SAND2020-8592C

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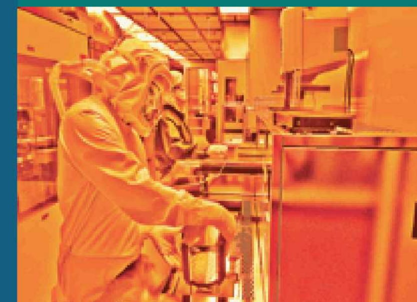
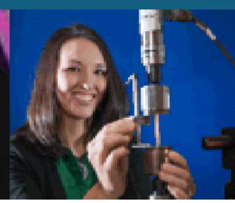
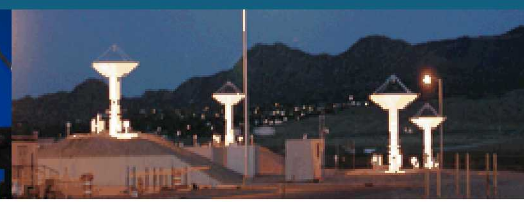
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Assessment of the MACCS Code Applicability for Nearfield Consequence Analysis







PRESENTED BY

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Presented at 2020 Virtual International MACCS Users' Group Meeting, August 31 to September 2, 2020

U.S. DEPARTMENT OF ENERGY NNSA

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Outline

Introduction/Setup

Code Trends

Code Comparisons

Wrap up

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Introduction (1/2)

1. The **adequacy** of the MELCOR Accident Consequence Code System (**MACCS**) **in the nearfield** is discussed in a **non-Light Water Reactor (LWR) vision and strategy report** that discusses computer code readiness for non-LWR applications developed by the Nuclear Regulatory Commission (NRC)

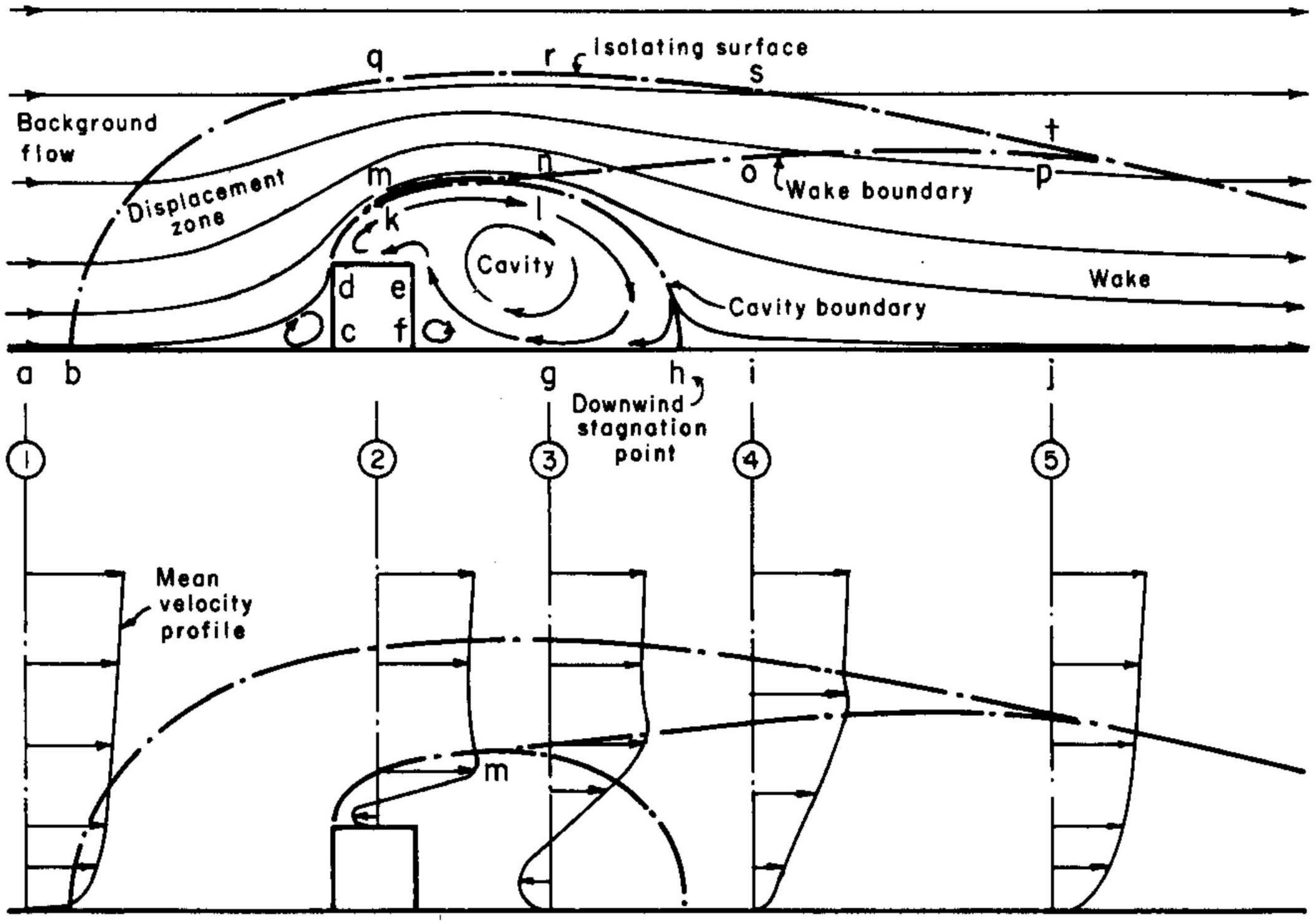
2. MACCS currently includes a **simple model** for building wake effects. The MACCS2 User's Guide suggests that this simple building wake model **should not be used at distances closer than 500 m**. This statement raises the first question of **whether MACCS can reliably be used to assess nearfield doses**, i.e., at distances less than 500 m

Introduction (2/2)

3. MACCS is a **highly flexible** Gaussian model and the **user can choose whether to model a variety of physical phenomena**, including such things as building wake effects, plume buoyancy, and plume meander. Furthermore, the user has flexibility in choosing how to model the Gaussian dispersion parameters

4. So, a **second question** goes beyond the first question of whether MACCS can be used in the nearfield to the related question of **how can MACCS be used to generate results that are bounding** of other codes intended for nearfield analysis

General Arrangement of Flow Zones Near a Sharp-edged Building



Meteorology and Atomic Energy, 1968

Objective

An **evaluation of modeling approaches** (**methods**) to estimate nearfield air concentrations and depositions **was performed** where several **candidate codes** were **ranked for comparison** and potential incorporation into the MACCS code

In this report, it is **assumed** that the **results from the selected codes** are all **adequate in the nearfield**, which is reasonable because these codes are specifically intended to be used in the nearfield

Hence, by **comparing the results** of these codes to the results from MACCS, the **adequacy of MACCS for assessing exposures in the nearfield can be evaluated**, along with determining how **MACCS can be used to generating bounding results**

Nearfield Code List

Four **candidate codes** were selected from the three **main methods** of atmospheric transport and dispersion (ATD) in the nearfield and evaluated

- CFD models – OpenFOAM
- Simplified wind-field models – QUIC
- Modified Gaussian models – AERMOD and ARCON96

	Model Characteristics					
Model	**Simplicity**	**Efficiency**	**Validation**	**Conservative Bias**	**Community Acceptance**	**Ease of Implementation**
OpenFOAM	3	3	1	2	1	3
QUIC	3	2	1	2	2	3
ARCON96	1	1	2	2	1	1
AERMOD	1	1	1	2	1	2

Based on these rankings, QUIC, AERMOD, and ARCON96 and were selected for comparison with MACCS

Test Cases

Two weather conditions

- 4 m/s, neutrally-stable (D stability class) – typical condition
- 2 m/s, stable (F stability class) – reduced dispersion condition

Three building configurations (HxWxL)

- 20m x 100m x 20m (5:1 W:H) – extreme width to height ratio
- 20m x 40m x 20m (2:1 W:H) – typical building size
- No building (point source) – evaluate differences for elevated releases with no building

Two power levels (heat content)

- 0 MW – without buoyancy
- 5 MW – with buoyancy

Weather/Energy Content	Building HxWxL (m)		
	20x100x20	20x40x20	None
4 m/s, D stability, 0 MW	Case01	Case05	Case09
2 m/s, F stability, 0 MW	Case02	Case06	Case10
4 m/s, D stability, 5 MW	Case03	Case07	Case11
2 m/s, F stability, 5 MW	Case04	Case08	Case12

Code Trends

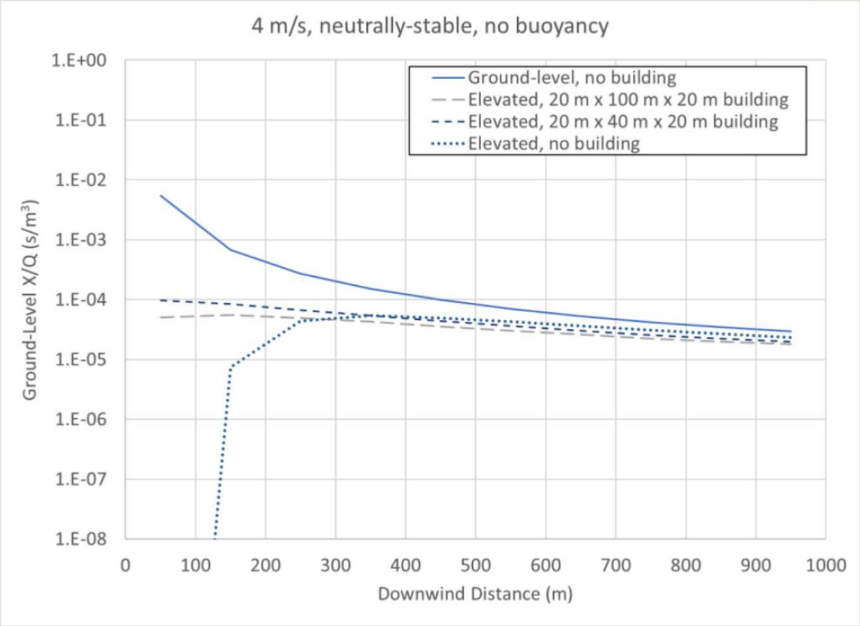
MACCS Results

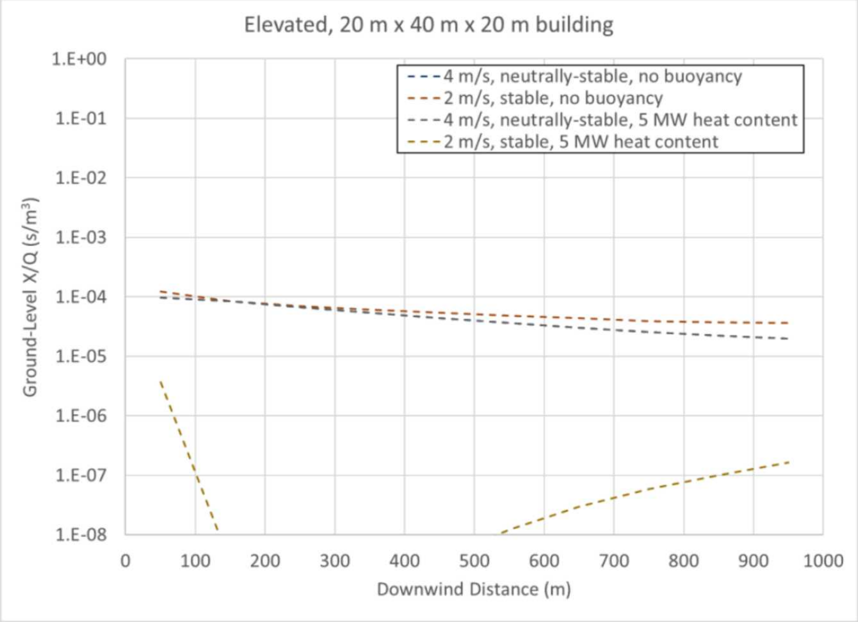
Building and **elevation** effects greatly **diminished** at 800 m **downwind**

Building significantly **increases dispersion** at short distances

Dilution for **stable** conditions generally **higher** than the corresponding dilution for **neutrally-stable** conditions

Buoyant plumes that escape building wake produce significantly **lower dilution values** due to fast plume rise compared with dispersion



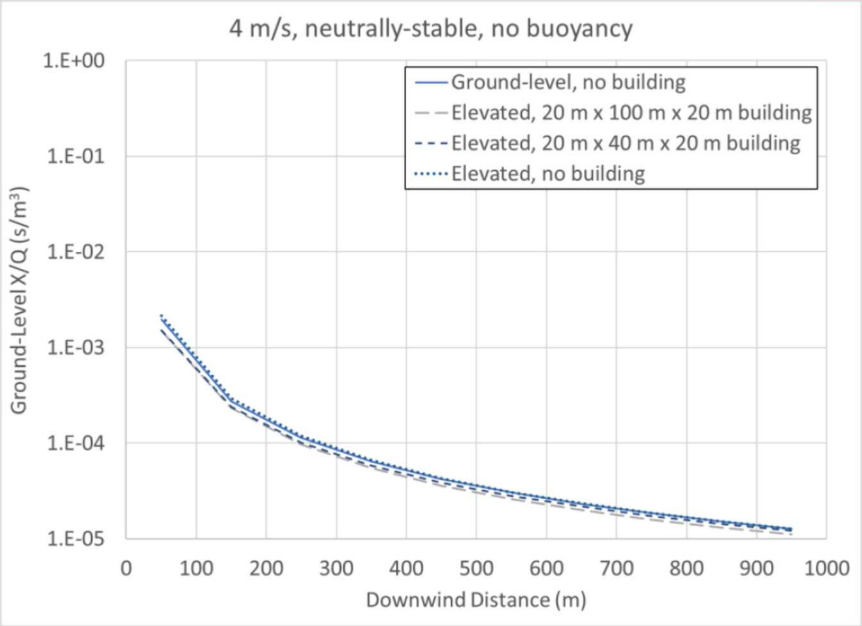


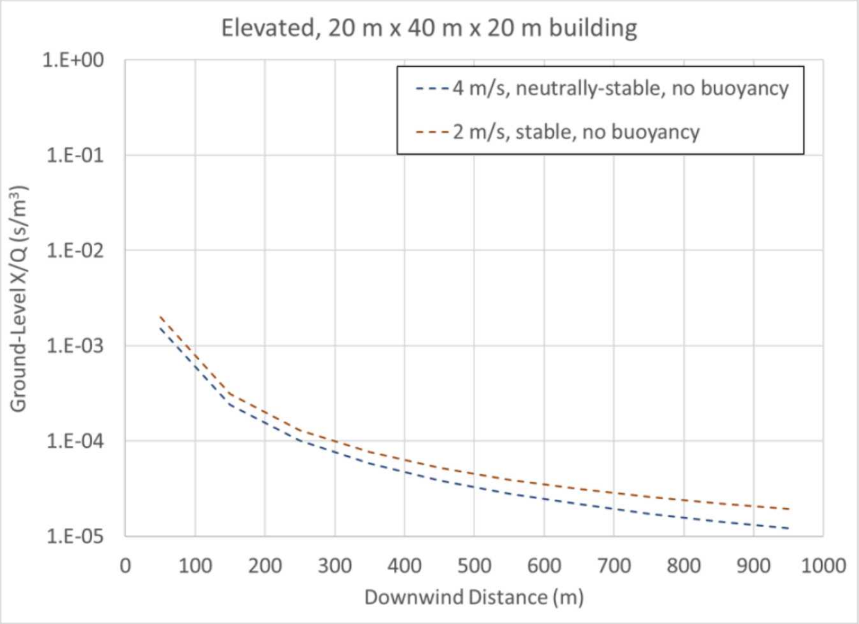
ARCON96 Results

Minimal change due to inclusion of **building** or **elevated** release within 1 km

Dilution for **stable** conditions generally **higher** than the corresponding dilution for **neutrally-stable** conditions

No plume rise model implemented; buoyant cases were not modeled





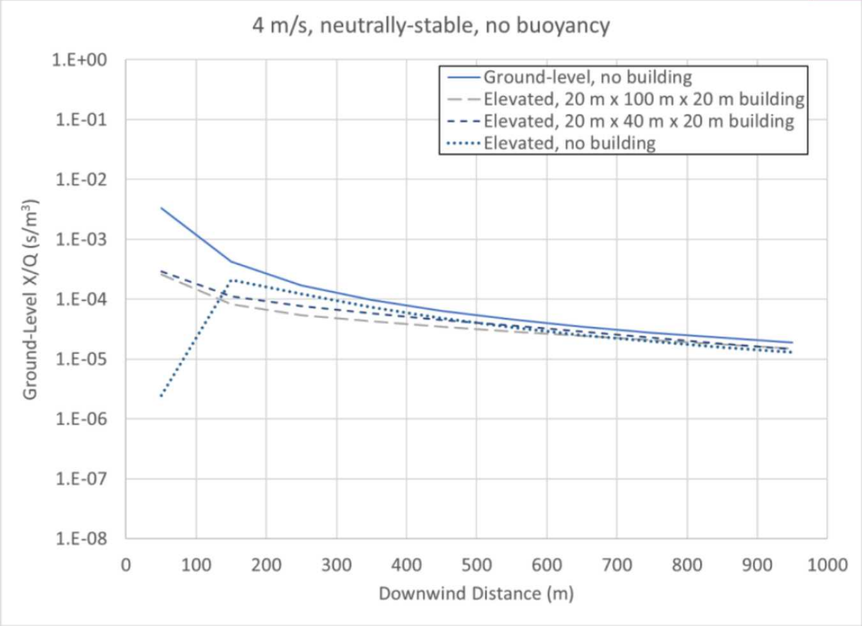
AERMOD Results

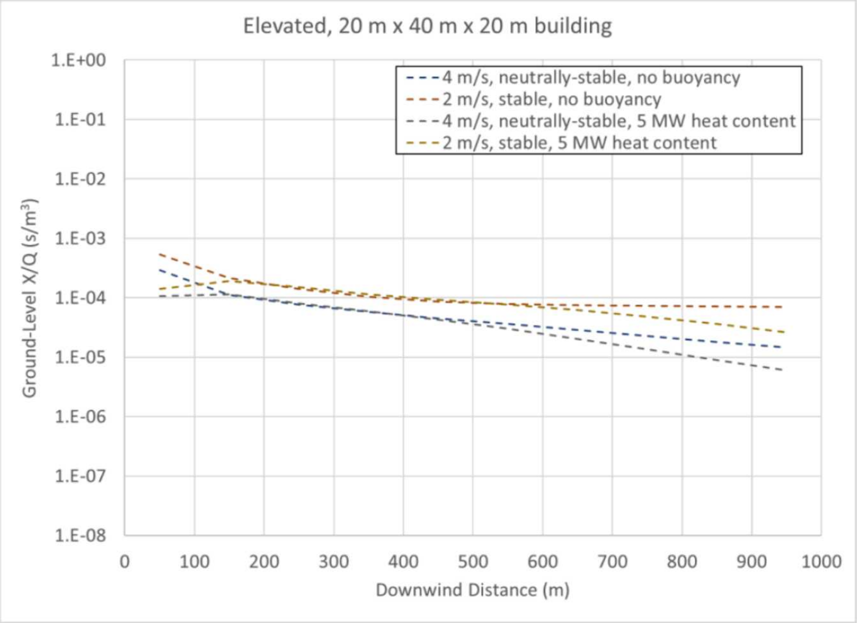
Building and **elevation** effects greatly **diminished** at 500 m **downwind**

Building significantly **increases dispersion** at short distances

Dilution for **stable** conditions generally **higher** than the corresponding dilution for **neutrally-stable** conditions

Minor differences due to **buoyancy**





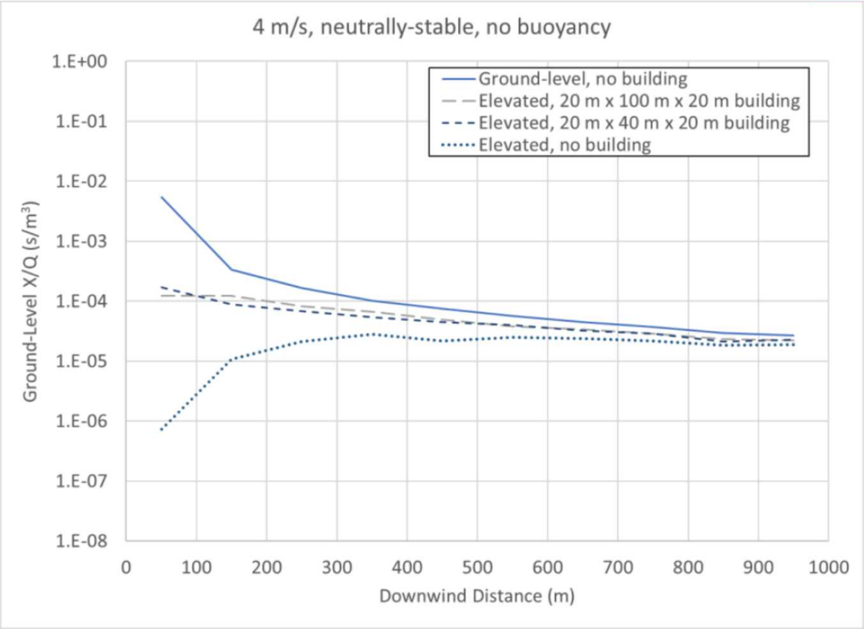
QUIC Results (1/2)

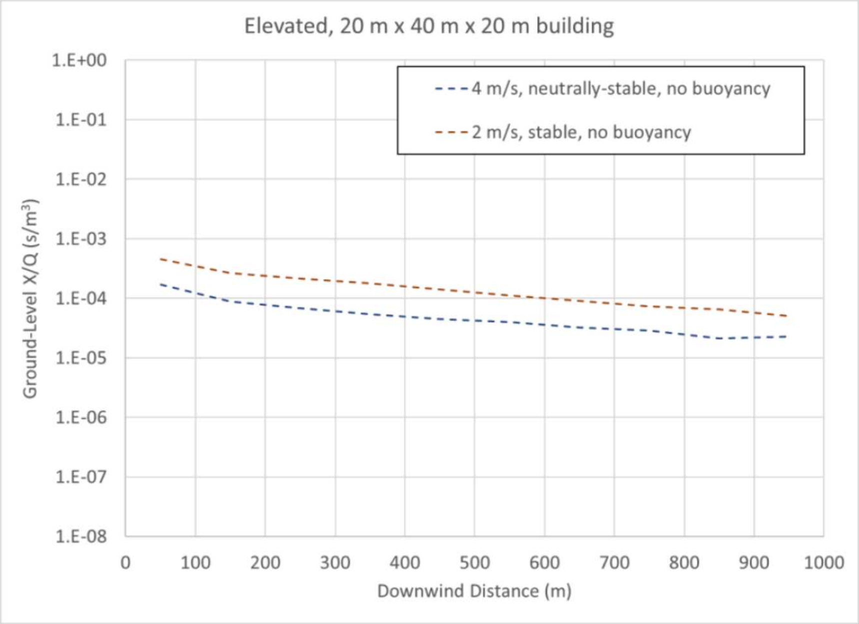
Building and **elevation** effects greatly **diminished** at 1 km **downwind**

Building significantly **increases dispersion** at short distances

Dilution for **stable** conditions generally **higher** than the corresponding dilution for **neutrally-stable** conditions

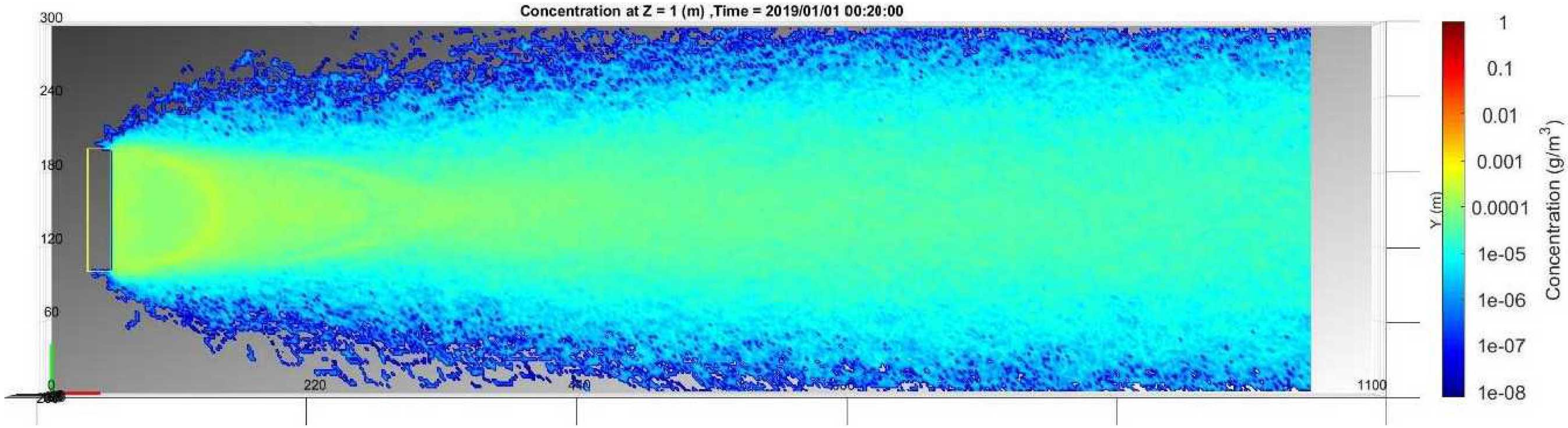
No straightforward way to implement buoyancy; buoyant cases were not modeled

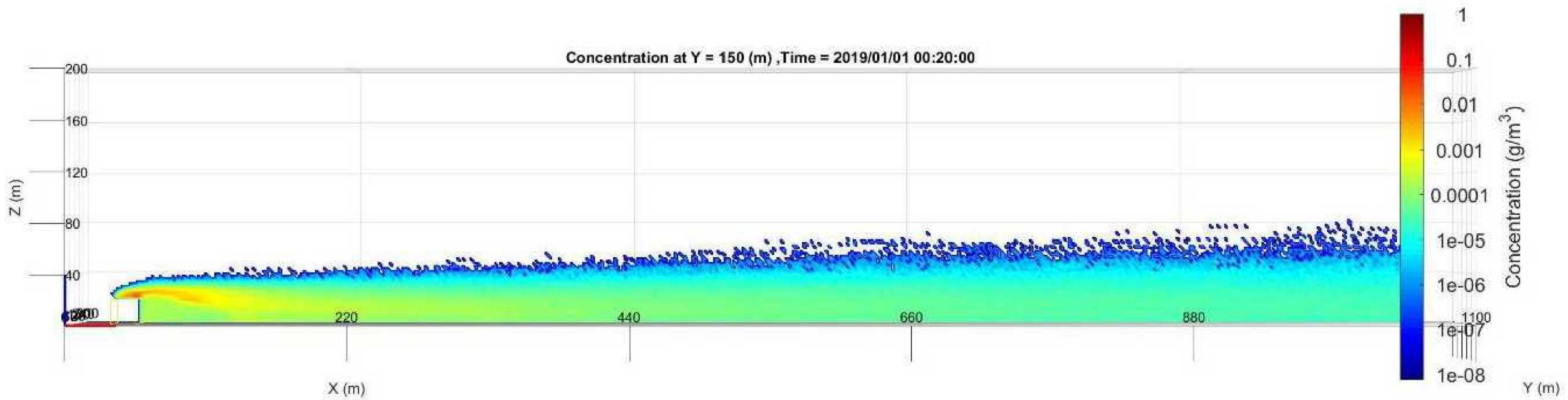




QUIC Results (2/2)

Horizontal and vertical slices for a 4 m/s, neutrally-stable weather condition with a non-buoyant, elevated release from a 20 m x 100 m x 20 m building (Case 01)





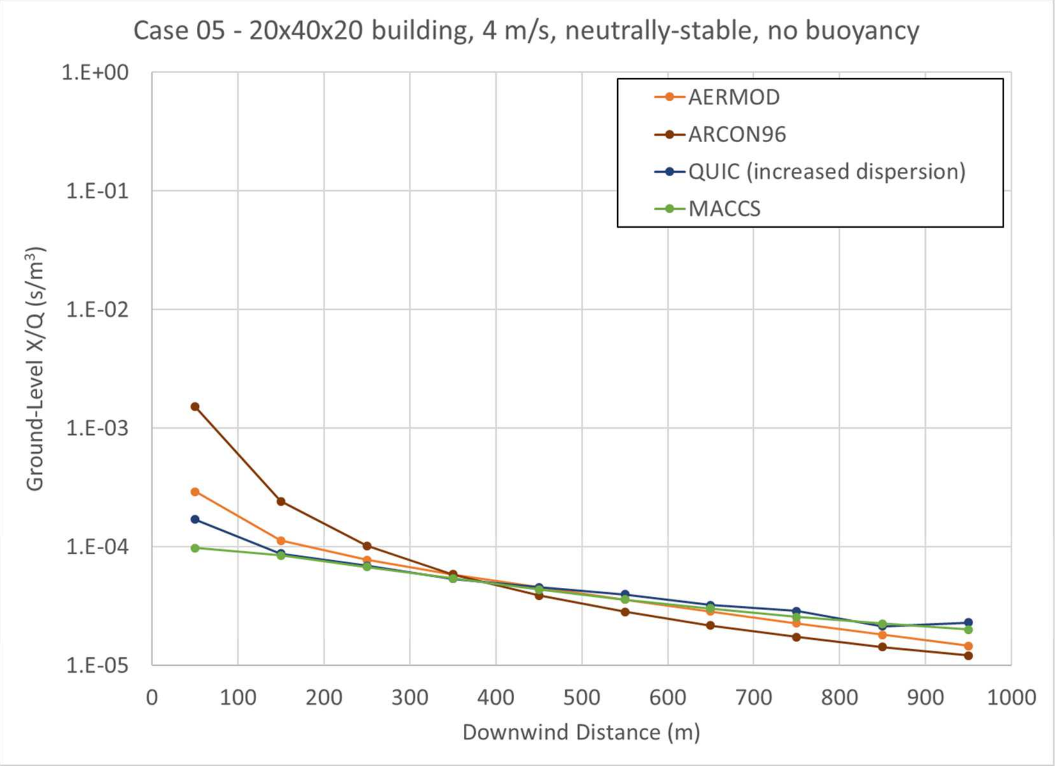
Code Comparisons

Comparison Results

At 50 m, order from **highest to lowest dilution** is ARCON96, AERMOD, QUIC, MACCS

Order changes with distance

- ARCON96 shifts from highest to lowest
- AERMOD shifts from 2nd highest to 2nd lowest
- Relative order between QUIC and MACCS is consistent



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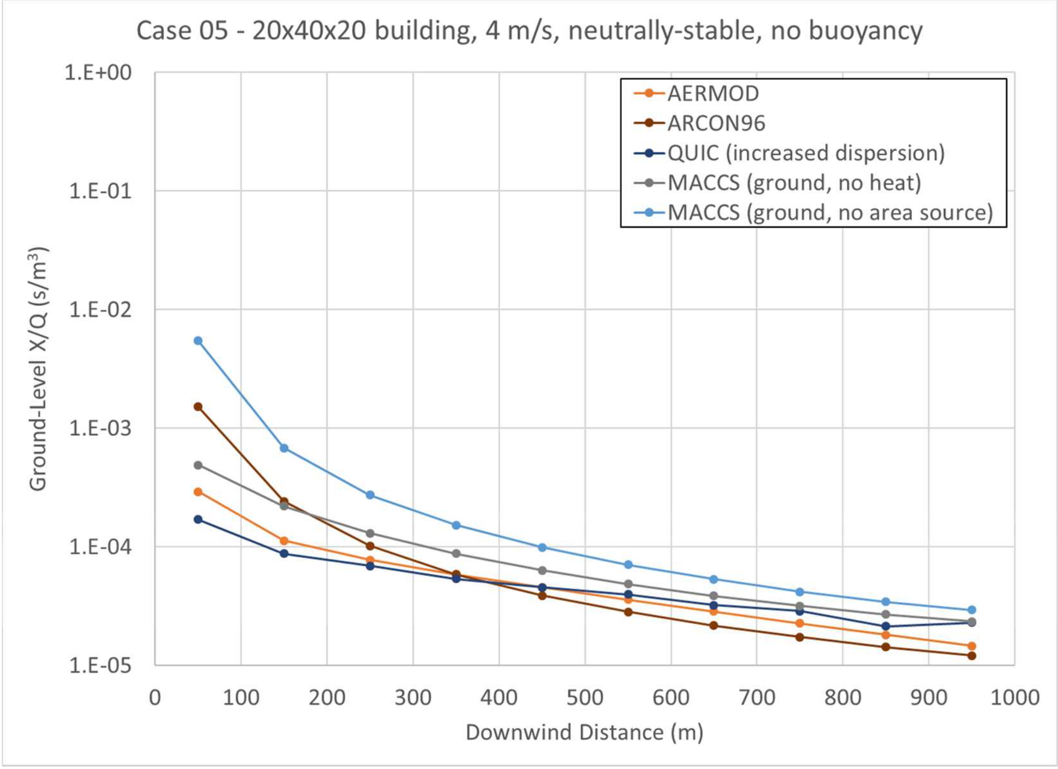
Potential Modifications to MACCS Input

1. Specify a **ground-level release**, instead of a release at the height of the building
   - **ARCON96** model showed **little dependence on elevation** of release
   - **Wake-induced building downwash** observed in QUIC output
   - **Regulatory Guide 1.145** discusses releases less than 2.5 times building height should be modeled as **ground-level releases**
2. Specify **no buoyancy** (plume trapped in building wake)
   - **AERMOD** model showed **little dependence on buoyancy**
3. If **additional conservatism** needed or desired, model as a **point source**
   - **ARCON96** model showed **little dependence on building** size
   - **DOE** approach used for **collocated workers**
   - If point source **too bounding**, use an **intermediate building** wake size

Updated Comparison Results

MACCS input **modified** to reflect a ground-level (1), non-buoyant (2) release (grey) **bounds AERMOD and QUIC** up to 1 km and **ARCON96** from 200 m up to 1 km

MACCS input **modified** to reflect a ground-level (1), non-buoyant (2), point-source (3) release (light blue) **bounds all three** up to 1 km



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Summary (1/3)

ARCON96, AERMOD, and QUIC selected for **comparison** with **MACCS** based on initial evaluation

Test cases developed to give a **broad range** of conditions, **not** to be **exhaustive**

- Two weather conditions
- Three building configurations
- Two buoyancy variations

Summary (2/3)

MACCS calculations configured with **point-source, ground-level, nonbuoyant plumes** provide conservative nearfield results that **bound** the centerline, ground-level air concentrations from **ARCON96, AERMOD, and QUIC** .

MACCS calculations with **ground-level, nonbuoyant plumes** that include the effects of the building wake (area source) provide nearfield results that **bound** the results from **AERMOD and QUIC** and the results from **ARCON96 at distances >200 m**

If using a **point-source** is **too conservative** and it is desired to bound the results from all three codes, another **alternative** is to use area source parameters in MACCS that are less than the standard values, i.e., an area source **intermediate** between the standard recommendation and a point source.

Summary (3/3)

MACCS can be used at distances significantly shorter than 500 m downwind (50 – 200 m) from a containment or reactor building

However, the MACCS user needs to **select** the MACCS input **parameters appropriately** to generate results that are adequately conservative for a specific application

A **conservative nearfield result** may be obtained using the **following MACCS parameter choices**:

- The parameterization of Eimutis and Konicek for the dispersion model.
- The plume meander model based on Regulatory Guide 1.145. This model is selected by setting the value of the MACCS parameter MNDMOD to NEW.
- The release modeled as a point-source, ground-level, nonbuoyant plume.

Additional information available from final technical report (Clayton D.J and N.E. Bixler, “Assessment of the MACCS Code Applicability for Nearfield Consequence Analysis” Sandia National Laboratories, Albuquerque, NM, February 2020, ADAMS Accession Number ML20059M032)