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MACCS-HYSPLIT Atmospheric Transport and Dispersion Model Benchmarking

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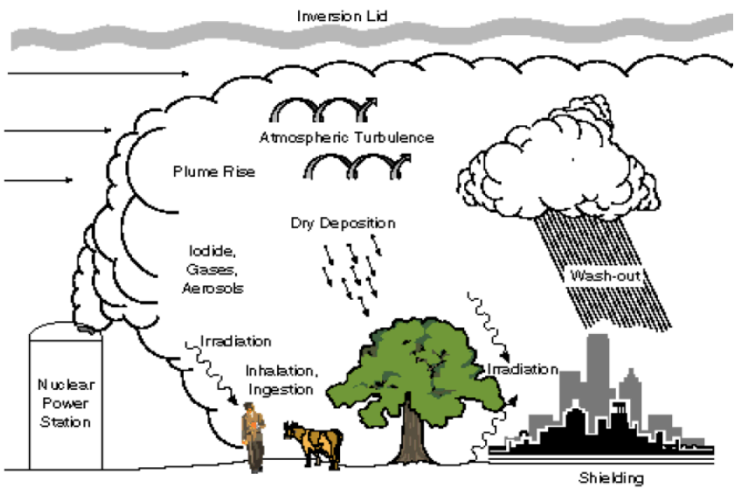
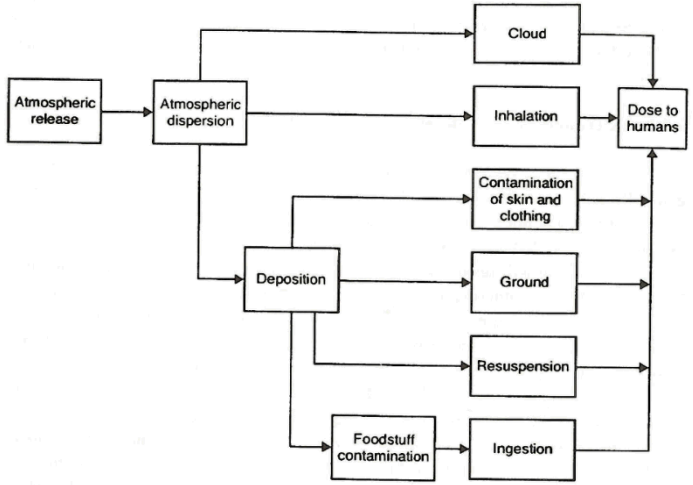
Outline

- Severe accident consequence analysis with MACCS
- MACCS inclusion of HYSPLIT atmospheric transport results
- Benchmarking results
- Summary

Overview of Severe Accident Consequence Analysis (MACCS)

- Typically includes modeling the radioactive release to the atmosphere (e.g. plume rise, dispersion, dry and wet deposition).





- Analysis estimates the health effects from: inhalation, cloudshine, groundshine, skin deposition, and ingestion (e.g. water, milk, meat, crops), as well as costs associated with protective actions to reduce exposure

Considerations for Severe Accident Assessments

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- Realistic assessment
- Prospective analysis
- Multiple figures of merit
- Wide temporal and spatial scales

MACCS Applications

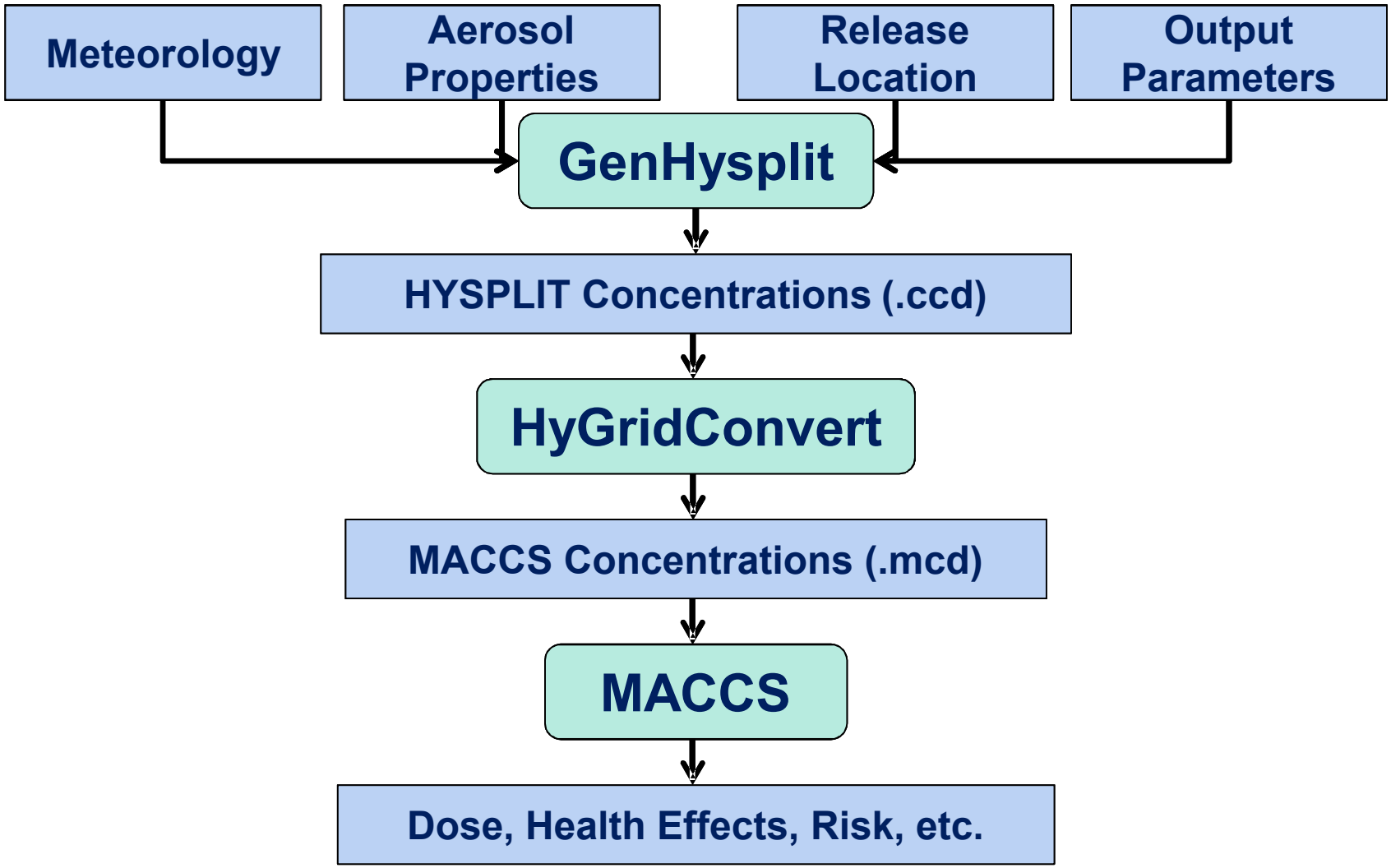
- Backfit Analyses (NUREG-1409)
- Regulatory Analyses (NUREG/BR-0058 and NUREG/BR-0184)
- Environmental Analyses (NUREG-1555 and RG 4.2)
- Other Analyses (Applied Research, Probabilistic Risk Assessment, etc.)

	Individual Early / Latent Fatality Risk	Total Early / Latent Fatality Cases	Collective Dose	Offsite Property Damage	Land Contamination
Backfit Analyses	X		X		
Regulatory Analyses	X	X	X	X	X
Environmental Assessment	X	X	X	X	X
Severe Accident Mitigation Alternatives			X	X	

MACCS Modules

- ATMOS
  - Source term definition
  - Weather sampling algorithms
  - Atmospheric transport, dispersion, and deposition
- EARLY (1 to 40 days)
  - Doses as modified by emergency-phase countermeasures such as sheltering, evacuation, relocation, and KI ingestion
  - Multiple population cohorts may be modeled
  - Acute and latent health effects from early acute exposure
- CHRONC (1 week to >50 years)
  - Doses as modified by intermediate and recovery-phase protective actions such as relocation, interdiction, decontamination, and condemnation
  - Latent health effects from chronic exposure to deposited materal
  - Economic impact from early and late phase protective actions

MACCS-HYSPLIT Coupling Process

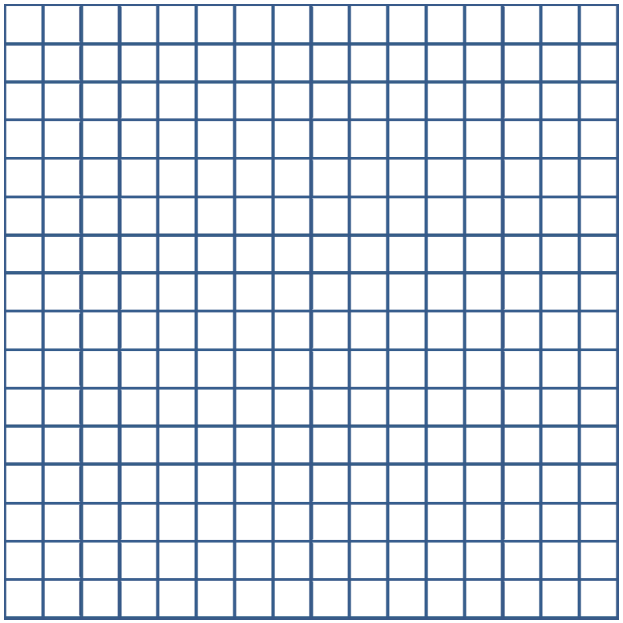


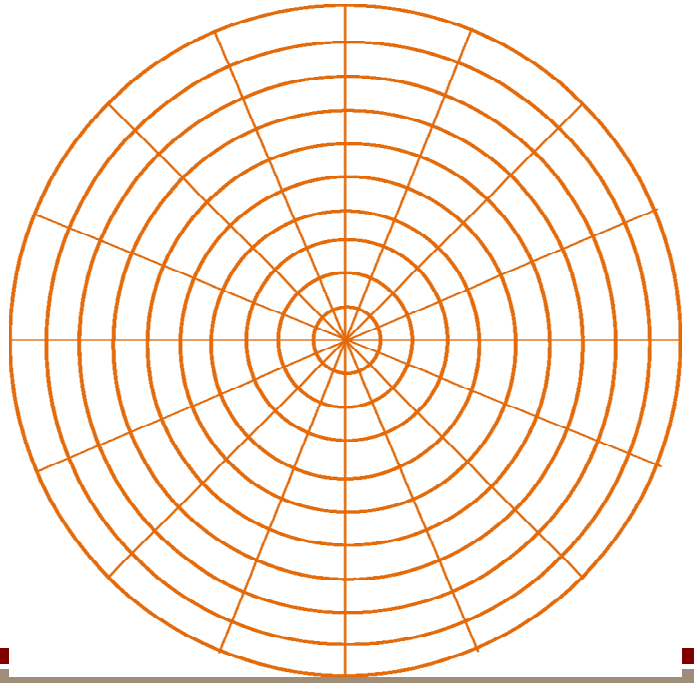
Normalized Release

- Release 1 Curie for various aerosol sizes over a 1 hour period and then track
  - Generating χ/Q and D/Q values for each period and aerosol size
  - For one year that equates to 8,760 simulations
  - Provides enough data to effectively model any source term over every hour for the entire year
  - Could be expanded to account for multiple release locations within a site and/or buoyancy effects
    - Requires additional sets (8,760 more runs per year) for each additional release location or height
    - Buoyancy accounted for by calculating the heat emission
      - Release height a function of weather

HyGridConvert Code

- MACCS utilizes a non-uniform polar grid
- Convert the HYSPLIT output concentrations to defined MACCS polar grid
- Configured to run on a Windows machine
- Can be run separately or called by WinMACCS (preferred).





Combination with Source Term

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- Break each plume into one hour segments
  - Account for partial hours if plume doesn't start or end on the hour
- Each one hour segment is then associated with a single HYSPLIT converted file
- For each segment, multiply the normalized concentrations for each aerosol bin by the actual hourly release amounts for each different radionuclide/aerosol size
- Store the air and ground concentrations in separate arrays
- Results in a single air and a single ground concentration array as a function of radionuclide, grid cell and time
  - All plumes/plume segments combined
- These concentrations are then converted to doses in MACCS

Input Meteorological File

- MACCS met file – one year's worth, nominally 8760 entries
  - Single location (site weather tower)
  - Wind direction, wind speed, stability class and precipitation
- NAM12 met data
  - Spans North American continent
  - 12 km lambert conformal grid, 26 vertical layers, every 3 hours
  - Data starting 2007 to present
- Utilize MWFG to extract data from NAM12
  - Calculate wind direction, speed and stability class
  - Interpolate to needed times

Benchmark Cases

- Five representative sites
  - Large river valley
  - Dry western region
  - Central Midwestern plain
  - Atlantic coast
  - Southeast river valley influenced by Bermuda high
- Source term
  - NUREG-1150 historic (puff release followed by a long duration tail)
  - SOARCA Short-Term Station Blackout (more delayed and prolonged)
- General evacuation scheme
  - Modeled with multiple, relocating cohorts/evacuation times
- Meteorological data - 2008

Benchmark Output Investigated

- Peak time-integrated air dilution
- Peak ground deposition
- Fraction suspended
- Normalized peak population dose
- Early fatality risk near site
- Variation in latent cancer fatality risk over region
- Normalized regional population doses
- Total regional economic losses
- Land areas that exceed various levels of contamination

Computational Cost

- GenHYSPLIT
  - ~31,000 processor hours total per site (four sets of 8,760 = 35,040)
  - Run on 200 Linux processors for ~6.5 days
  - Total disk space per site = 500 GB

- HyGridConvert
  - 24 processor hours per site
  - Run on one Windows processor for 24 hours
  - Total disk space per site = 200 GB

Computational Cost (2)

- MACCS
  - NUREG-1150 source term
    - Run on one Windows processor
    - Gaussian ADT model, ~2 ½ processor minutes per site
    - HYSPLIT ADT model, ~20 processor hours per site (480 times longer)
  - SOARCA, Short-Term Station Blackout (STSBO)
    - Run on one Windows processor
    - Gaussian ADT model, ~35 processor minutes per site
    - HYSPLIT ADT model, ~130 processor hours per site (225 times longer)

Benchmarking Results

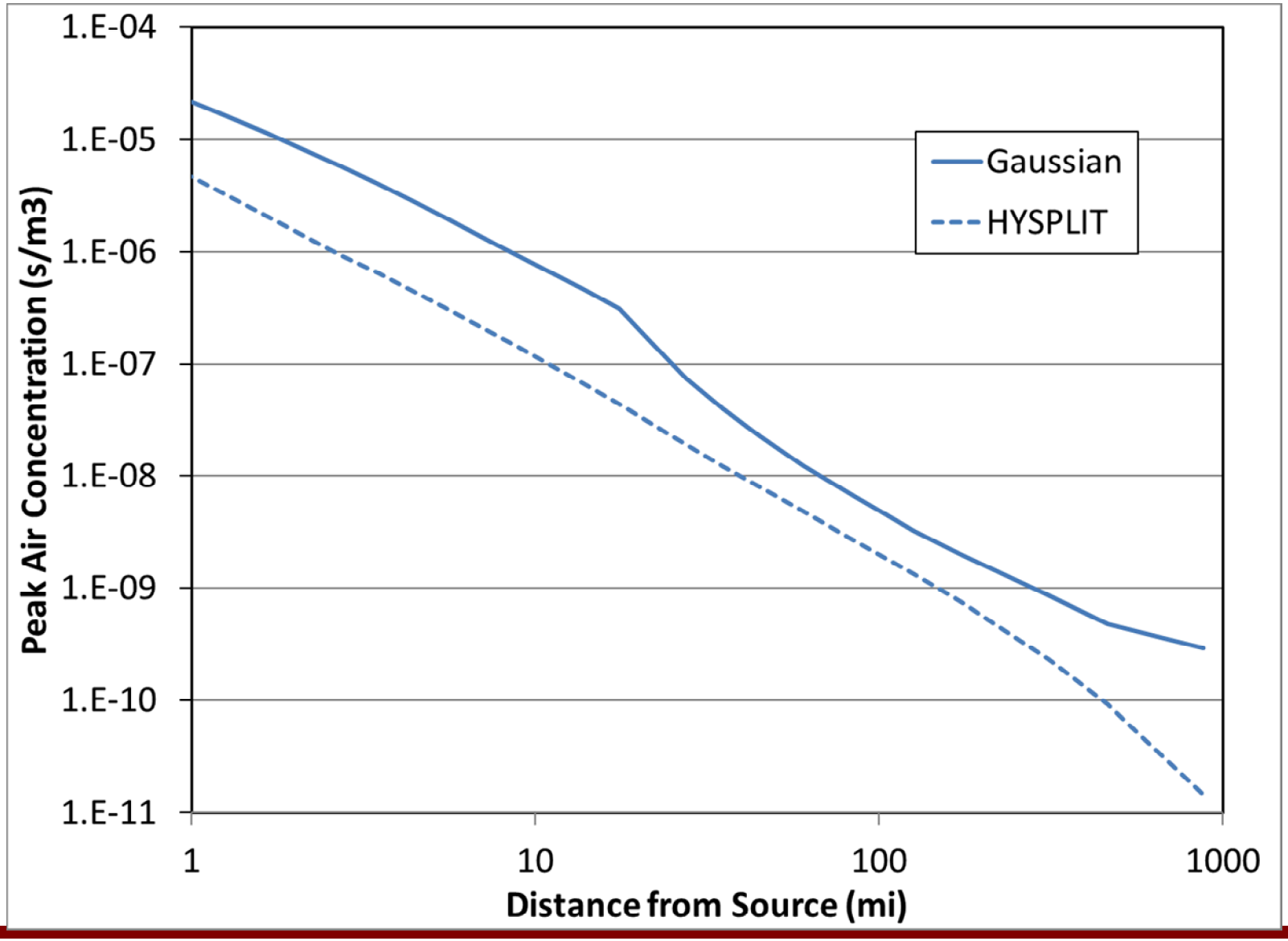
- Large River Valley
  - SOARCA, STSBO Source Term
    - Comparison #1 - HYSPLIT/Gaussian, NAM12 weather
      - Gaussian model run with input weather file generated from NAM12 data
      - HYSPLIT model run with input weather file generated from NAM12 data
    - Comparison #2 - Gaussian, NAM12/site weather
      - Gaussian model run with input weather file generated from NAM12 data
      - Gaussian model run with input weather file generated from site data
  - NUREG-1150 source term
    - Comparison #3 - HYSPLIT/Gaussian, NAM12 weather
      - Gaussian model run with input weather file generated from NAM12 data
      - HYSPLIT model run with input weather file generated from NAM12 data
- Site to site comparison
  - Comparison #4 - HYSPLIT/Gaussian, NAM12 weather

Caveats

- Presenting draft results
  - Inform technical discussion
  - Subject to uncertainty/still under review
- Detailed results shown for one site
  - Caution to not draw any broad conclusions based on the results for one site

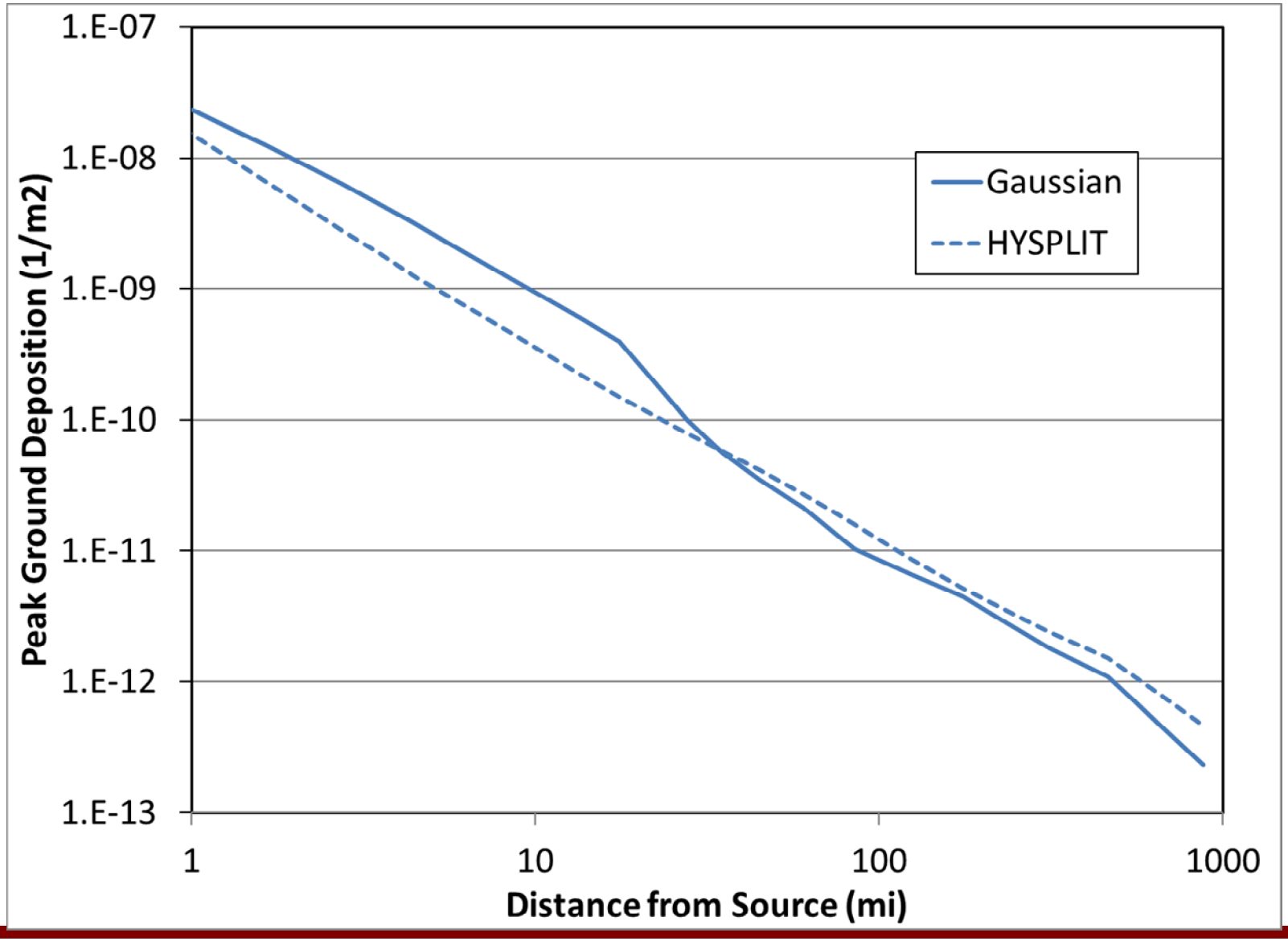
Comparison #1 Peak Time-Integrated Air Dilution

(Large River Valley, STSBO Source Term, HYSPLIT/Gaussian, NAM12 weather)



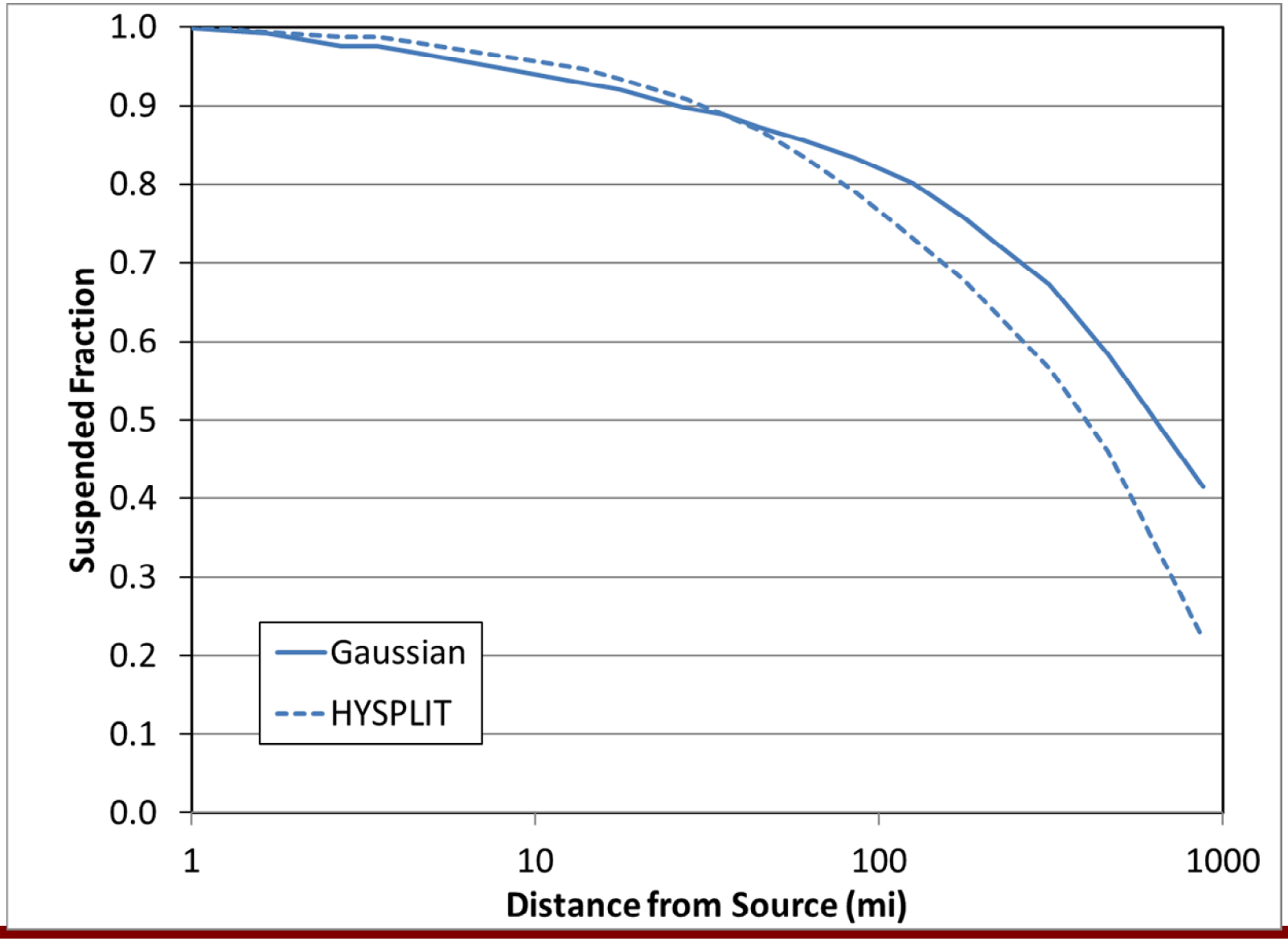
Comparison #1 Peak Ground Deposition

(Large River Valley, STSBO Source Term, HYSPLIT/Gaussian, NAM12 weather)



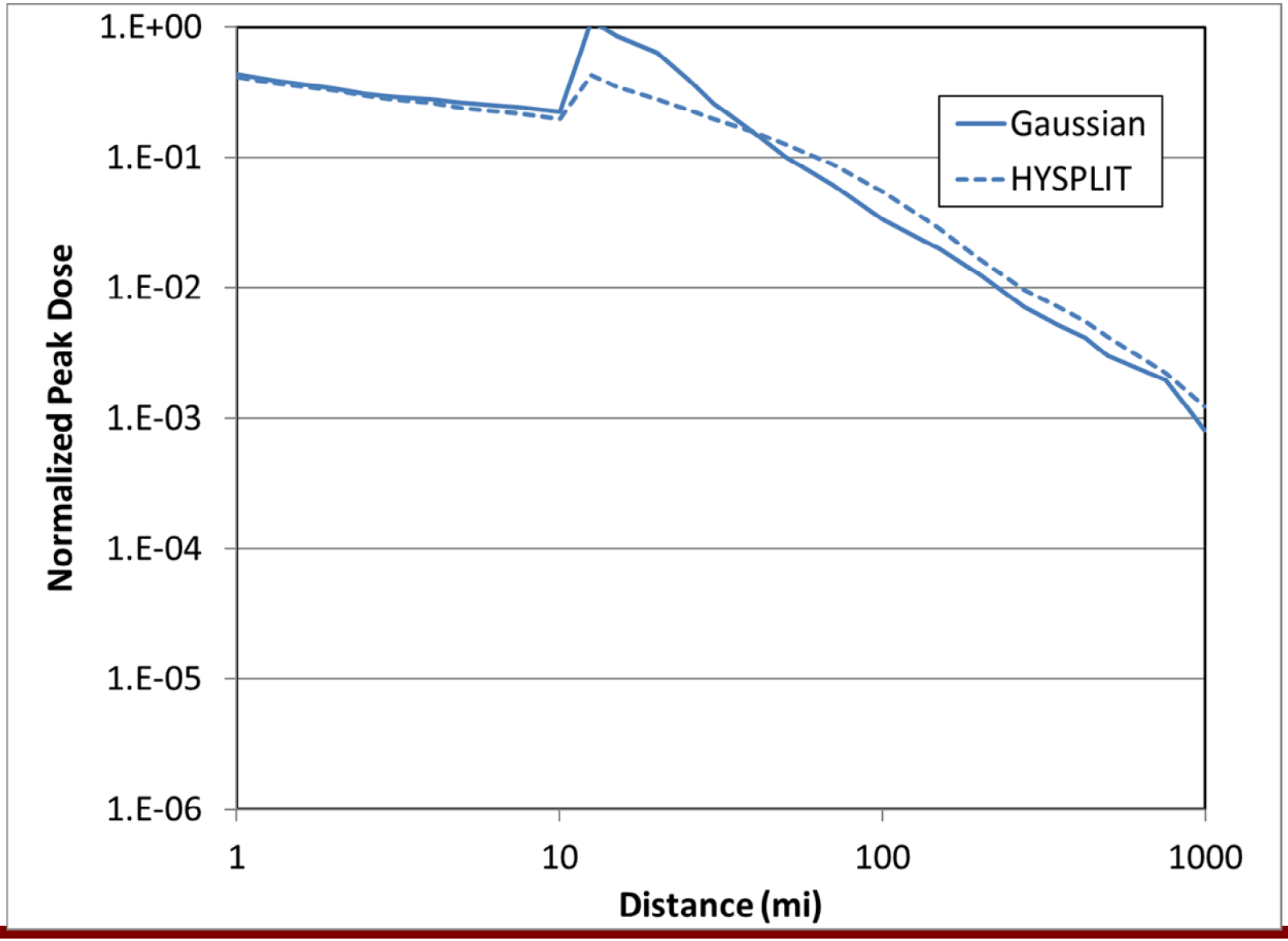
Comparison #1 Fraction Suspended

(Large River Valley, STSBO Source Term, HYSPLIT/Gaussian, NAM12 weather)



Comparison #1 Normalized Peak Population Dose

(Large River Valley, STSBO Source Term, HYSPLIT/Gaussian, NAM12 weather)



Comparison #1 Integrated Quantities

(Large River Valley, STSBO Source Term, HYSPLIT/Gaussian, NAM12 weather)

Ratio of Integrated Results (Gaussian = 1)	1 mi	2 mi	5 mi	10 mi
Early Fatality Risk	a	a	a	a

Ratio of Integrated Results (Gaussian = 1)	10 mi	20 mi	50 mi	100 mi	200 mi	500 mi
Latent Cancer Risk	0.8	0.7	0.8	1.0	1.1	1.1
Population Dose	1.0	0.8	0.8	1.0	1.1	1.1
Total Economic Losses	0.8	0.8	0.8	0.9	1.0	1.1

Ratio of Integrated Results (Gaussian = 1)	1 Ci/km^2	5 Ci/km^2	15 Ci/km^2	40 Ci/km^2
Land Area that Exceeds	1.4	1.4	1.2	0.9

a Both Gaussian and HYSPLIT calculations have zero values, which precluded the ability to determine a ratio

Comparison #1 Summary

(Large River Valley, STSBO Source Term, HYSPLIT/Gaussian, NAM12 weather)

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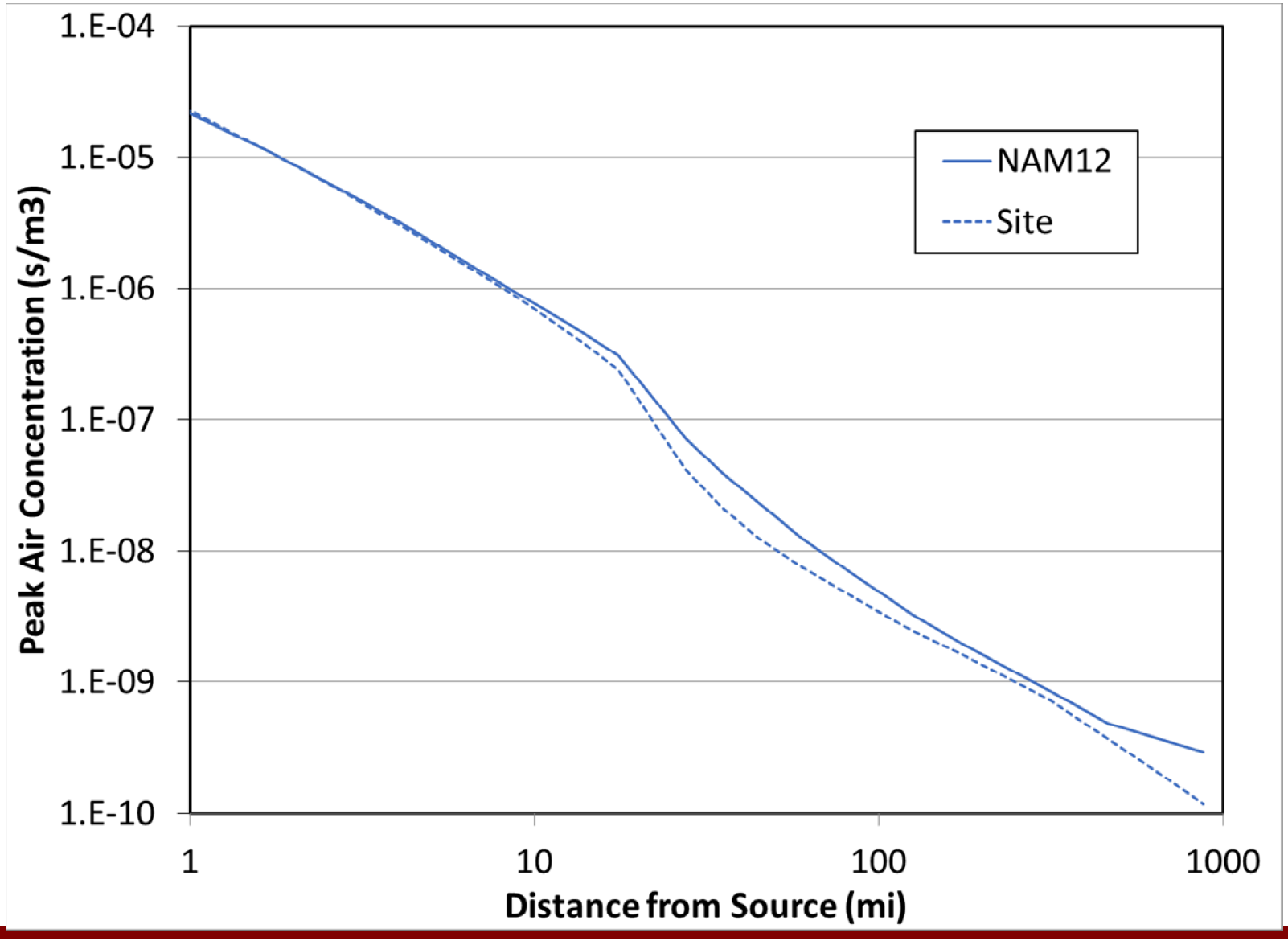
- Peak time-integrated air dilution lower on average by a factor of five for HYSPLIT calculation
- Peak ground deposition within a factor of two for HYSPLIT calculation
- Fraction suspended within 0.1 for HYSPLIT calculation up to 400 miles
- Normalized peak population dose within a factor of two for HYSPLIT calculation
- Integrated quantities within a factor of 1.1 for HYSPLIT calculations, except for land contamination which is within a factor of 1.4

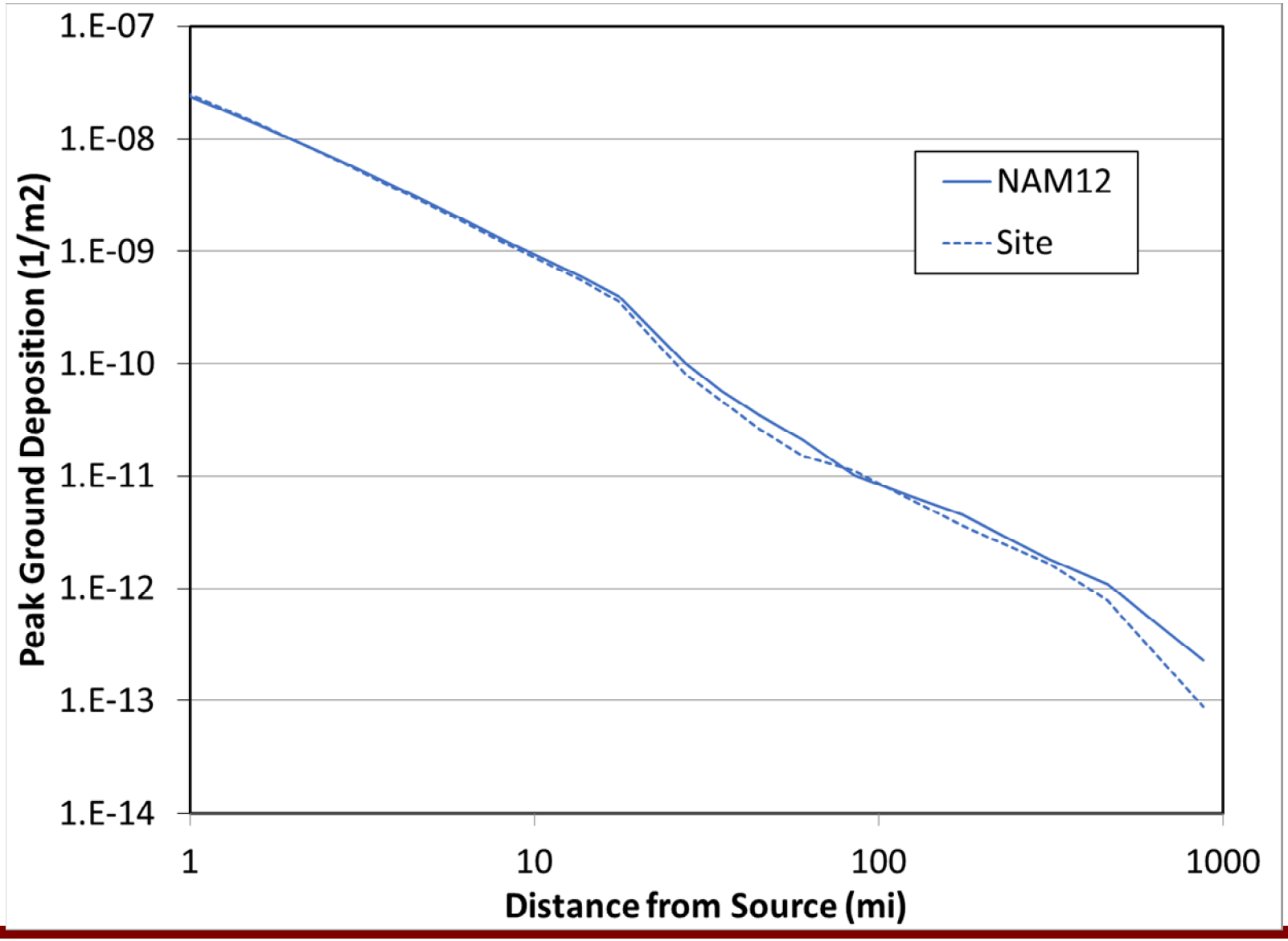
Comparison #2 Peak Time-Integrated Air Dilution

(Large River Valley, STSBO Source Term, Gaussian, NAM12/site weather)



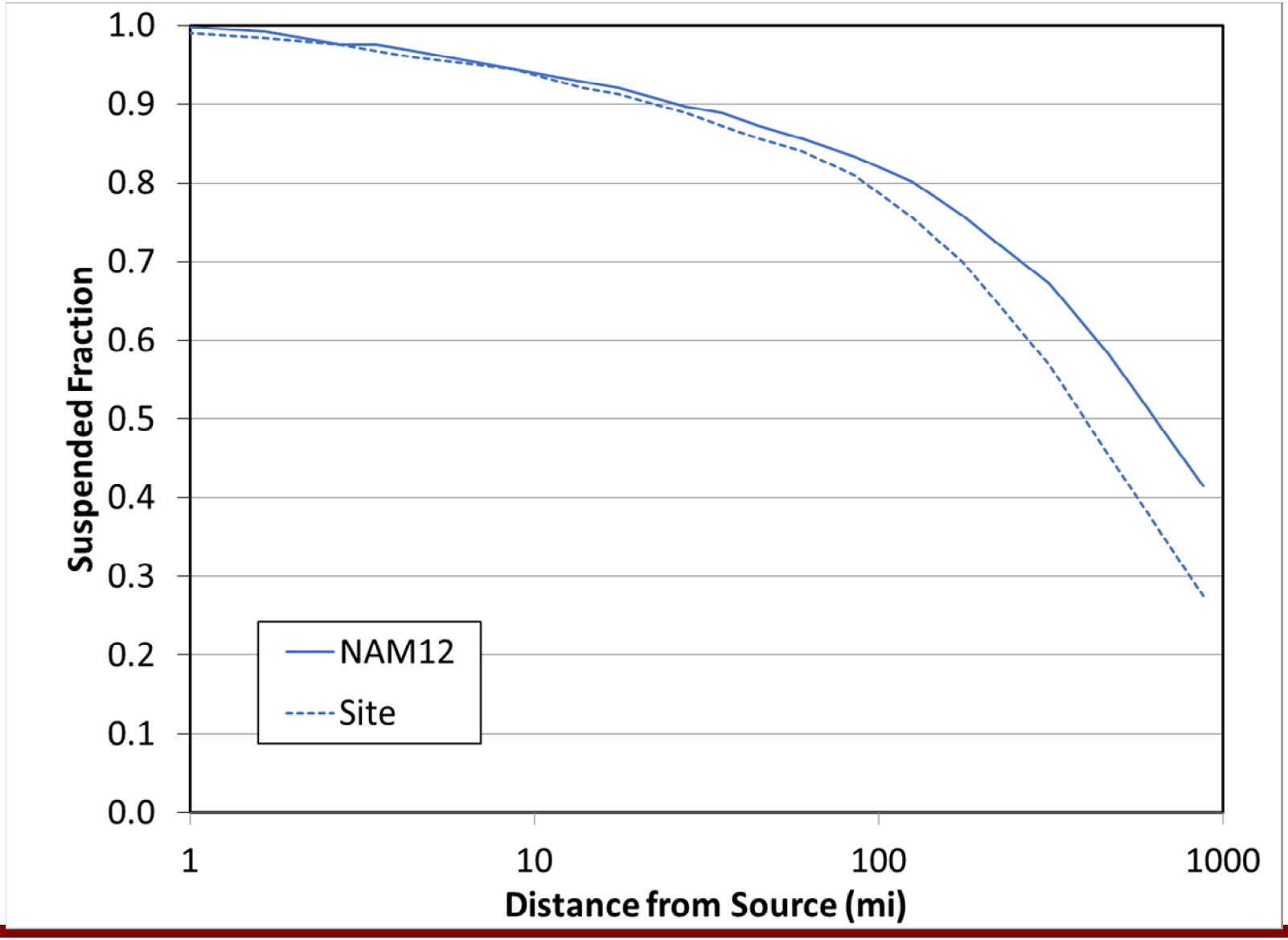
Comparison #2 Peak Ground Deposition

(Large River Valley, STSBO Source Term, Gaussian, NAM12/site weather)



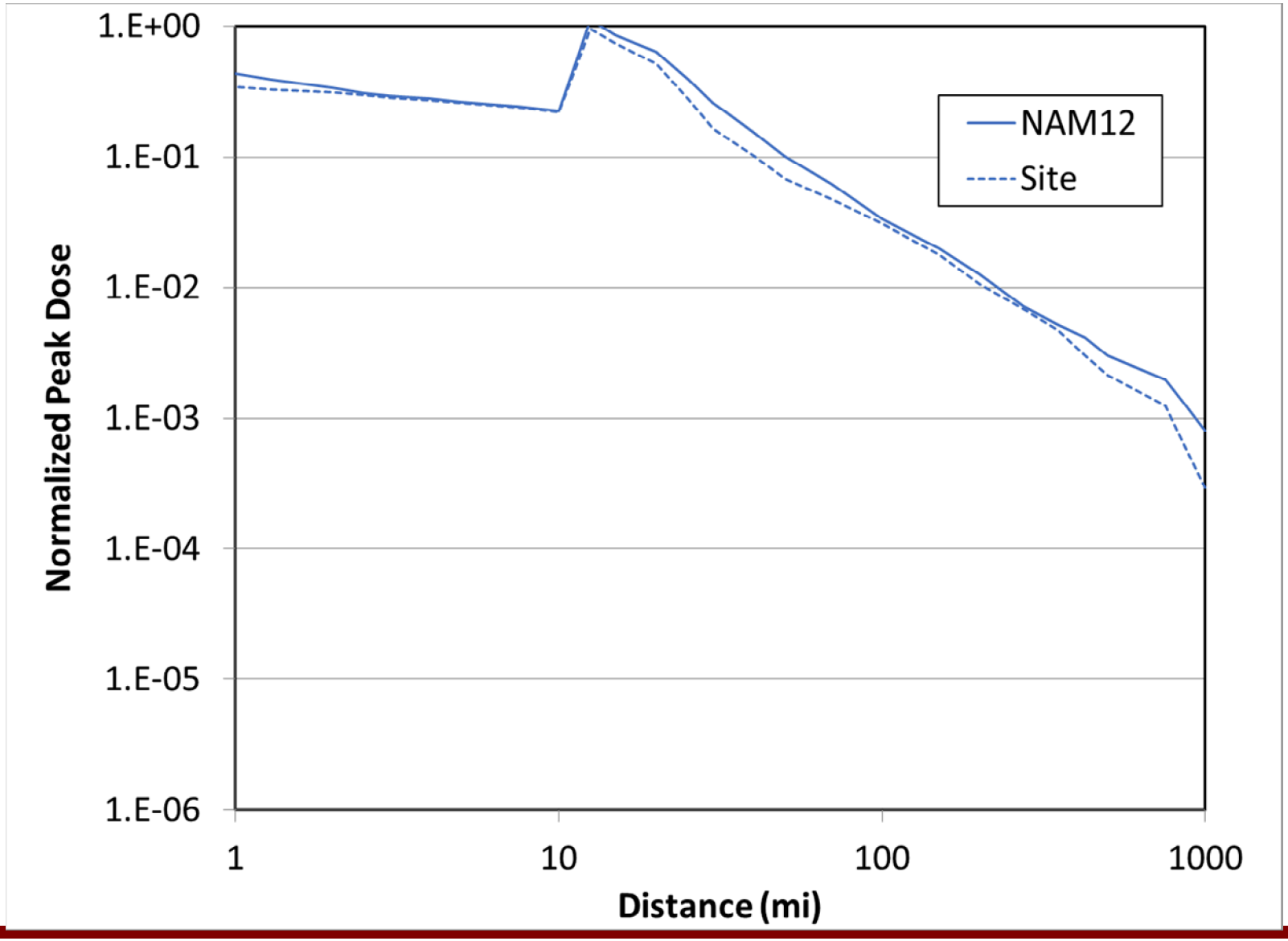
Comparison #2 Fraction Suspended

(Large River Valley, STSBO Source Term, Gaussian, NAM12/site weather)



Comparison #2 Normalized Peak Population Dose

(Large River Valley, STSBO Source Term, Gaussian, NAM12/site weather)



Comparison #2 Integrated Quantities

(Large River Valley, STSBO Source Term, Gaussian, NAM12/site weather)

Ratio of Integrated Results (NAM12 = 1)	1 mi	2 mi	5 mi	10 mi
Early Fatality Risk	a	a	a	a

Ratio of Integrated Results (NAM12 = 1)	10 mi	20 mi	50 mi	100 mi	200 mi	500 mi
Latent Cancer Risk	1.0	1.1	1.1	1.1	1.2	1.2
Population Dose	1.0	1.1	1.1	1.1	1.2	1.3
Total Economic Losses	0.9	1.0	1.1	1.1	1.1	1.1

Ratio of Integrated Results (NAM12 = 1)	1 Ci/km^2	5 Ci/km^2	15 Ci/km^2	40 Ci/km^2
Land Area that Exceeds	1.2	1.1	1.2	1.1

a Both NAM12 and site calculations have zero values, which precluded the ability to determine a ratio

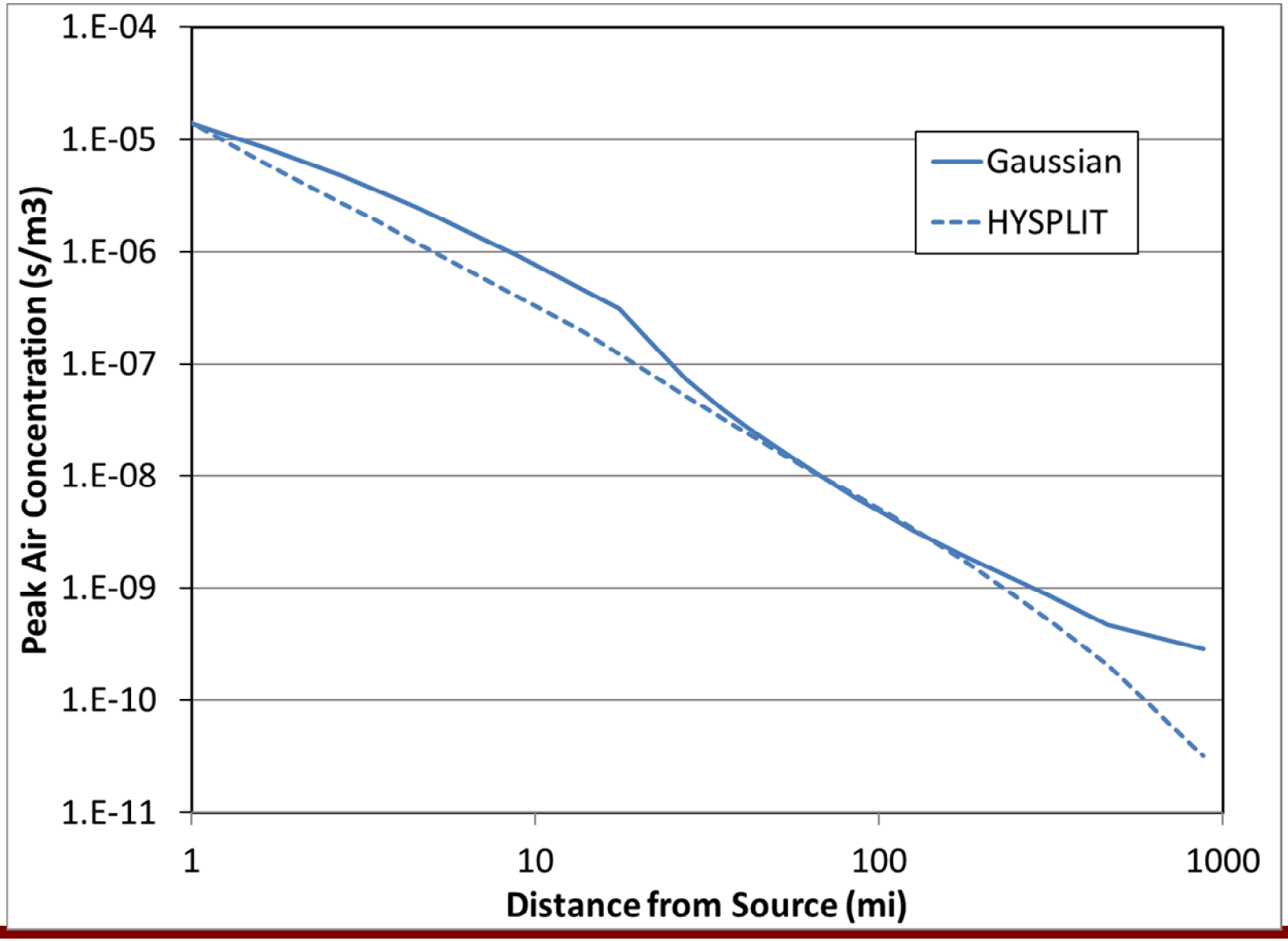
Comparison #2 Summary

(Large River Valley, STSBO Source Term, Gaussian, NAM12/SOARCA weather)

- Peak time-integrated air dilution lower on average by a factor of 1.4 for site weather calculation
- Peak ground deposition lower on average by a factor of 1.2 for site weather calculation
- Fraction suspended within 0.1 for site weather calculation up to 400 miles
- Normalized peak population dose lower on average by a factor of 1.3 for site weather calculation
- Integrated quantities within a factor of 1.3 for site weather calculations

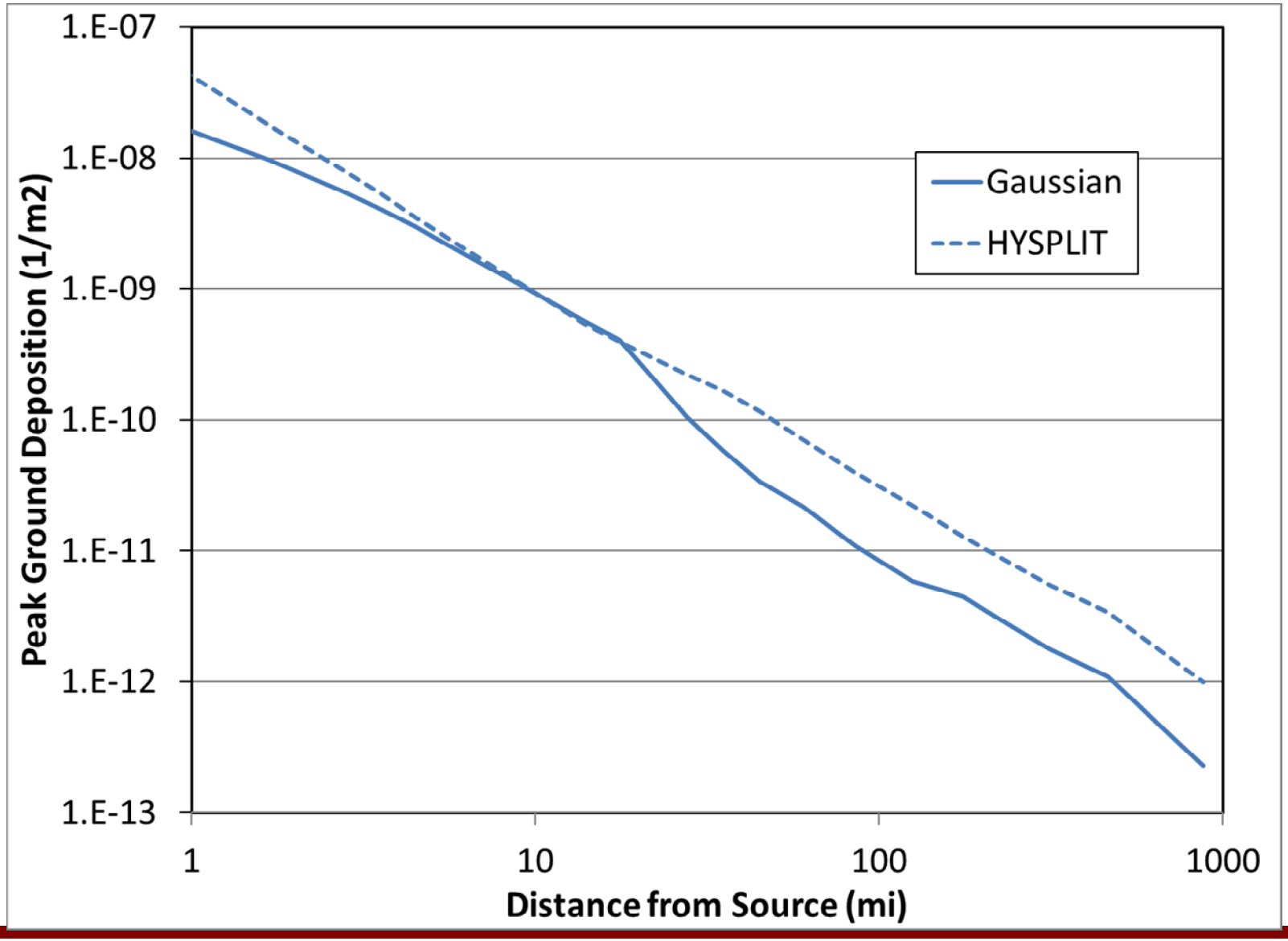
Comparison #3 Peak Time-Integrated Air Dilution

(Large River Valley, NUREG-1150 Source Term, HYSPLIT/Gaussian, NAM12 weather)



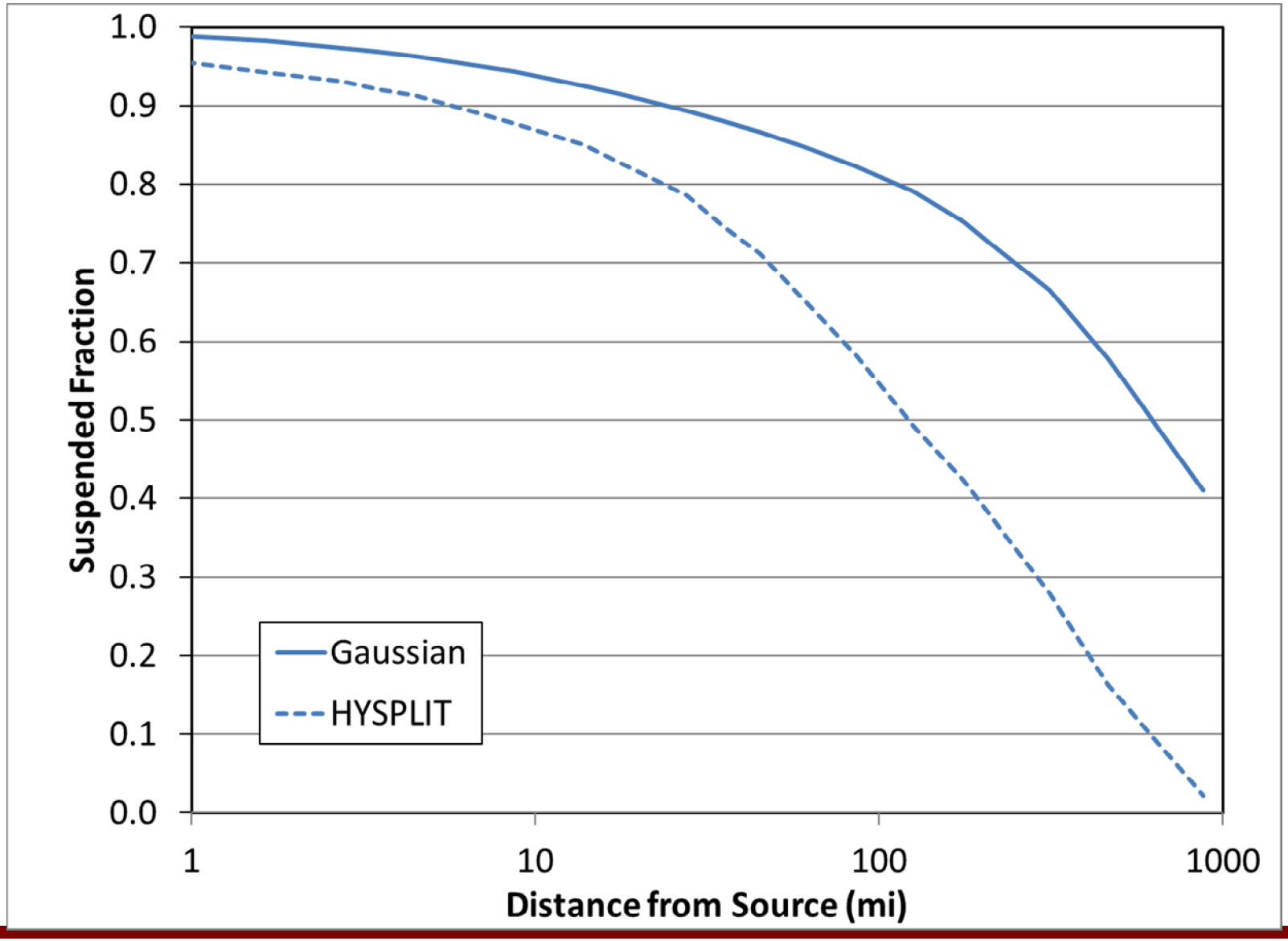
Comparison #3 Peak Ground Deposition

(Large River Valley, NUREG-1150 Source Term, HYSPLIT/Gaussian, NAM12 weather)



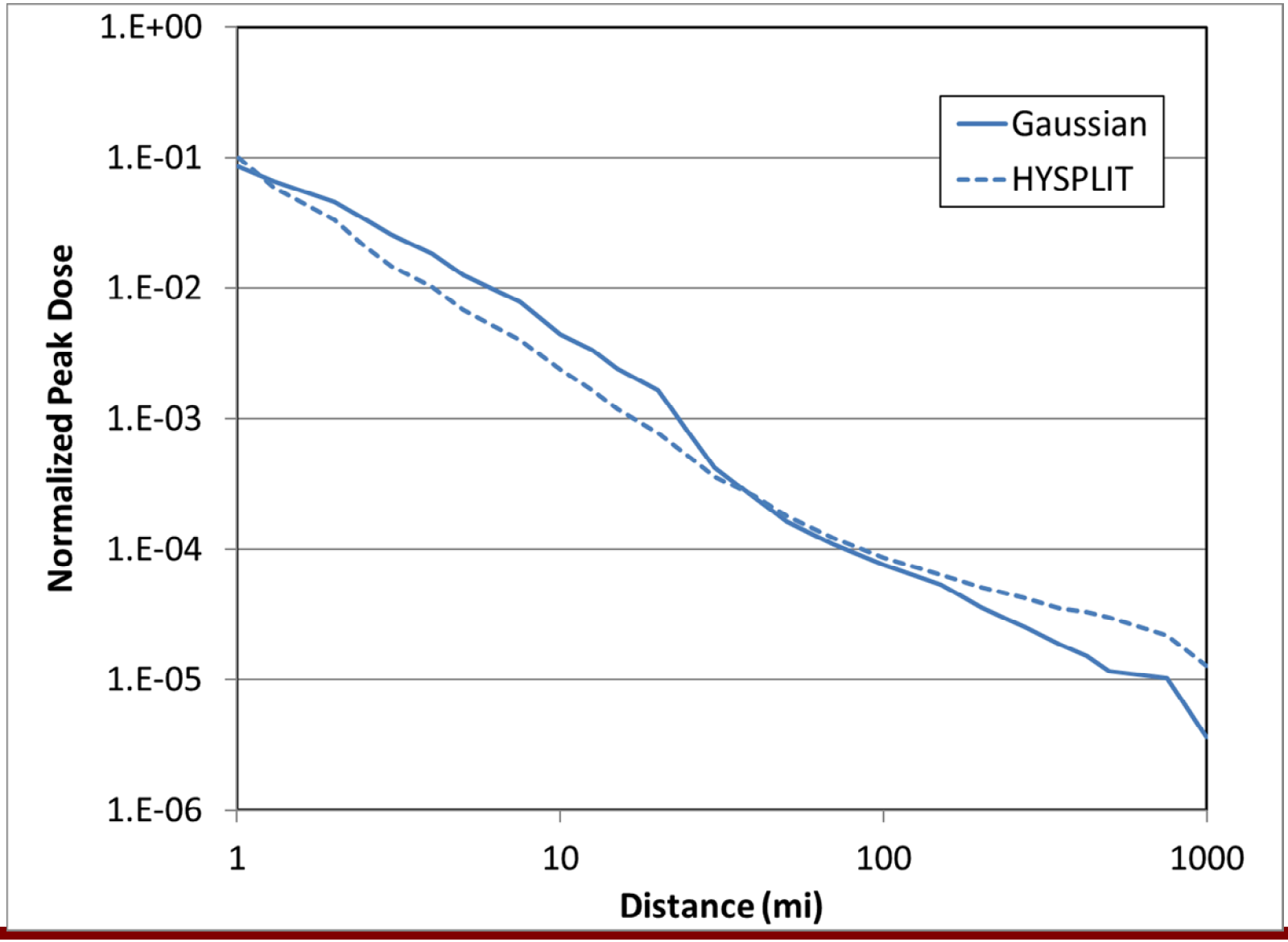
Comparison #3 Fraction Suspended

(Large River Valley, NUREG-1150 Source Term, HYSPLIT/Gaussian, NAM12 weather)



Comparison #3 Normalized Peak Population Dose

(Large River Valley, NUREG-1150 Source Term, HYSPLIT/Gaussian, NAM12 weather)



Comparison #3 Integrated Quantities

(Large River Valley, NUREG-1150 Source Term, HYSPLIT/Gaussian, NAM12 weather)

Ratio of Integrated Results (Gaussian = 1)	1 mi	2 mi	5 mi	10 mi
Early Fatality Risk	1.5	1.2	1.2	1.2

Ratio of Integrated Results (Gaussian = 1)	10 mi	20 mi	50 mi	100 mi	200 mi	500 mi
Latent Cancer Risk	0.8	0.8	0.8	1.0	1.1	1.5
Population Dose	0.9	1.0	1.0	1.1	1.2	1.5
Total Economic Losses	1.8	1.9	1.7	2.1	2.4	2.4

Ratio of Integrated Results (Gaussian = 1)	1 Ci/km^2	5 Ci/km^2	15 Ci/km^2	40 Ci/km^2
Land Area that Exceeds	1.7	2.0	2.5	2.7

a Both Gaussian and HYSPLIT calculations have zero values, which precluded the ability to determine a ratio

Comparison #3 Summary

(Large River Valley, NUREG-1150 Source Term, HYSPLIT/Gaussian, NAM12 weather)

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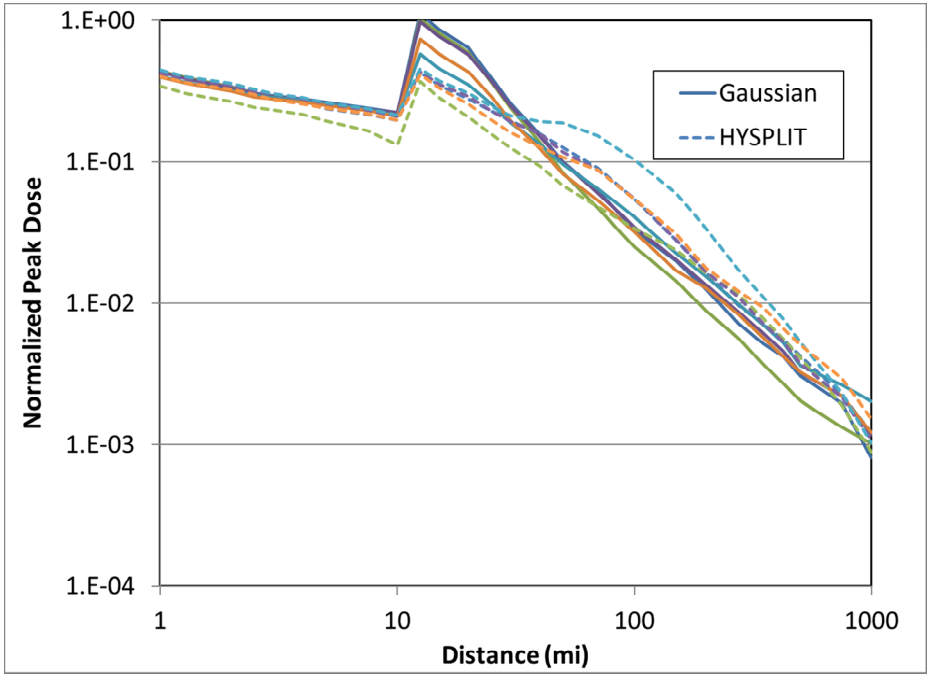
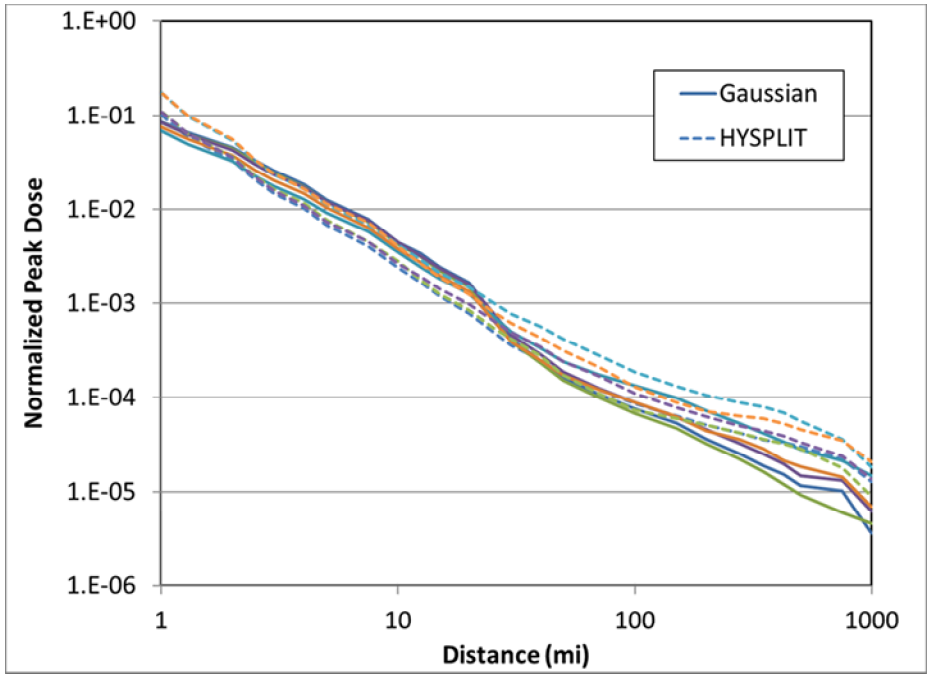
- Peak time-integrated air dilution lower on average by a factor of two for HYSPLIT calculation
- Peak ground deposition higher on average by a factor of two for HYSPLIT calculation
- Fraction suspended within 0.25 for HYSPLIT calculation up to 100 miles
- Normalized peak population dose within a factor of two for HYSPLIT calculation
- Integrated quantities within a factor of 1.5 for HYSPLIT calculations, except for land contamination and economic losses which are within a factor of three

Comparison #4 Site to Site Variation

- Similar behavior with noticeable differences for other sites as was shown for the Large River Valley site
- Site to site variations show differences between sites similar to differences between Gaussian plume segment and HYSPLIT models



SOARCA, STSBO Source Term



NUREG-1150 Source Term

Test Result Summary

- Draft results shown
- Differences between Gaussian and HYSPLIT fairly reasonable
- Differences in Gaussian calculations from weather input file smaller than differences seen between Gaussian and HYSPLIT comparison
- Differences between Gaussian and HYSPLIT smaller using SOARCA, STSBO source term compared with NUREG-1150 source term
- Differences between sites, similar to the magnitude of differences between Gaussian and HYSPLIT results

Summary

- Implementation of HYSPLIT results into MACCS completed
- Draft results
  - HYSPLIT versus Gaussian Plume Segment
  - Gaussian varying input weather file
  - Source term differences
  - Site to site differences
- Future work includes
  - Further investigation into results and observed differences
  - Documentation of results
  - Support an upcoming peer review