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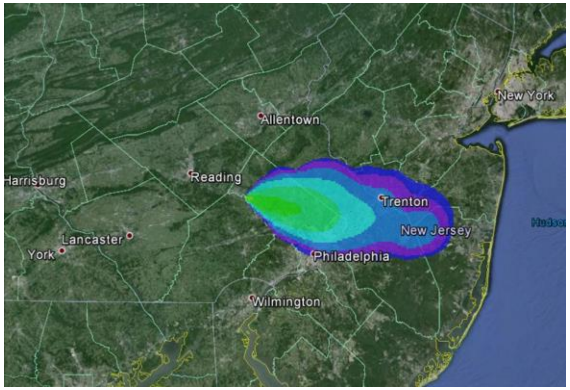

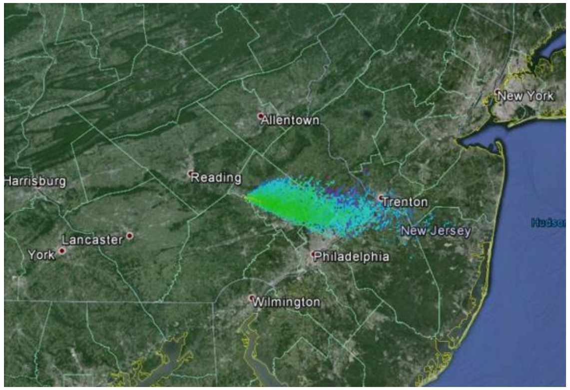

Implementation of the HYSPLIT Atmospheric Transport Model in MACCS

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International MACCS Users' Group, Bethesda, MD

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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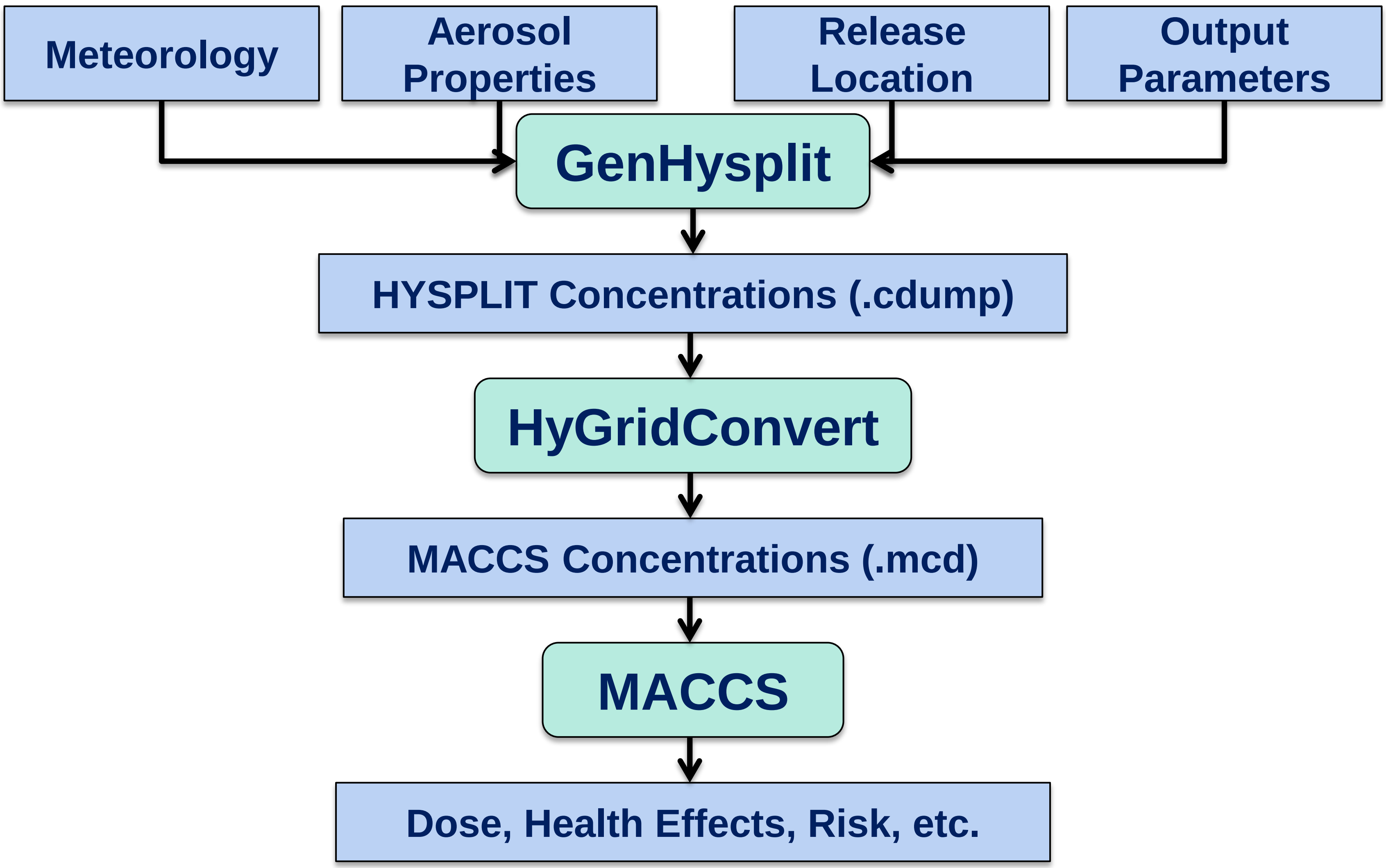
Objective

- Provide an alternative Atmospheric Dispersion and Transport (ADT) option for MACCS

- Add the capability to handle complex local weather patterns and terrain

Overall Process



Generating HYSPLIT Files

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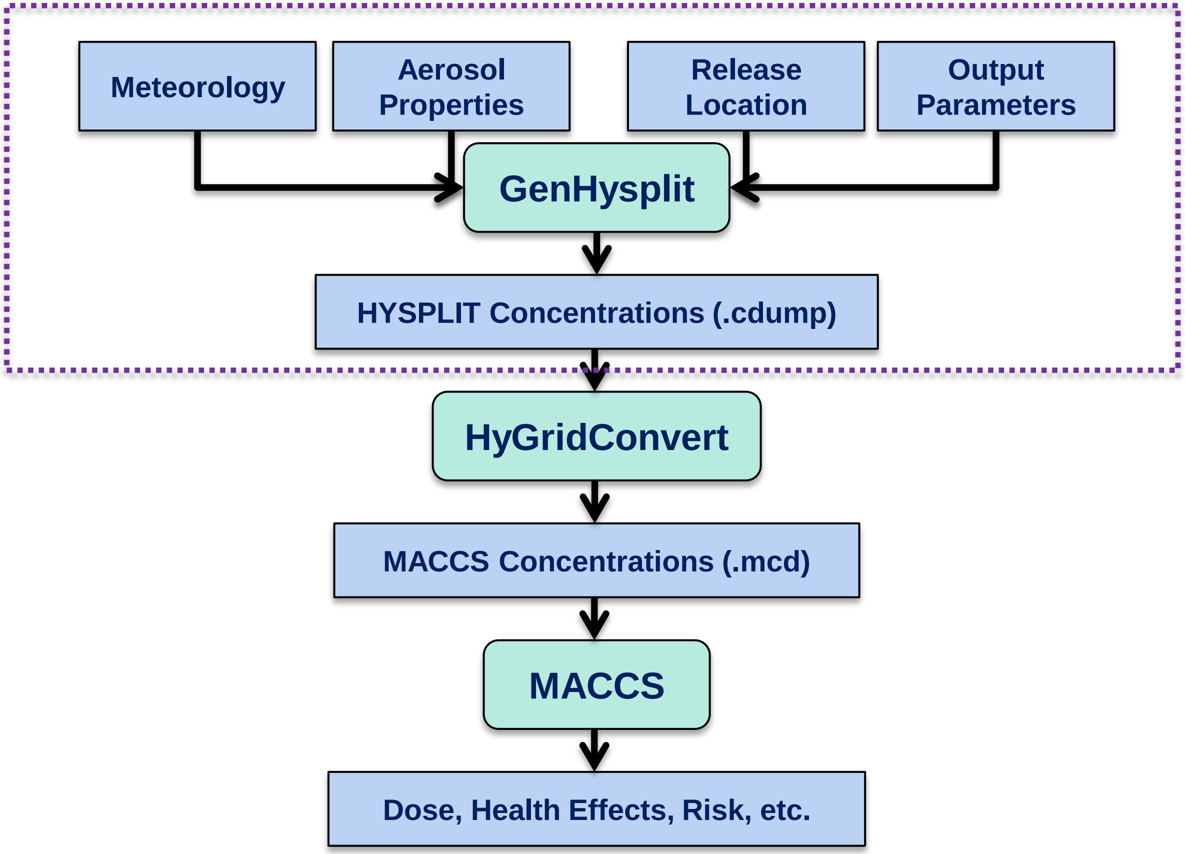
- Normalized release
- GenHysplit code
- Example



Normalized Release

- Release 1 unit for 10 aerosol sizes over a 1 hour period and then track
  - Generating X/Q and D/Q values for each period and aerosol size
  - For one year that equates to 8760 simulations
  - Provides enough data to effectively model any source term over every hour for the entire year

GenHysplit Code

- Used to generate and organize the HYSPLIT output concentration files
- Configured to run on a Linux system to be able to access large computer resources at Sandia National Laboratories
- Many options controlled by input file, with others hard coded

Input File Options

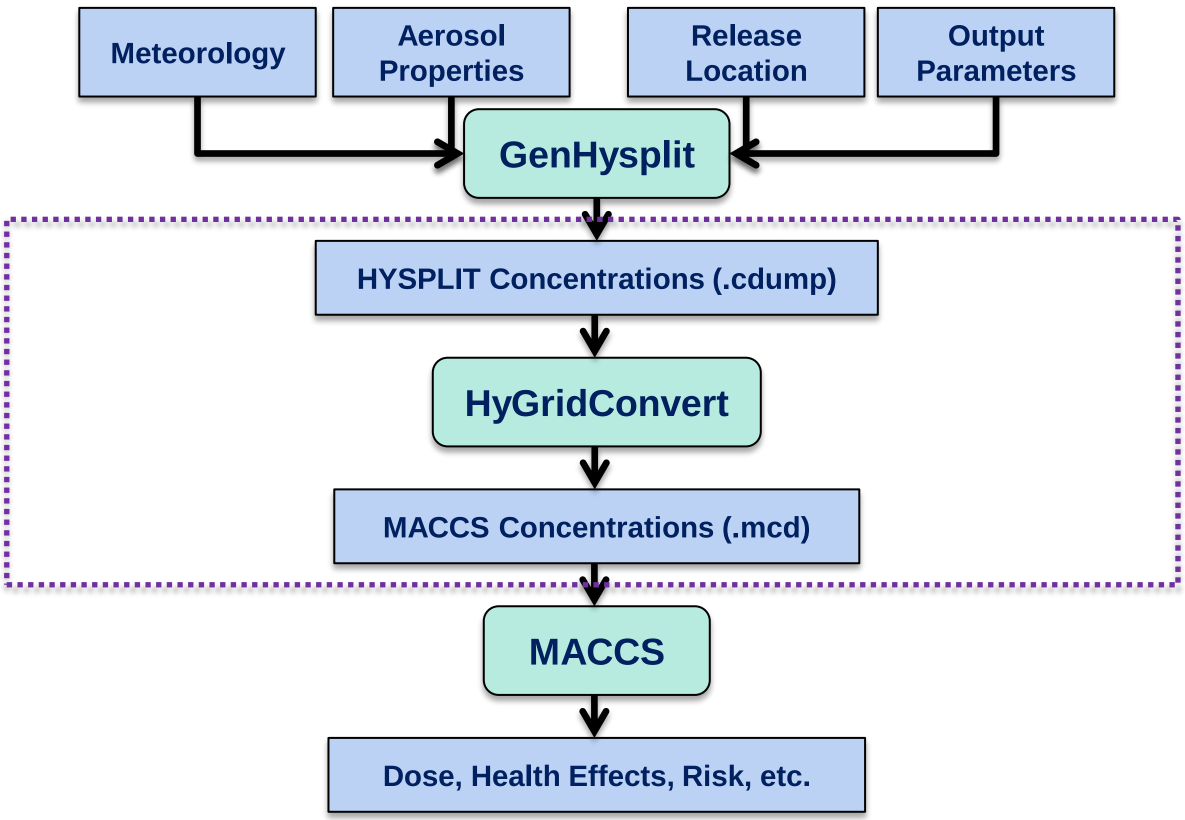
- Weather days/data set
- Release location and height
- Run time after release
- Time step for output
- Output grid parameters
- Modeling approach – particles/puffs
- Number of particles/puffs in simulation
- Aerosol bin sizes, densities and deposition velocities

Examples

- GenHysplit input file
- Output .cdump files

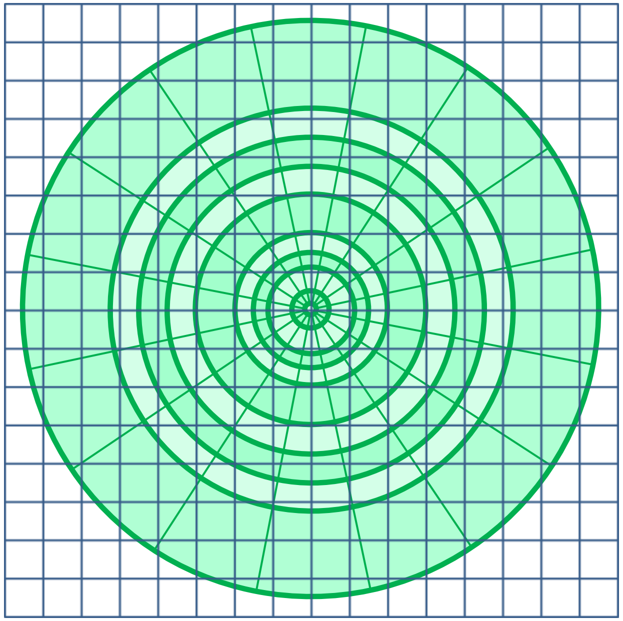
Converting HYSPLIT Output to MACCS Input

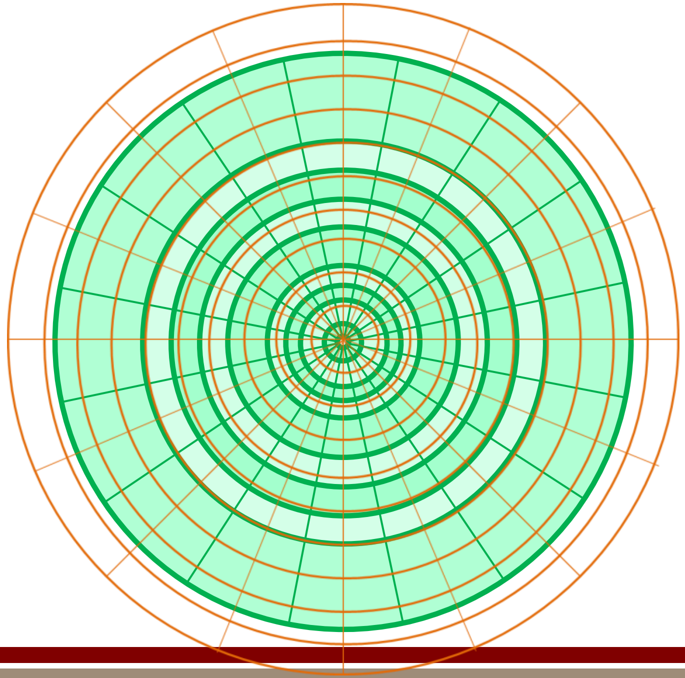
- HyGridConvert code
- Algorithm
- Example



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)





Algorithm

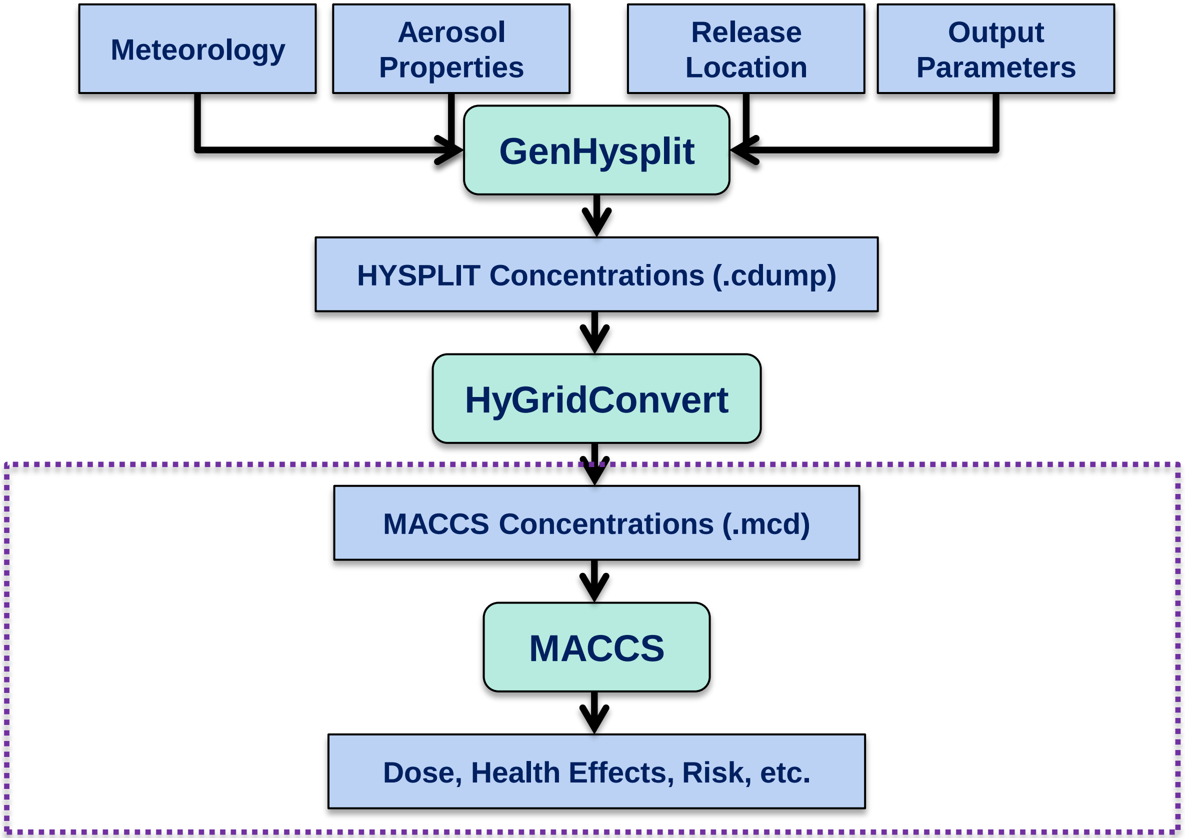
- Use area weighted averages of the appropriate HYSPLIT grid cells to determine the concentration of the MACCS grid cell
  - Determine finest grid available for each radii (if using multiple grids)
  - Divide HYSPLIT output results into smaller grid cell portions (if necessary), based on relative size of the MACCS grid cell (assume uniform deposition)
  - Determine area based weighting factor for each HYSPLIT grid cell to each MACCS grid cell
- Ensure that grid centers and grid parameters for other files in the folder match
- Apply determined conversion factors to all remaining data sets in folder

Example

- Convert files in WinMACCS

MACCS Use of HYSPLIT Data

- Weather sampling
- Combination with source term
- Example



Weather Sampling

- Determine sampling type
  - Fixed start time
    - Only need enough files to cover all plumes
  - Uniform bin sampling
    - Requires both HYSPLIT converted files and MACCS formatted weather file
    - Option to construct MACCS formatted file from gridded data in progress
  - Stratified random sampling
    - Currently configured to only sample one year between 1/1 and 12/31
    - Only requires HYSPLIT converted files (one year plus extras)
- New MACCS input parameters
  - HYSPLIT Converted File Folder
  - HY_FIXED (date)
  - HY_HOUR (hour in day 1-24)
  - HY_START (date)
  - HY_END (date)
  - HY_BEFORE (number of days)
  - HY_AFTER (number of days)

Combination with Source Term

- 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 one 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

Example

- Show MACCS run

Testing Overview

- Test problems compare
  - HYSPLIT model using Lagrangian Particle Tracking option with rectangular concentration grid
  - HYSPLIT model using Lagrangian Particle Tracking option with polar concentration grid
  - Gaussian plume segment model using Tadmor-Gur lookup tables from MACCS2 Sample Problem A

Testing Overview: Compared Results

- Atmospheric Model Outputs
  - Peak air concentration (around the compass as specific distance) as a function of distance
  - Peak ground concentration as a function of distance
  - Apparent deposition velocity (ratio of ground concentration to air concentration) as a function of distance
  - Adjusted source (suspended activity) as a function of distance
- Dose and Risk Outputs (based on unit release of each of the standard 69 isotopes)
  - Peak dose as a function of distance
  - Collective population dose within 10, 50, and 1000 miles
  - Population-weighted latent cancer fatality risk within 10 miles

Test Case Goals and Expectations

- Test Case 1 – very simple problem for which the models should agree (Test Case 1)
  - Goal is to confirm that implementation is correct.
  - Agreement should be very good but not perfect due to different approaches for dispersion.
- Test Case 2 – add complexity of standard set of aerosol bins, each with it's own deposition velocity
  - Goal is to confirm that implementation is correct.
  - Agreement should be similar to Test Case 1.
- Test Case 3 – allow HYSPLIT to use its native aerosol model in which deposition velocity depends on atmospheric conditions and local surface roughness
  - Goal is to gauge the influence of deposition velocity treatment.
  - Agreement should be poorer than Test Case 2, but doses should be within factor of 2 or 3.

Test Case Goals and Expectations

- Test Case 4 – second plume segment
  - Goal is to demonstrate that multiple plume segments are correctly modeled.
  - Expectation is that agreement should be the same as Test Case 3.
- Test Case 5 – standard weather treatment for the two models
  - Goal is to determine the influence of nonuniform and complex weather.
  - Expectation is that agreement should be poorer than any of the previous cases but results should be within about a factor of ten.
- Test Case 6 – weather sampling over one year
  - Goal is to demonstrate that weather sampling works correctly.
  - Expectation is that results should be similar to those for Test Case 5.
- Test Cases 1 – 5 also evaluate rectangular and polar-representations of HYSPLIT air and ground concentrations

Test Result Caveats

- Source term is atypical – same activities for 69 isotopes.
- Gaussian dispersion is based on the commonly used Tadmor-Gur (1969) model.
  - Current model from NRC/CEC study (Harper et al. 1995, Bixler et al. 2013) would have resulted in lower concentrations.
  - Accounting for near- and far-field characteristics of vertical dispersion might have produced better agreement.
- HYSPLIT model options may not have been set optimally for the best comparison with a Gaussian model.
- Seabrook may have unique characteristics that are not representative of other sites.

Test Case 1 – Description

- Inputs chosen to make models behave similarly
- Constant, uniform weather generated for input to HYSPLIT with the following characteristics
  - 4 m/s to the west
  - Stability class B
  - Mixing height 300 m
  - No precipitation (wet deposition)
- Fixed, single deposition velocity, 0.1 cm/s
- Single 1-hr plume segment

Test Case 1 – Air Concentrations

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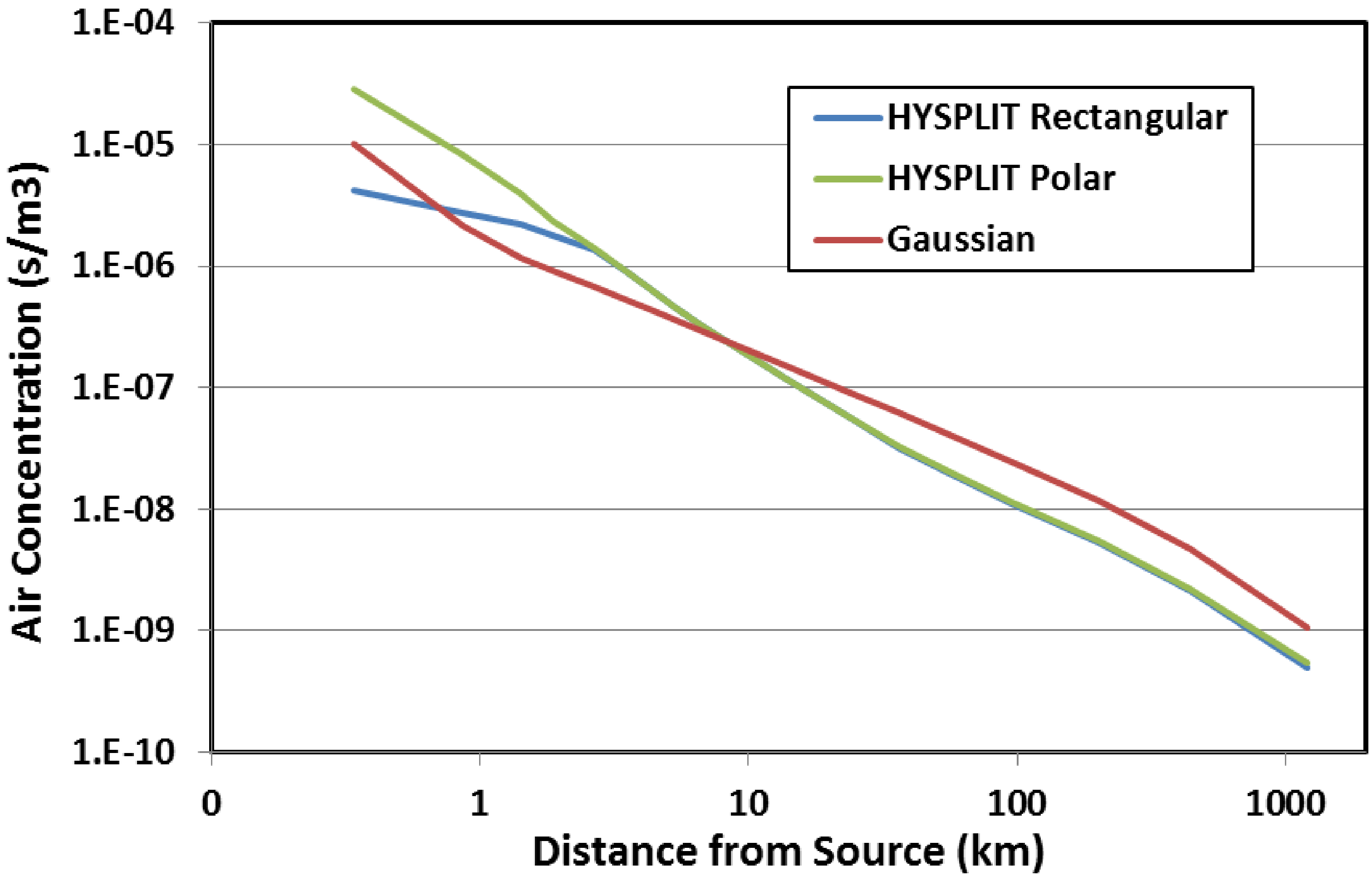
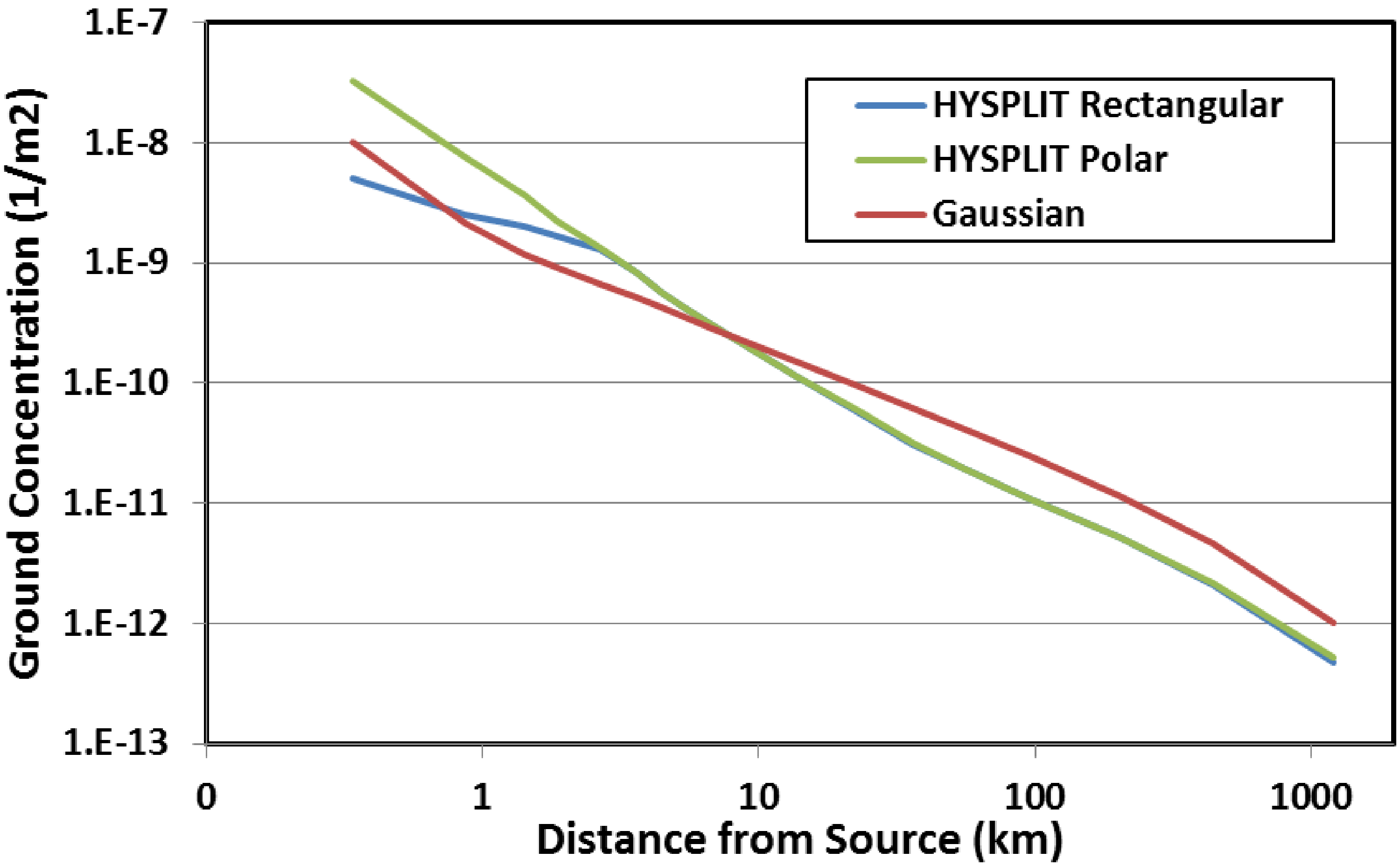
Steady, uniform weather, single deposition velocity



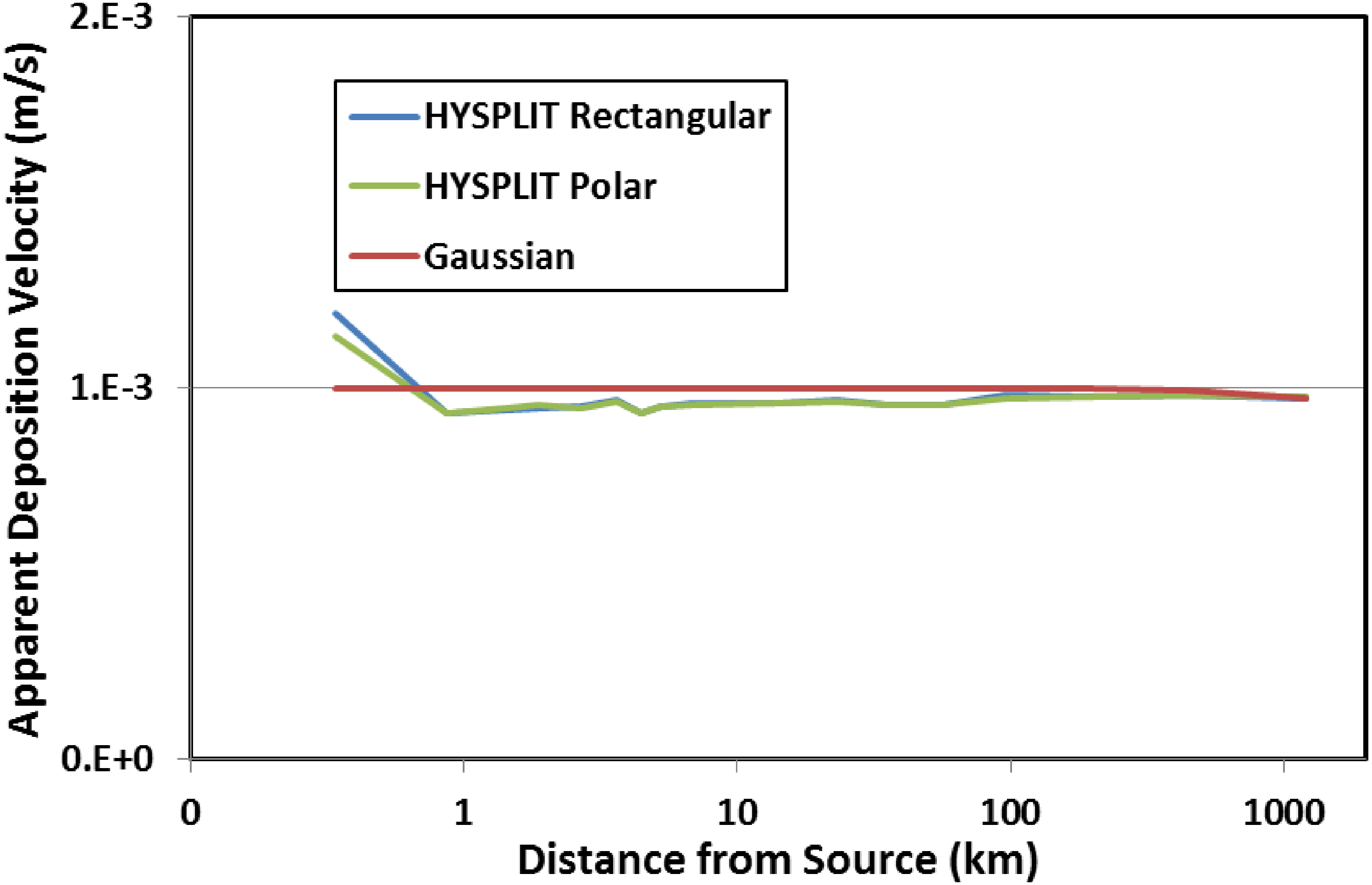
Test Case 1 – Ground Concentrations

Steady, uniform weather, single deposition velocity



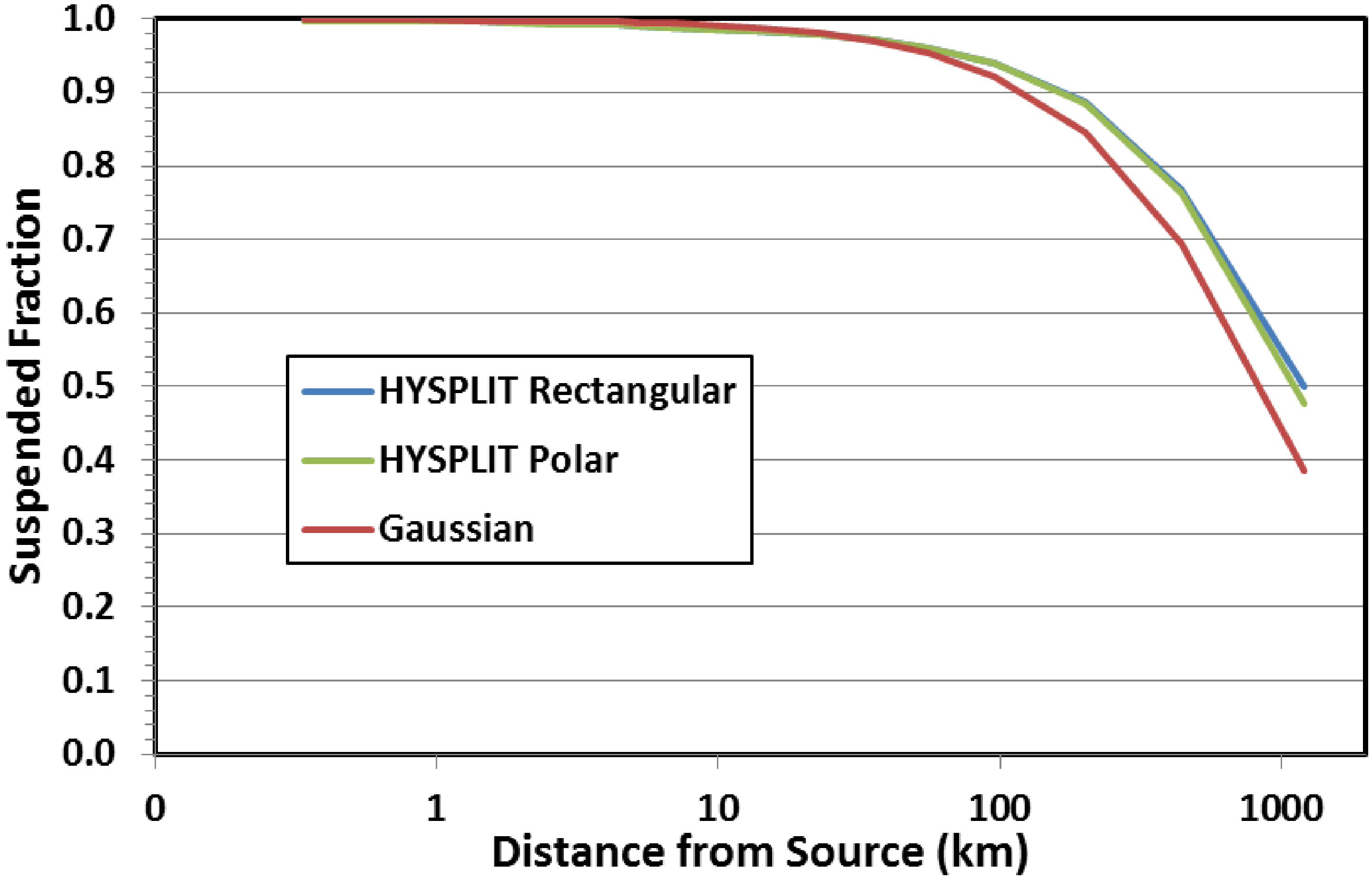
Test Case 1 – Deposition Velocities

Steady, uniform weather, single deposition velocity



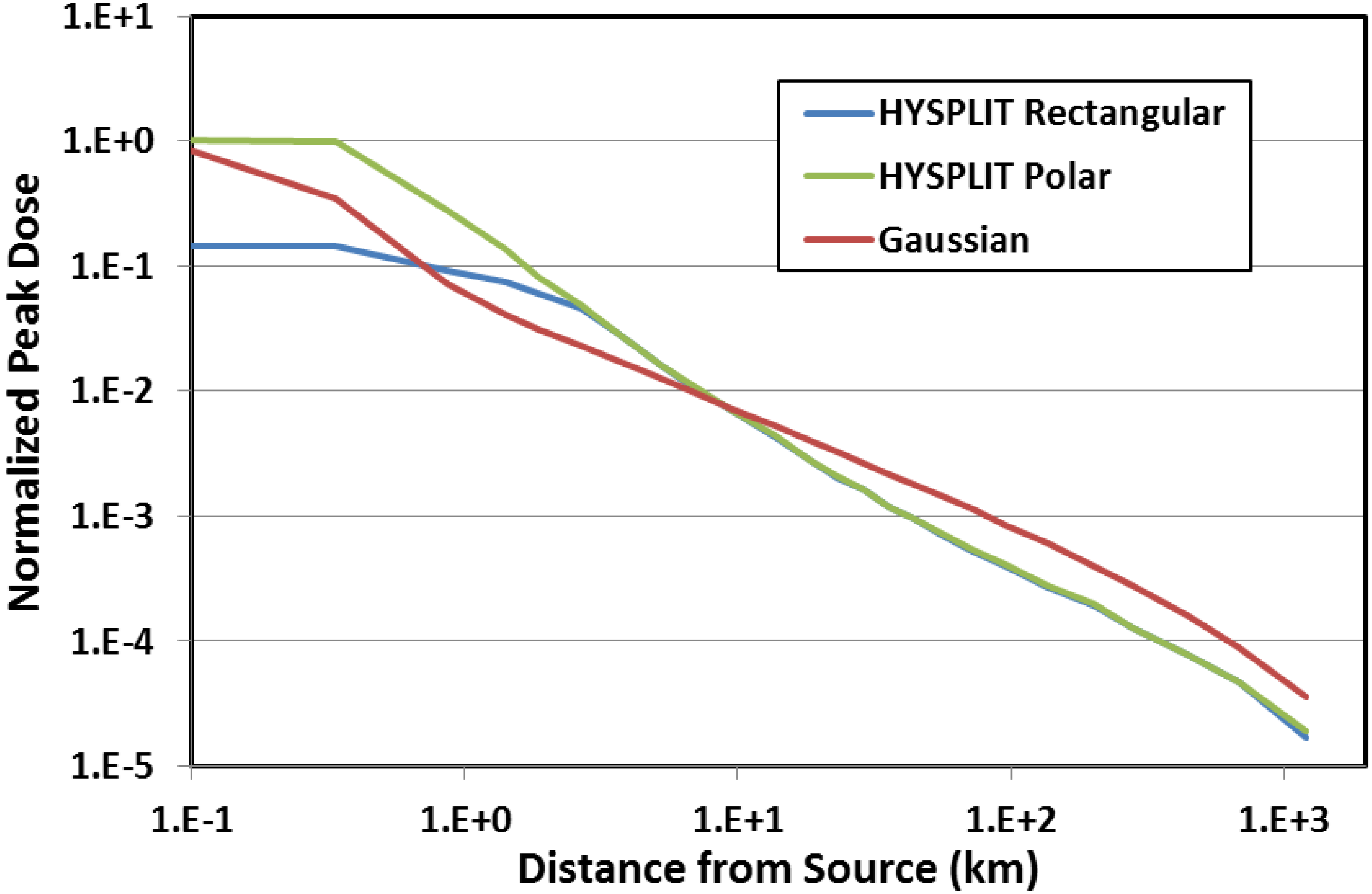
Test Case 1 – Adjusted Source

Steady, uniform weather, single deposition velocity



Test Case 1 – Peak Dose

Steady, uniform weather, single deposition velocity



Test Case 1 – Consequences

Ratio of Integrated Results (Gaussian = 1)	10 mi	50 mi	1000 mi
Total Cancer Fatalities	1.22	0.78	0.73
Population Dose	1.25	0.76	0.73
Population Weighted Risk	1.22		

Test Result Summary – Cases 1, 2, 4

Confirmatory tests

- Results meet expectations.
- Results provide preliminary confirmation that HYSPLIT implementation in MACCS is correct.
- Bug with polar-coordinate representation of HYSPLIT ground concentrations has been fixed.
- Polar representation of HYSPLIT concentrations seems to capture near-field trends.
- For these test cases, Gaussian model predicts
  - Lower concentrations than HYSPLIT at short range
  - Higher concentrations than HYSPLIT at long range
  - Trends are opposite of those observed for LODI in NUREG/CR-6853.

Test Result Summary – Case 3

Standard deposition models

- Results meet expectations.
- Differences between deposition models significantly increase deviations in ground concentrations at some distances.
- HYSPLIT deposition velocities across the distance range are lower than ones typically used with the Gaussian model.
- Higher deposition velocities cause the suspended aerosols to be depleted faster.

Test Result Summary – Case 5

Standard weather data for both models

- Results meet expectations.
- Differences between weather data significantly increase deviations in air concentrations across the range of distances.
- Ground concentrations are surprisingly similar over most of the distance range.
- Ground concentrations appear to be influenced by wet deposition.
- Consistent with ground concentrations, plume depletion is similar over much of the distance range.

Test Result Summary – Case 6

Weather sampling

- Results meet expectations.
- Differences in air concentrations are similar to Case 5, i.e., much larger than previous cases with simple weather.
- Ground concentrations are smoother than for Case 5 because results are averaged over a large set of weather trials.

References

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- Tadmor, J., and Y. Gur. 1969. Analytical Expressions for the Vertical and Lateral Dispersion Coefficients in Atmospheric Diffusion. Atmospheric Environment, Vol. 3, pp. 688–689.