MACCS2 v1.13.1 to WinMACCS v3.11.2 Code to Code Comparison

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Overview

- Background

- Case Matrix

- Key Metrics

- Acceptance Criterion

- Sigma-z Code Error Correction

- Conclusions

- Recommendations

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Background

- Kinectrics has performed a number of assessments using MACCS2 1.13.1:
  - Level III PSA for NPPs in Ontario
  - Dose calculations to support consequences of a radionuclide release from a hypothetical severe accident at an NPP
  - Dose calculations to support refurbishment
  - Dose calculations to support new nuclear build
  - Assessment to support life extension

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Background

- Since the release of MACCS v1.13.1 in 2004, there have been 9 subsequent releases of the MACCS code.
  - Referring to MACCS engine, not WinMACCS
  - Latest release is WinMACCS 3.11.2
- A code to code comparison is required to determine impact of code changes on previous results
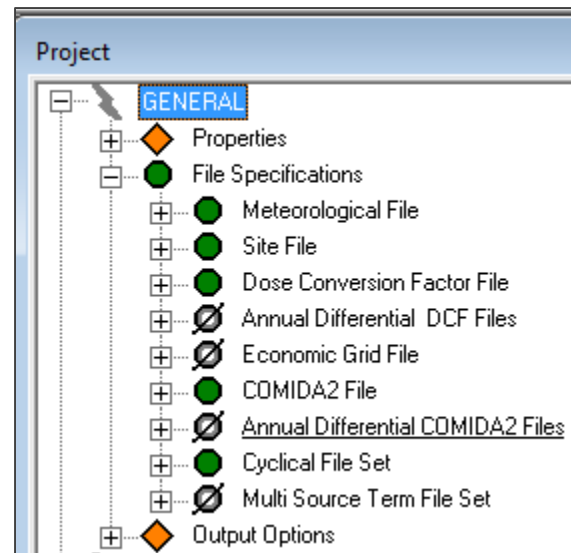
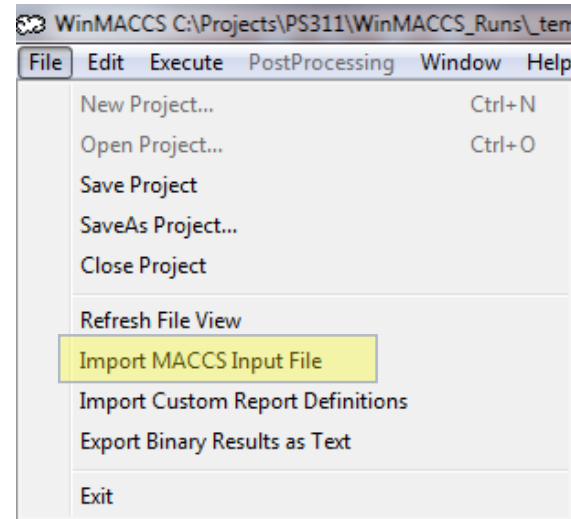**KINECTRICS**

Metrics

- **The following MACCS output was compared:**
  - Constant Wind Direction Centreline Dose
    - Represents the mean value of highest dose receivable by any individual at a given distance.
  - Highest Directional Centerline Dose
    - Corresponds to the highest mean dose estimated to be incurred by a representative individual assumed to reside at the centreline of a sector.
  - Average Dose
    - Corresponds to the calculated average population dose from all weather trials divided by the mean population in the designated region. The Avg dose is suitable for calculating health risk over large populations of the order of 100,000 or more.

Acceptance Criterion

- The discrepancies in the mean individual and population doses between the two code versions were documented

- Differences less than ±10% were considered acceptable and were not dispositioned
  - The criterion is reasonable given the number of changes over the past 9 code versions and the overall uncertainties in atmospheric dispersion and dose assessments.

- For instances where the acceptance criterion is not met, the bug fixes of each code revision were reviewed to rationalize the discrepancy.

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Input Alignment

- Approach:
  - Under File Menu, select "Import MACCS Input File", then select the ATMOS/EARLY/CHRONC input files
  - Other input files specified under "GENERAL", then "File Specifications"

- New parameters:
  - OALARM,
  - Protection factors in CHRONC phase,
  - Chemical group names

Results

- The results of the comparison between all dose outputs all followed the same trend:
    - At distances close to the release point (~1 km to 6 km), the doses calculated with WinMACCS are less than those calculated with MACCS2 and were within the +/-10% acceptance criteria.
    - At further distance from the release point (12 km- 90 km) the doses produced by WinMACCS showed a significant decrease relative to the MACCS2 doses of up to ~55%; exceeding the acceptance criterion.
    - The deviations are larger as the plume release is longer.

- The release notes were reviewed to identify code changes that could account for the differences in results
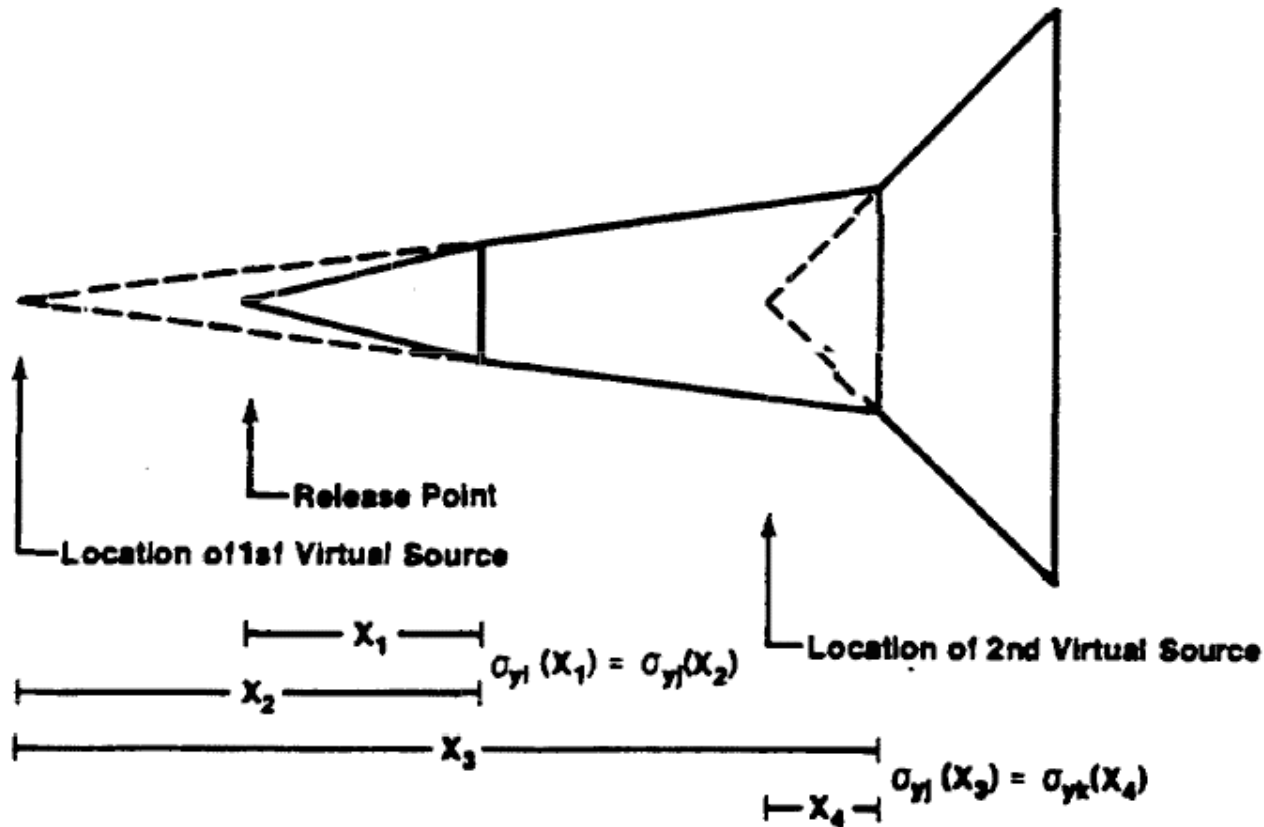
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Sigma-z Modelling

- Sigma-z refers to the vertical dispersion parameter in the Gaussian plume model:

$$\chi(x,y,z) = \frac{Q}{2\pi u \sigma_y \sigma_z} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \exp\left[-\frac{1}{2}\left(\frac{z-h}{\sigma_z}\right)^2\right]$$

  - The parameter governs the vertical spread of the plume with downwind distance.
  - The rate of expansion of a plume during downwind transport will also vary with stability class.

- Tabular experimental data of the dispersion parameters as a function of distance and stability class are provided as inputs into the code.
  - MACCS then uses a cubic spline interpolation algorithm for intermediate values

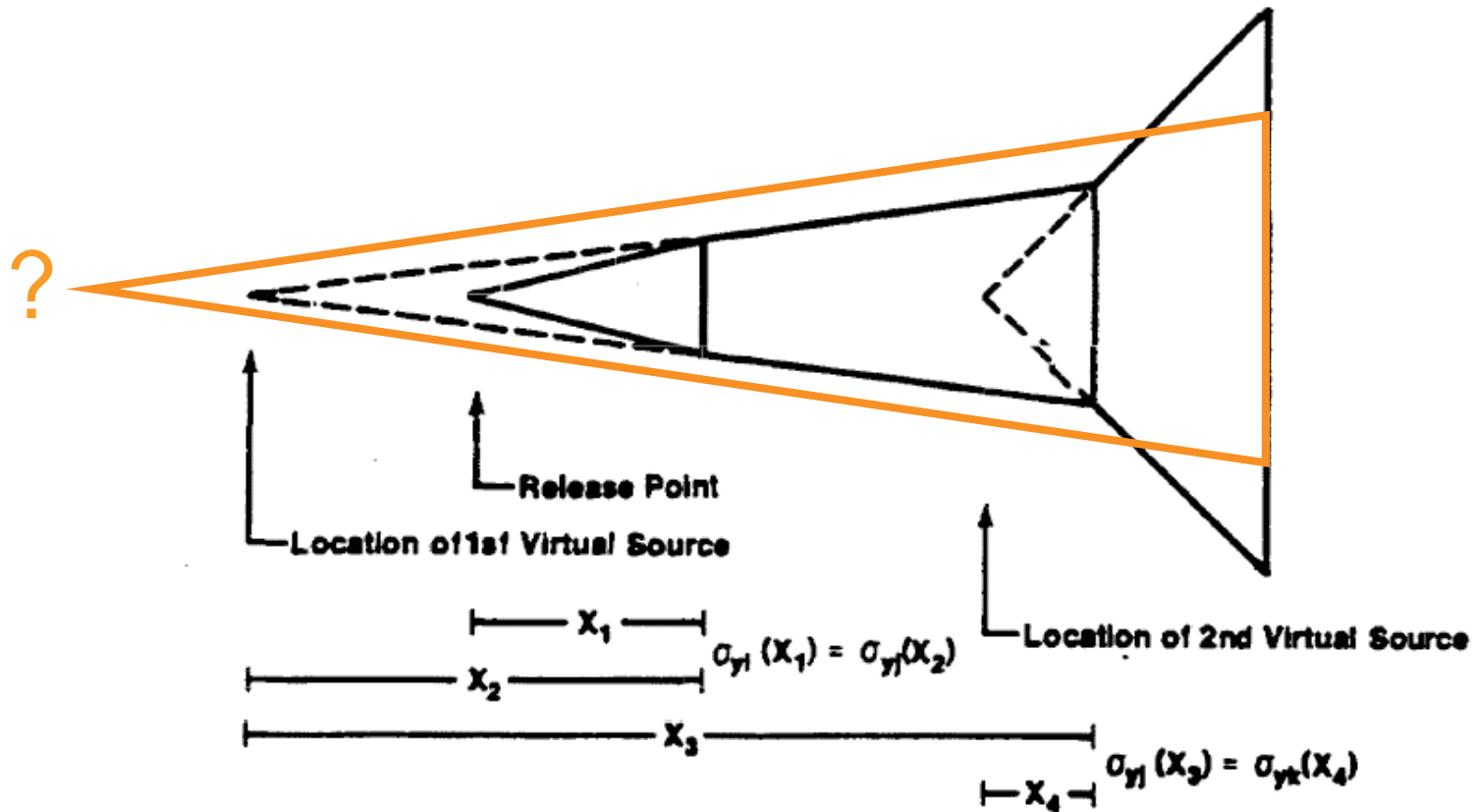- To ensure continuous growth of the plume, virtual source concept is used

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Sigma-z Modelling (Cont'd)

Growth of sigma-y during three time periods characterized by different atmospheric stabilities I, j, k [NUREG/CR-4691, Vol. 2]

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Error Description

- In MACCS2 v1.13.1, this algorithm fails when required to extrapolate beyond the range of the provided tabular data.
  - The error occurs if a stability class with a large sigma-z (A, B, or C) was used but then changes to D, E, or F, where the maximum sigma-z value in the lookup table was exceeded.
    - A virtual source location could not be calculated for the new stability class because the maximum value in the table for that stability class was exceeded

- In MACCS2 v2.4.0.5 and beyond:
  - When this occurs, the code version now uses the previous valid value of sigma-z until the stability class changes so that the maximum sigma-z value in the table is no longer exceeded (i.e., stability class becomes A, B, or C).
    - The code also issues a warning message in the output file

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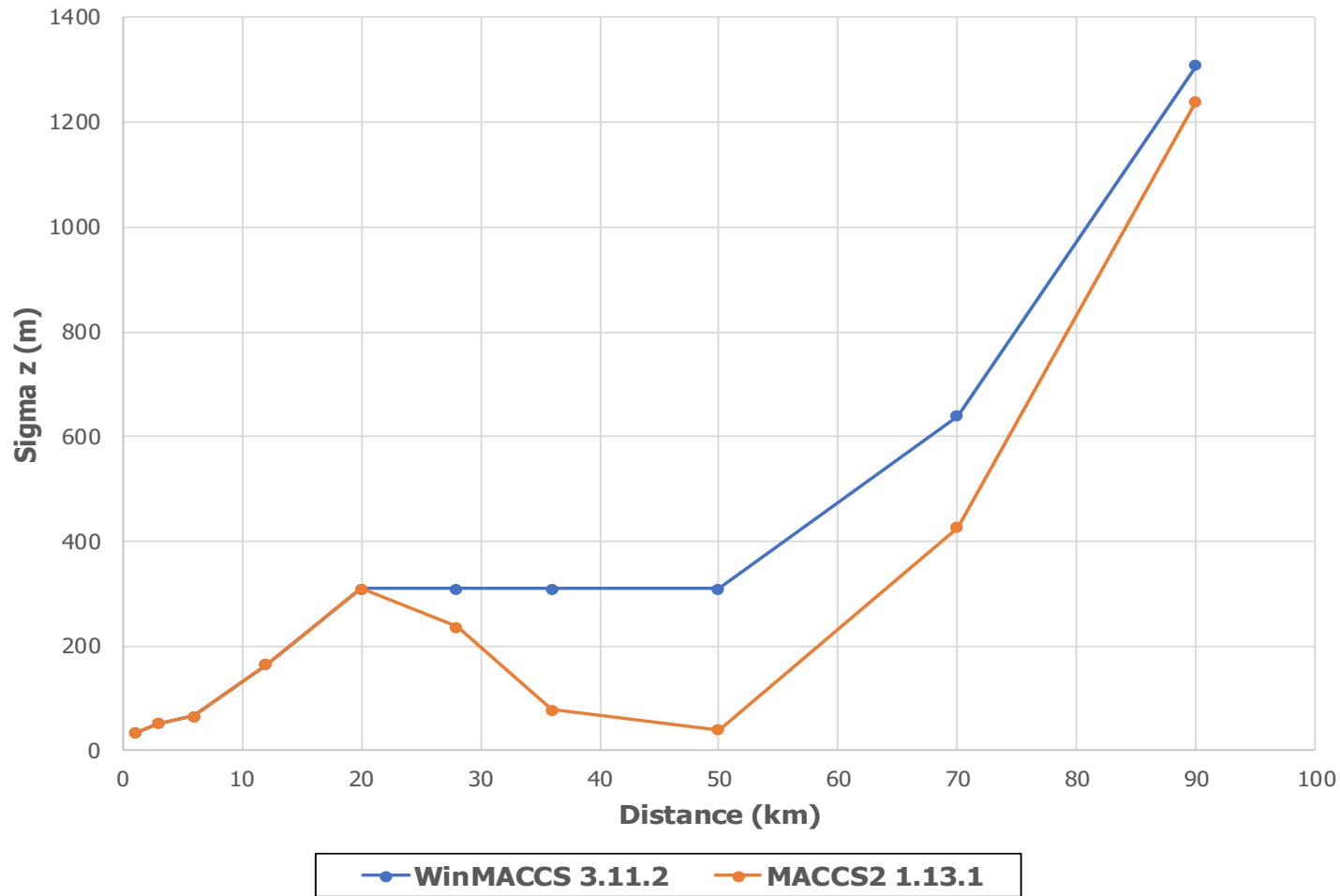**KINECTRICS**

Error Description in MACCS2 v1.13.1

Growth of sigma-y during three time periods characterized by different atmospheric stabilities I, j, k [NUREG/CR-4691, Vol. 2]

Error Confirmation

- Review of the WinMACCS output files confirms the presence of the newly added warning message in a large fraction of the weather trials.

- The weather trials were compared between code versions:
  - The ATMOS debug mode produces intermediate results for every weather trial.
  - Weather trials that do not display this warning message have identical dispersion results.

- For further confirmation, the vertical dispersion parameter (sigma z) is plotted with distance for one weather trial affected by the error

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Error Confirmation (Cont'd)

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Conclusions

- The impact assessment looked at dose from three scenarios and two wind direction assumptions.

- An acceptance criterion of ±10% was considered acceptable and would not require a disposition.

- Based on a review of the results, the sigma-z code error correction was determined to have a significant impact on the dose results, resulting in lower WinMACCS predictions of up to 55%.

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Recommendations

- Due to lack of available verification and validation information, it is difficult to qualify WinMACCS for certain applications
  - E.g., plant habitability assessments, emergency response planning, etc.

- QA documentation would help support compliance with codes and standards
  - E.g., regression testing from version to version which informs the code error reporting (i.e., what results are affected, how significant is the effect, etc.)
  - Verification and validation documentation

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