Current Toolbox Models: MACCS2

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- **Phenomenological models in MACCS2**

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- **How MACCS2 Calculates χ/Q**

- **Parameters and Their Conservatism**

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Phenomenological Models: ATMOS

- **Source term**
  - Assumed to be known (e.g., predicted by MELCOR)
- **Weather data**
  - Usually represent one or more years of observations
  - Sampled within a single MACCS2 run
- **Plume**
  - Initial dimensions
  - Release height and additional plume rise
  - Downwind transport and dispersion
  - Depletion by radioactive decay and dry and wet deposition

Phenomenological Models: EARLY

- **Emergency phase – 1 day to 1 week**

- **Exposure pathways**
  - **Cloudshine, groundshine, direct inhalation, and inhalation of resuspended aerosols**

- **Emergency responses**
  - **Evacuation, sheltering, and relocation**

- **Heath effects**
  - **Acute health effects and latent cancer**

- **Economic consequences**
  - **Evacuation/Relocation costs**

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Phenomenological Models: CHRONC

- **Exposure pathways**
  - **Groundshine, inhalation of resuspended particles, and food and water ingestion**

- **Mitigative actions**
  - **Decontamination**
  - **Interdiction**
  - **Condemnation**

- **Economic consequences**
  - **Cost of decontamination**
  - **Loss of use of property**
  - **Disposal of agricultural products**
  - **Relocation of population**
  - **Condemnation of property**

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MACCS2 Version 1.13 (Toolbox)

- **First released in 2001**

- **Recompiled with Intel's FORTRAN compiler to be compatible with Windows 2000 and XP**

- **Includes a validate-only option**

- **Enhanced error handling and reporting**

- **Resolved errors leading to defect notifications**

- **Added check to ensure reasonable bounds on σ_y**

- **Corrected error in food-chain output for leafy vegetables**

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MACCS2 Version 2.5 (Current) Improvements Useful for DOE Safety Analyses

- **Some limits have been increased**
  - **Plume segments – 200**
  - **Isotope groups – 20**
  - **Aerosol bins – 20**
  - **Evacuation cohorts - 20**
- **New DCF file for FGR-13**
- **Reg. Guide 1.145 plume meander model**
- **Angular resolutions allowing up to 64 compass sectors**
- **Meteorological data frequency of 15, 30, and 60 minutes**
- **Flow rate/density option for specifying buoyancy**
- **Optional improved Briggs model**
- **Diurnal variations in mixing height**

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MACCS2 Version 2.5 (Current)
Other Modeling Improvements

- **Option for time-based, long-range dispersion**

- **Annual and piecewise-linear dose threshold models**

- **KI ingestion model**

- **Effect of adverse weather on evacuation speeds**

- **Concentration and dose output by grid element and land area exceeding specified concentration or dose**

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MACCS2 Version 2.5 (Current) Significant Bug and Other Fixes

- Warning and error messages more informative

- Added dynamic memory capability

- Fixed an error with travel times for network evacuation model

- Enforced increasing order of plume delay times

- Fixed over-counting of fatalities

- Fixed problem with exceeding limits of σ_z look-up table

- Increased number of reflective terms considered in Gaussian implementation

- Better checking for missing hours in met file

MACCS2 Version 2.6 (Near Future) Improvements Useful for DOE Safety Analyses

- **Optional units for results**
  - **Activities in Bq or Ci**
  - **Distances in units of km or mi**
  - **Area in units of hectares, km^2, mi^2**
  - **Doses in units of Sv or rem**

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MACCS2 Version 2.6 (Near Future) Significant Bug and Other Fixes

- Error message printed when bounds for σ_y exceeded in lookup table

- Several fixes made for SUMPOP site-file option

- Fixed conflict with pointer used for KI model

- Fixed issue with land area calculation for Types C and D output

- Longer file names allowed

- Correction to Reg. Guide 1.145 plume meander model

How MACCS2 Calculates χ/Q

- **Calculating χ/Q for a grid element**
  - Values are calculated at the inner and outer boundary
  - Value for grid cell is the average of the boundary values
- **Virtual source locations are used to adjust σ_y and σ_z**
  - Match dimensions of area source
  - Enforce continuity when stability class changes
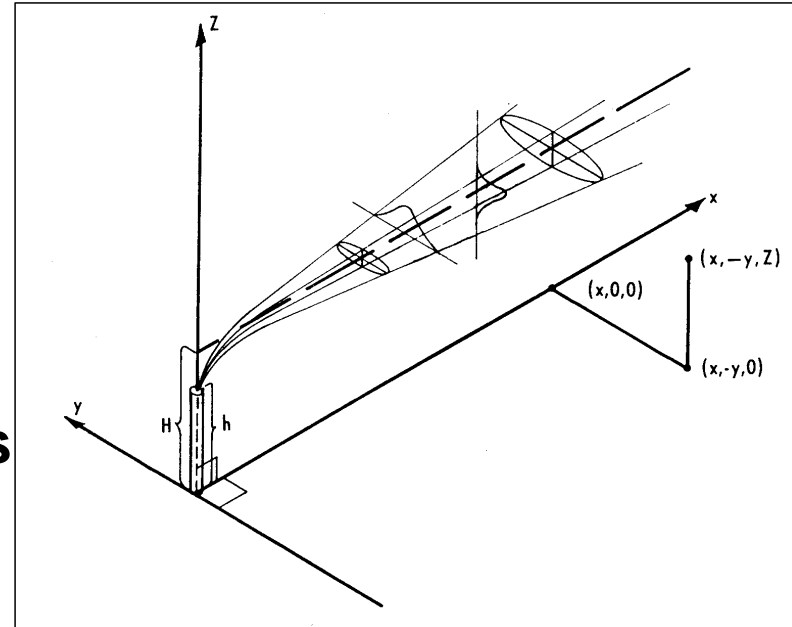
User Specification of Dispersion Parameters

- σ_y and σ_z can be defined as power-law functions or with lookup tables
  - Exceeding bounds of σ_y lookup table results in fatal error
  - Exceeding bounds of σ_z lookup table results in
    - Warning message
    - σ_z remains constant until stability class changes

A — EXTREMELY UNSTABLE
B — MODERATELY UNSTABLE
C — SLIGHTLY UNSTABLE
D — NEUTRAL
E — SLIGHTLY STABLE
F — MODERATELY STABLE

σ_z, VERTICAL DISPERSION COEFFICIENT (m)

DISTANCE FROM SOURCE (m)
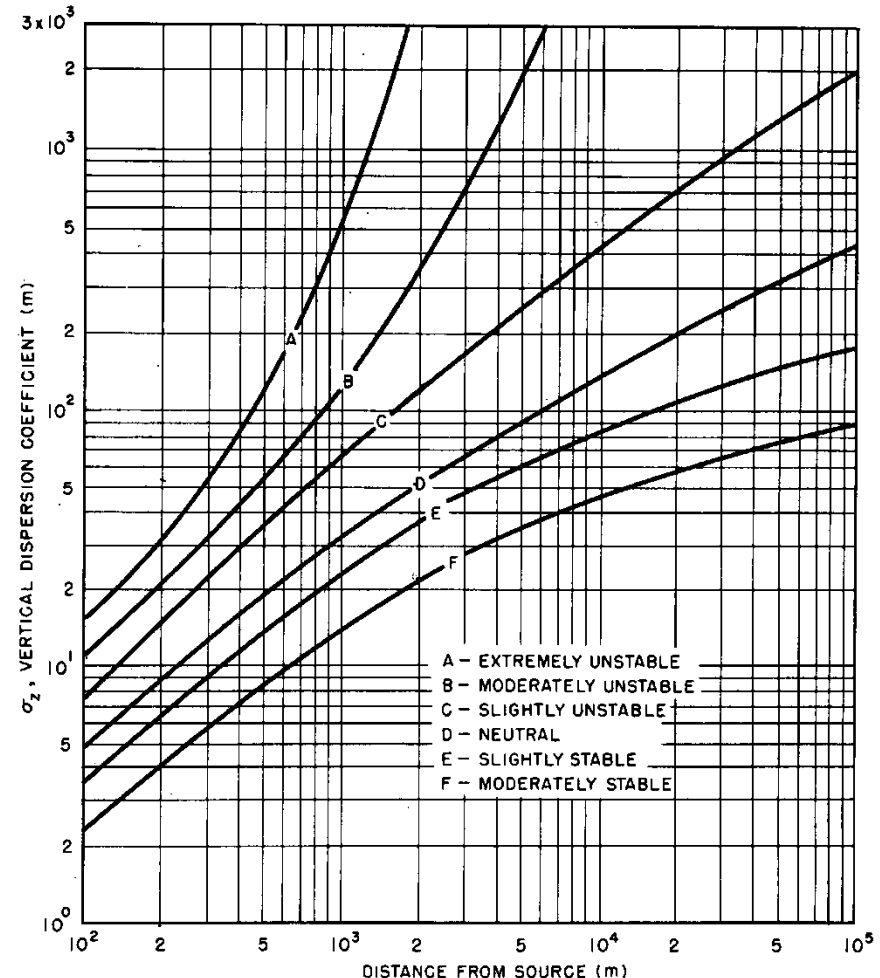
User Specification of Dispersion Parameters

- **User can provide multipliers on σ_y and σ_z**
  - Multiplier on σ_y commonly used to treat plume meander
  - Additional σ_y multiplier usually set to unity
  - User-specified multiplier for σ_z commonly used to account for surface roughness

- **Treatment of surface roughness should be consistent with meteorological data**

Plume Meander Models

- **Version 1.13.1 contains the original MACCS2 plume meander model**
  - **Meander factor proportional to plume duration raised to the 0.2 (< 1 hr) or 0.25 (> 1 hr) power**

- **Version 2.5 also includes Reg. Guide 1.145 plume meander model**
  - **Based on release duration of 1 hour**
  - **Meander factor depends on wind speed and stability class**
  - **Meander factor reaches a maximum at 800 m then diminishes**
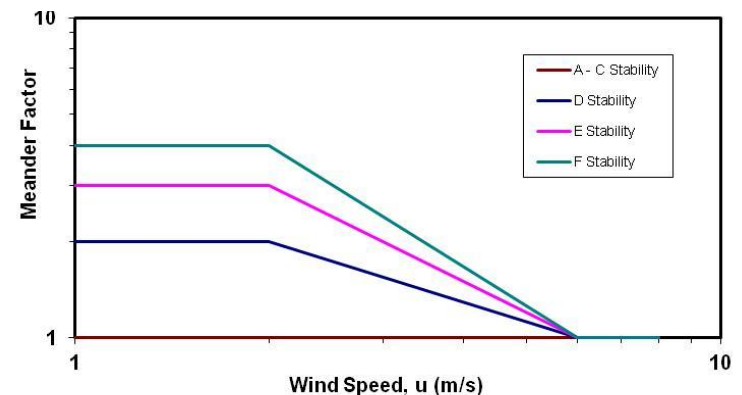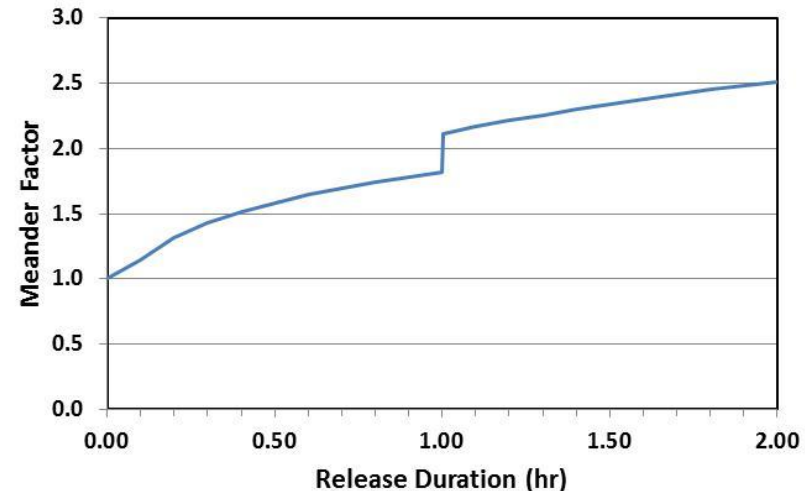
Model Conservatisms

- **Gaussian plume model has some conservative tendencies**
  - Straight-line Gaussian plume model produces maximum peak doses at site boundaries
  - Other results, e.g., population doses and predicted health effects, are not necessarily conservative
- **Other aspects of model are mostly controlled by user input and can be conservative or best estimate, e.g.,**
  - Choice of dispersion parameters
  - Choice of deposition velocity

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Parameter Conservatisms – Wind Speed

- **Requiring minimum 0.5 m/s wind speed may or may not be conservative**
  - **Contaminants may build up in region close to source during calm winds (nonconservative when receptor is in cloud)**
  - **Contaminants may have spread over a significant area during calm winds before getting transported downwind when winds are stronger (conservative if point source is assumed)**
- **<u>MACCS2 is probably not the right tool for sites with calm winds more than 5% of the time</u>**

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Parameter Conservatisms – Deposition Velocity

■ **Deposition velocity can be chosen conservatively for specific results**

- ● **Small deposition velocity <u>maximizes</u> inhalation dose (important for alpha emitters)**
- ● **Small deposition velocity <u>minimizes</u> groundshine dose (important for gamma emitters and longer exposure times)**

■ **Small deposition velocities are generally conservative when only inhalation and cloudshine are important**

Normalized Pu-238 Dose

Vd = 0
Vd = 0.1
Vd = 1
Vd = 10

Relative Dose — Downwind Distance (km)

Normalized Cs-137 Dose

Vd = 0
Vd = 0.1
Vd = 1
Vd = 10

Relative Dose — Downwind Distance (km)

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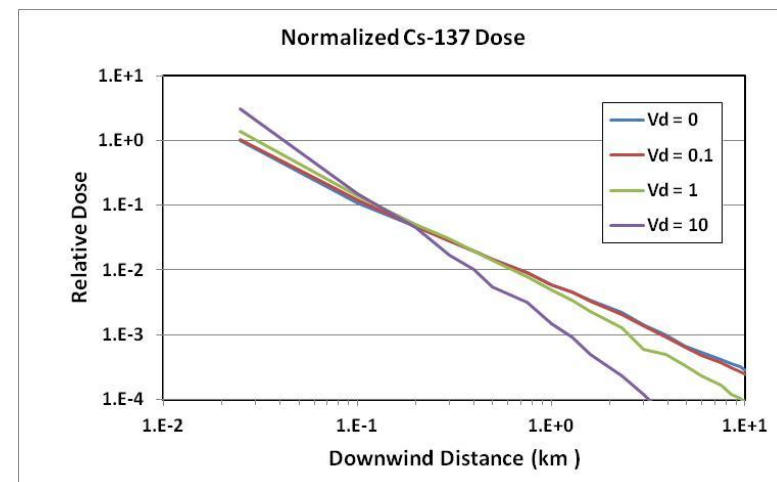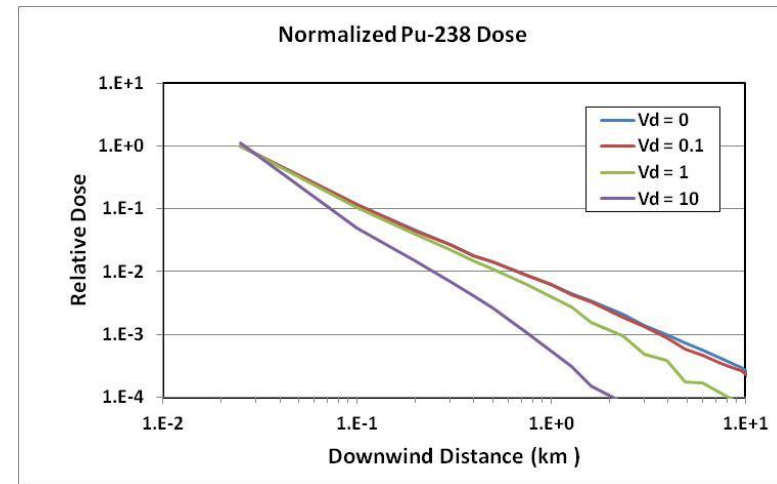
Parameter Conservatisms – Dispersion

- **Gaussian plume model with point source at short distances can be highly conservative (dose to collocated worker)**

- **Notes on dispersion at short distances**
  - **Tadmor and Gur dispersion correlation should not be used at distances less than 500 m, as recommended by authors**
  - **NRC correlation of Pasquill-Gifford is valid at shorter distances**
  - **NRC correlation is more conservative than Briggs Open Country model**

- **Most dispersion correlations provide similar results between 500 m and 10 km**

- **Comparison of Briggs Open Country and Pasquill-Gifford**
  - **Briggs is less conservative at distances less than ~10 km**
  - **Briggs is more conservative at distances beyond ~10 km**

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Modeling Uncertainties

- **Atmospheric transport is inherently uncertain**

- **Uncertainty occurs at many levels**
  - **Uncertainty and lack of resolution of atmospheric data**
  - **Use of simplified dispersion and deposition models to reduce CPU time**
  - **Lack of knowledge of dispersion and deposition parameters that apply under specific conditions**
  - **Stochastic uncertainties in weather**

- **WinMACCS (distributed with newer versions of MACCS2) contains a framework for sampling uncertain inputs**

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Goals of WinMACCS Interface to MACCS2

- **Increased usability**
  - **Reduce potential for errors**
  - **Improve productivity**

- **Compatibility with current input files (import function)**

- **Simple interface with SECPOP, COMIDA2, and MELCOR**

- **LHS shell for sampling uncertain inputs**

- **Capability to create and export graphs**

- **Preservation of current capabilities**

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WinMACCS Overview

- **Interface shows**
  - **Menu**
  - **Project properties, parameters, and files**
  - **Calculation progress and error messages**
  - **Run Models screen**
  - **Legend**

# Project Properties

- **Project properties determine what data are needed**

- **Color coding shows the input categories that require attention**

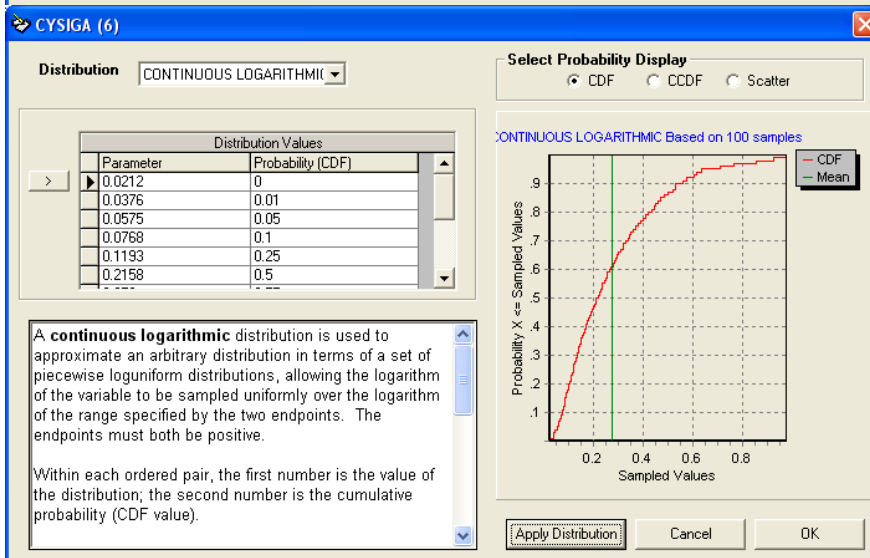# Viewing and Editing Files
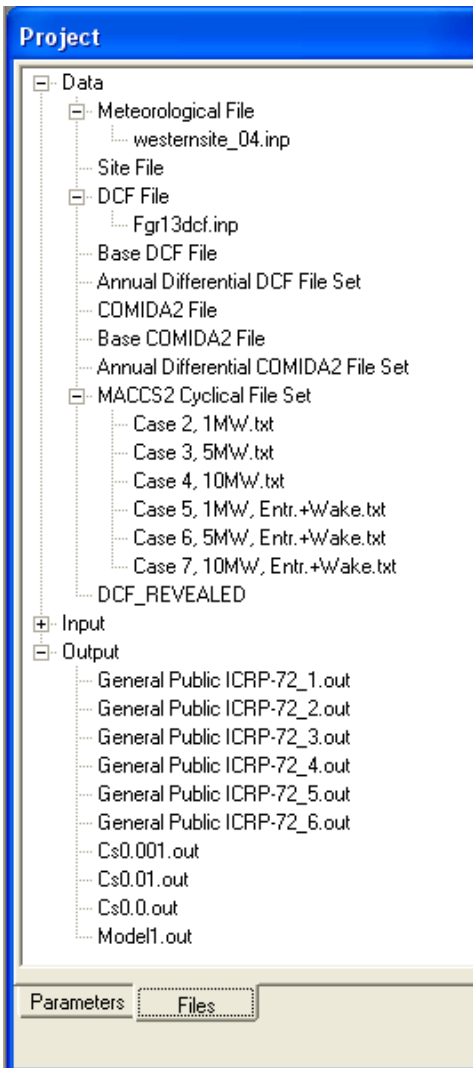
- **Data, input, and output files can be accessed**

- **Double clicking on file name opens it for viewing and editing**

- **Input files are created by WinMACCS**

- **Output files are created by MACCS2**
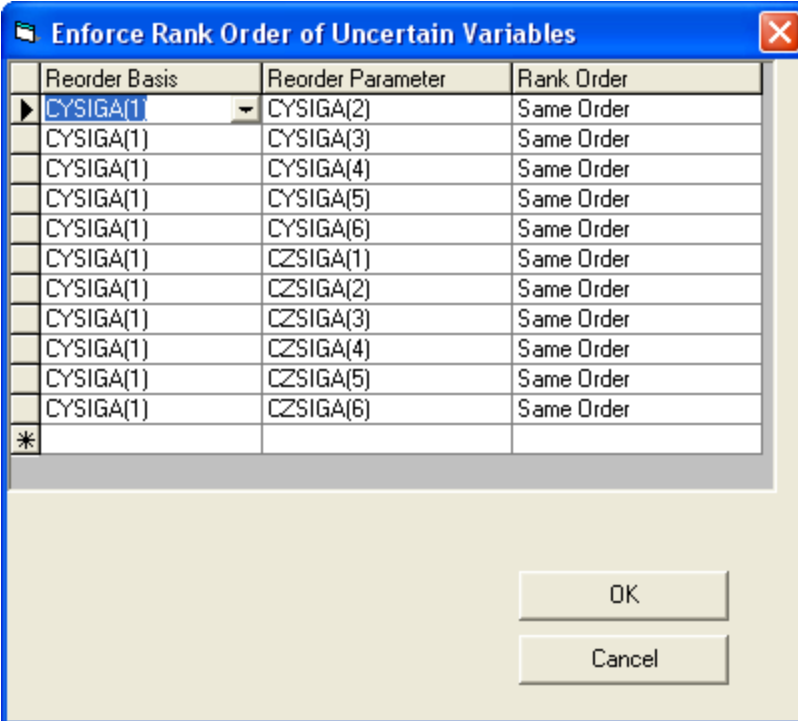
Making Input Parameters Uncertain
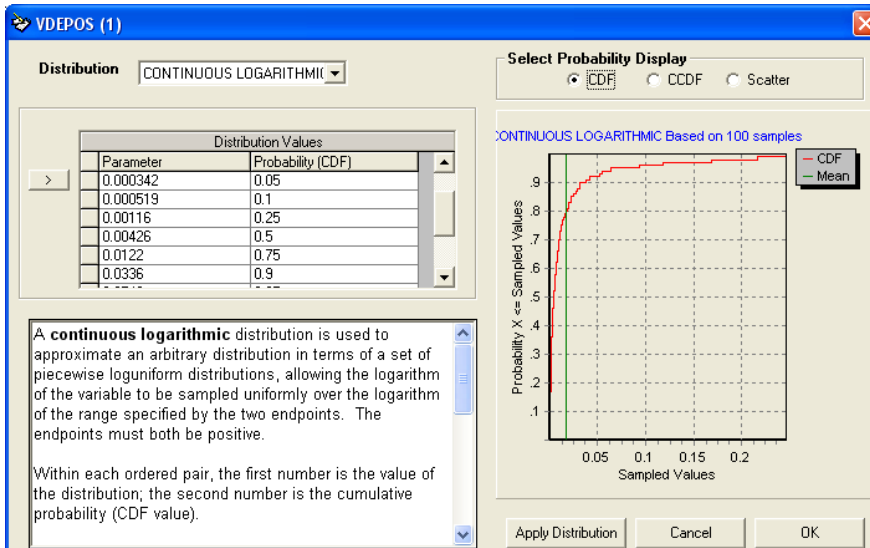
■ **Input parameters can be assigned distribution functions to reflect degree of belief**

■ **Parameter sampling is performed by LHS**

Correlating Input Parameters

- **Perfect rank correlation in same order or inverse order (same order illustrated)**

- **Partial rank correlation assigned by correlation coefficient between -1 and 1**

Evaluation of Uncertain Inputs

- **DOE currently uses the 95th percentile weather result to characterize peak dose at site boundary**
  - **Some inputs are chosen as best estimates**
  - **Other inputs are chosen conservatively**
    - ▸ **Piling up a number of conservative assumptions can lead to results representing 99th or higher percentile**

- **An alternative strategy is to evaluate uncertain input values (in addition to weather)**
  - **Create distributions for uncertain inputs**
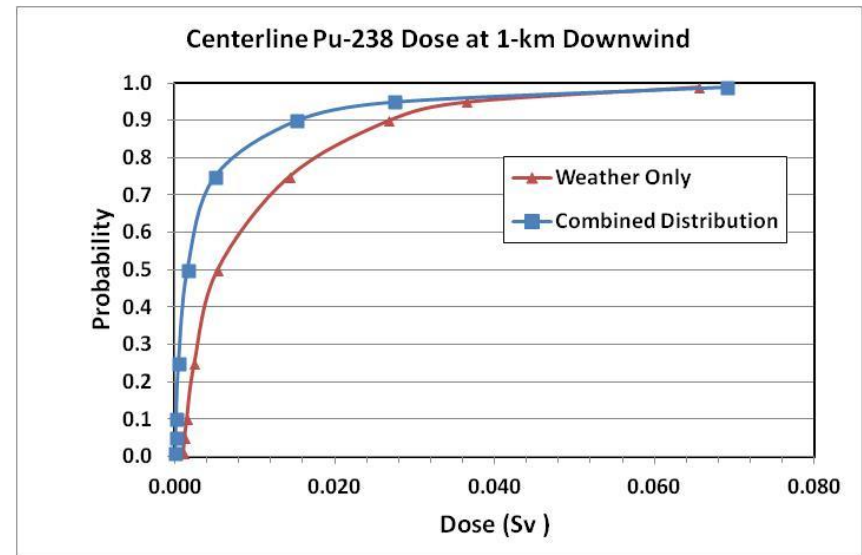 - **Use WinMACCS to sample inputs and evaluate overall 95th percentile results**

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Evaluate Uncertainty

- ■ **Weather**

- ■ **Dispersion coefficients**

- ■ **Deposition Velocity**

- ■ **Duration of Release**
  - ● **Uniform from 15 min to 2 hr**
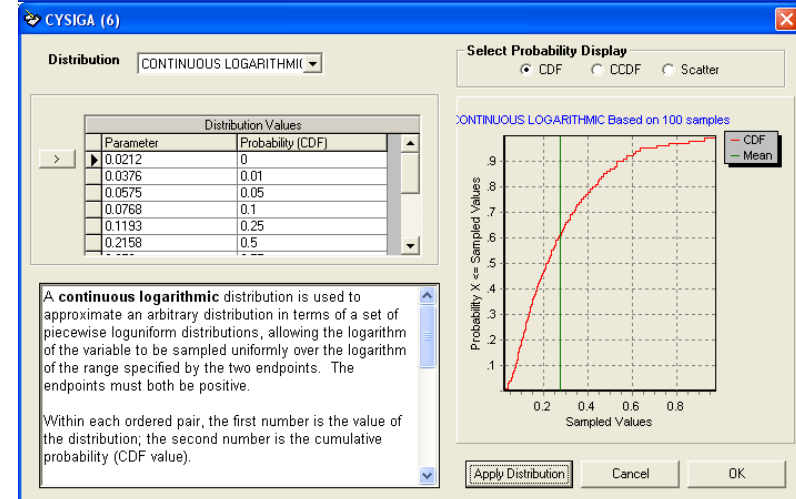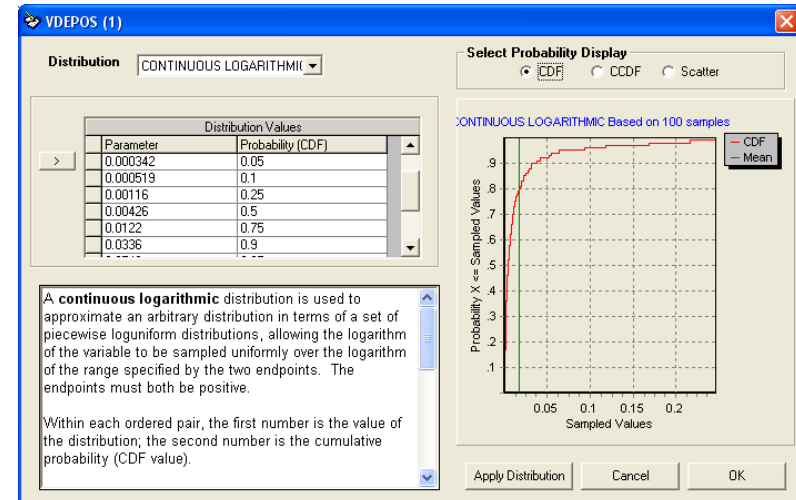
Comparison of DOE Point Estimate with Distribution Representing Uncertain Inputs
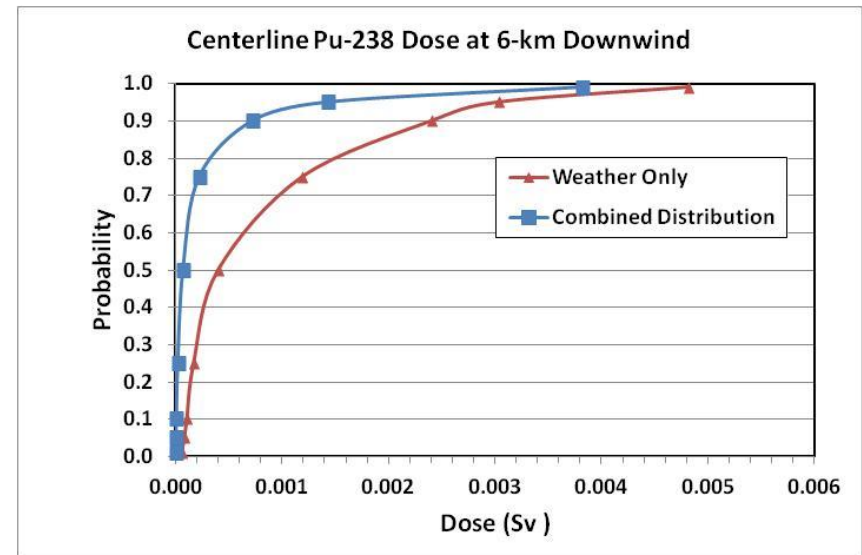
Dose Results at 1 km Downwind of Source

- **Combined Distribution Curve represents**
  - **Weather uncertainty**
  - **Uncertainty in deposition velocity**
  - **Uncertainty in dispersion**
  - **Uncertainty in release duration**

- **Weather Only Curve represents weather uncertainty**

- **95th percentile result aligns with 96th percentile of Combined Distribution**

Centerline Pu-238 Dose at 1-km Downwind

Legend: Weather Only, Combined Distribution

x-axis: Dose (Sv), y-axis: Probability

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Comparison of DOE Point Estimate with Distribution Representing Uncertain Inputs

Dose Results at 6 km Downwind of Source

- **95th percentile of Weather Only curve aligns with 98th percentile of Combined Distribution curve**

- **95th percentile of Combined Distribution curve aligns with 80th percentile of Weather Only curve**

Centerline Pu-238 Dose at 6-km Downwind

Comparison of DOE Point Estimate with Distribution Representing Uncertain Inputs

Dose Results at 15 km Downwind of Source

- **95th percentile of Weather Only curve aligns with 99th percentile of Combined Distribution curve**

Centerline Pu-238 Dose at 15-km Downwind
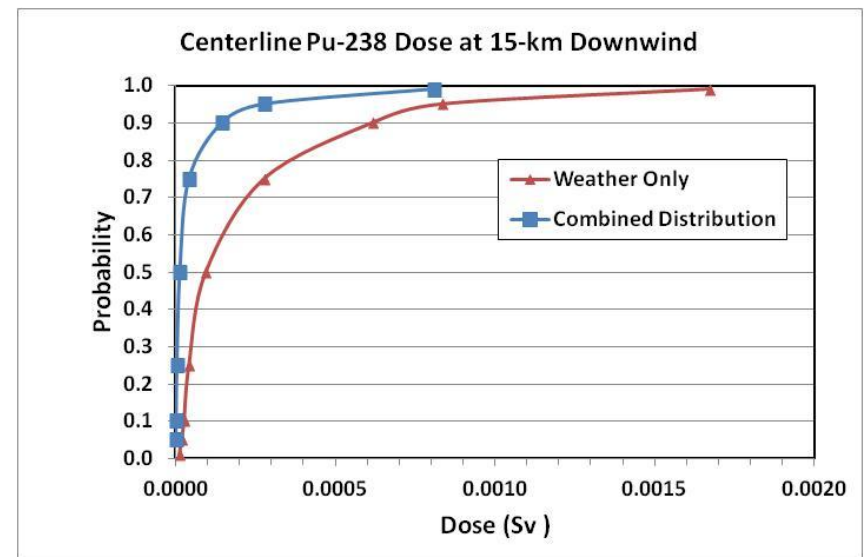
Graphical Output
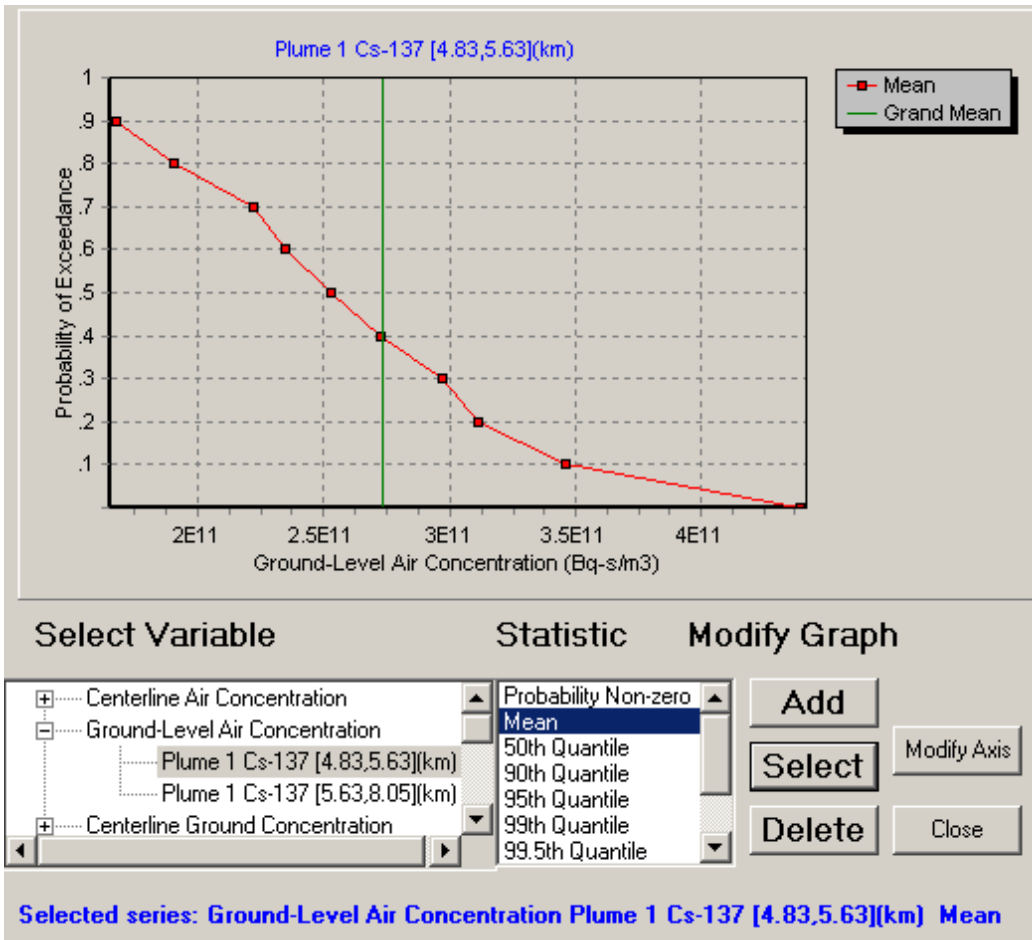
- **CCDFs displayed for uncertain**
  - **Weather data**
  - **Input parameters**

- **Grand mean**

- **Data can be exported for further analysis and plotting**

MACCS2 Support and Development

- **Sandia is continuing to support and develop MACCS2**
  - **User support**
  - **Distribution of code versions (1.13.1, 2.4, and 2.5)**
  - **Version 2.6 will be released this month**
  - **Code updates in response to user feedback**
- **A Windows interface, WinMACCS, is available**
  - **Versions 3.5 and 3.6 have been released**
  - **Version 3.7 (coupled with MACCS2 2.6) is scheduled to be released very soon**

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