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Sandia National Laboratories

Stability Class Determination Method Impacts on MACCS Outputs

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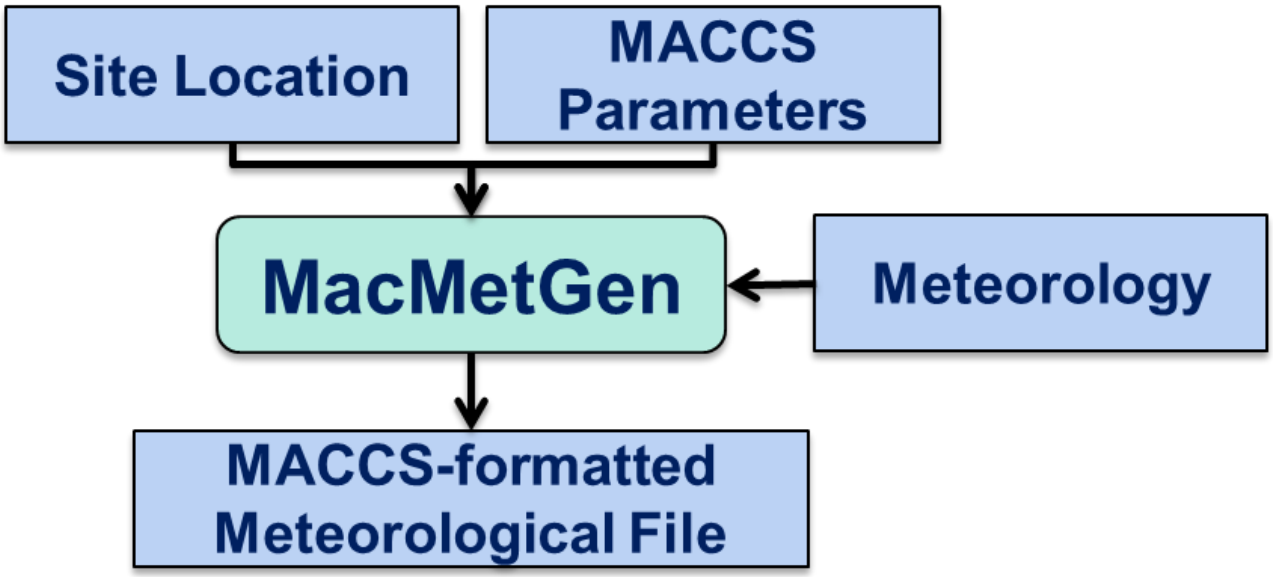
Outline

- MacMetGen description
- Sensitivity study setup
- Effects of stability class methods on MACCS results

MacMetGen

- Formatted meteorological file needed for MACCS calculations
- Time consuming to collect site data and compile into file
- MacMetGen developed to automate MACCS formatted meteorological file generation
- Makes use of meteorological files available from the NOAA ARL ftp site
  - Multiple years
  - North American and global data sets
  - Can be any data set if in similar format

MacMetGen



- Input parameters specified in input file
  - Location
  - Time frame
  - Meteorological data set
  - Stability class determination method
  - MACCS file setup

Supported Stability Class Determination Methods

- Delta Temperature/Delta Z (height) (DTDZ)
  - Based on the surface vertical temperature gradient
  - Consistent with criteria provided in Reg Guide 1.23 (NRC 2007)
- Turner's method
  - Based on net radiation index, wind speed and cloud cover
  - Consistent with criteria provided in EPA 2000
- Solar Radiation/Delta Temperature (SRDT)
  - Based on solar radiation, wind speed and surface vertical temperature gradient
  - Retains the basic structure of Turner's method, without the need for cloud cover information
  - Consistent with criteria provided in EPA 2000

Delta Temperature/Delta Height

- Determine temperature gradient from surface to at least 100 m above ground
  - Depends on vertical spacing of meteorological data
- Consistent with criteria below (Reg Guide 1.23, NRC 2007)

Vertical Temperature Gradient Delta T/Delta Z [K/100 m]	Stability Class
< -1.9	1 (A)
-1.9 to -1.7	2 (B)
-1.7 to -1.5	3 (C)
-1.5 to -0.5	4 (D)
-0.5 to 1.5	5 (E)
1.5 to 4.0	6 (F)
> 4.0	7 (G)

Turner's Method

- Determine net radiation index from procedure defined in EPA 2000.

Procedure for Determining the Net Radiation Index

1. If the total cloud[1] cover is 10/10 and the ceiling is less than 7000 feet, use net radiation index equal to 0 (whether day or night).
2. For nighttime: (from one hour before sunset to one hour after sunrise):
   (a) If total cloud cover ≤ 4/10, use net radiation index equal to -2.
   (b) If total cloud cover > 4/10, use net radiation index equal to -1.
3. For daytime:
   (a) Determine the insolation class number as a function of solar altitude from Table 6-5.
   (b) If total cloud cover ≤5/10, use the net radiation index in Table 6-4 corresponding to the isolation class number.
   © If cloud cover >5/10, modify the insolation class number using the following six steps.
      (l) Ceiling <7000 ft, subtract 2.
      (2) Ceiling ≥7000 ft but <16000 ft, subtract 1.
      (3) total cloud cover equal 10/10, subtract 1. (This will only apply to ceilings ≥7000 ft since cases with 10/10 coverage below 7000 ft are considered in item 1 above.)
      (4) If insolation class number has not been modified by steps (1), (2), or (3) above, assume modified class number equal to insolation class number.
      (5) If modified insolation class number is less than 1, let it equal 1.
      (6) Use the net radiation index in Table 6-4 corresponding to the modified insolation class number.

EPA 2000

Table 6-5

Insolation Class as a Function of Solar Altitude

Solar Altitude Φ (degrees)	Insolation	Insolation Class Number
60 < Φ	strong	4
35 < Φ ≤ 60	moderate	3
15 < Φ ≤ 35	slight	2
Φ ≤ 15	weak	1

Turner's Method

- Based on combination of wind speed and net radiation index to determine stability class

Table 6-4

Turner's Key to the P-G Stability Categories

Wind Speed		Net Radiation Index						
(knots)	(m/s)	4	3	2	1	0	-1	-2
0,1	0 - 0.7	1	1	2	3	4	6	7
2,3	0.8 - 1.8	1	2	2	3	4	6	7
4,5	1.9 - 2.8	1	2	3	4	4	5	6
6	2.9 - 3.3	2	2	3	4	4	5	6
7	3.4 - 3.8	2	2	3	4	4	4	5
8,9	3.9 - 4.8	2	3	3	4	4	4	5
10	4.9 - 5.4	3	3	4	4	4	4	5
11	5.5 - 5.9	3	3	4	4	4	4	4
≥ 12	≥ 6.0	3	4	4	4	4	4	4

EPA 2000

Solar Radiation/Delta Temperature

- Day - determine solar radiation
- Night - determine vertical temperature gradient
- Find stability class as a function of wind speed

Table 6-7

Key to Solar Radiation Delta-T (SRDT) Method for Estimating Pasquill-Gifford (P-G) Stability Categories

DAYTIME

	Solar Radiation (W/m^2)			
Wind Speed (m/s)	≥ 925	925 - 675	675 - 175	< 175
< 2	A	A	B	D
2 - 3	A	B	C	D
3 - 5	B	B	C	D
5 - 6	C	C	D	D
≥ 6	C	D	D	D

NIGHTTIME

	Vertical Temperature Gradient	
Wind Speed (m/s)	< 0	≥ 0
< 2.0	E	F
2.0 - 2.5	D	E
≥ 2.5	D	D

EPA 2000

Sensitivity Study Setup

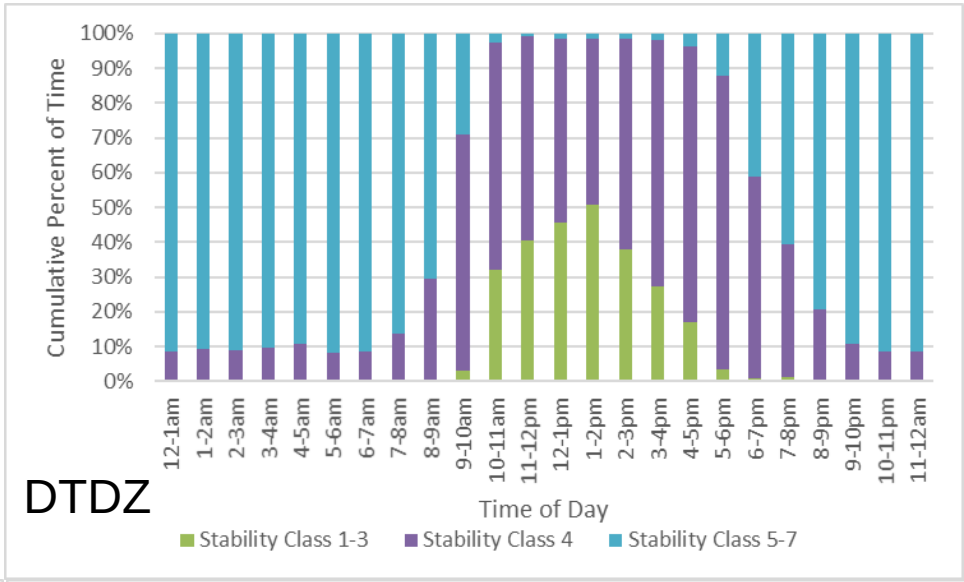
- Large river valley site
- Source term
  - NUREG-1150 historic (puff release followed by a longer duration tail)
- General evacuation scheme
  - Modeled with multiple evacuating cohorts
- MACCS Gaussian Plume Segment atmospheric transport and dispersion model
- Weather bin sampling
  - ~900 samples
  - Mean, 95th and 5th percentiles
- NAM12 meteorological data set
- Three stability class determination methods
  - DTDZ – MacMetGen
  - SRDT – MacMetGen
  - VMIX – HYSPLIT
    - Stability class determined from wind speed and turbulent kinetic energy

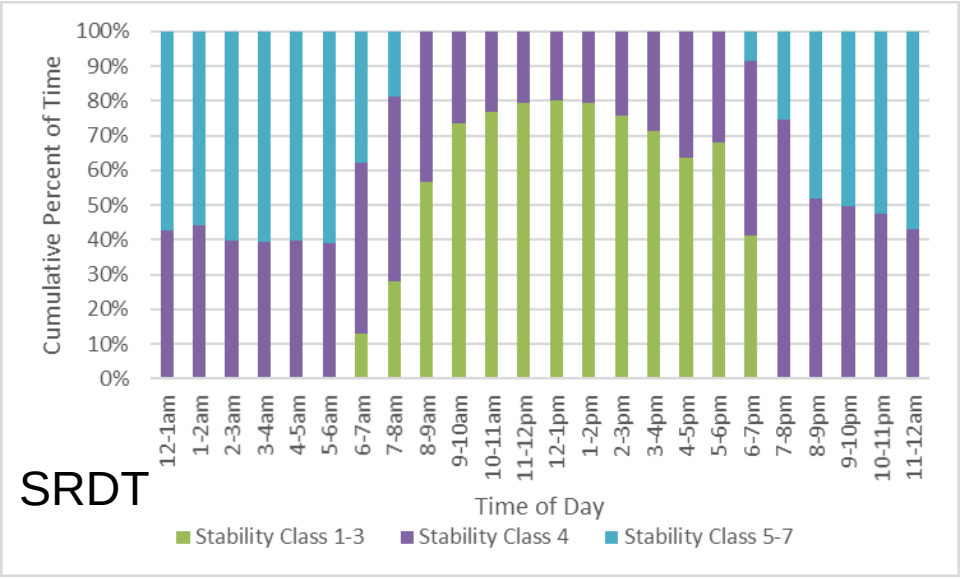
Output Metrics

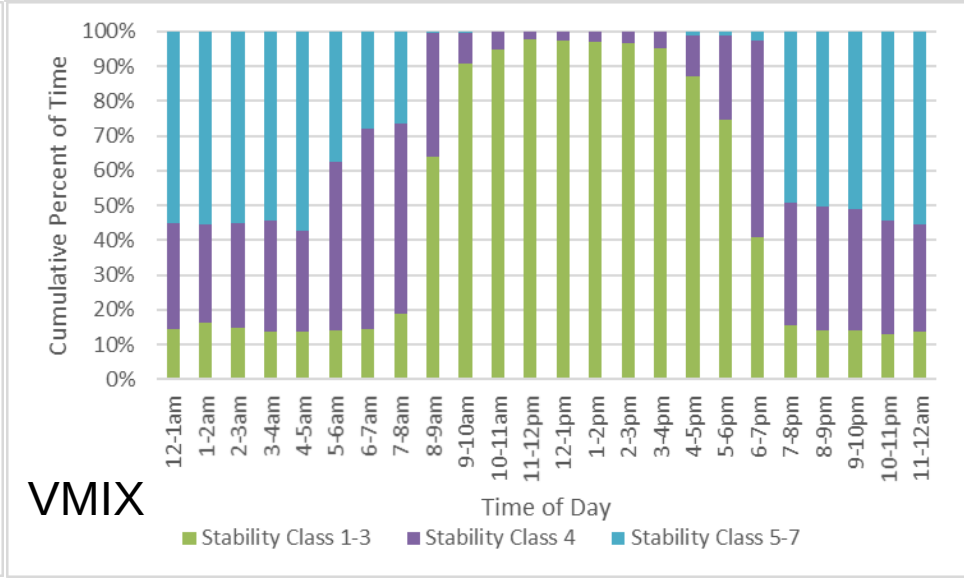
- Peak (around the compass) time-integrated air concentration (χ/Q, s/m^3)
- Peak (around the compass) ground deposition (D/Q, 1/m^2)
- Normalized peak dose (unitless)
- Normalized population-weighted early fatality risk within a circular area near the point of release
- Normalized regional population doses
- Normalized population-weighted latent cancer fatality risk over region
- Normalized land areas that exceed various levels of contamination
- Normalized total regional economic losses

Stability Class Differences

- DTDZ – Highest probability of stable conditions
- SRDT – Highest probability of neutral conditions
- VMIX – Highest probability of unstable conditions

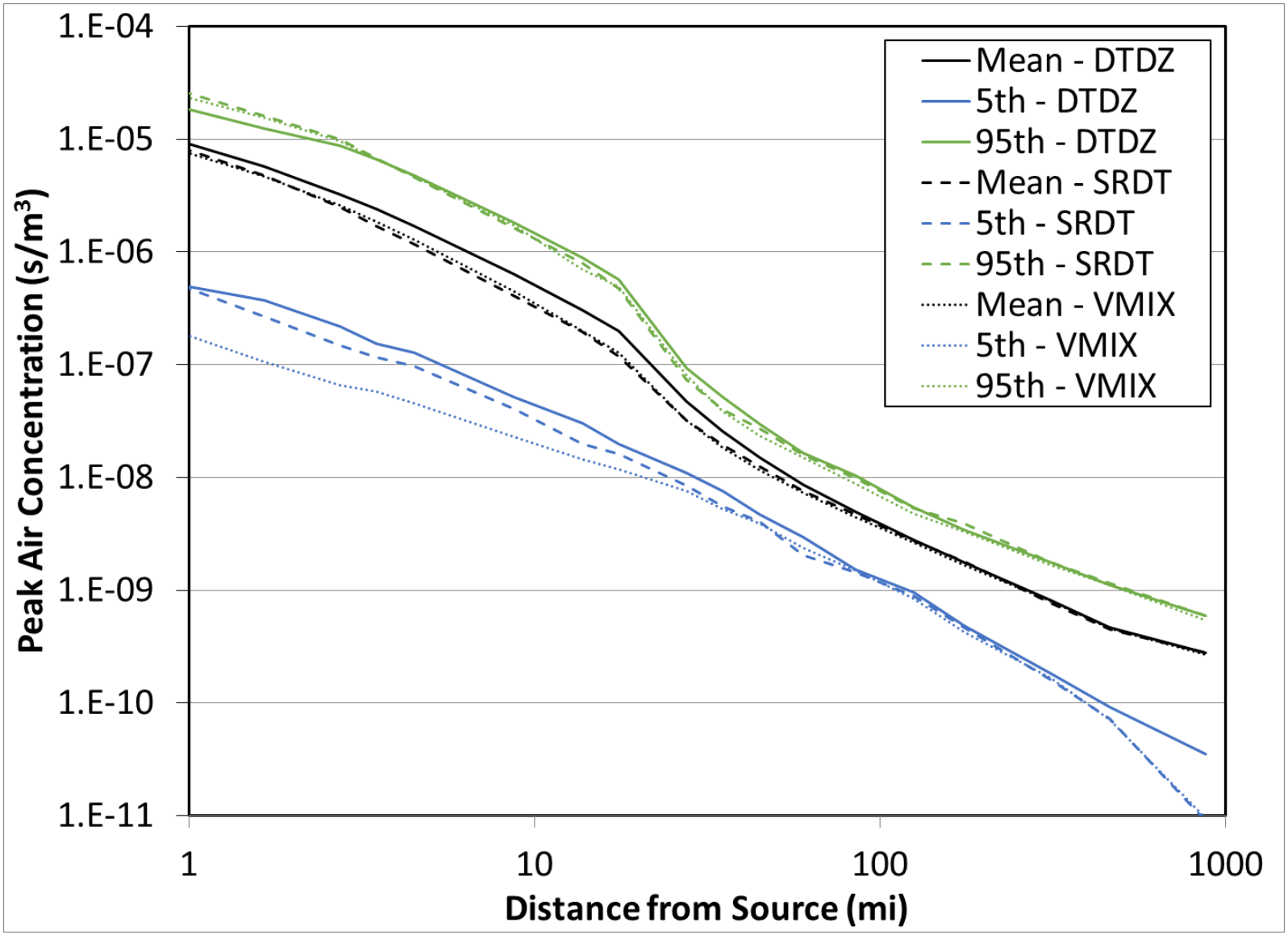






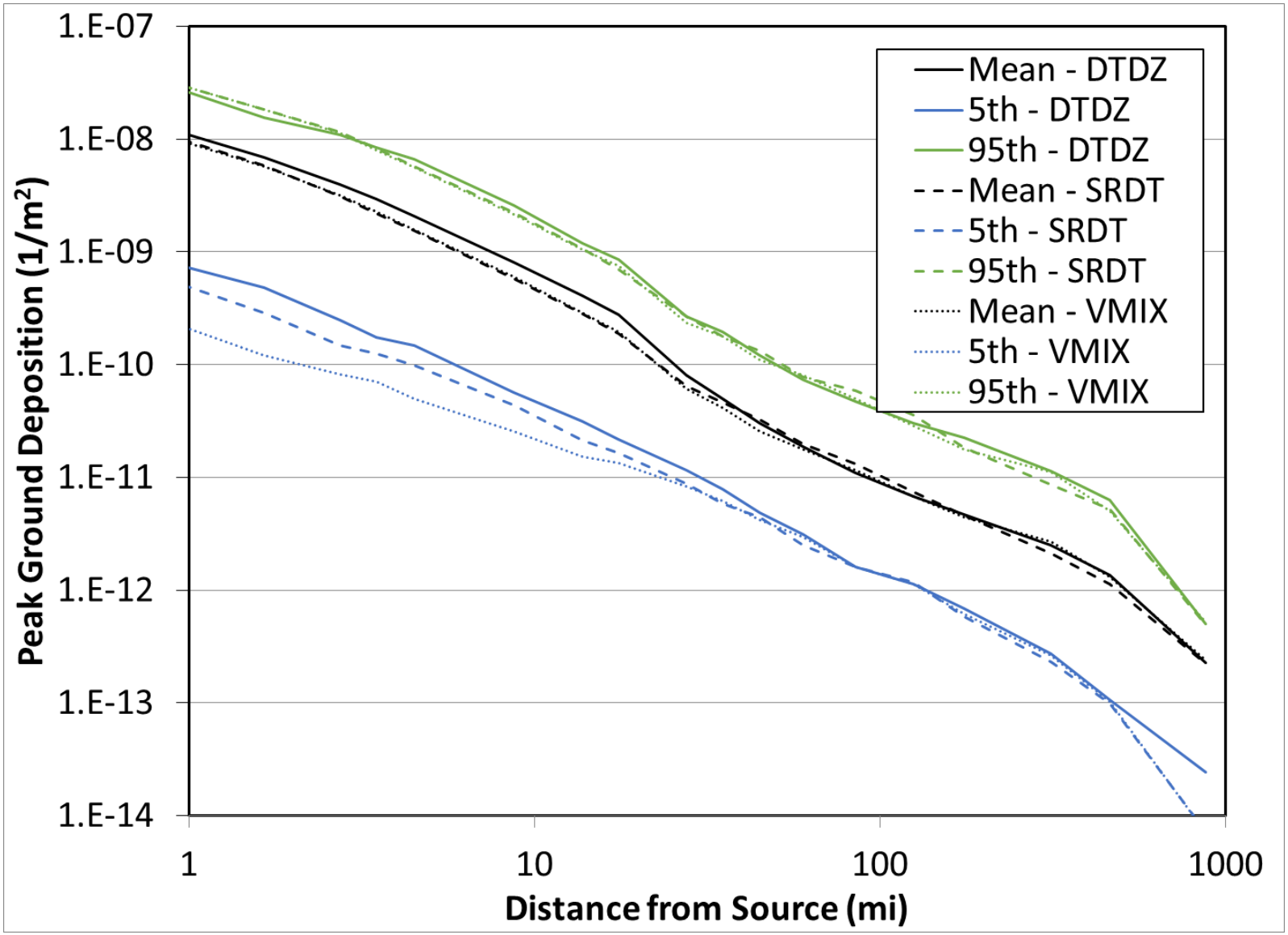
Comparison #1 Peak Air Concentration

(Large River Valley, NUREG-1150 Source Term)



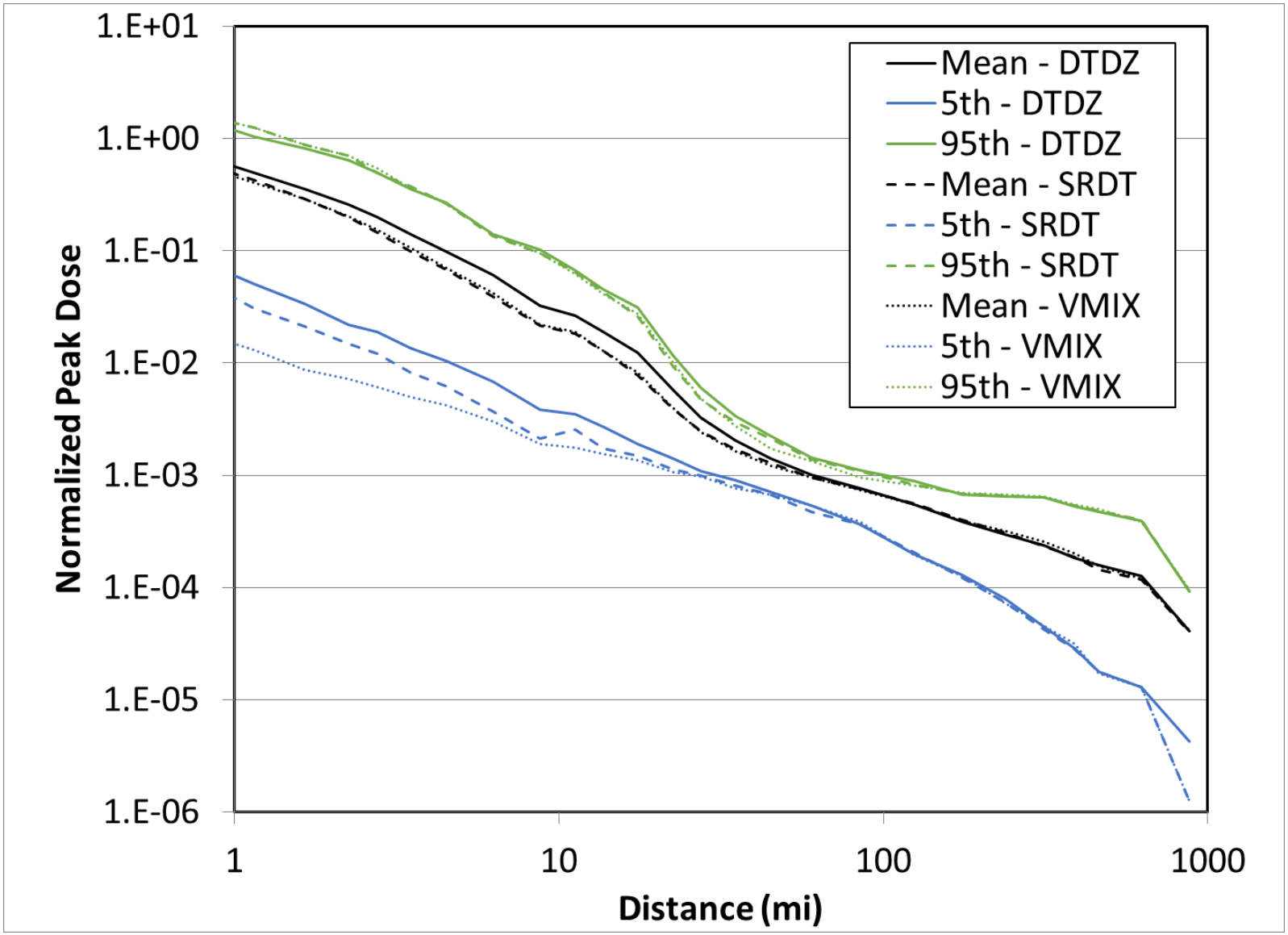
Comparison #1 Peak Ground Deposition

(Large River Valley, NUREG-1150 Source Term)



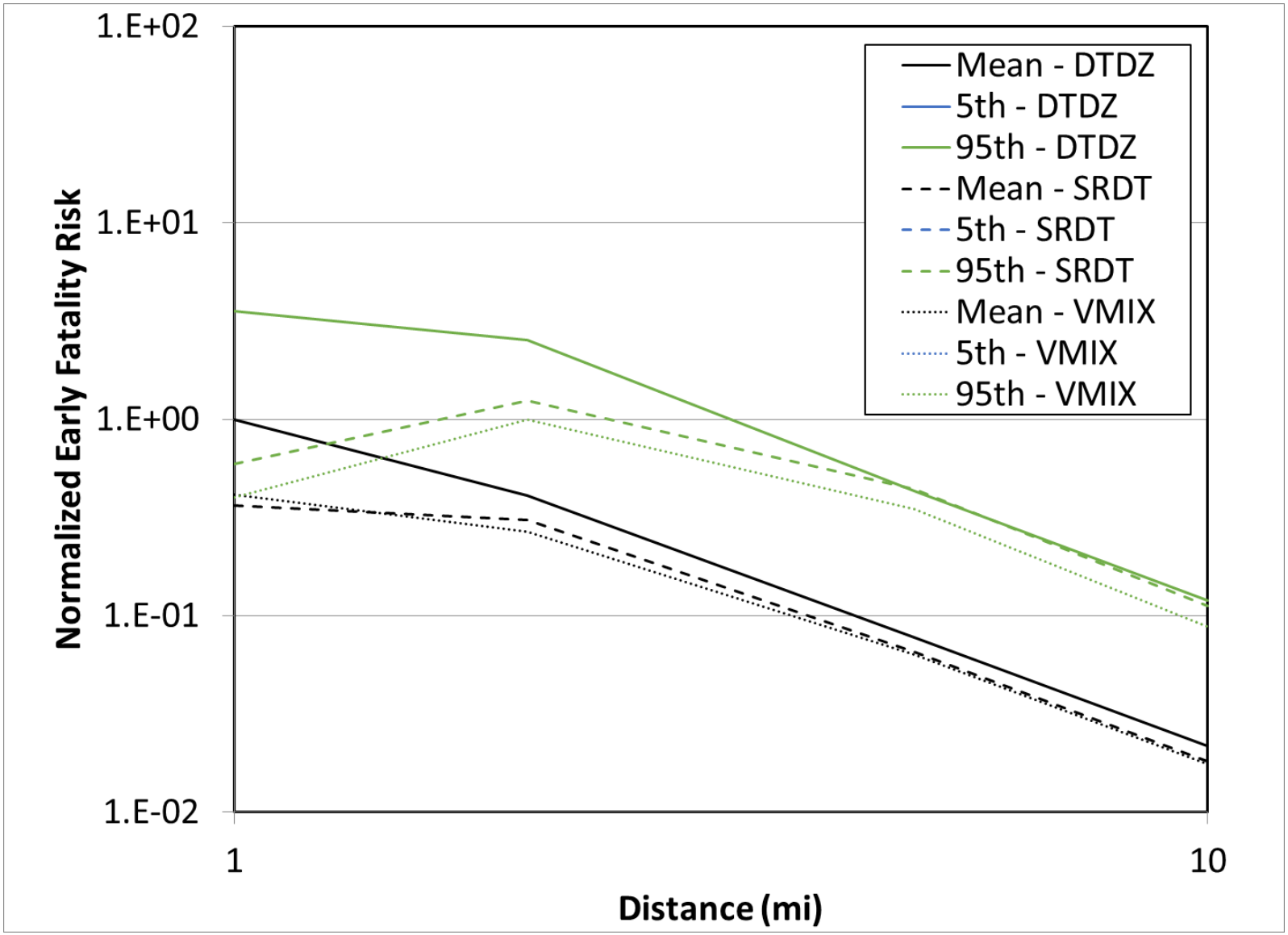
Comparison #1 Peak Dose

(Large River Valley, NUREG-1150 Source Term)



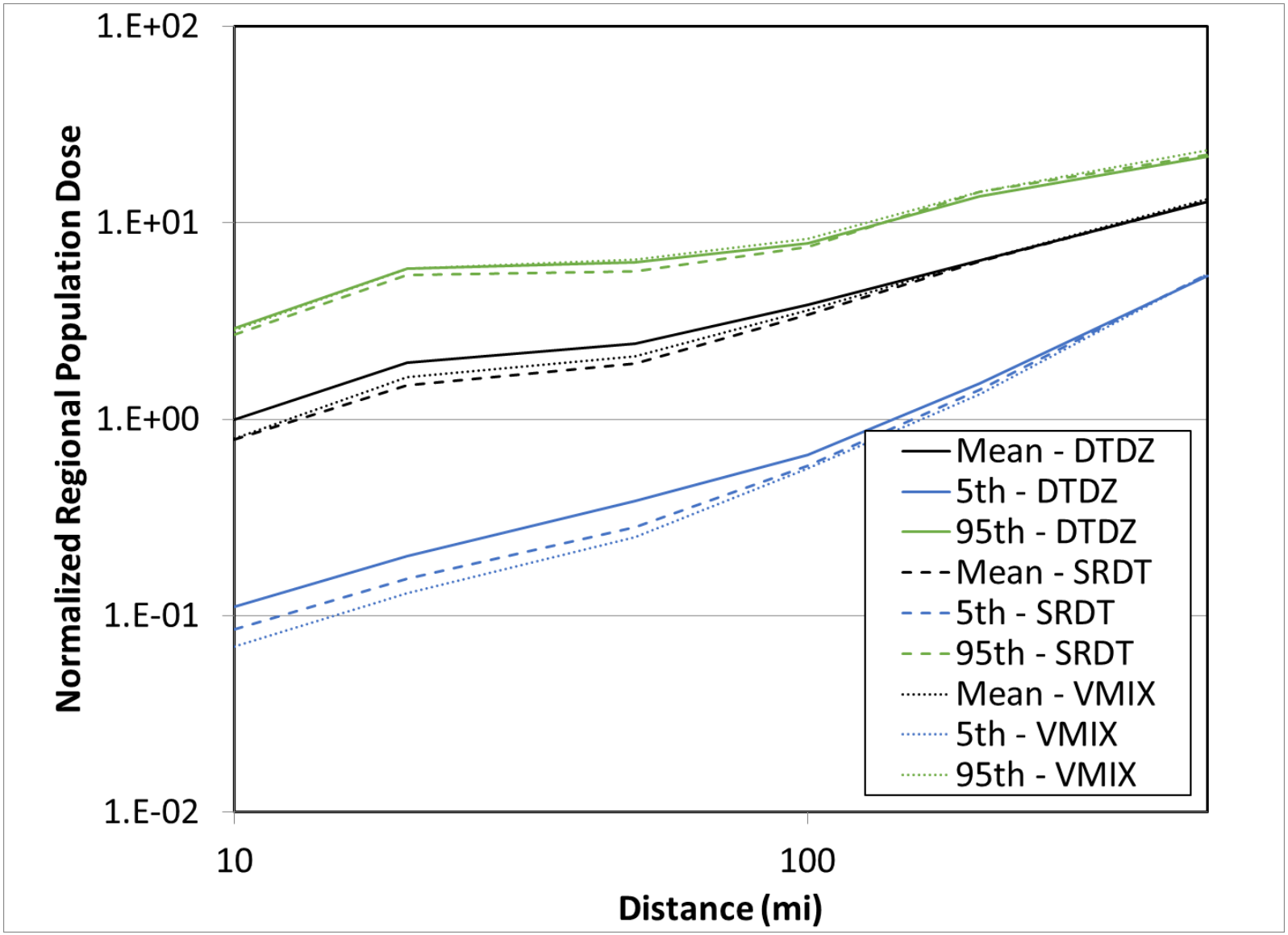
Comparison #1 Early Fatality Risk

(Large River Valley, NUREG-1150 Source Term)



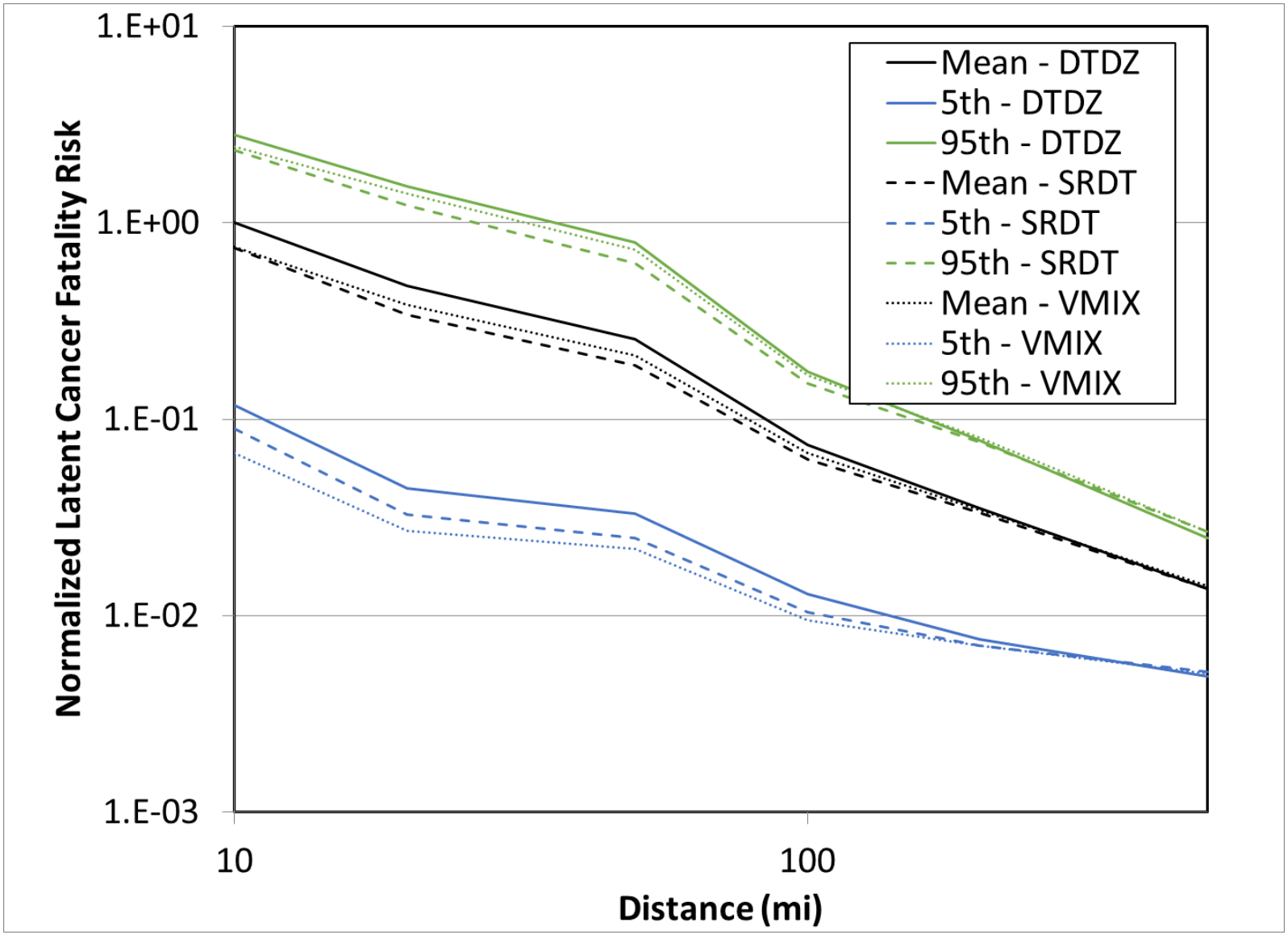
Comparison #1 Population Dose

(Large River Valley, NUREG-1150 Source Term)



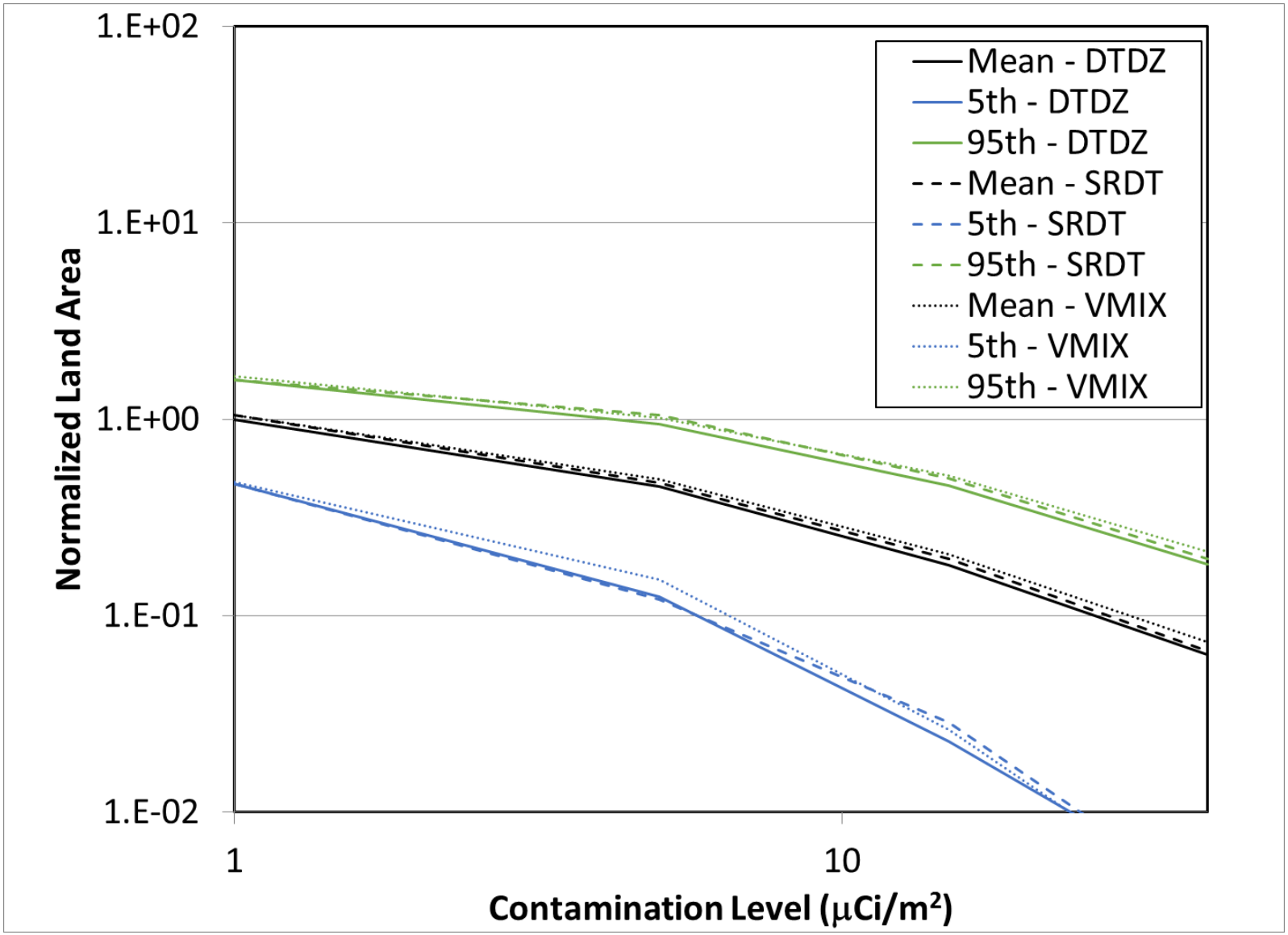
Comparison #1 Latent Cancer Fatality Risk

(Large River Valley, NUREG-1150 Source Term)



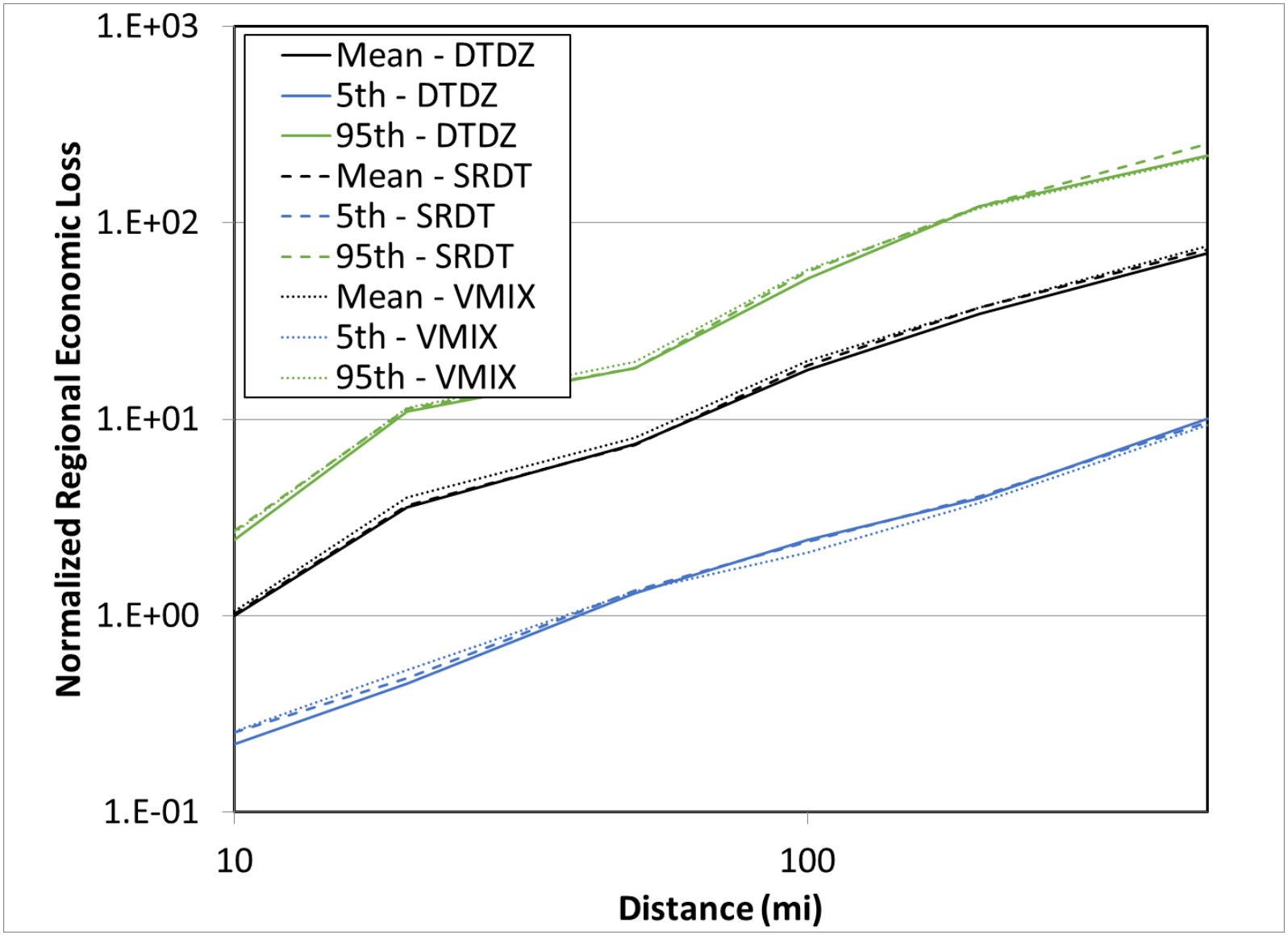
Comparison #1 Land Contamination Area

(Large River Valley, NUREG-1150 Source Term)



Comparison #1 Economic Loss

(Large River Valley, NUREG-1150 Source Term)



Summary

- High level of agreement between all three cases
- The largest differences are at short distances (<30 mi)
- Very similar at longer distances due to change to time-based dispersion which is not a function of stability class

- DTDZ (more stable conditions)
  - Highest peak air concentration, peak ground deposition, peak dose, normalized regional population does and latent cancer fatality risk
- VMIX (more unstable conditions)
  - Lowest in same categories
- SRDT (more neutral condition)
  - In between

References

- EPA (2000). "Meteorological Monitoring Guidance for Regulatory Modeling Application." EPA-454/R-99-005. February 2000.
- NRC (2007). "Meteorological Monitoring Programs for Nuclear Power Plants, Revision 1." Regulatory Guide 1.23. March 2007.

Backup

Stability Class Differences

- DTDZ – Highest probability of stable conditions
- SRDT – Highest probability of neutral conditions
- VMIX – Highest probability of unstable conditions