MACCS Code Applicability for Nearfield Consequence Analysis

PRESENTED BY

Dan Clayton

Sandia National Laboratories

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Outline

Introduction/Setup

Code Trends

Code Comparisons

MACCS Updates

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 first question of **whether MACCS can reliably be used to assess nearfield doses**, i.e., at distances less than 500 m

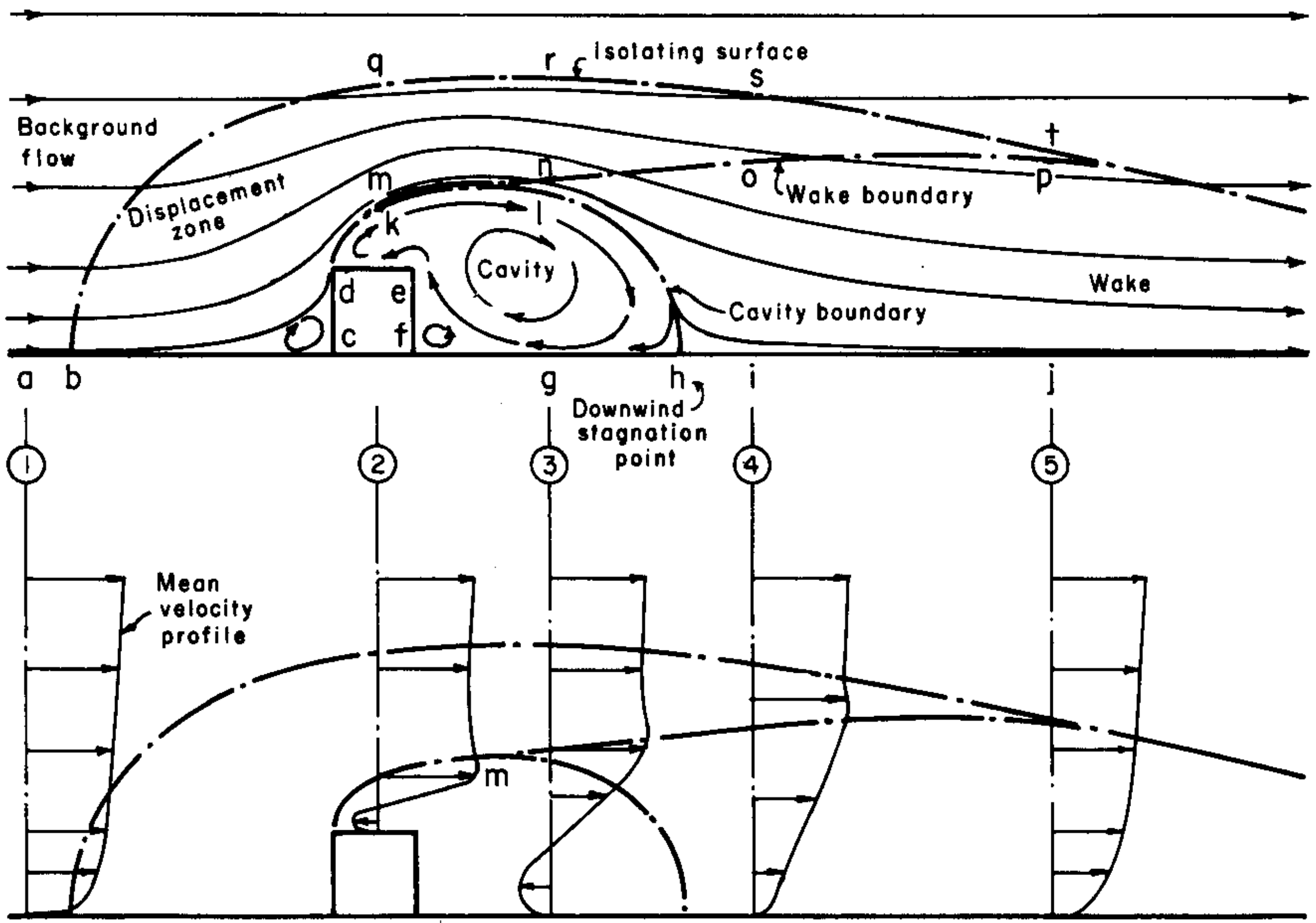
Introduction (2/2)

3. MACCS is a **highly flexible** Gaussian model and the **user can choose whether to model a variety of physical phenomena**, including:
   - Building wake effects
   - Plume buoyancy
   - Plume meander

   Furthermore, the user has flexibility in choosing how to model the Gaussian dispersion parameters

4. Second question, can MACCS be used in the nearfield? If so, **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 assessment, 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 generate 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 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

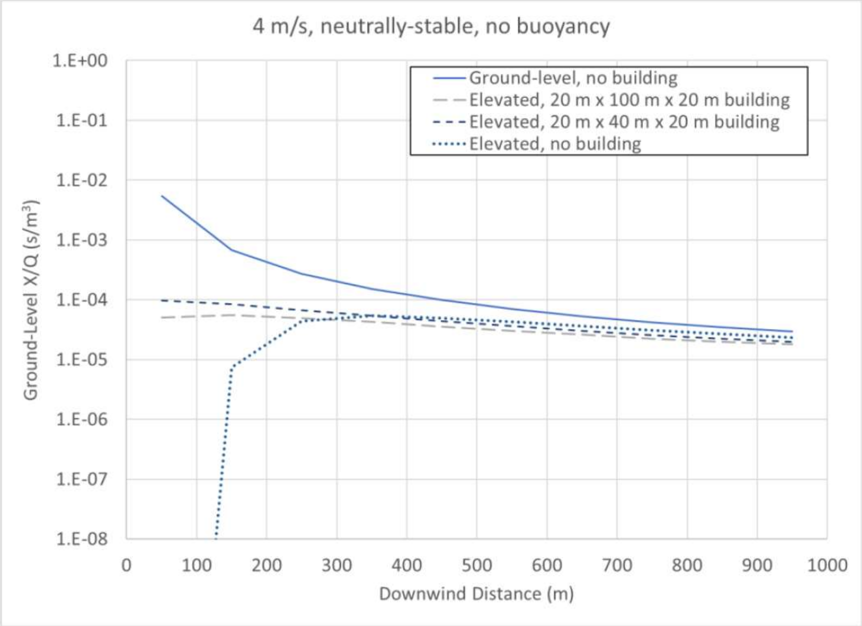
MACCS Results

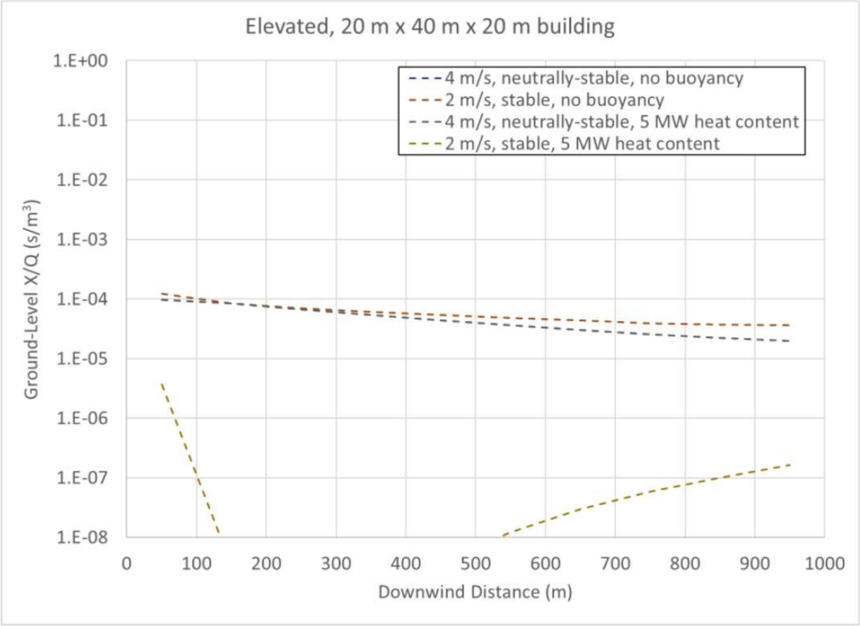
Building and **elevation** effects greatly **diminished** at 800 m **downwind**

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



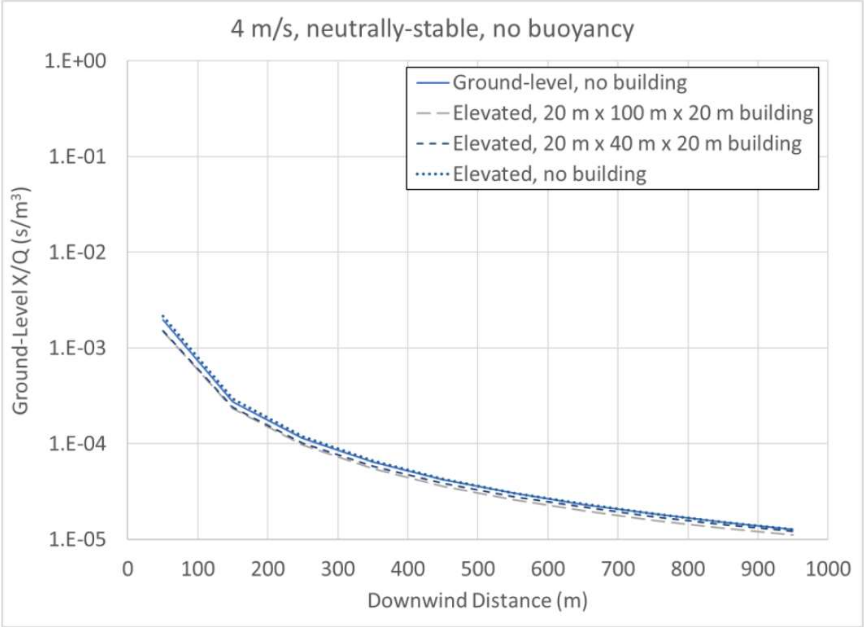


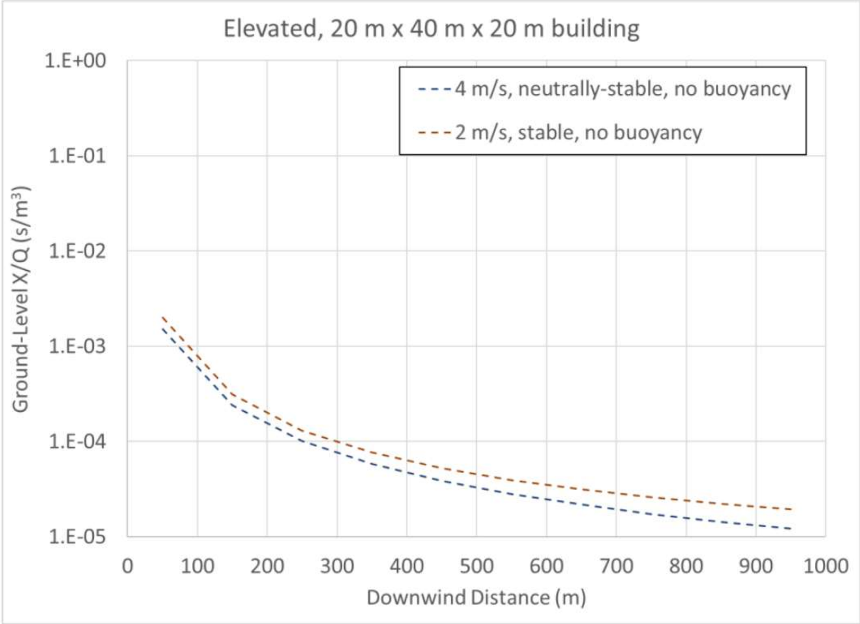
ARCON96 Results

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





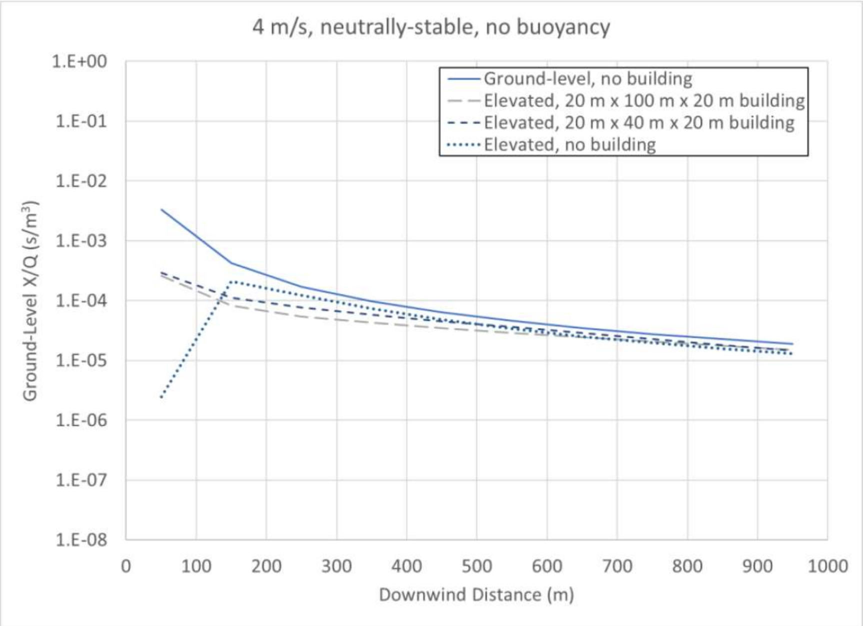
AERMOD Results

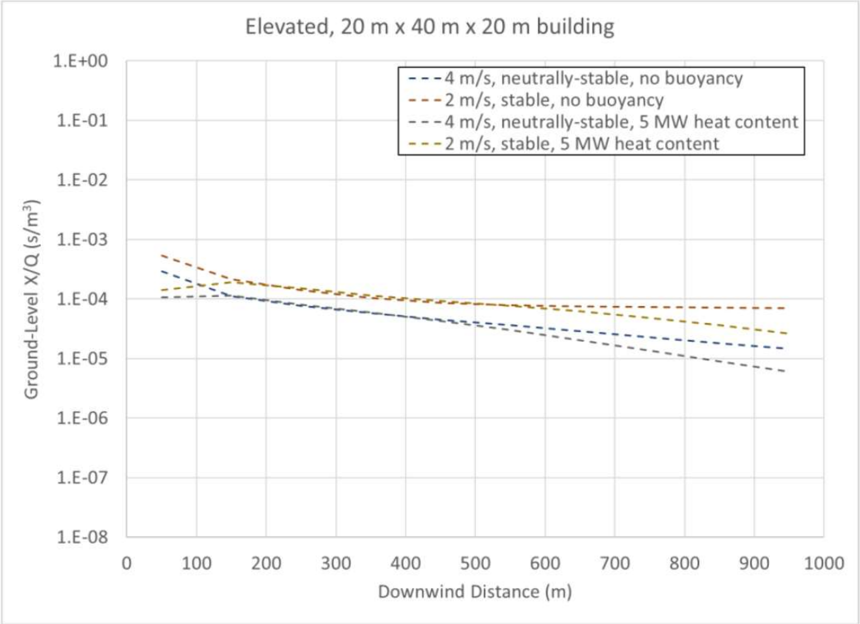
Building and **elevation** effects greatly **diminished** at 500 m **downwind**

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**





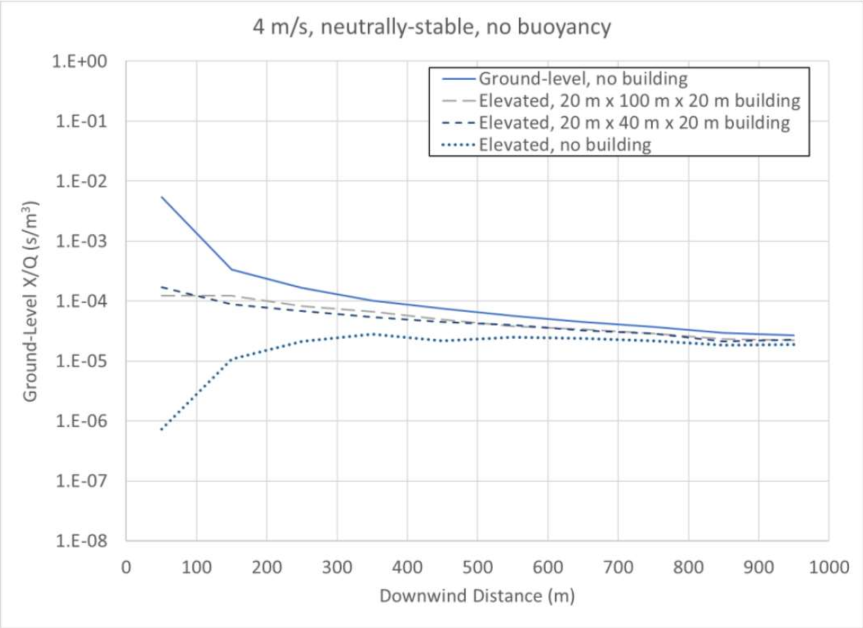
QUIC Results (1/2)

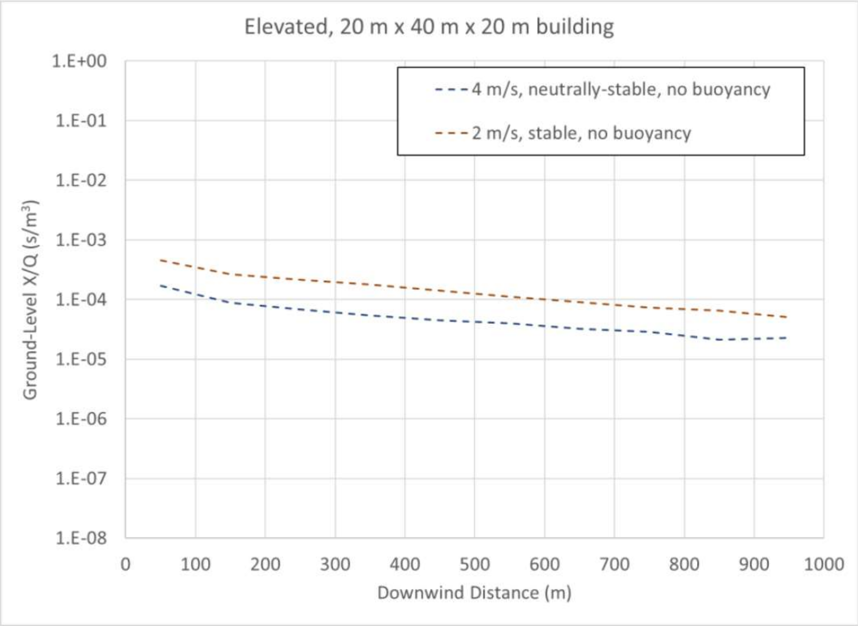
Building and **elevation** effects greatly **diminished** at 1 km **downwind**

Building significantly **increases dispersion** at short distances

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

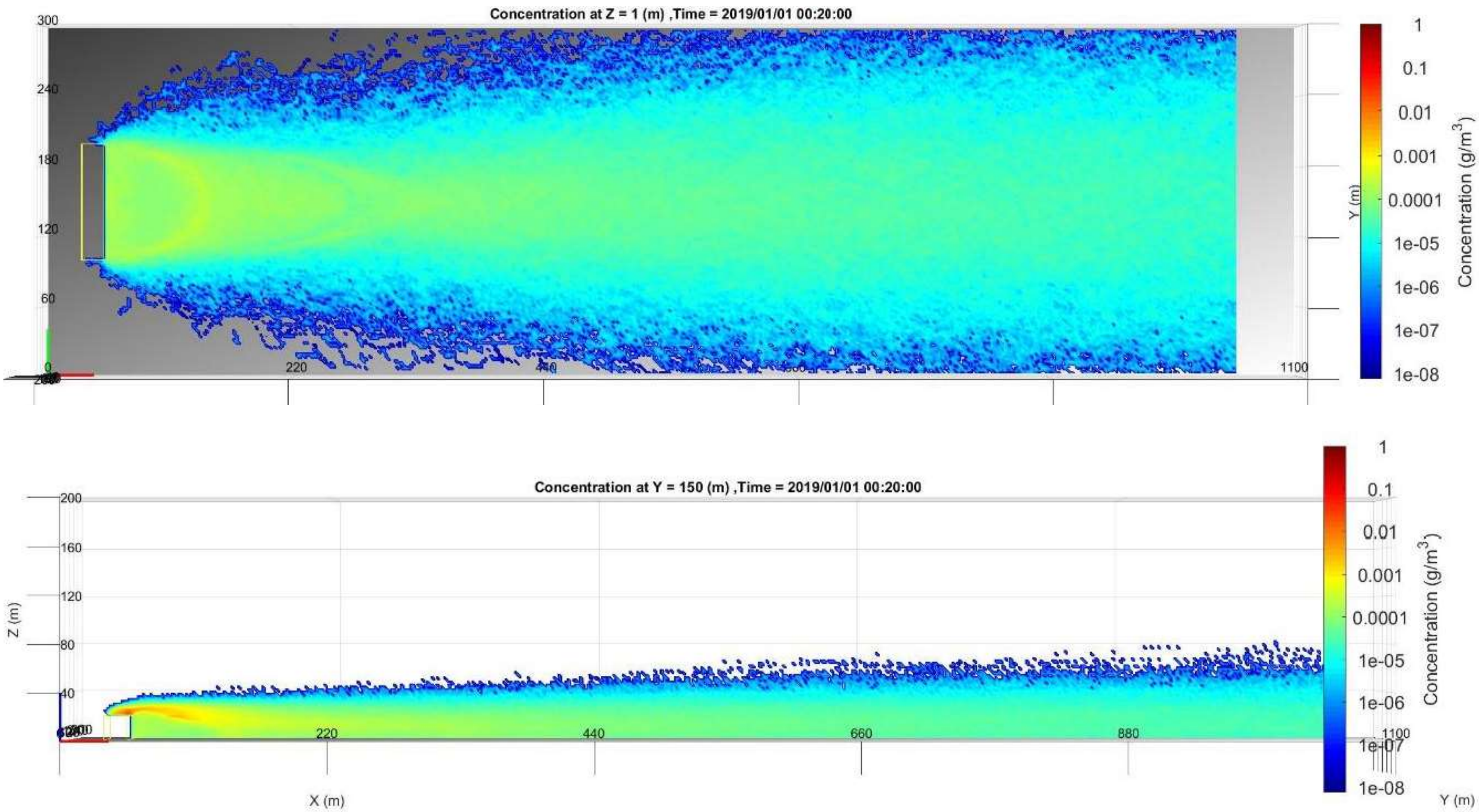
No straightforward way to implement buoyancy; buoyant cases were not modeled





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)



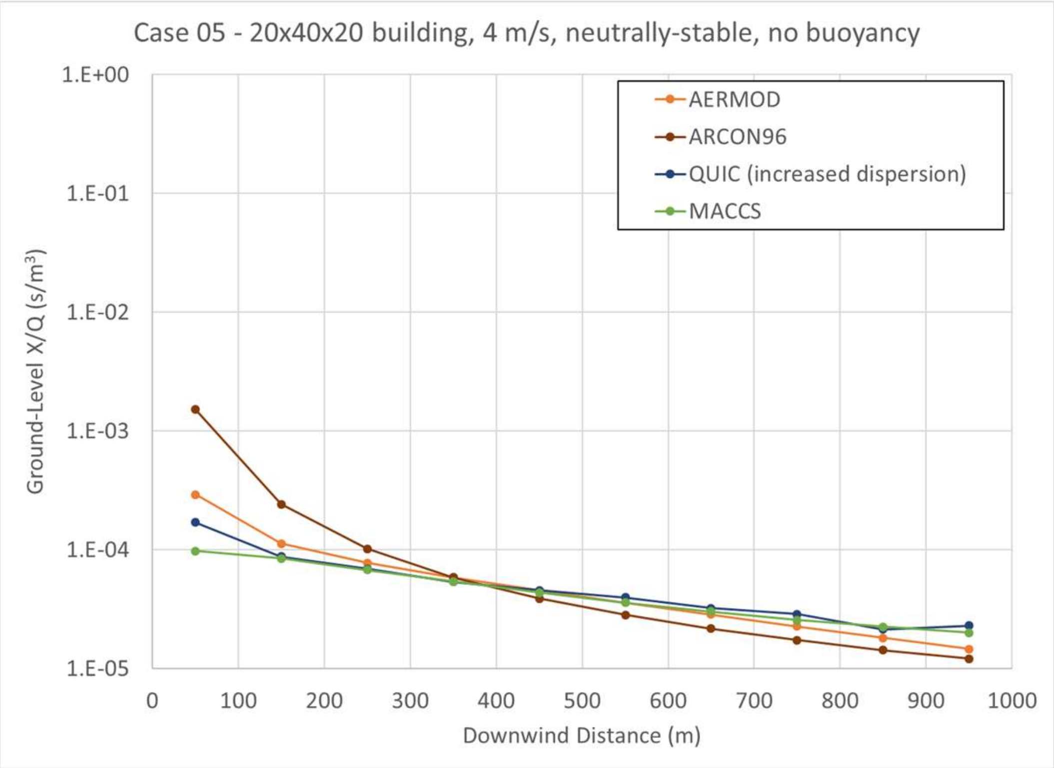
Code Comparisons

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



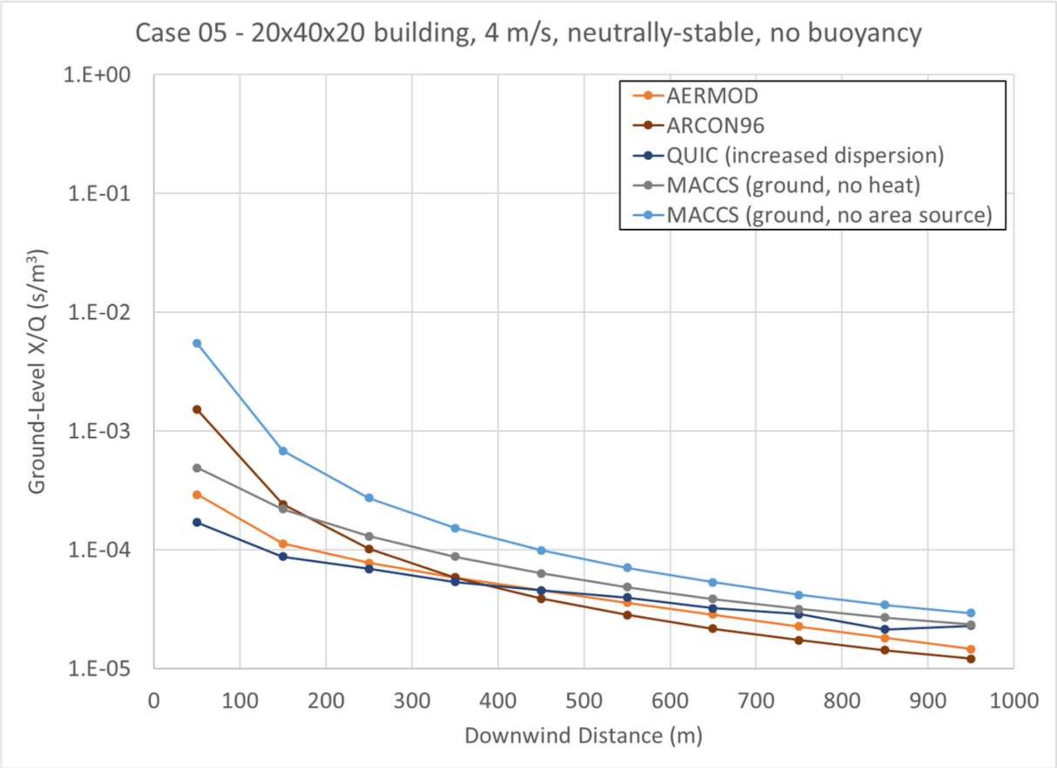
Potential Modifications to MACCS Input

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

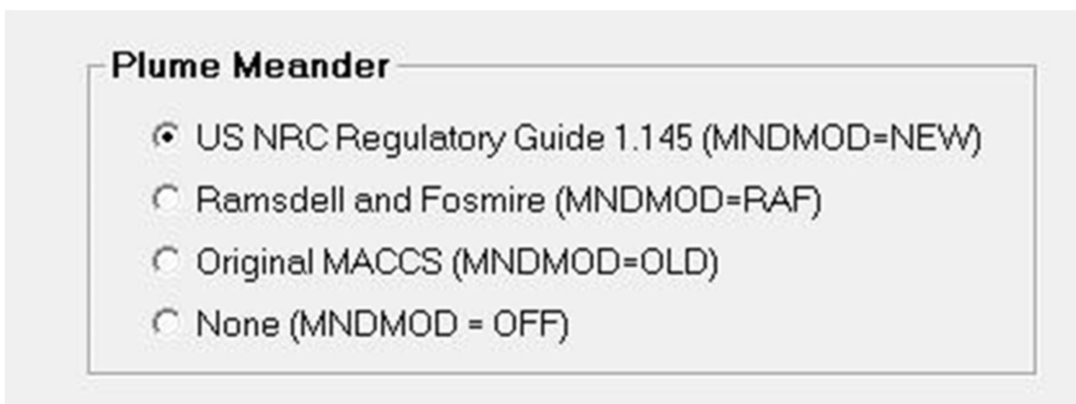


MACCS Updates

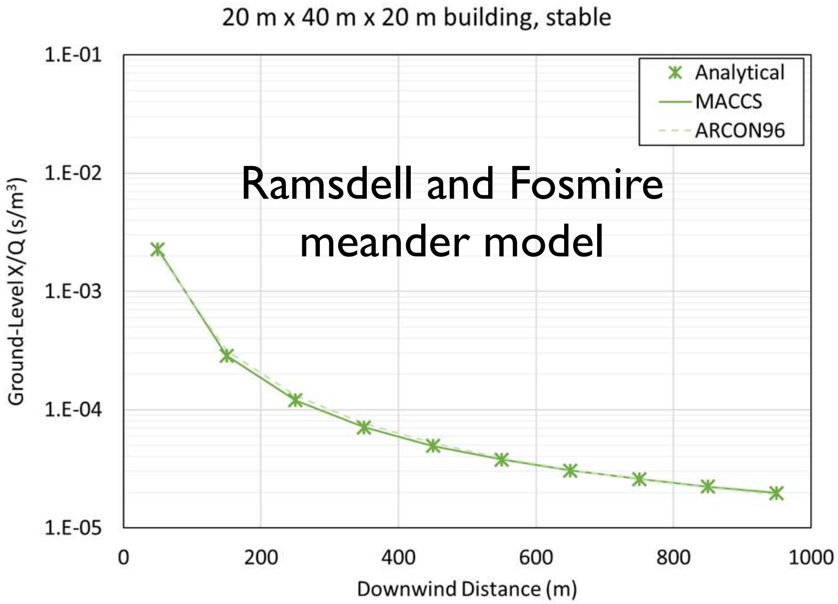
MACCS Update Plan

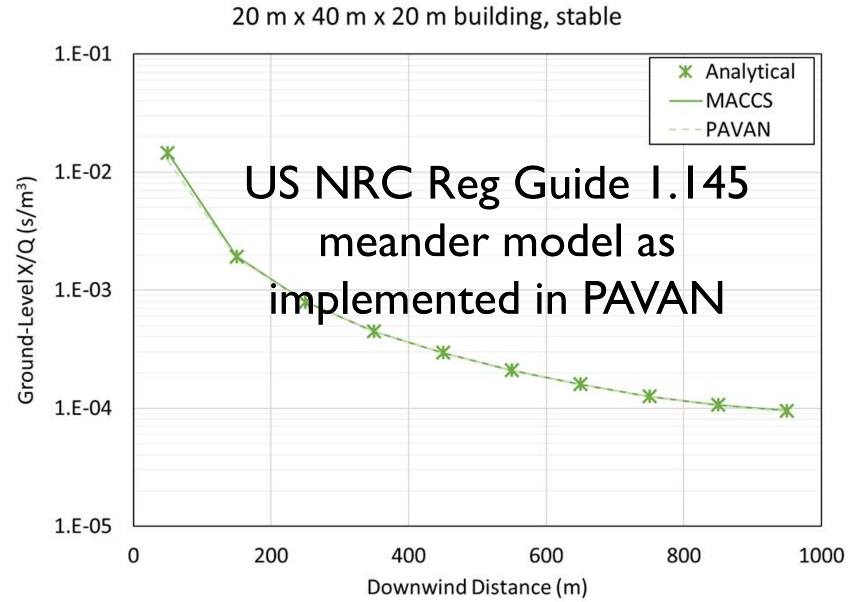
Provide **additional capabilities** in **MACCS** to facilitate **simulating** or **bounding** nearfield calculations performed with **other codes**

- Ramsdell and Fosmire meander model used in ARCON96
- US NRC Regulatory Guide 1.145 meander model as implemented in PAVAN
- Maintain existing MACCS capabilities

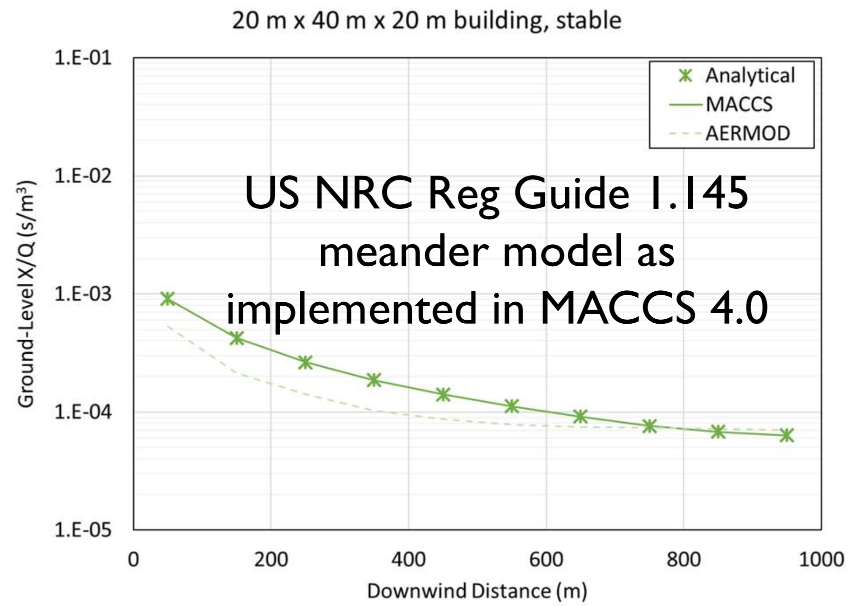


Verification Results (1/2)

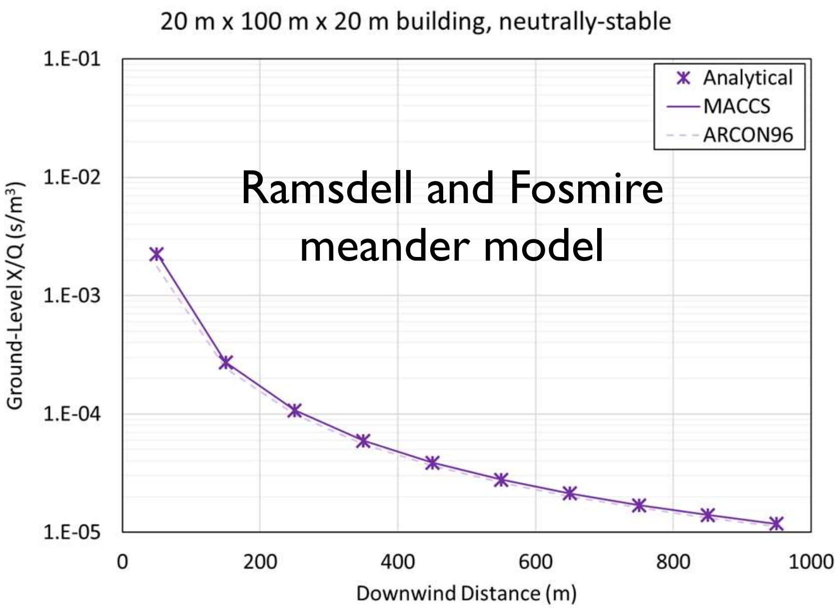


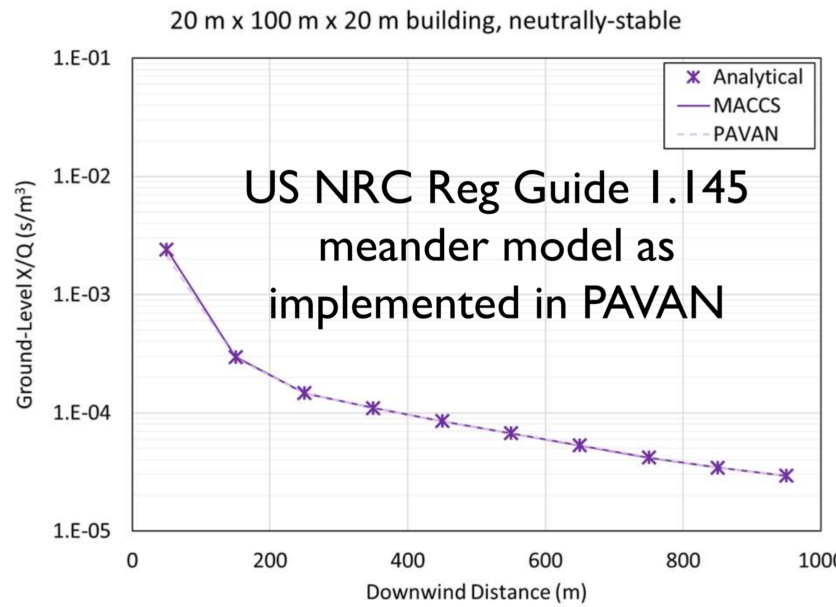


20 m x 40 m x 20 m building,
2 m/s, F stability

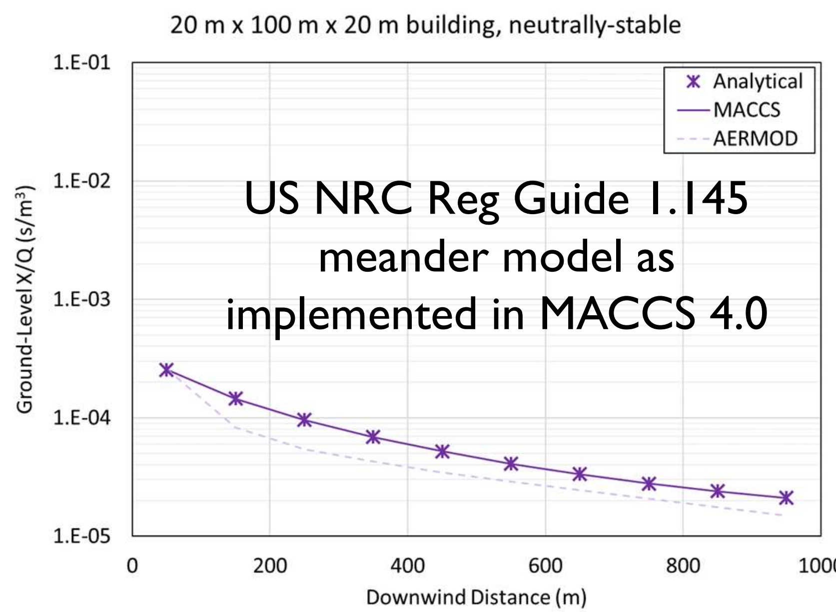


Verification Results (2/2)

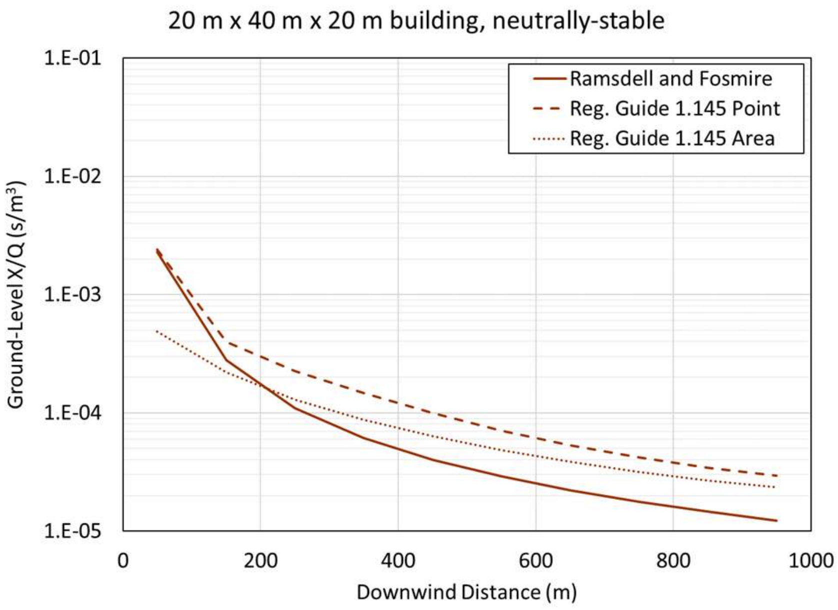


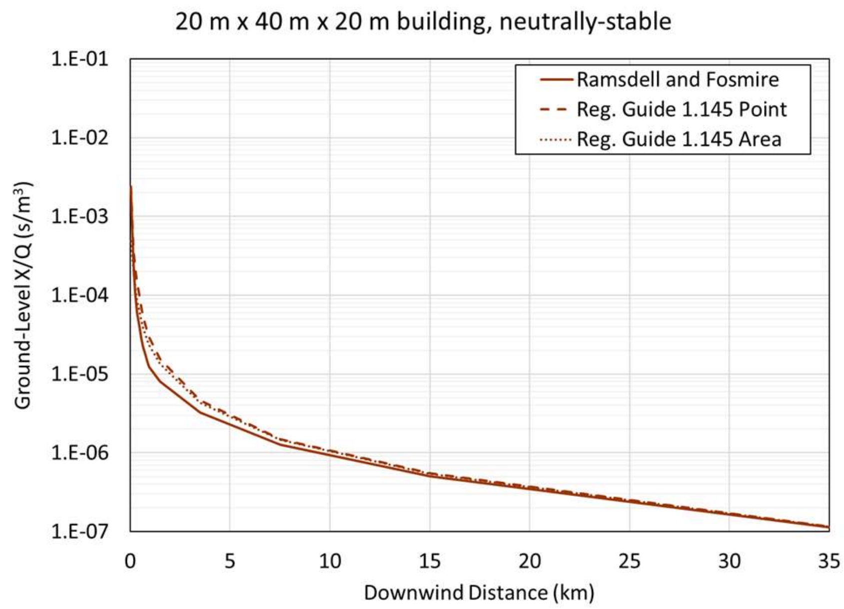


20 m x 100 m x 20 m building,
4 m/s, D stability



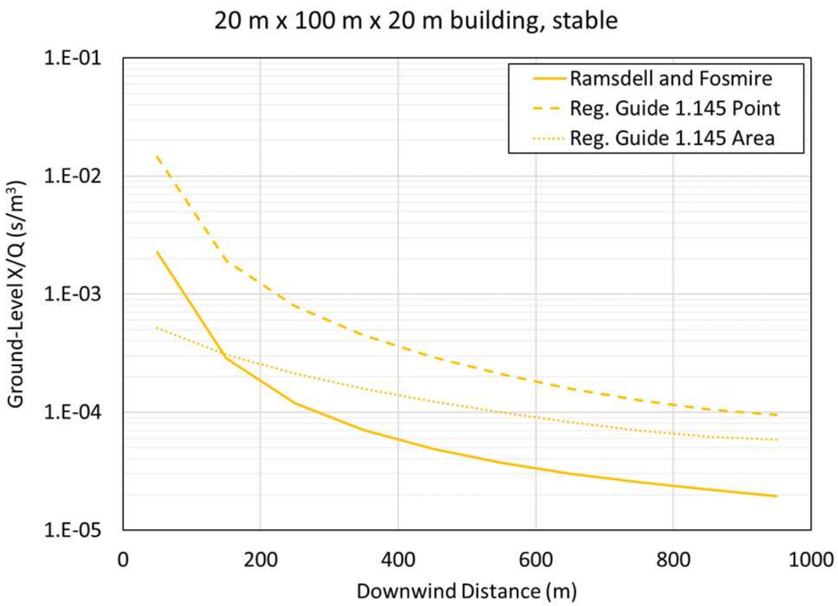
Model Comparisons (1/2)



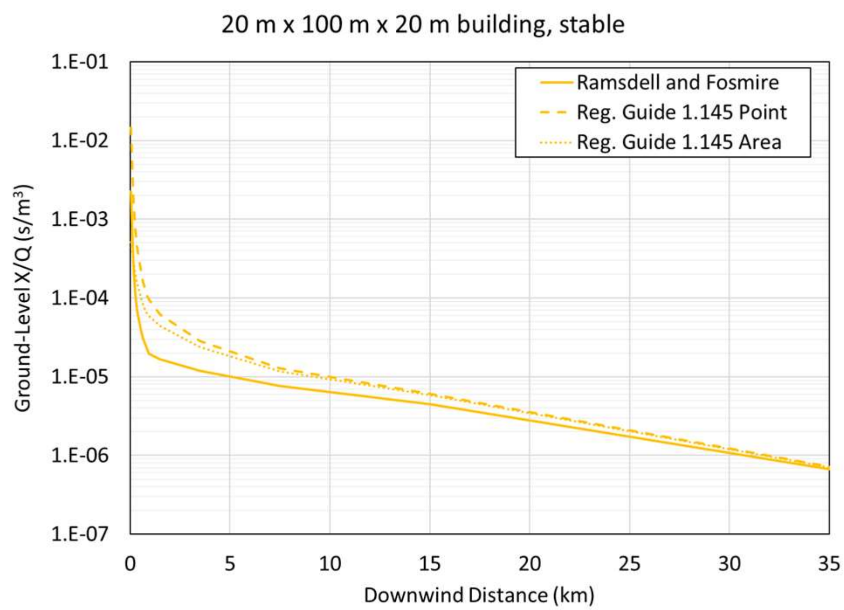


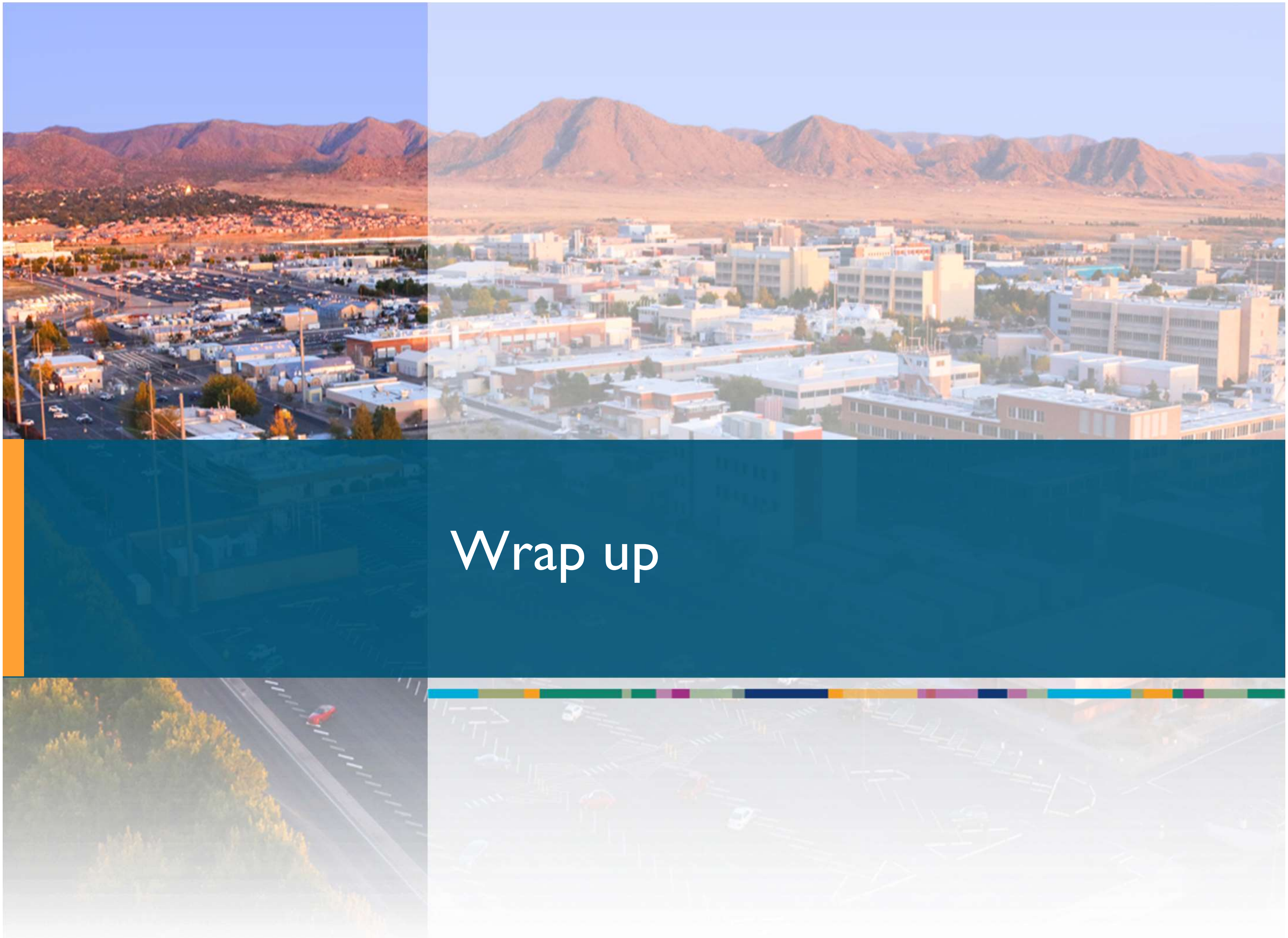
20 m x 40 m x 20 m building,
4 m/s, D stability

Model Comparisons (2/2)



20 m x 100 m x 20 m building,
2 m/s, F stability





Wrap up

Summary (1/4)

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 (2/4)

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 (3/4)

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” SAND2020-2609, Sandia National Laboratories, Albuquerque, NM, February 2020, ADAMS Accession Number ML20059M032)

Summary (4/4)

Additional **nearfield meander models** are **included** with **MACCS 4.1**

- Simulate results from ARCON96 with MACCS when using the Ramsdell and Fosmire meander model
- Simulate results from PAVAN with MACCS when using the full US NRC Regulatory Guide 1.145 meander model
- Maintain capability to bound AERMOD and QUIC results using recommended MACCS parameter choices

Comparing the plume meander model **results** shows

- When using the full **US NRC Regulatory Guide 1.145 meander model**, the X/Q values for the test cases are **higher** than for the other two models
- The X/Q values for the test cases with **MACCS Ramsdell and Fosmire plume meander model** are lower than the other two models except at distances of less than 200-300 m
- Beyond 1 km, **the three models converge** with differences on the order of 5-10% at a distance of 35 km.

Additional information available from final technical report (Clayton D.J, "Implementation of Additional Models into the MACCS Code for Nearfield Consequence Analysis" SAND2021-6924, Sandia National Laboratories, Albuquerque, NM, June 2021)