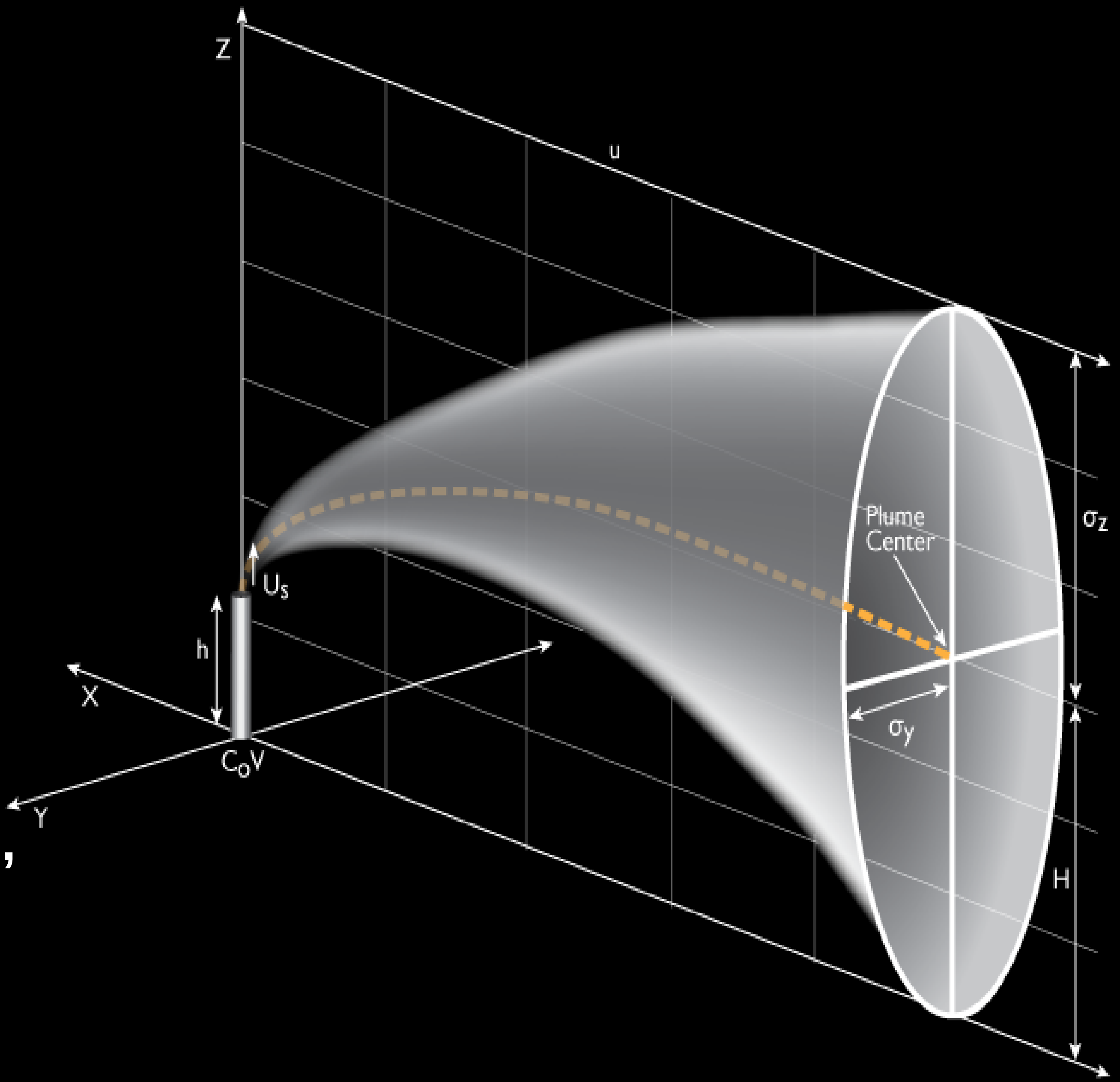
The Increasing Role of Dispersion Modeling in Facility Design



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Rocky Mountain Environmental, Health, & Safety Peer Group

January 21, 2021

Sergio Guerra

Dr. Sergio Guerra is an Environmental Engineer with over 18 years of experience in Air Quality. Dr. Guerra is a dispersion modeling expert and a skilled Project Manager with experience leading complex projects with tight deadlines. Clients include oil and gas, refinery, manufacturing, power plants, foundries, oil processing, food and beverage, silica sand processing, and pulp and paper industries. Dr. Guerra's expertise in research, regulations, and consulting gives him a unique insight into the interaction of the theoretical and practical aspects of air quality. This experience is at the core of his interest in advanced methods to achieve accurate results from regulatory tools such as AERMOD. Dr. Guerra delivers presentations about his research at local and national forums of technical and non-technical audiences. This includes national webinar presentations to teach basic and advanced level dispersion modeling classes. His research has been published in peer reviewed journals such as the Journal of Air and Waste Management Association, the EM Magazine, and other conference proceedings. Sergio also assists industrial facilities in permit application development, regulatory analysis and support, and air dispersion modeling.

Air and Waste Management Association member, Chair of the Atmospheric Modeling and Meteorology Committee (APM) of the A&WMA, Board Member of the Rocky Mountain Section States Chapter of the A&WMA

Why do we regulate the air?

- In December 1930, 63 people died in Belgium's Meuse Valley during a five-day fog; most of the deaths occurring on the fourth and fifth days.
- In October 1948, a thick cloud of air pollution formed above the industrial town of Donora, Pennsylvania. The cloud which lingered for five days, killed 20 people and caused sickness in 6,000 of the town's 14,000 people.
- In 1952, over 3,000 people died in what became known as London's "Killer Fog." The smog was so thick that buses could not run without guides walking ahead of them carrying lanterns.

Why do we regulate the air?

ITV REPORT 31 January 2017 at 10:39am

Air pollution is now the 'biggest worry of people living in London'

Two out of three Londoners have considered moving away from the capital to escape toxic air, a report suggests.

Experts say the pollution was being caused by cold and windless weather

Smog levels in Beijing off the charts

Air quality reading exceeds maximum 500 mark on index, US embassy says, as blanket of acrid air descends across north, hitting holiday plans

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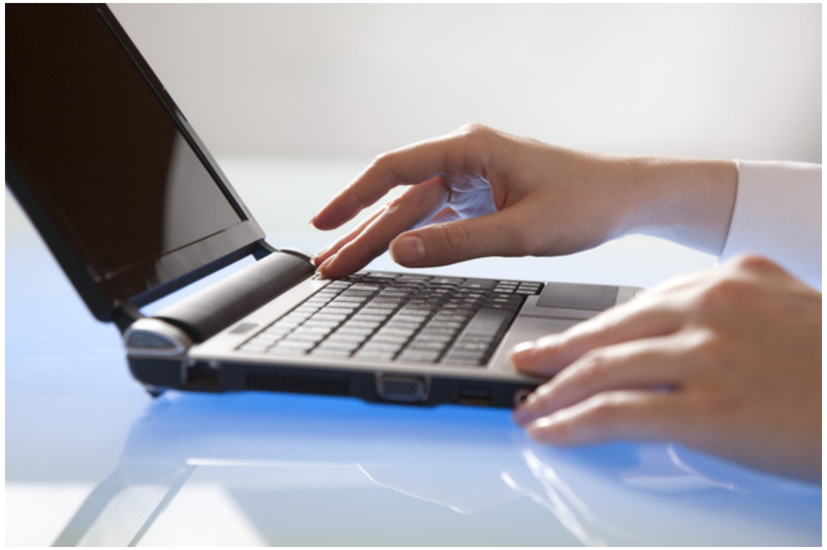
COMMENTS: 10

Dispersion Modeling

- A series of equations that mathematically describe pollutant behavior in the atmosphere
- Can be simple or complex depending on the assumptions and mathematical equations used
- Is a tool used in air permitting to ensure that the air quality will not be compromised
- Based on best available science
- Performance is evaluated for specific scenarios
- Like any other numerical tool it has its limitations



What are the Reasons to Model?

- Regulatory purposes
- Design purposes
- Health
- Ecology

New Source Review

- Pre-construction program for major sources or major modifications
- Types of permits
  - Prevention of Significant Deterioration
  - Nonattainment NSR
  - Minor Source

National Ambient Air Quality Standards (NAAQS)

- Established to protect public health for 6 criteria pollutants
  - NO2, CO, SO2, PM/PM10/PM2.5,Ozone (VOCs) and Lead
- Compliance is based on monitoring and dispersion modeling
- Recent updates include new short-term standards for NO2, SO2, and PM2.5
- Modeling evaluation may include background concentrations and nearby sources

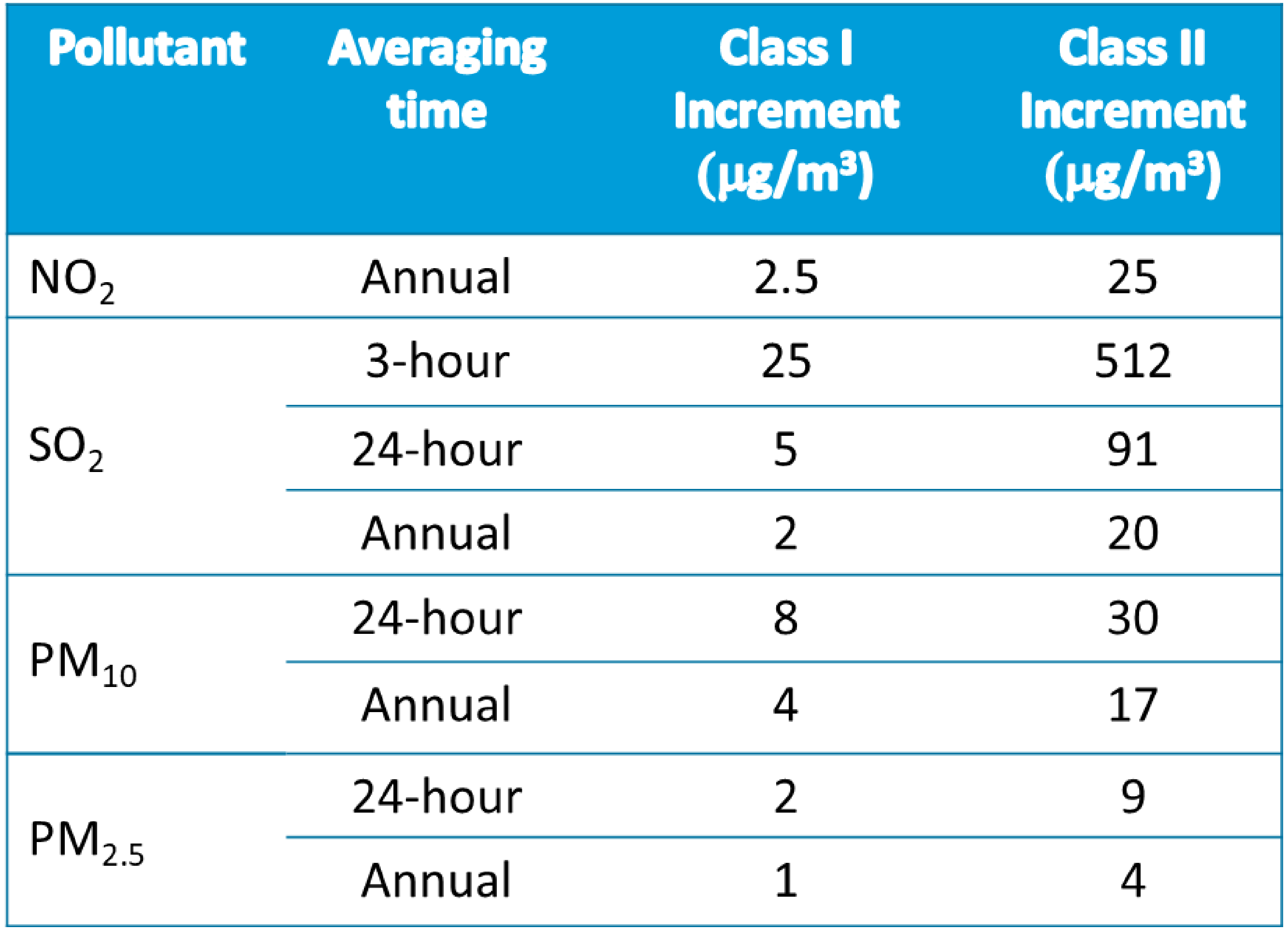
Table of NAAQS

Pollutant	Averaging time	Standard ($\mu g/m^3$)	Form of the Standard
NO_2	Annual	100	Annual arithmetic mean
	1-hr	188	98th percentile (H8H)
SO_2	Annual	Revoked	Annual arithmetic mean
	24-hour	Revoked	Not to be exceed more than once per year
	3-hour	1,300	Not to be exceed more than once per year
	1-hour	196	99th percentile (H4H)
PM_{10}	Annual	Revoked	Annual arithmetic mean
	24-hour	150	Not to be exceed more than once per year
$PM_{2.5}$	Annual	12	Annual arithmetic mean
	24-hour	35	98th percentile (H8H)
CO	8-hour	10,000	Not to be exceed more than once per year
	1-hour	40,000	Not to be exceed more than once per year
Pb	3-month	0.15	Not to be exceeded (rolling 3 mo. avg.)
O_3	8-hour	70 ppb	Annual H4H daily max 8-hr

Prevention of Significant Deterioration (PSD) Increments

- Modeling evaluation include increment consuming sources
- Background concentrations not included

Prevention of Significant Deterioration (PSD) Increments



Pollutant	Averaging time	Class I Increment (µg/m³)	Class II Increment (µg/m³)
NO_2	Annual	2.5	25
SO_2	3-hour	25	512
	24-hour	5	91
	Annual	2	20
PM_{10}	24-hour	8	30
	Annual	4	17
$PM_{2.5}$	24-hour	2	9
	Annual	1	4

Significant Impact Levels (SIL)

Pollutant	Averaging time	NAAQS SIL ($\mu g/m^3$)
NO_2	Annual	1
	1-hour	7.5
SO_2	Annual	1
	24-hour	5
	3-hour	25
	1-hour	4 (in CO)
PM_{10}	Annual	1
	24-hour	5
$PM_{2.5}$	Annual	0.2
	24-hour	1.2
CO	8-hour	500
	1-hour	2,000

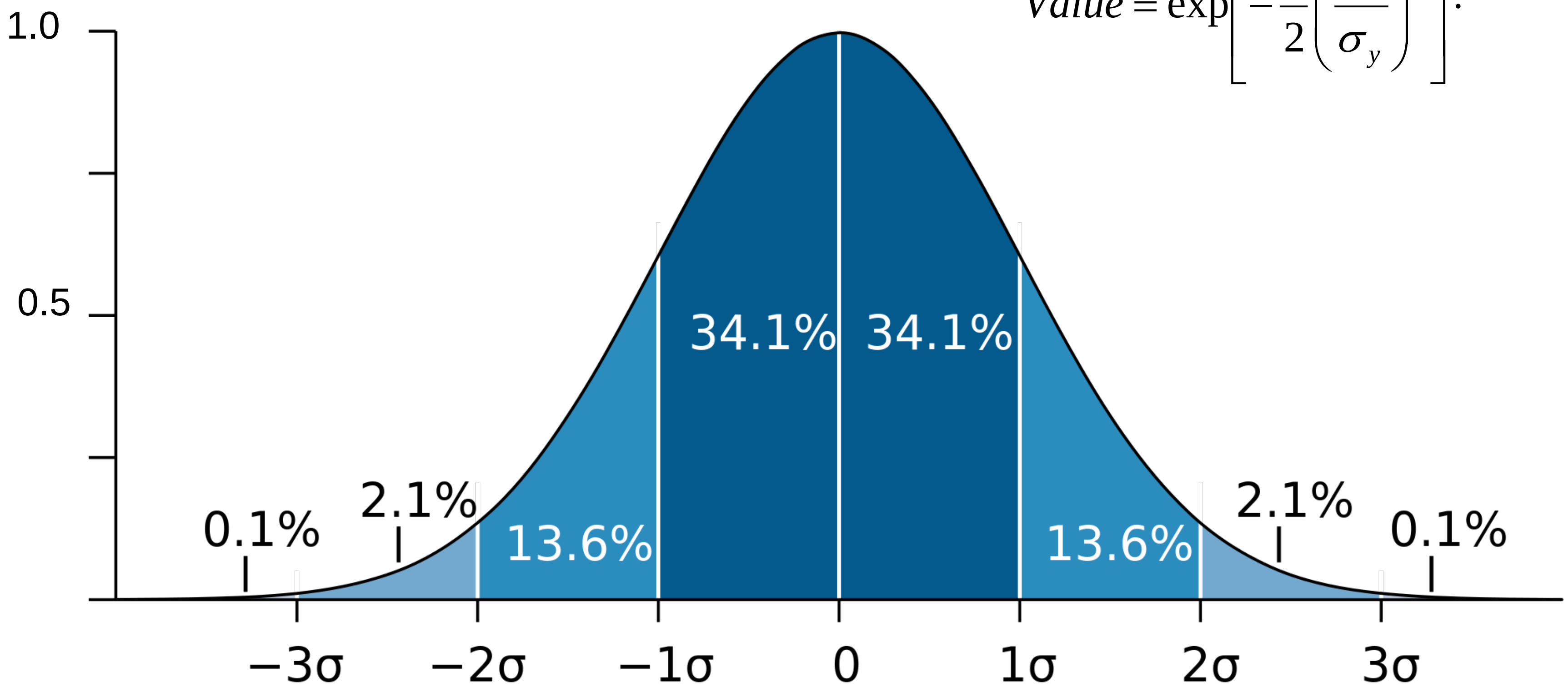
AERMOD

“A steady-state plume model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain.” SCRAM web site: www.epa.gov/scram001/dispersion_prefrec.htm

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Gaussian Distribution

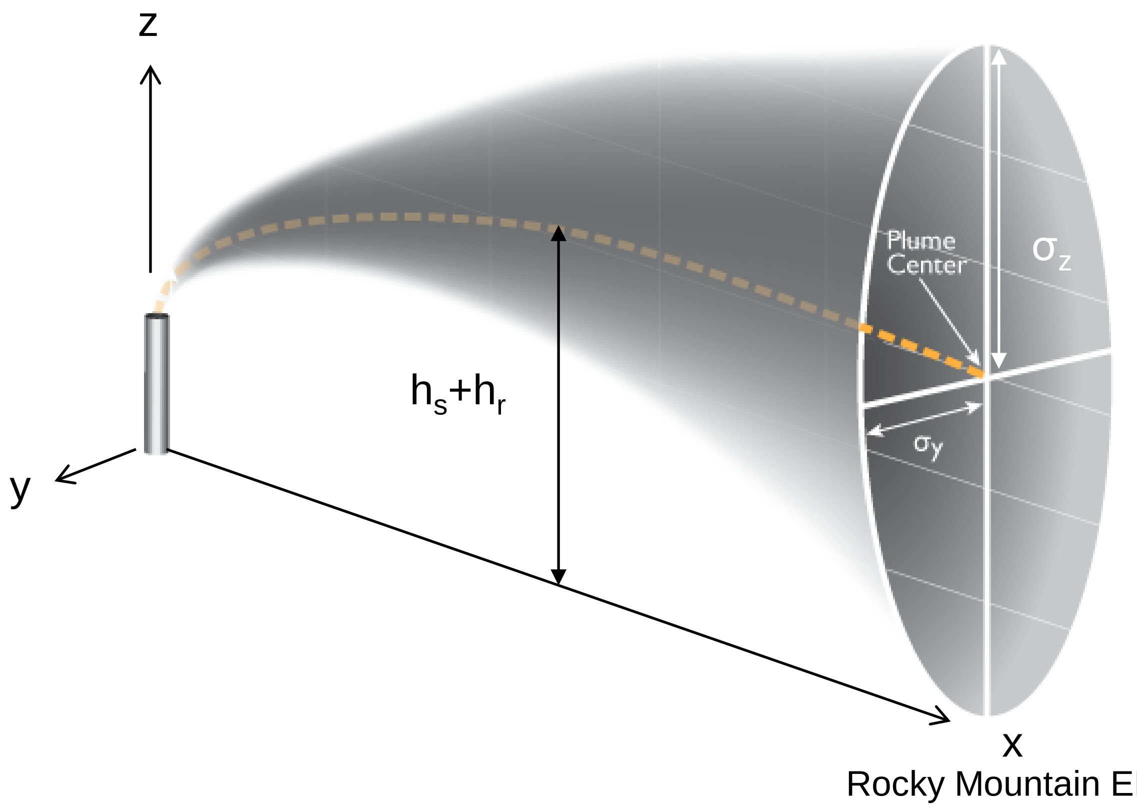
$$Value = \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right].$$



Horizontal and Vertical Dispersion

σ_y / σ_z vary with:

- Downwind distance
- Surface roughness
- Ambient turbulence levels
- Atmospheric stability
- Urban or rural
- Building downwash



Rocky Mountain EHS Peer Group

Plume Rise Example Result

INPUTS

Hb = 40 m

Hs = 90 m

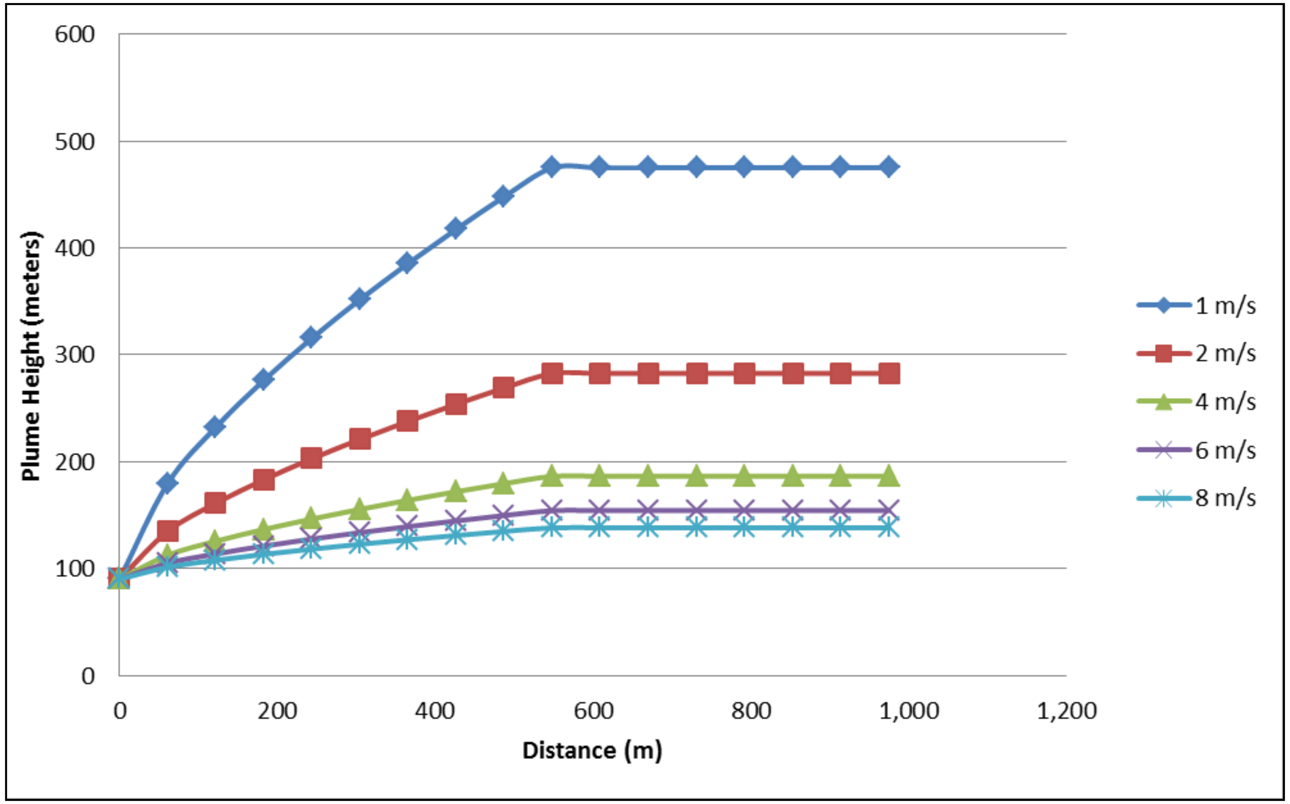
Ve = 5 m/s

Ts = 430K

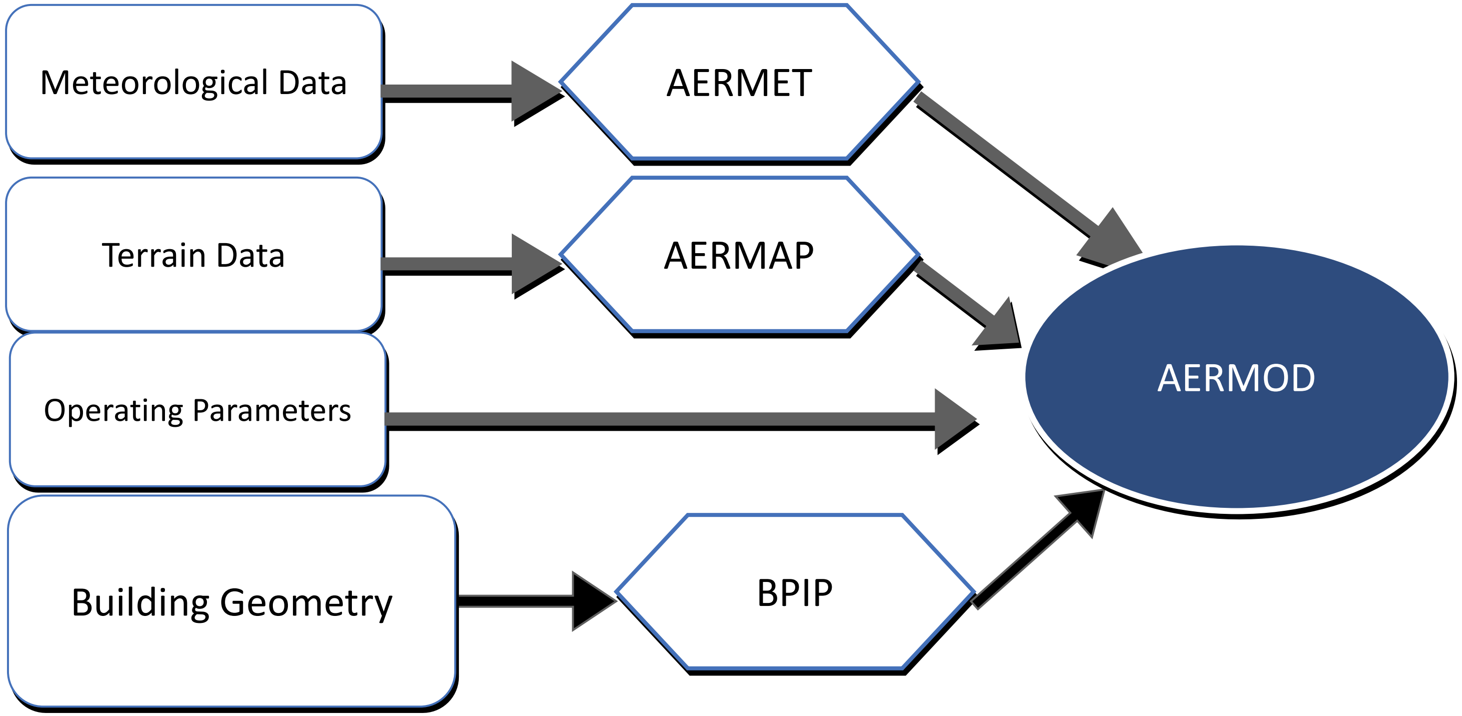
Ta = 279K

D = 2.1 m

Neutral stability



Inputs



Meteorological Data

AERMET

Terrain Data

AERMAP

Operating Parameters

Building Geometry

BPIP

AERMOD

Source Types

Point source

Volume source

Area source

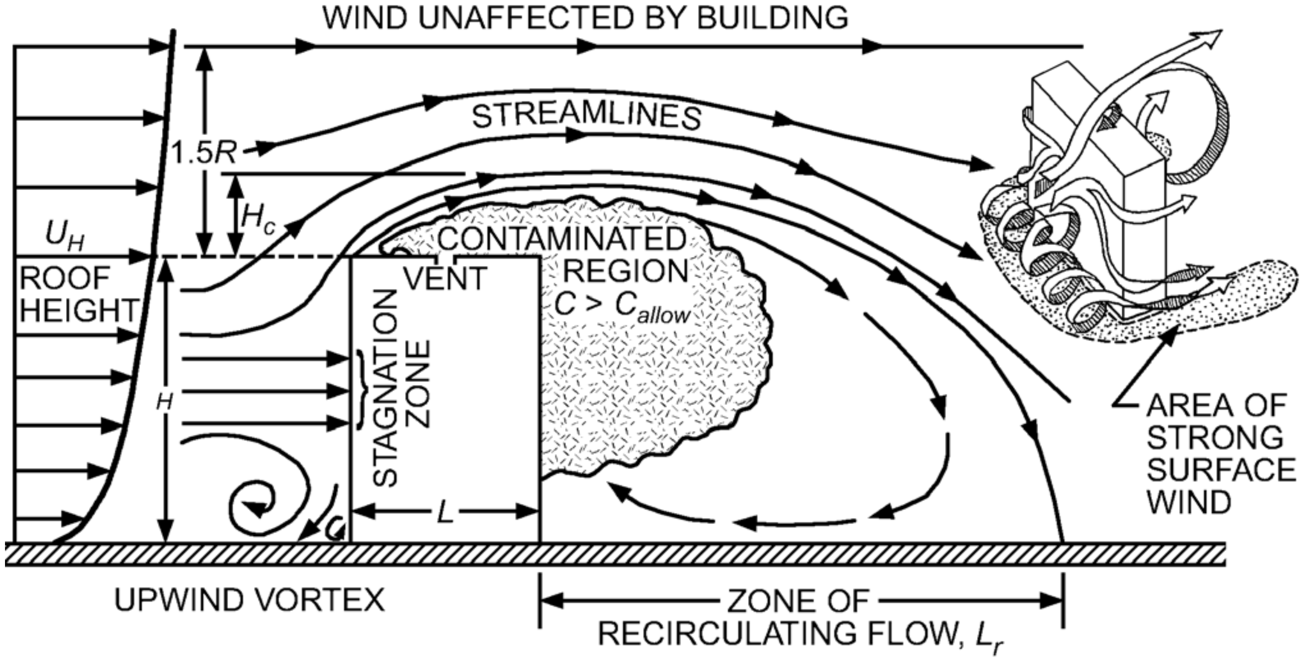
Line source

Open pit

Input Source Parameters

- Location
- Release height
- Stack diameter
- Emission rate
- Release temperature
- Volume flow rate
- Initial lateral dimension (volume source)
- Initial vertical dimension (area and volume sources)

Building Downwash



ASHRAE 2011 HVAC Handbook, Chapter 45.

Building Profile Input Program (BPIP)

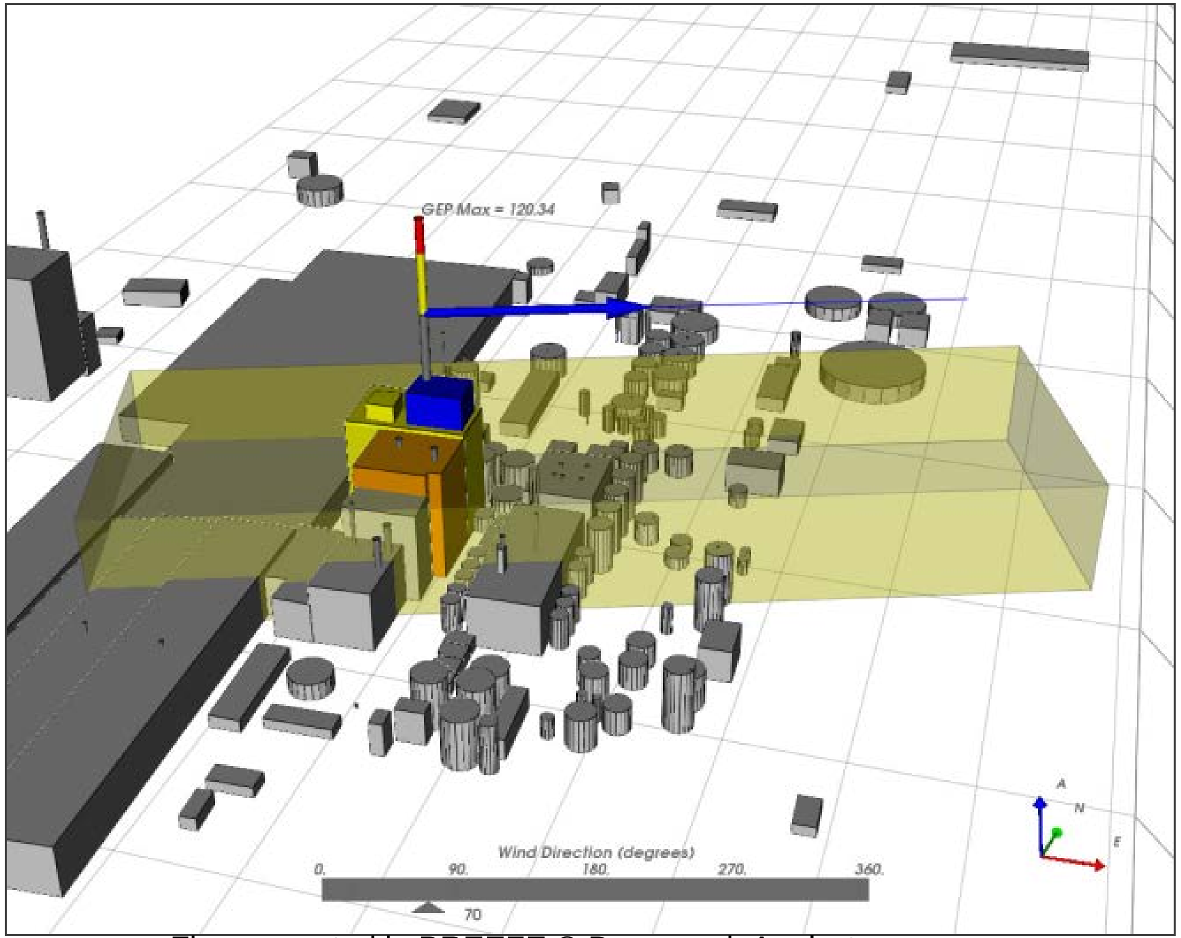


Figure created in BREEZE ® Downwash Analyst
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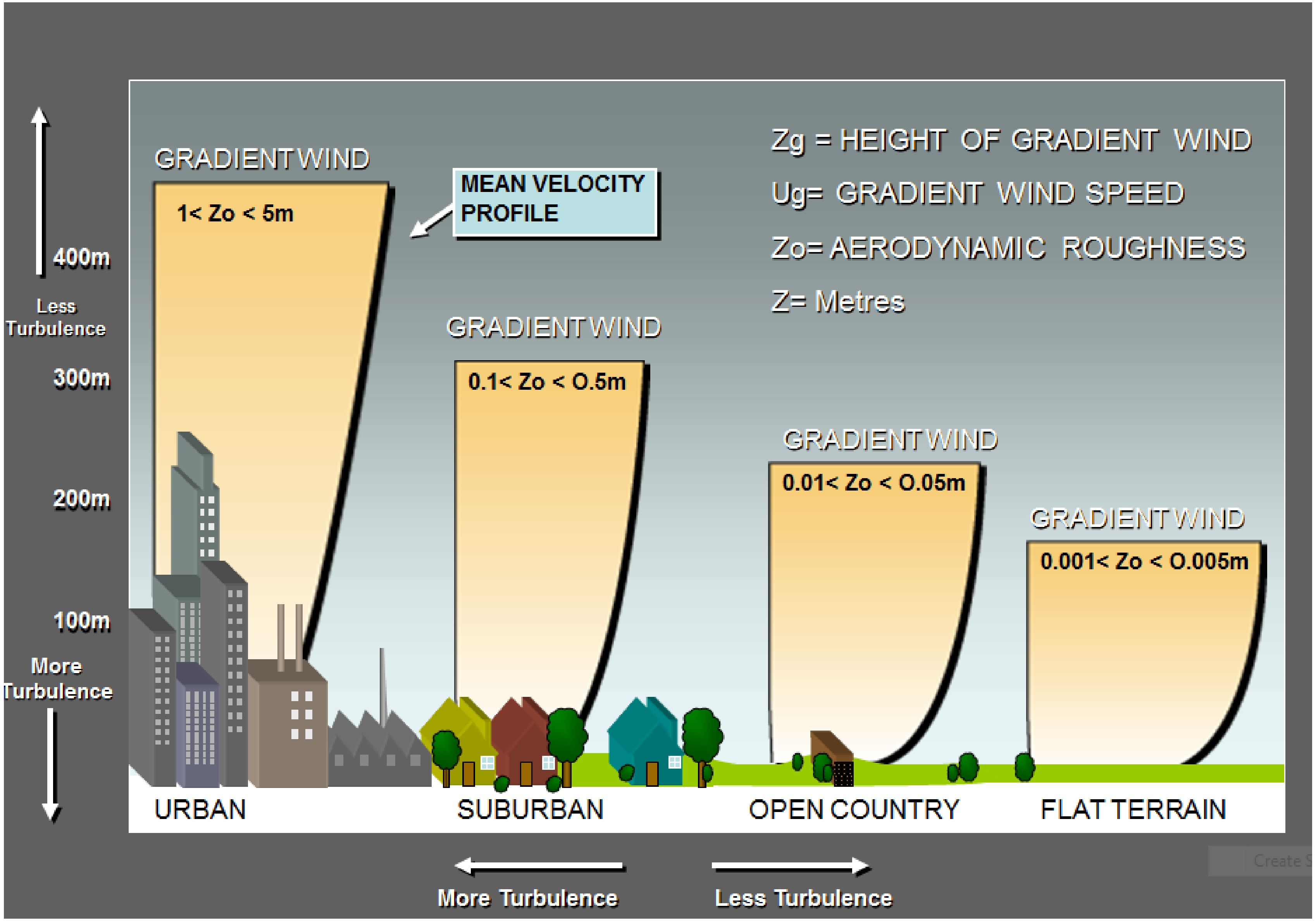
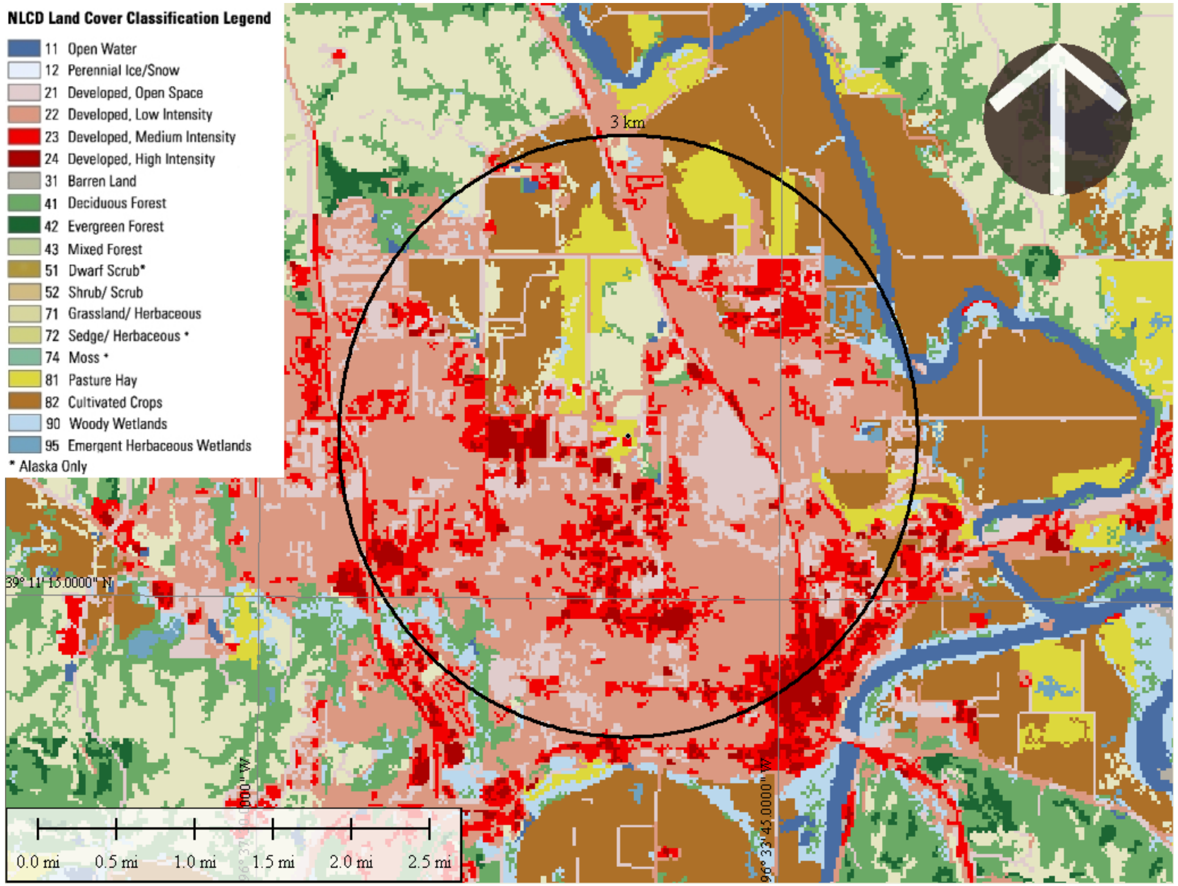
Wind and Turbulence Profiles



Surface Roughness (AERSURFACE)

1992 National Land Cover Database (NLCD) Used

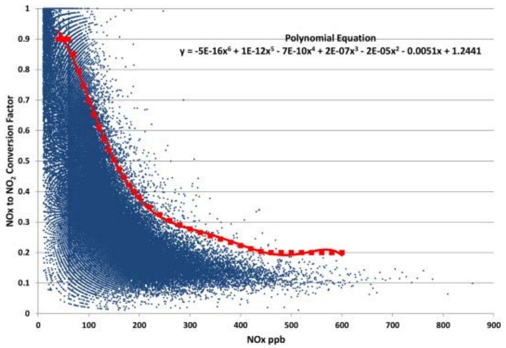
- Current guidance requires 1km radius about the airport to determine z_o
- New version 20060 includes impervious and tree canopy data
- Compatible with NLCD from 2016



Newer Regulatory Options

NO_2 modeling

- Tier 1 (regulatory default): 100% NO_x to NO_2 conversion
- Tier 2 (regulatory default): ARM2 replaces ARM
  - NO_2/NOx Minimum Ambient Ratio (MAR) of 0.5
  - Alternative lower MARs need justification/approval
- Tier3:
  - a) Ozone Limiting Method (OLM)
  - b) Plume Volume Mole Ratio Method (PVMRM)
- AERMET’s u-star option

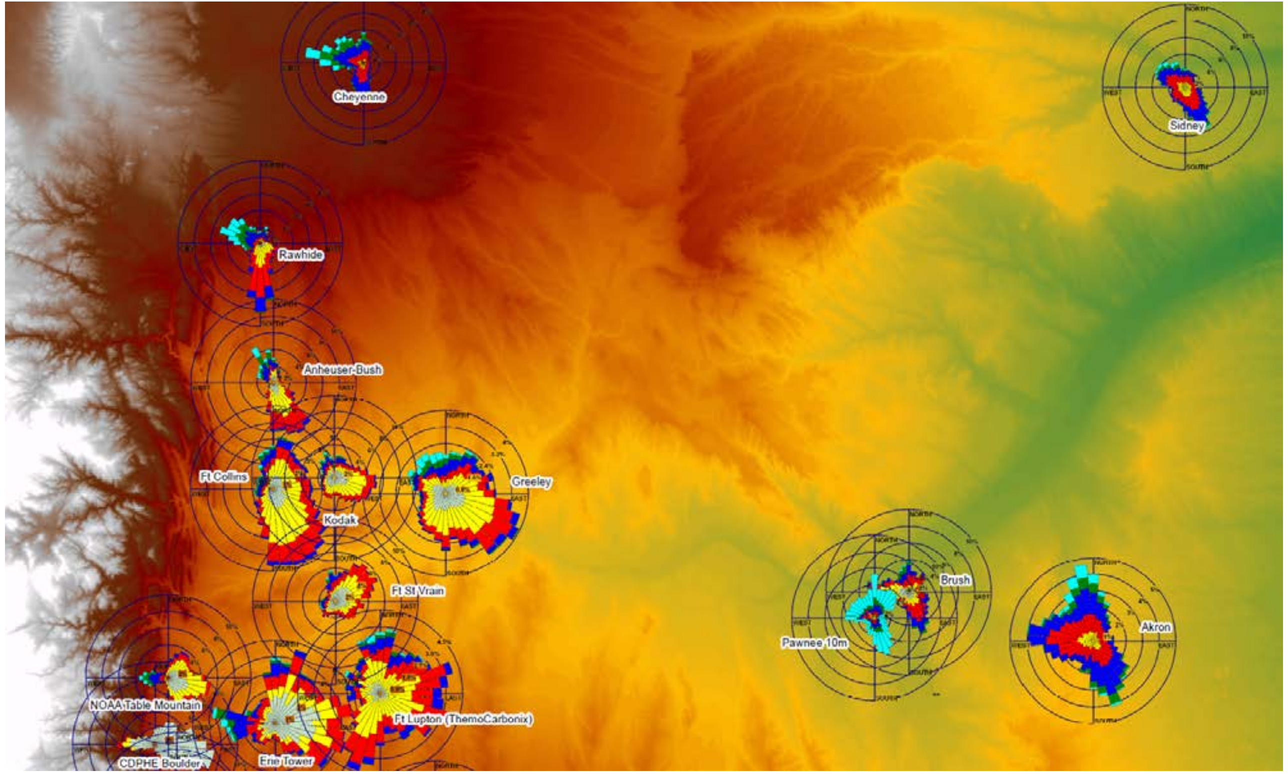


Podrez, M. (2015), An update to the ambient ratio method for 1-h NO_2 air quality standards dispersion modeling, Atmos. Env. http://dx.doi.org/10.1016/j.atmosenv.2014.12.021

Modeling in Colorado

CDPHE's Modeling Workgroup of the Stationary Source Control Fund (SSCF)

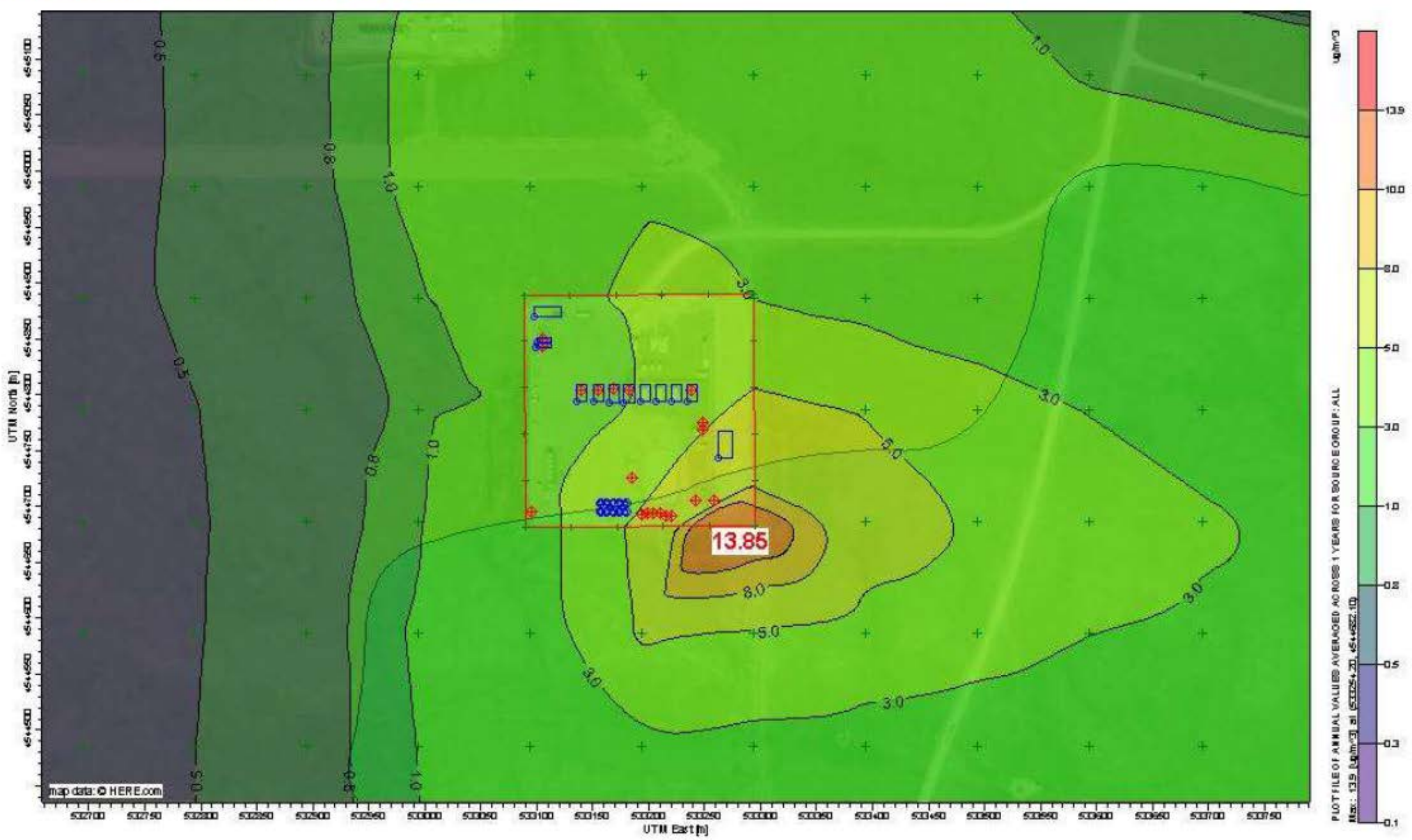
- Streamlining Met Data Determination
- Alternative to using the H1H when Met Data is deemed not representative
- Modeling thresholds are being re-evaluated



Modeling in Wyoming

- For minor sources, required to model Annual NO2 NAAQS (100 ug/m3) and PSD Increment (25 ug/m3)
- 1-hr NO2 modeling not required for minor sources
- Also required to model Formaldehyde cancer risk, 100-in-one-million considered acceptable

NO₂ Isopleth-with Maximum Annual Impact from 2008



Questions?

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