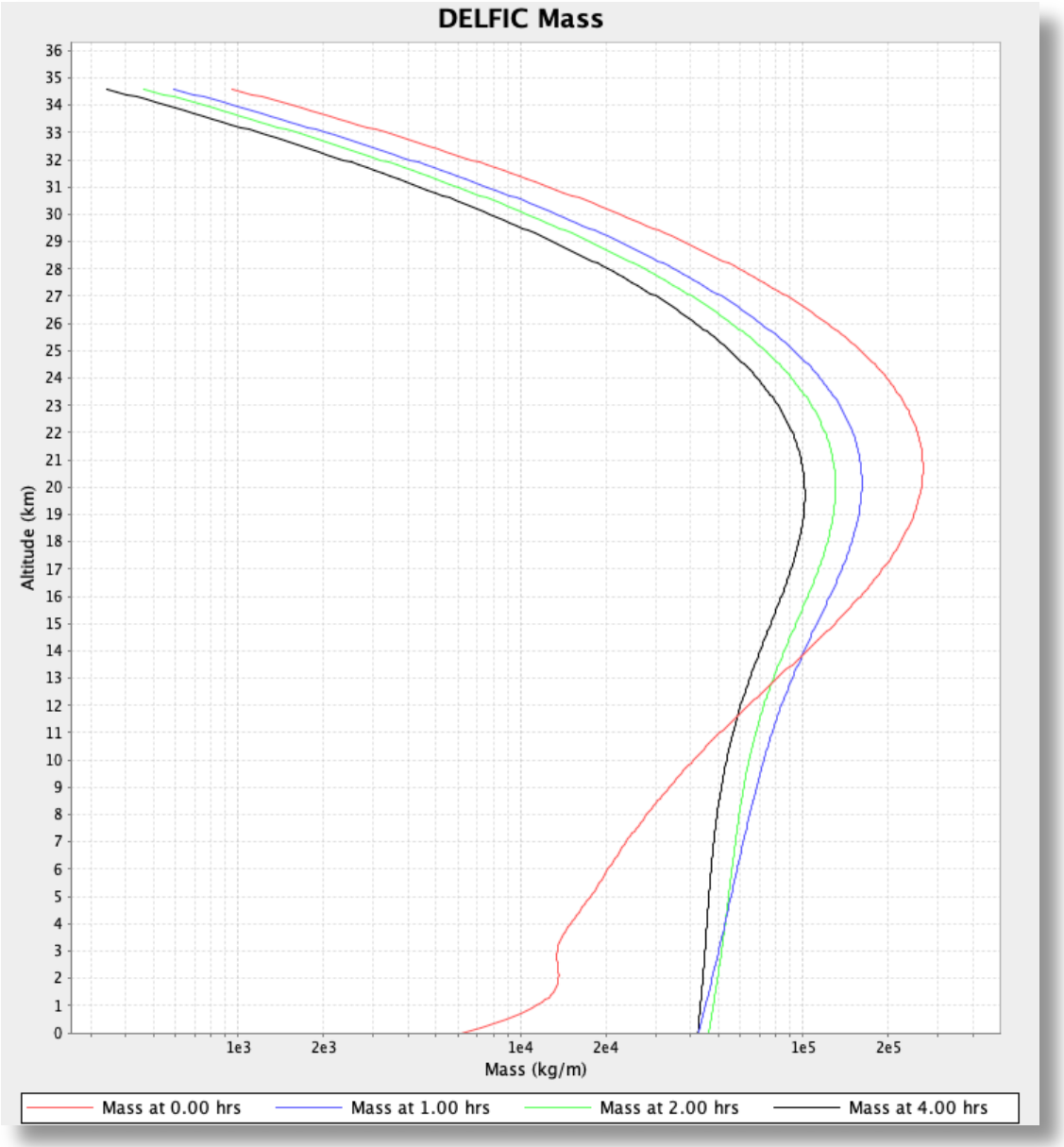

Figure 4—DELFIC 100 Particle Bin 10 Mt Vertical Mass Distribution

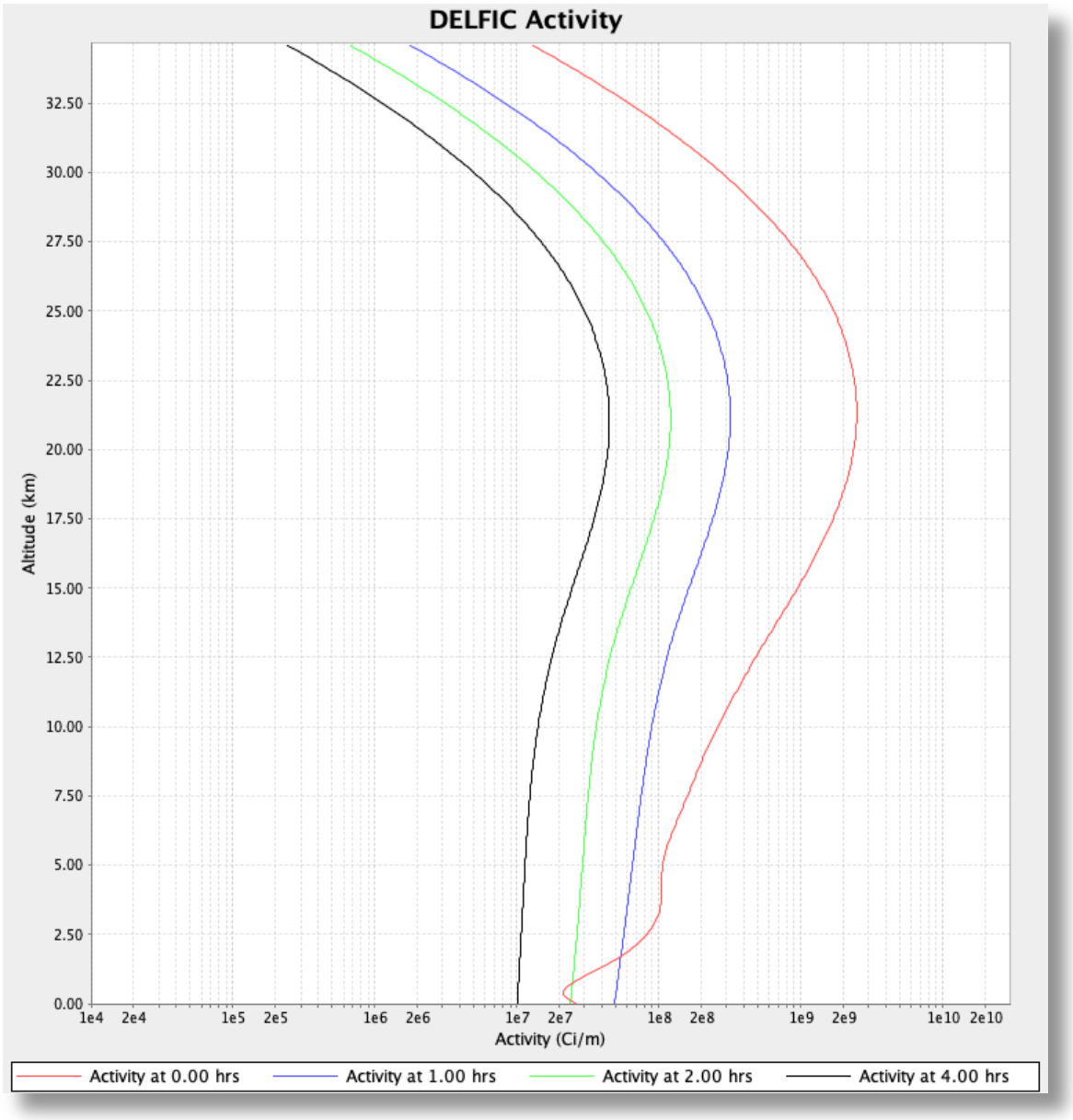

Figure 5—DELFIC 100 Particle Bin 10 Mt Vertical Activity Distribution

Comparing Figures 2 and 3 to Figures 4 and 5, there is an unexpected shape to the mass and activity below about 4 to 5 kilometers for the 10 Mt yield. Plotting several different particle size distributions, it was discovered that the anomalous shaped curves only occurred at yields at or above 1 Mt, and for particle size distributions that had particles larger than about 500 micron radius.

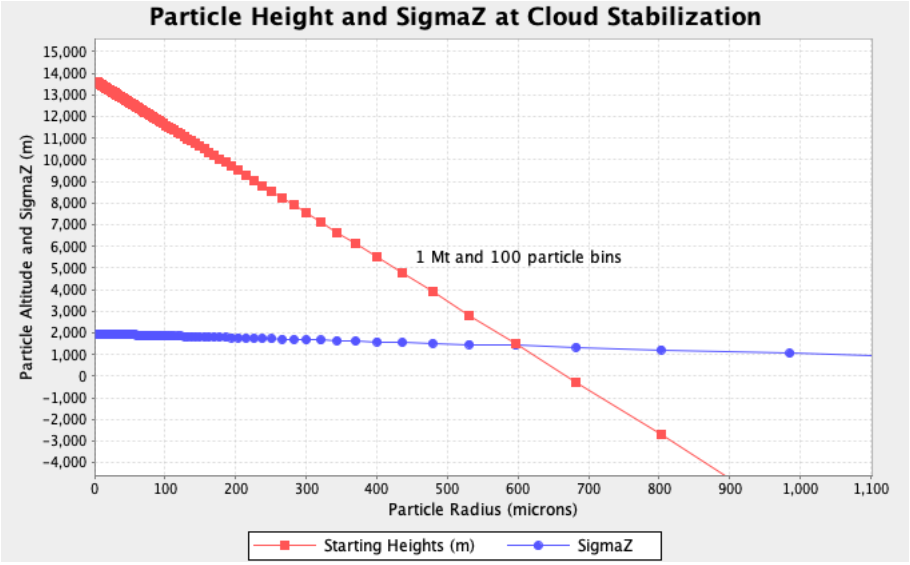

Figure 6—Particle Height and SigmaZ at Stabilization for 1 Mt

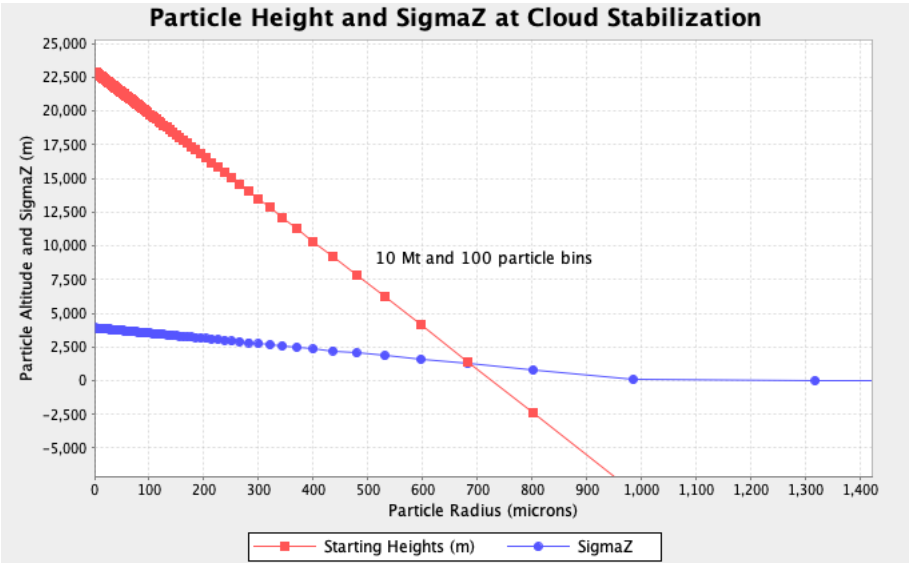

Figure 7—Particle Height and SigmaZ at Stabilization for 10 Mt

The AFIT dust cloud is modeled as a cylinder, with each particle bin being normally distributed in three dimensions. Figures 6 and 7 show the particle bin heights and vertical cloud standard deviations at cloud stabilization for 1 Mt and 10 Mt.

For 1 Mt, the 670 micron radius particle is on the ground, and all larger particles are on the ground. For particles near the ground, the separation between particle bins is about 1500 m in height, and the sigmaZ is about 1500 m. So about 5 particle bins are making contributions to the dust mass near the ground.

For 10 Mt, the 730 micron particle is on the ground. For particles near the ground, the separation between particles bins is about 4,200 m in height, and the SigmaZ is about 1400 m. So only one or two particle bins is contributing to the dust mass near the ground.

This suggests that the anomalous shape in the distribution curves is caused by the vertical separation of the larger particle bins near the ground. To test this, the dust model was modified to have 1,000 particle size bins. Figures 8 and 9 show the vertical dust and activity distribution for a 10 Mt detonation, with 1,000 DELFIC particle bins.

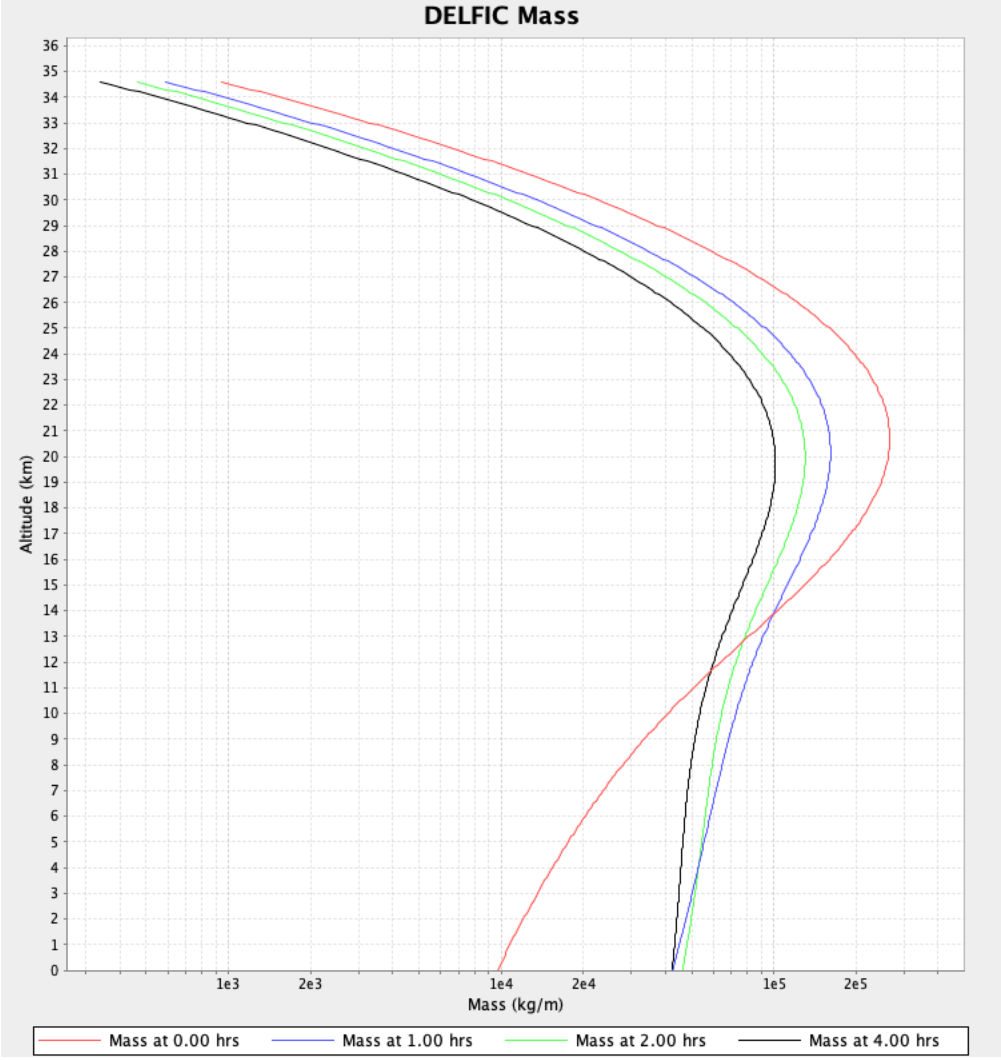

Figure 8—DELFIC 1,000 Particle Bin 10 Mt Vertical Mass Distribution

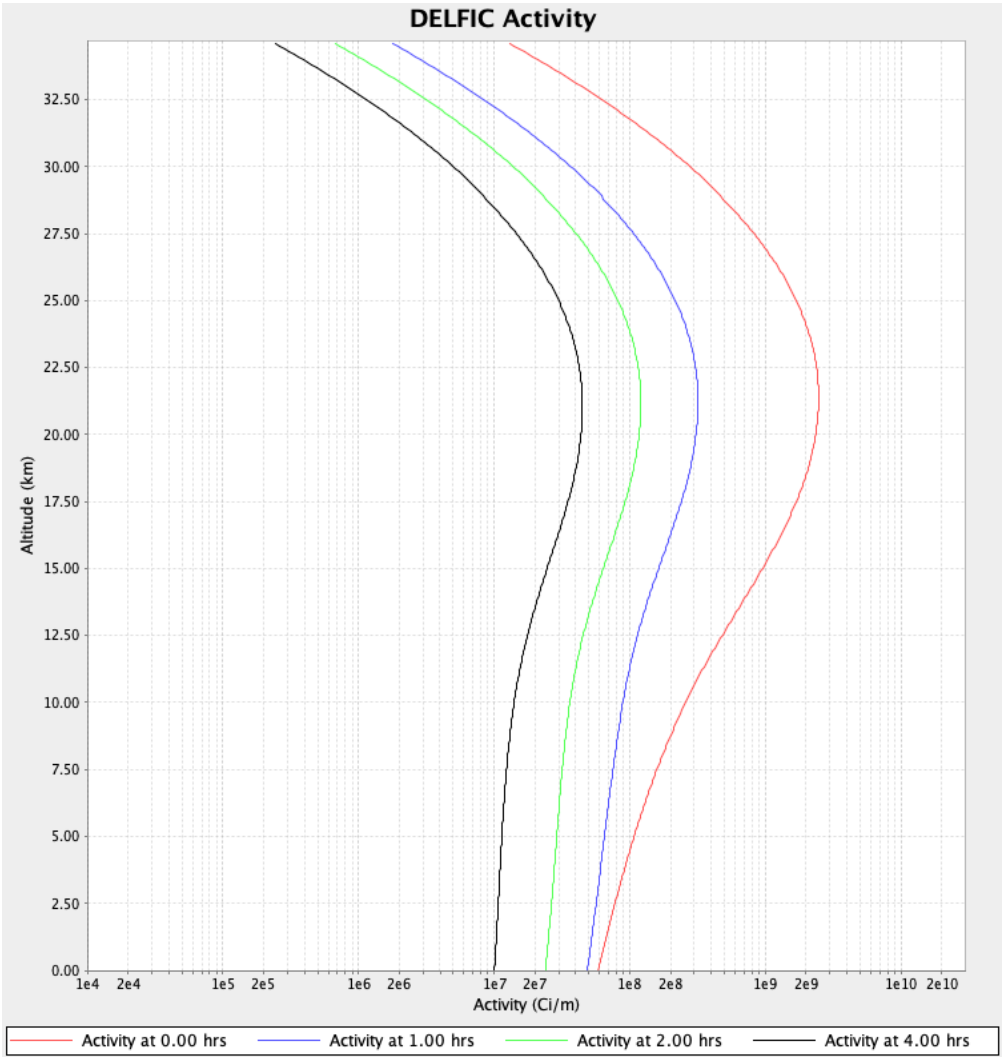

Figure 9—DELFIC 1,000 Particle Bin 10 Mt Vertical Activity Distribution

The 1,000 particle bin vertical distributions are very closely matched by the 100 bin distributions, until the altitude is less than about 5 km. Then the 1,000 particle bin distributions no longer have the anomalous shape. At later times for 100 particle bins there is no anomalous shape, because the largest particles are on the ground, and the smaller particles near the ground at later times are closer together, and have larger standard deviations in the vertical direction.

Conclusion

The anomalous shapes in the vertical distribution curves for higher yields in the AFIT dust cloud model are caused by the model using a discrete numeric particle size model. Increasing the number of particle bins can make the curves have a more expected shape, but the run time is much greater.

References

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Glossary of Terms

AFIT	Air Force Institute of Technology
DELFIC	Defense Land Fallout Interpretive Code
km	kilometers
kt	kilotons
LANL	Los Alamos National Laboratory
m	meters
WSEG	Weapon System Evaluation Group

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