

Assessment of the MACCS Code Applicability for Nearfield Consequence Analysis



PRESENTED BY

Dan Clayton, Nate Bixler



Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Outline

Introduction/Setup

Code Trends

Code Comparisons

Wrap up



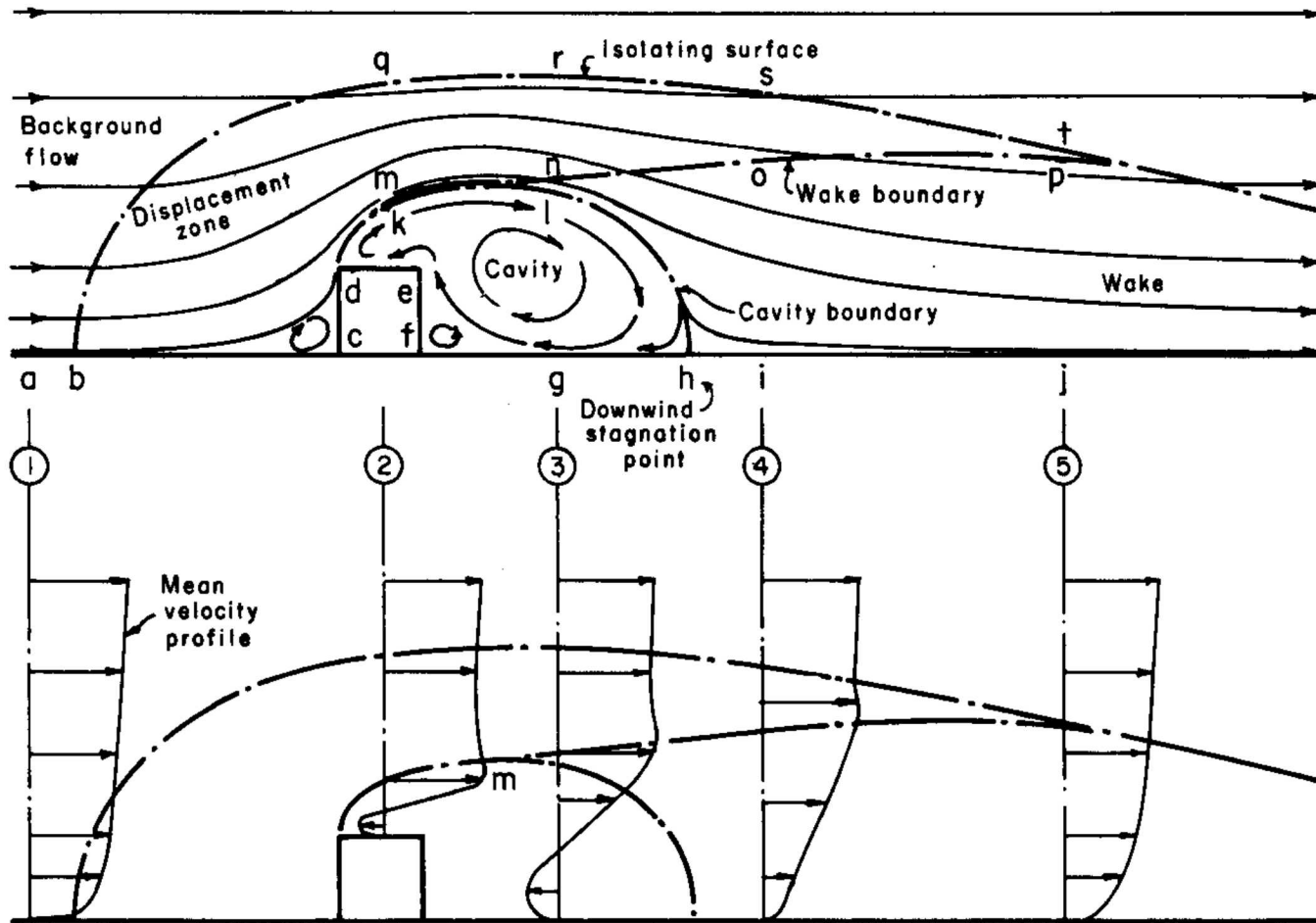
Introduction (1/2)

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 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 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



Objective

An **evaluation of modeling approaches (methods)** to estimate nearfield air concentrations and depositions **was performed**

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

7 Nearfield Code List

A set of **candidate codes** were selected from the **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	Model Characteristics					
	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

Implementation into Codes (1/2)

Required weather data

- MACCS – wind speed, direction, and PG stability class
- ARCON96 – wind speed, direction and PG stability class
- AERMOD – surface- and vertical-profile weather files, friction velocity, and Monin-Obukhov length (L)
- QUIC – wind speed vertical profile and direction, and $1/L$

Compared against a ground-level, point-source release to ensure correct implementation

Adjusted QUIC weather parameters to account for meander

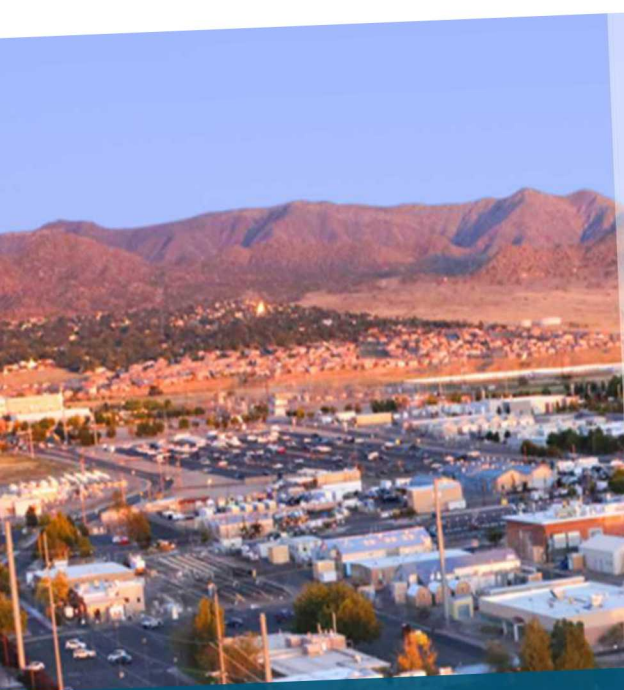
Implementation into Codes (2/2)

Required building data

- MACCS – building dimensions » initial dispersion parameters
- ARCON96 – building projected area
- AERMOD – building dimensions into a preprocessor
- QUIC – buildings defined graphically

Required buoyancy data

- MACCS – rate of release of sensible heat
- ARCON96 – no plume rise model
- AERMOD – define stack parameters (diameter, velocity, temperature)
- QUIC – no straightforward way to implement



Code Trends



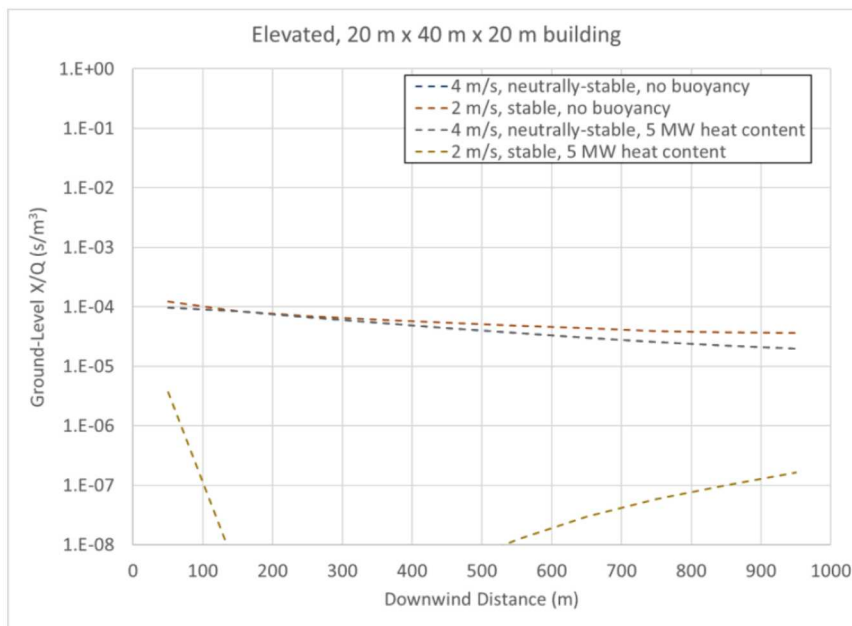
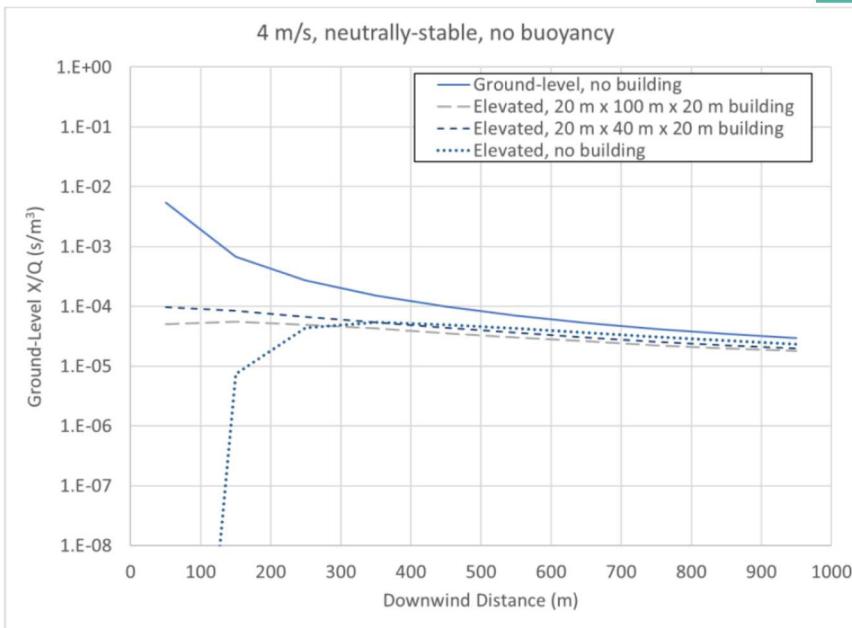
MACCS Results

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

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

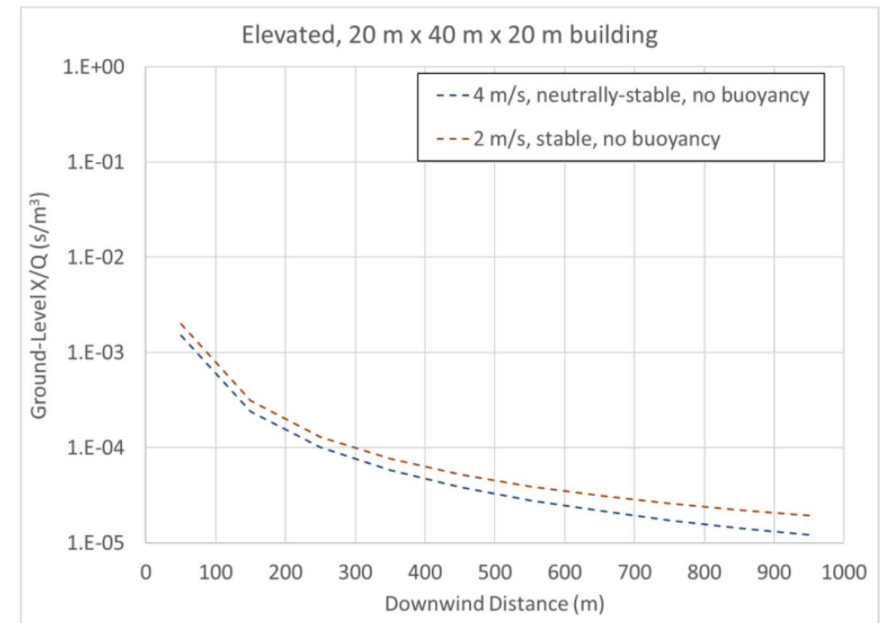
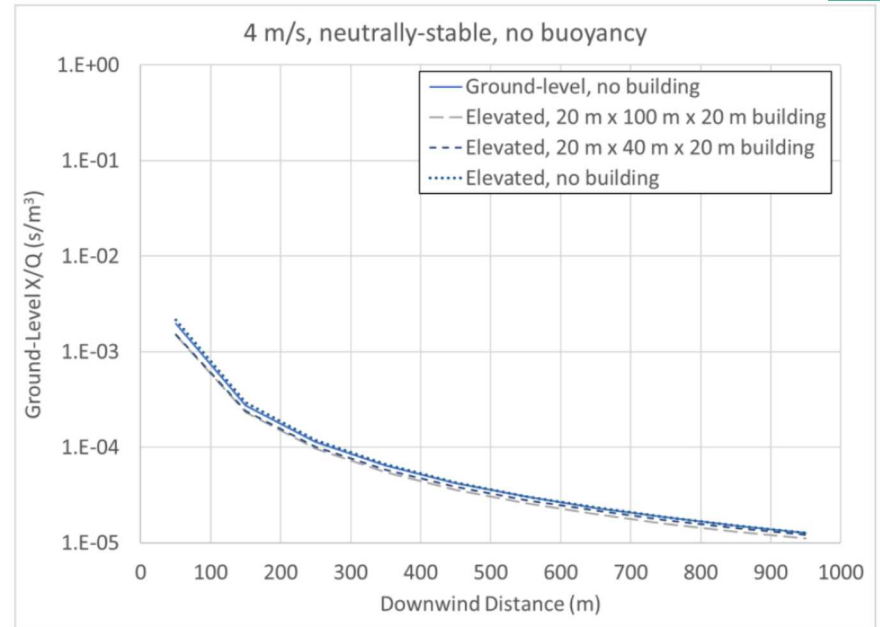


ARCON96 Results

Minimal change due to inclusion of **building** or **elevated** release

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

Buoyancy not modeled



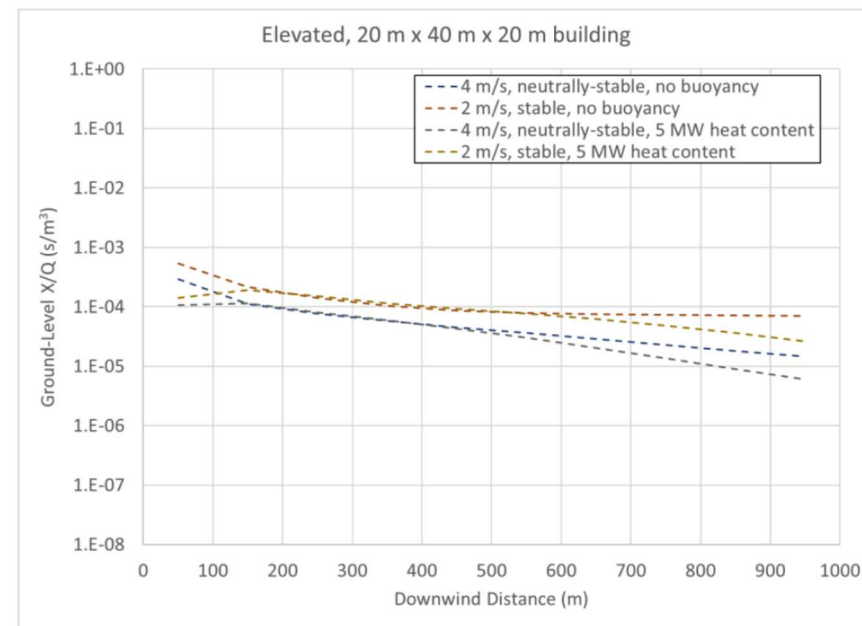
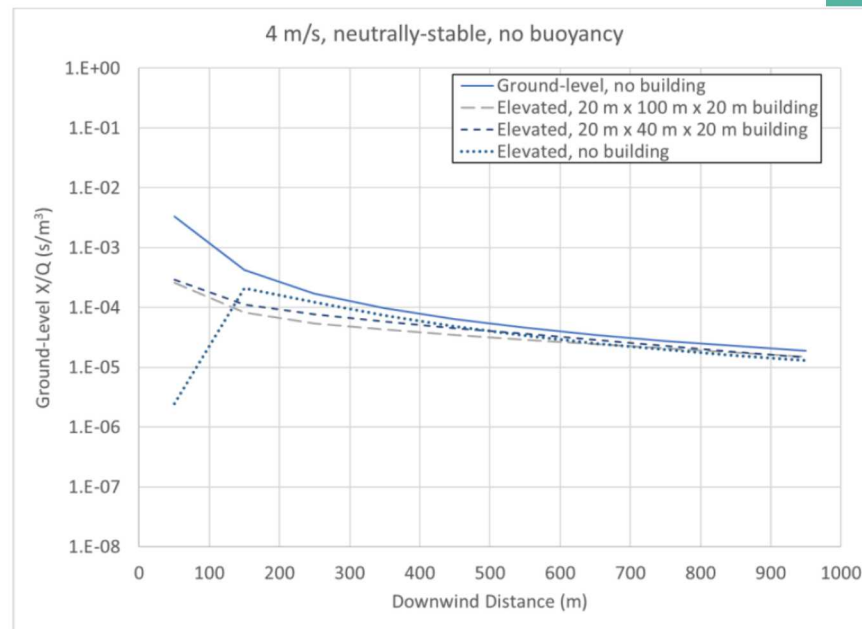
AERMOD Results

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

Minor differences due to buoyancy



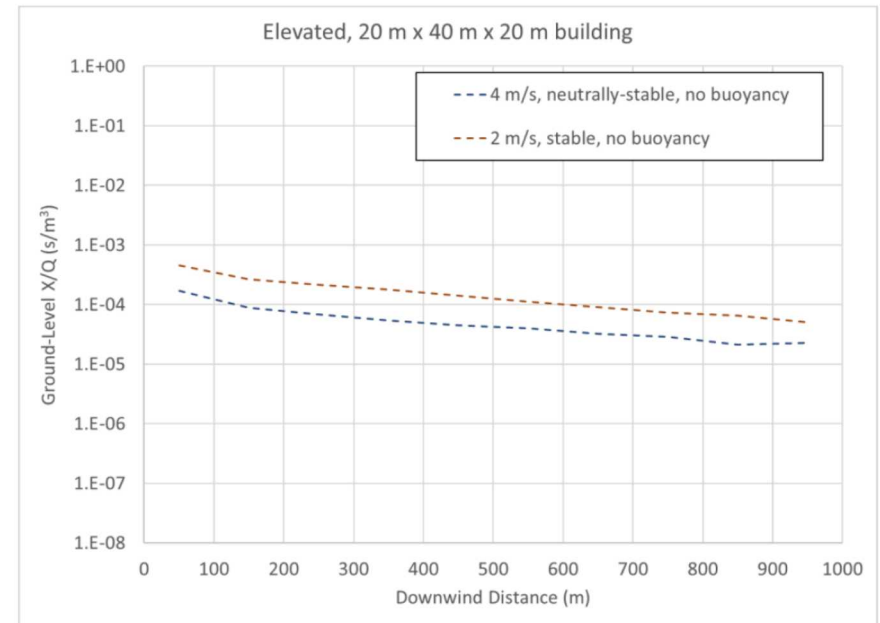
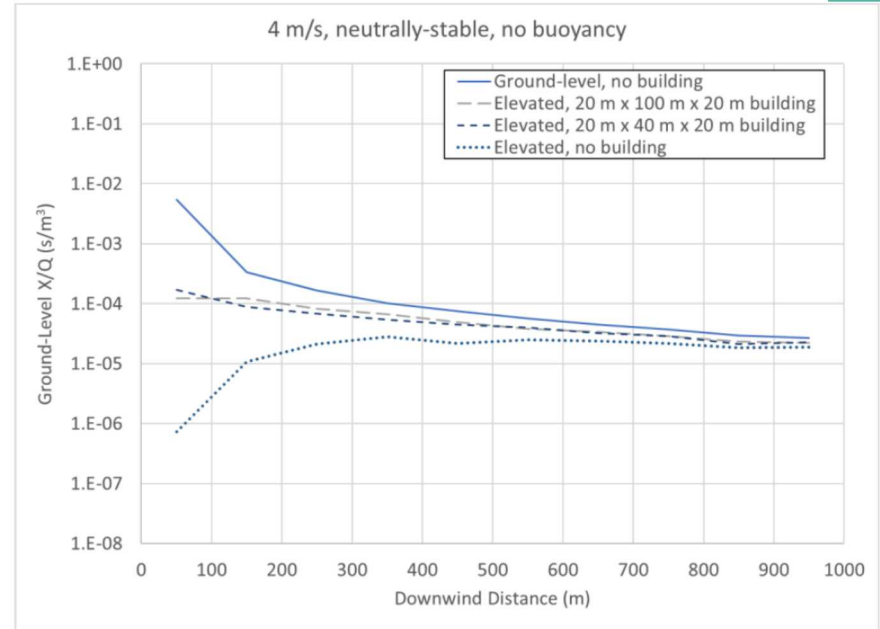
QUIC Results (1/2)

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

Building significantly **increases dispersion** at short distances

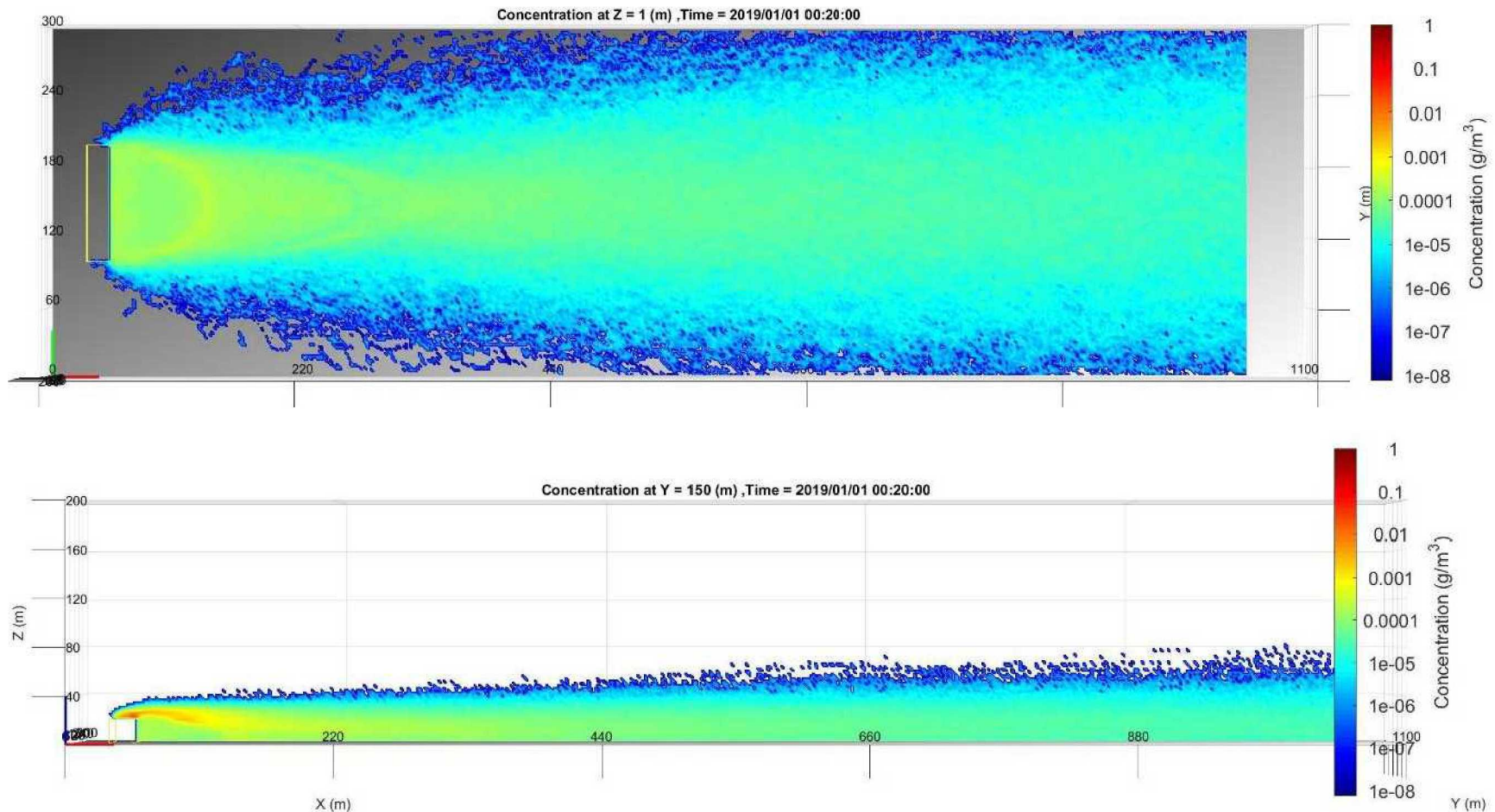
Dilution for **stable** conditions generally **higher** than the corresponding dilution for **neutrally-stable** conditions

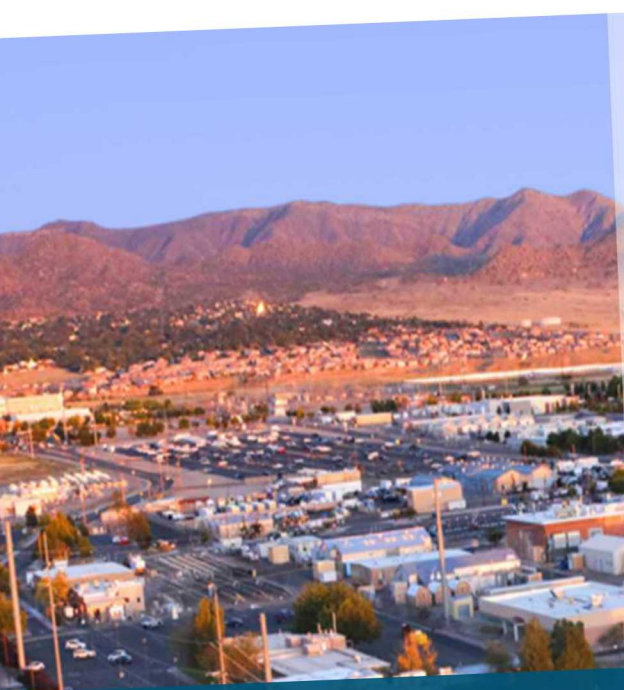
Buoyancy not modeled



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

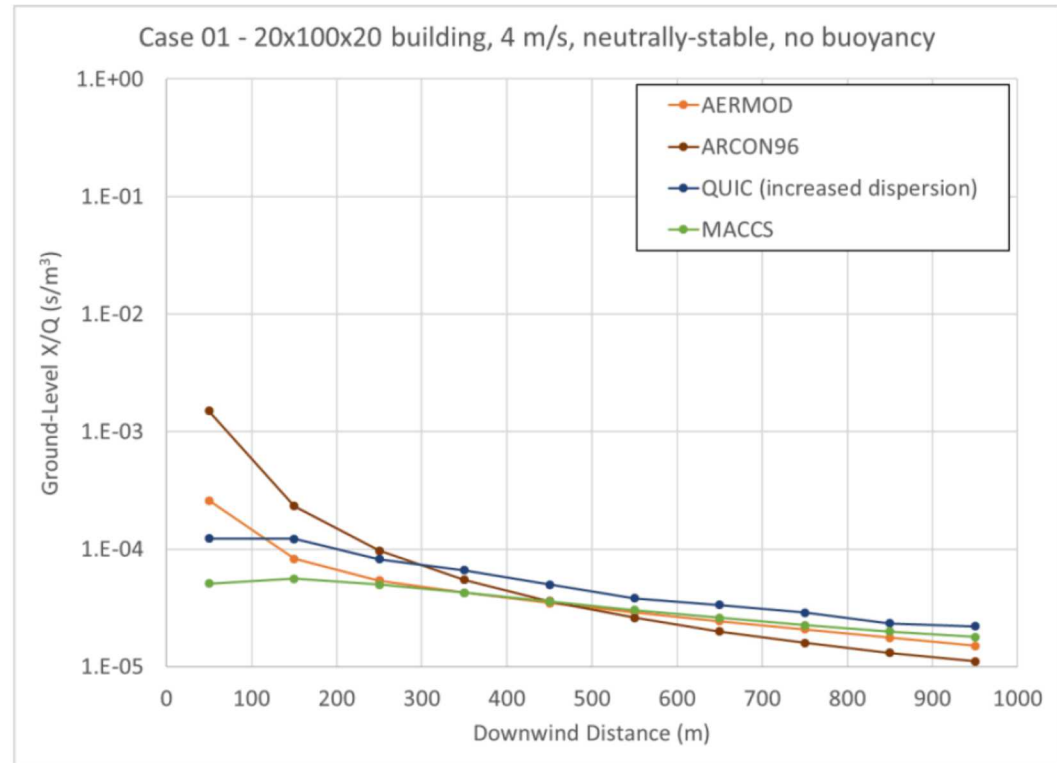


Comparison Results

At 50 m, order from highest to lowest 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



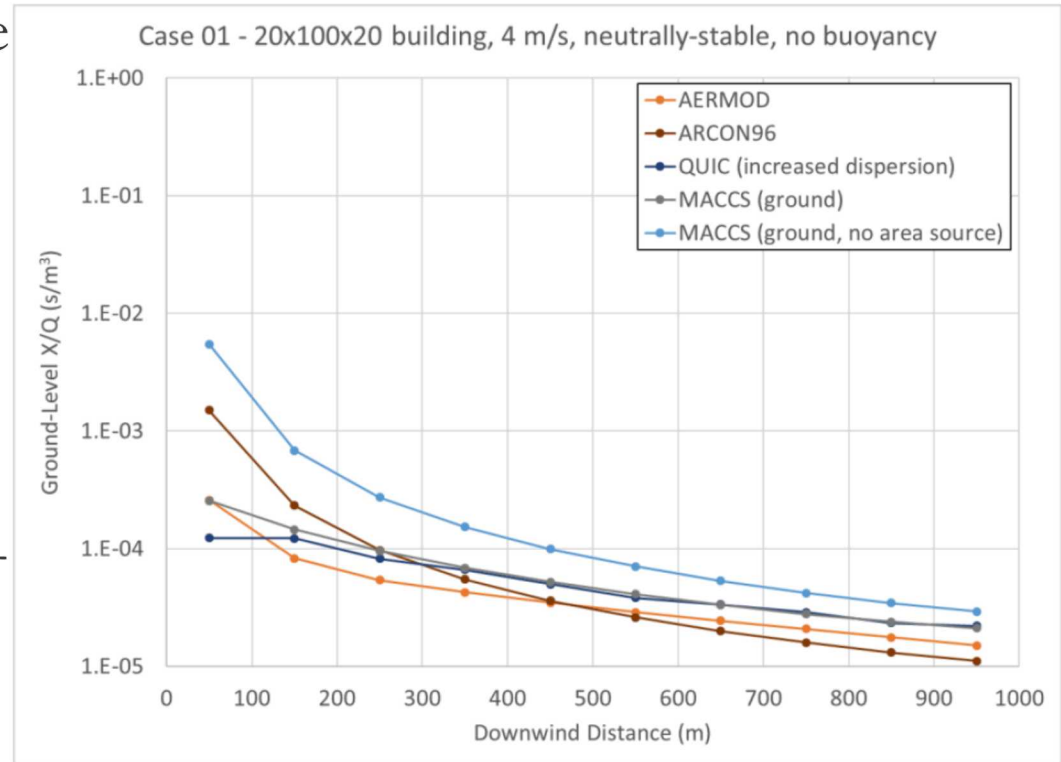
Potential Modifications to MACCS Input

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 release 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 250 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





Wrap up



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 >250 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 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