AERMOD Technical Forum

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Presentation Outline

- Brief History of AERMOD
- Basic Physics of Air Dispersion in AERMOD
- Comparisons of AERMOD and ISCST3
- AERMOD Performance Evaluation
- AERMOD Consequence Analysis
- Other AERMOD Features
- Potential AERMOD Pitfalls
- Questions

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Brief History of AERMOD

- **Developed** by AMS/EPA Regulatory Model Improvement Committee (**AERMIC**)
- **Proposed** as Replacement for ISCST3 Model in **April 2000**
- EPRI-sponsored **PRIME** Downwash Algorithms **Incorporated** in AERMOD in **2001**
- **Promulgated** as EPA's Preferred Model on **December 9, 2005**

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AERMOD Design Criteria

- Up-to-date Science
- Simple – Captures Essential Physical Processes
- Robust – Applies Over Range of Meteorology
- Easily Implemented – Simple I/O, User-friendly
- Can Evolve – Easily Updated

Basic Physics of Dispersion

- Air Dispersion is Driven by Two Main Forces – **Buoyancy** Effects and **Shear** Stress Effects
- **Buoyancy** Controlled by **Solar Heating** (Day) and **Radiative Cooling** (Night)
- **Shear Stress** (Friction) Controlled by **Surface Roughness** Elements and Aerodynamic Effects

Physics of Dispersion - Daytime

- **Buoyancy** Caused by Daytime Solar Heating **Generates** Large Scale **Convective Cells**
- **Convection** Causes Rapid **Vertical Spread** of Plumes and Growth of the **Mixed Layer**
- Strength of **Convection** Controlled by **Solar Angle** (time-of-day, season and latitude), **Cloud Cover** and **Surface Characteristics** (Albedo and Bowen Ratio)

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Physics of Dispersion - Daytime

- **Albedo**
  - Measure of reflectivity of surface, from 0 to 1
  - Typical values ranges from about 0.1 for water to 0.6 or higher for full snow cover
- **Bowen Ratio**
  - Ratio of sensible to latent heat flux
  - Determines how much solar heating goes to evaporation of surface moisture
  - Ranges from about 0.1 (very wet) to 10 (very dry)

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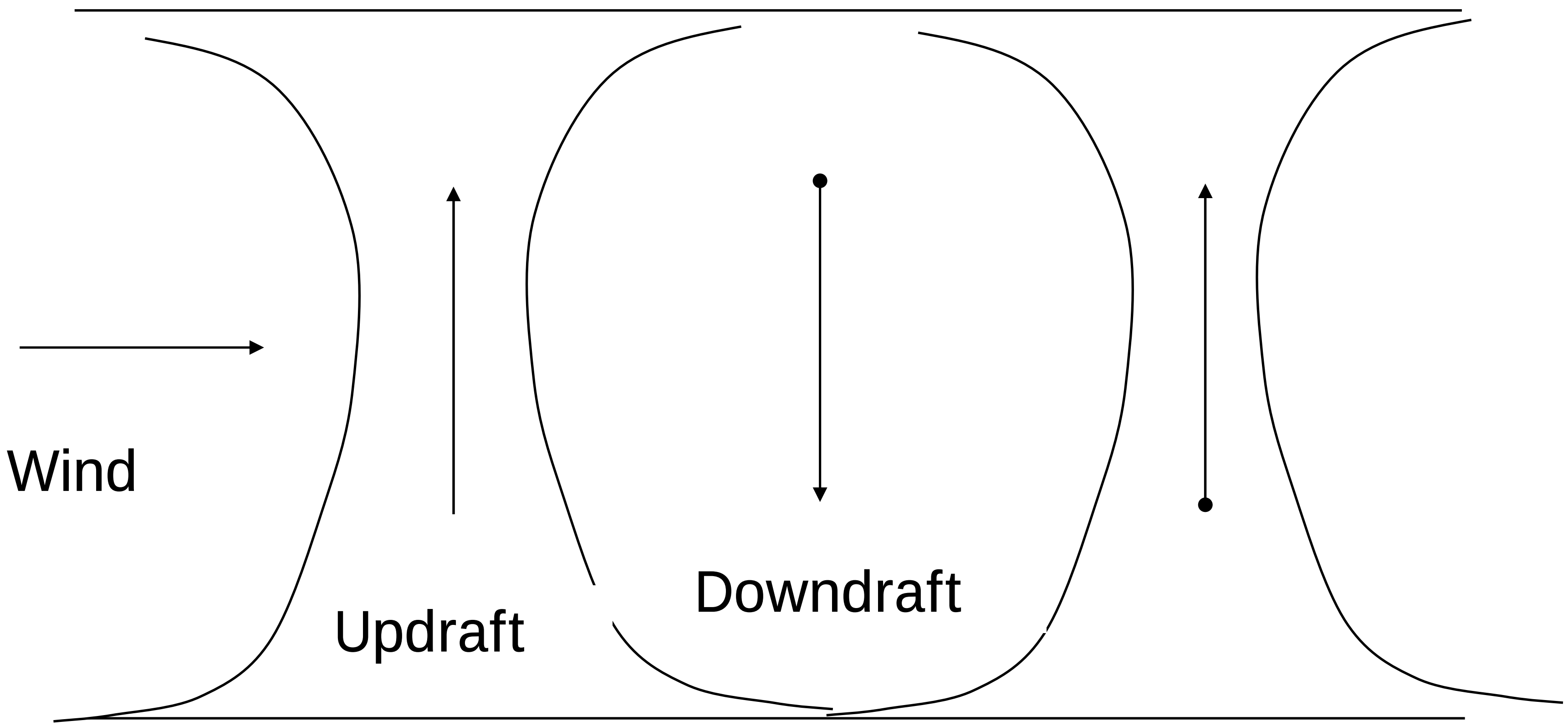
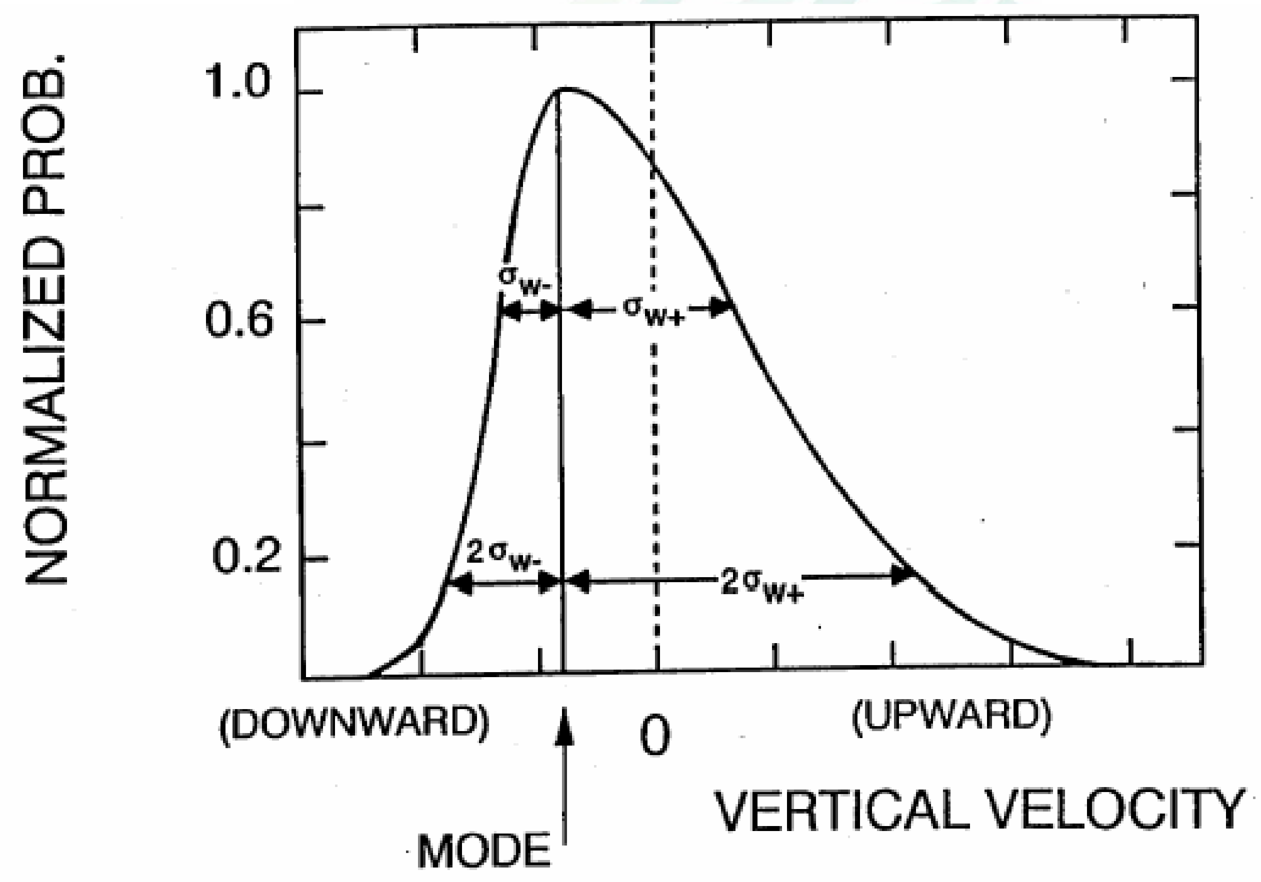
Convective Boundary Layer Structure

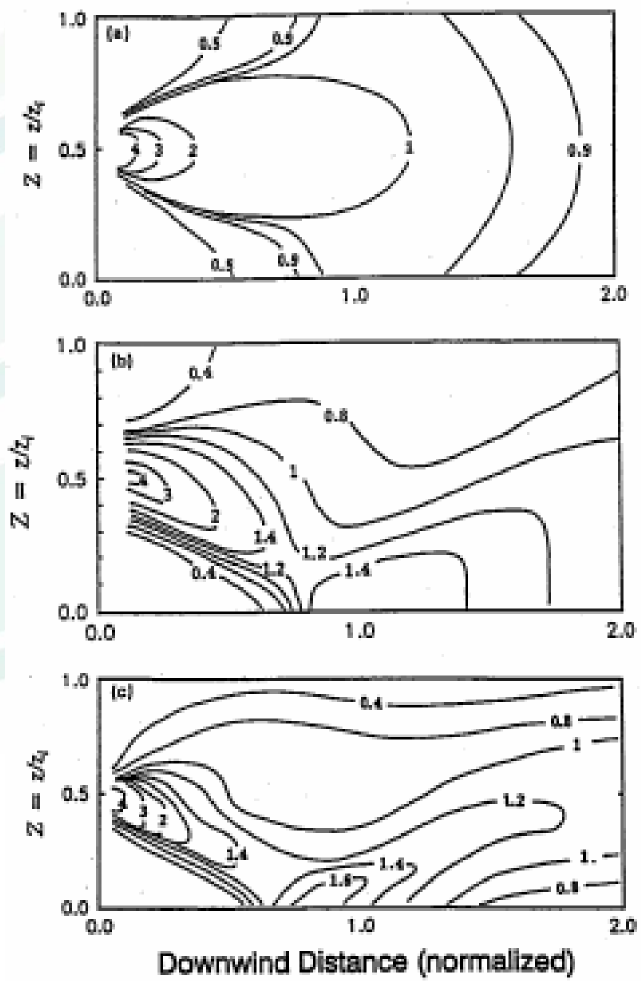


Vertical Velocity Distribution in CBL



CBL Dispersion Comparisons - CWIC

- ISCST3
- AERMOD
- Tank Study



Physics of Dispersion - Nighttime

- **Radiative Cooling** at Night Causes **Stable** Lapse Rate to Develop – **Suppresses** Propagation of **Turbulence**
- Generation of **Turbulence Dominated by** Friction-Induced **Shear Stress**
- Turbulence **Intermittent;** Low-level Jets and Gravity Waves may Contribute
- Shear Stress or **Mechanical Turbulence** Controlled by **Wind Speed** and **Surface Roughness**

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Physics of Dispersion - Nighttime

- **Surface Roughness Length (z_o)**
  - Height at which wind speed goes to zero (0), based on theoretical logarithmic profile
  - Related to the surface roughness elements, but is not = height of elements
  - Ranges from less than 0.001m (1mm) over water to 1.0m or higher for forests and urban areas
  - May vary by season and wind sector

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AERMOD vs. ISCST3

- **Theoretical Similarities**
  - Both AERMOD and ISCST3 are Steady-State Plume Models
- **Theoretical Differences**
  - AERMOD Similarity Theory vs. ISCST3 PG-Stability
  - AERMOD Terrain uses Critical Dividing Streamline vs. ISCST3 Terrain uses COMPLEX1 Screen Model
  - AERMOD uses PRIME Downwash vs. ISCST3 Huber-Snyder and Schulman-Scire Downwash
    - *PRIME downwash accounts for location of stack relative to building; ISCST3 downwash assumes stack and building are collocated. PRIME also includes cavity algorithm.*

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AERMOD vs. ISCST3

- **Theoretical Differences (cont.)**
  - AERMOD uses Non-Gaussian Vertical Dispersion for Convective (Unstable) Conditions vs. ISCST3 Gaussian Vertical Dispersion for All Conditions
  - AERMOD Partial Penetration of Plume Through Mixing Height vs. No Partial Penetration for ISCST3
  - AERMOD Urban Option Scaled by Population vs. ISCST3 Non-varying Urban Option
  - AERMOD Incorporates Horizontal Plume Meander

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AERMOD vs. ISCST3

- **Practical Similarities**
  - AERMOD Model Inputs and Outputs are Intentionally Similar to ISCST3 Model – AERMOD Code Developed from ISC Code
- **Practical Differences**
  - AERMOD Terrain Algorithms Require Special Terrain Data Processing – Performed by AERMAP
  - AERMOD Meteorological and Dispersion Algorithms Require Special Meteorological Data Processing – Performed by AERMET
  - AERMET Requires User-specified Surface Characteristics: Albedo, Bowen Ratio and Surface Roughness Length

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AERMOD Similarity Theory Concepts

- Wind, Temperature and Turbulence are **Scaled** with Height Based on **Similarity Theory**
- Mechanical (Shear Stress) Turbulence Scaled by **Friction Velocity (u_*)**
- Convective Turbulence Scaled by **Convective Velocity Scale (w_*)**
- **Monin-Obukhov Length (L)** Stability Parameter
  - Positive for stable conditions; negative for unstable
  - ~ Height at which friction and buoyant forces balance

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Monin-Obukhov Length vs. PG Class

Roughness	~L (m)	PG Stability Class
0.1 m	-12.5	A
	-25	B
	-65	C
	--	D
	+65	E
	+30	F

Roughness	~L (m)	PG Stability Class
0.5 m	-16	A
	- 50	B
	-100	C
	--	D
	+100	E
	+50	F

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AERMOD Terrain Treatment

- Uses CDTM+ Dividing Streamline Height Concept
  - Portion of plume above dividing streamline goes over the hill (terrain-responding plume)
  - Portion of plume below dividing streamline impacts or goes around hill (horizontal plume)
- Requires Representative "Hill Height Scale" for Each Receptor
- AERMAP Determines "Hill Height Scale" Based on Highest Terrain Above a 10:1 Slope

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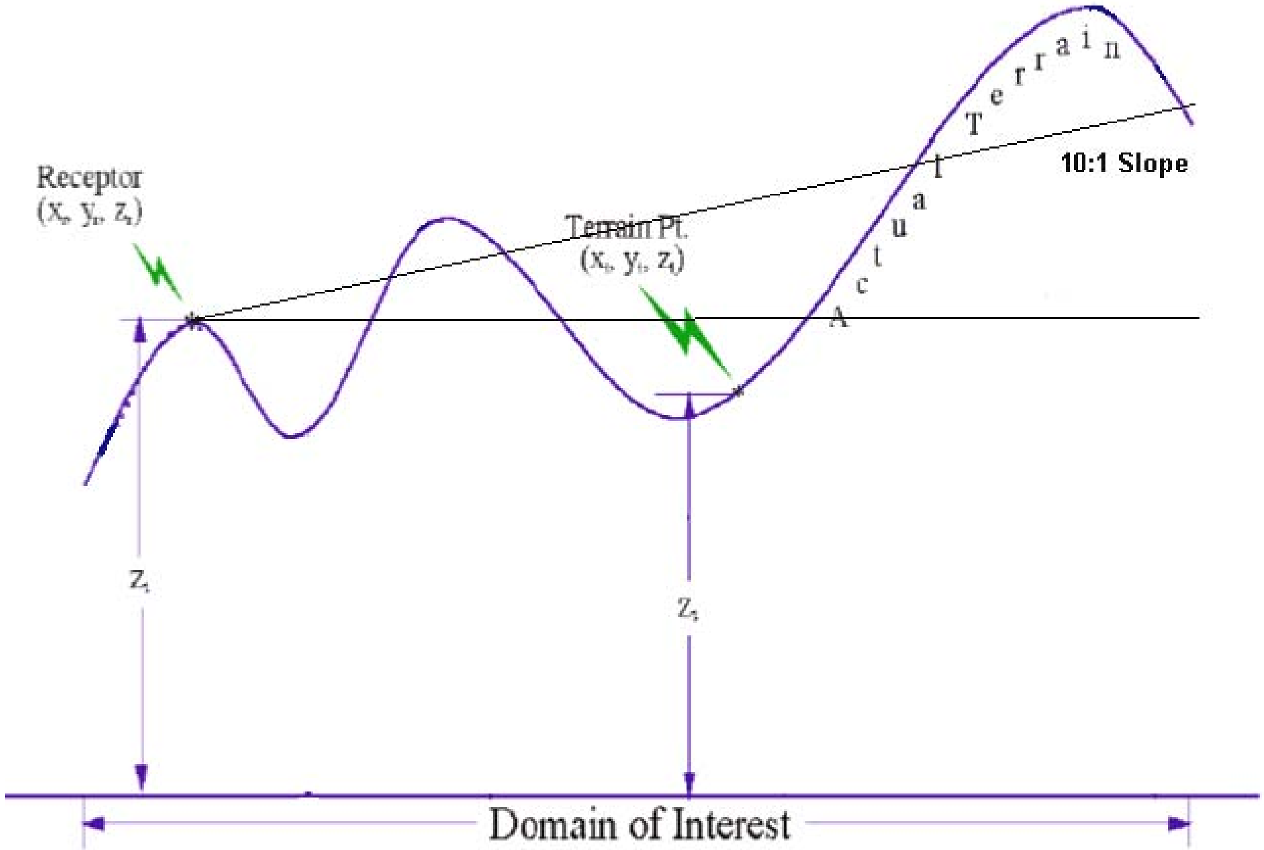
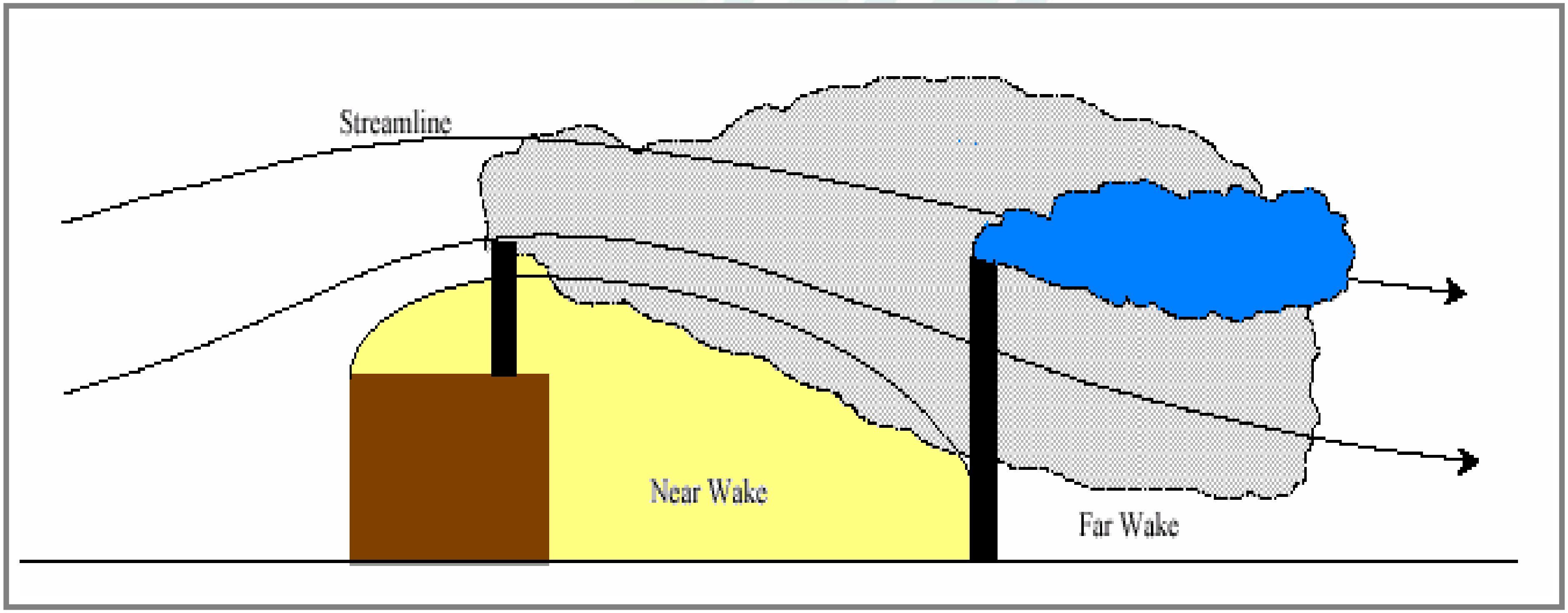
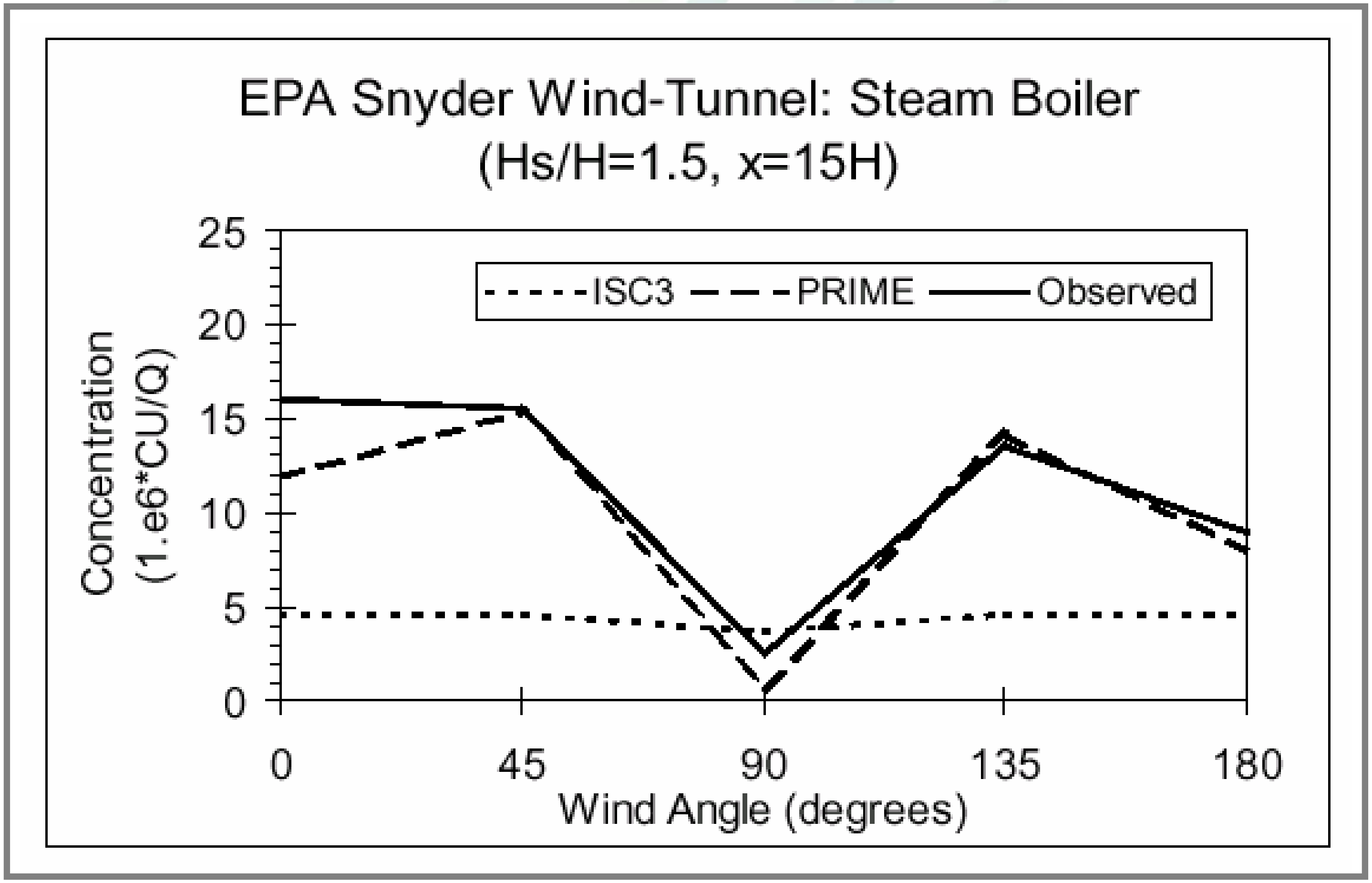
AERMOD Terrain Treatment



PRIME Building Downwash in AERMOD



PRIME Wind-Tunnel Evaluation



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AERMOD Performance Evaluation

- Evaluated on Total of 17 Field Study Databases
  - 10 without Building Downwash, 7 with Downwash
  - 13 with Flat or Rolling Terrain, 4 with Complex Terrain
- Developmental and Independent Evaluations
- Compared to ISCST3 for Non-downwash Databases and CTDMPLUS for Complex Terrain Databases
- Compared to ISC-PRIME for Downwash Databases
- AERMOD Consistently Outperformed ISCST3, ISC-PRIME and CTDMPLUS

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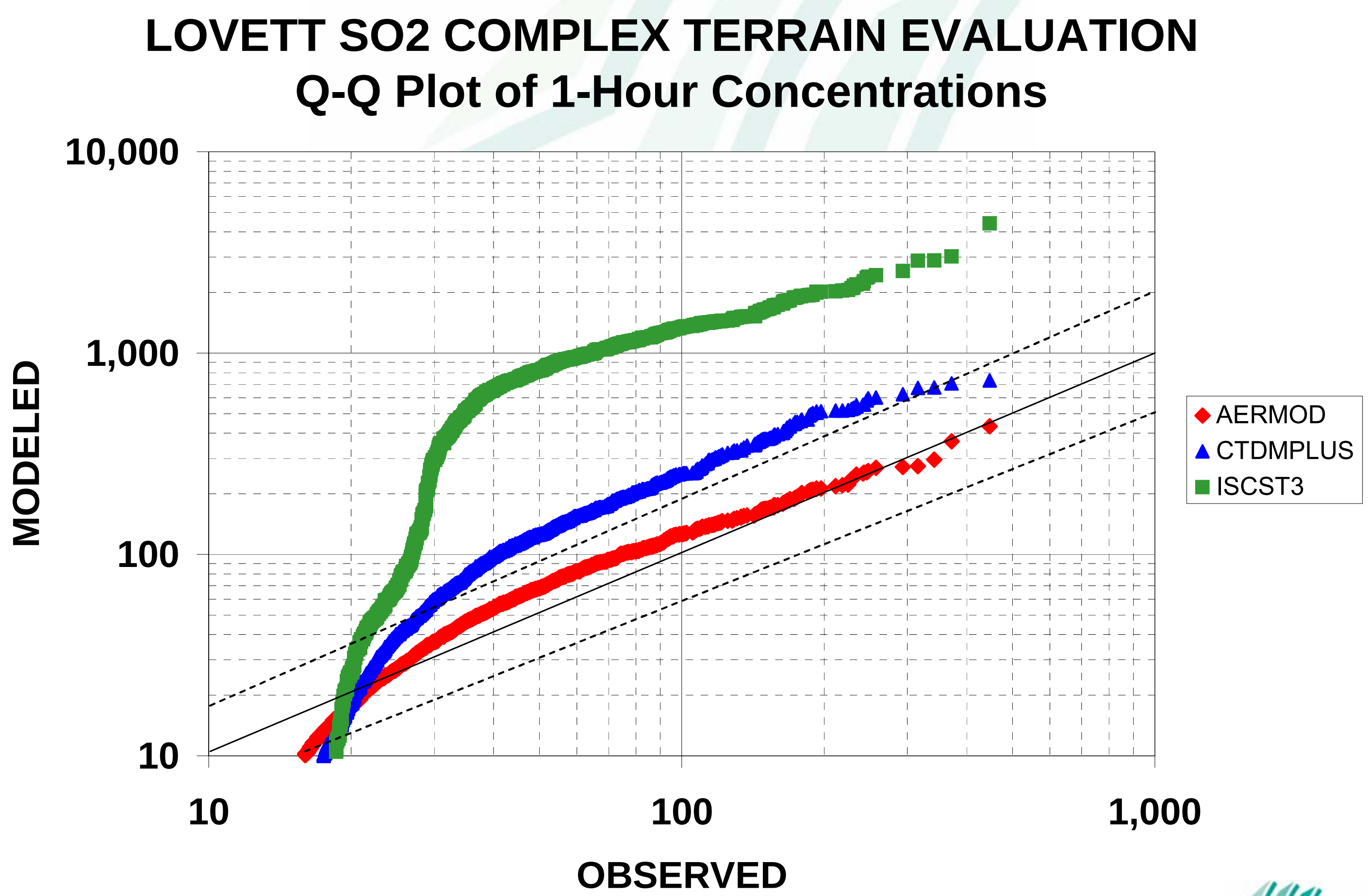
Complex Terrain Model Performance



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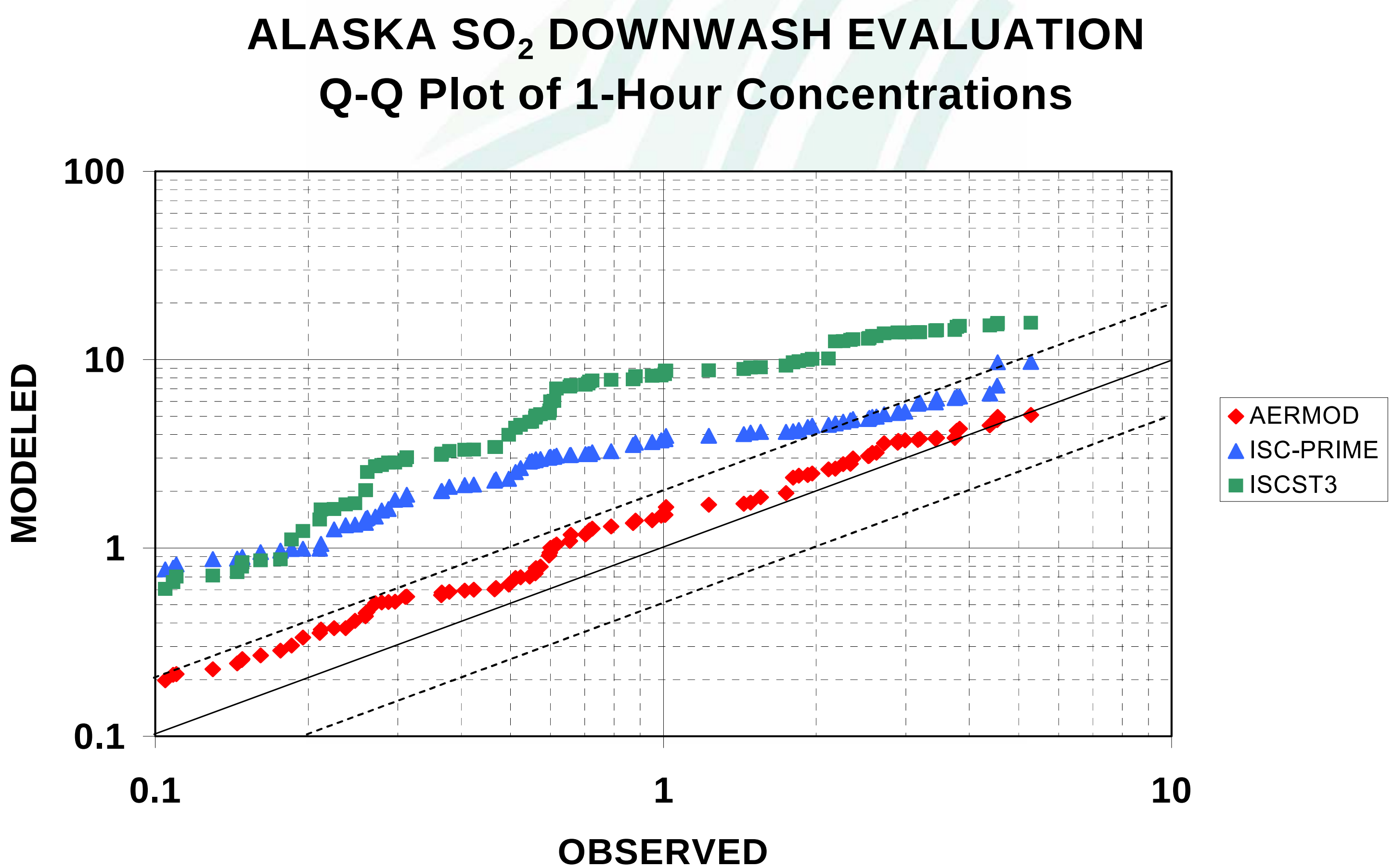
Downwash Model Performance



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AERMOD Consequence Analysis

- Model-to-Model Comparisons of AERMOD with ISCST3 and ISC-PRIME
- AERMOD vs. ISCST3 Results Vary by Source, Meteorology and Topography/Land Use
- AERMOD Generally Predicts Lower – More Realistic – Concentrations in Complex Terrain
- Peak Short-term Concentrations Similar for Tall Stacks in Rural/Flat Terrain with AERMOD Slightly Higher
- AERMOD/ISCST3 Ratio Generally Increases with Longer Averaging Time – ISCST3 Underpredicts Annual Averages

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AERMOD Consequence Analysis

- Flat and simple terrain with point, volume and area sources
- Ratios of AERMOD-predicted high concentrations to ISCST3-predicted high concentrations

	1hour	3hour	24hour	Annual
average	1.04	1.09	1.14	1.33
high	4.25	2.82	3.15	3.89
low	0.32	0.26	0.24	0.30
No. cases	48	48	48	48

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AERMOD Consequence Analysis

- Flat terrain and point sources with significant downwash
- Ratios of AERMOD-predicted high concentrations to ISCST3-predicted and ISC-PRIME (ISC3P) predicted high concentrations

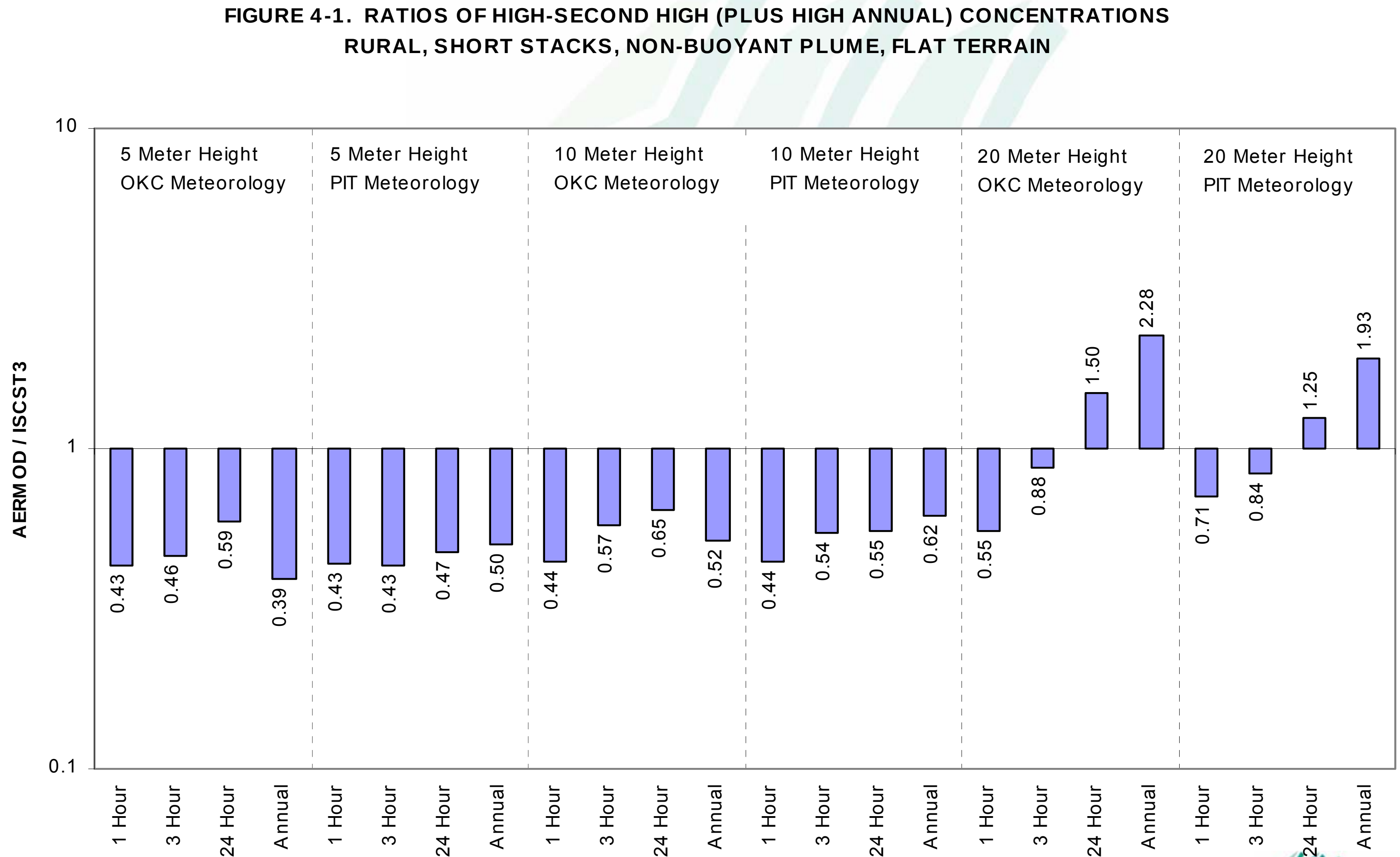
	ANNUAL		24-HR		3-HR	
	AER/ISC3	AER/ISCP	AER/ISC3	AER/ISCP	AER/ISC3	AER/ISCP
ave	1.08	1.05	1.25	1.01	0.71	1.05
max	1.35	1.29	1.87	1.14	1.20	1.17
min	0.69	0.79	0.69	0.84	0.38	0.93
No. cases	6		6		6	

AERMOD Consequence Analysis

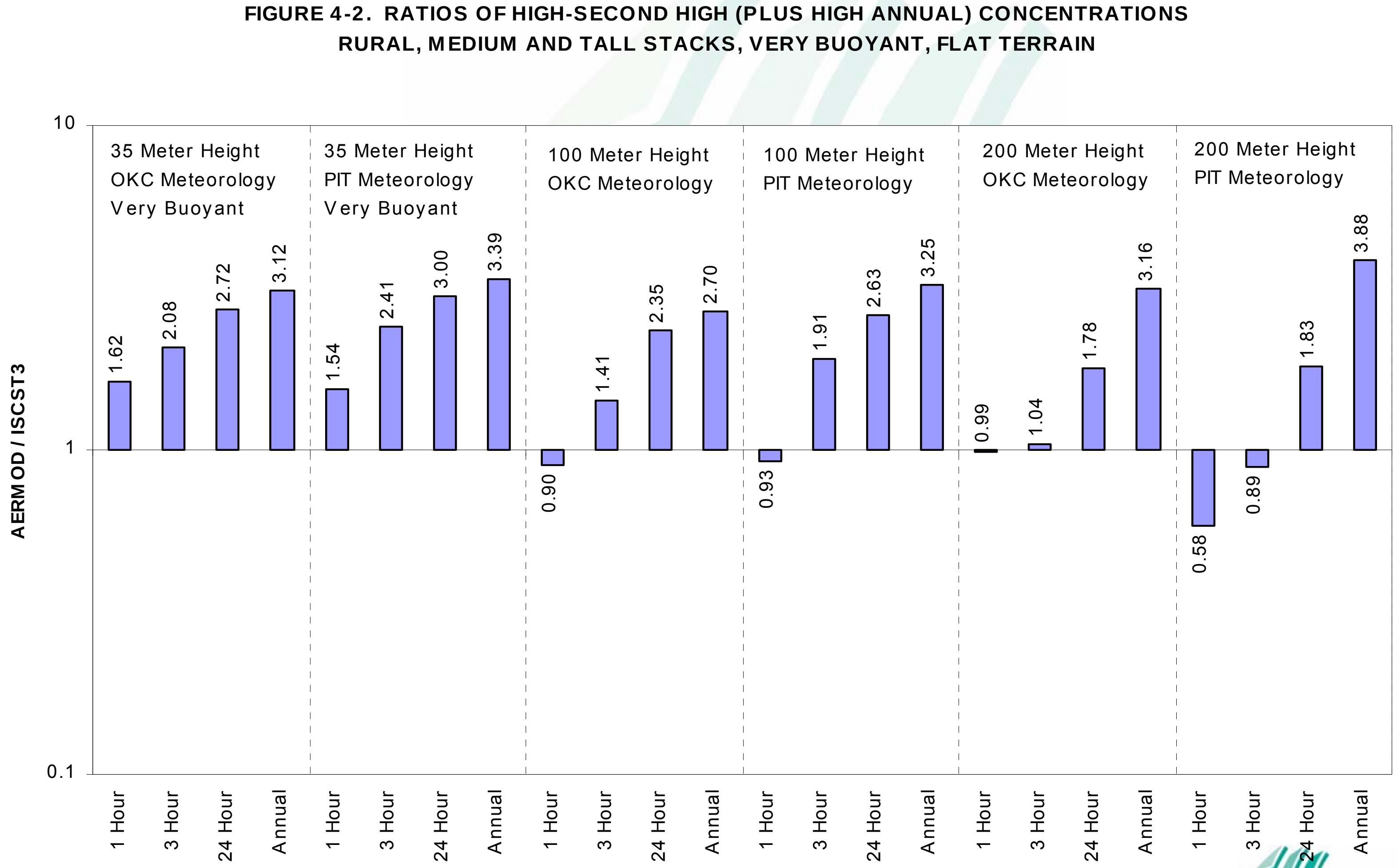
- Complex terrain with point sources
- Ratios of AERMOD-predicted high concentrations to ISCST3-predicted high concentrations

	AER/ISC3
AVE	0.24
MAX	0.79
MIN	0.07
No. of cases	196

AERMOD Consequence Analysis

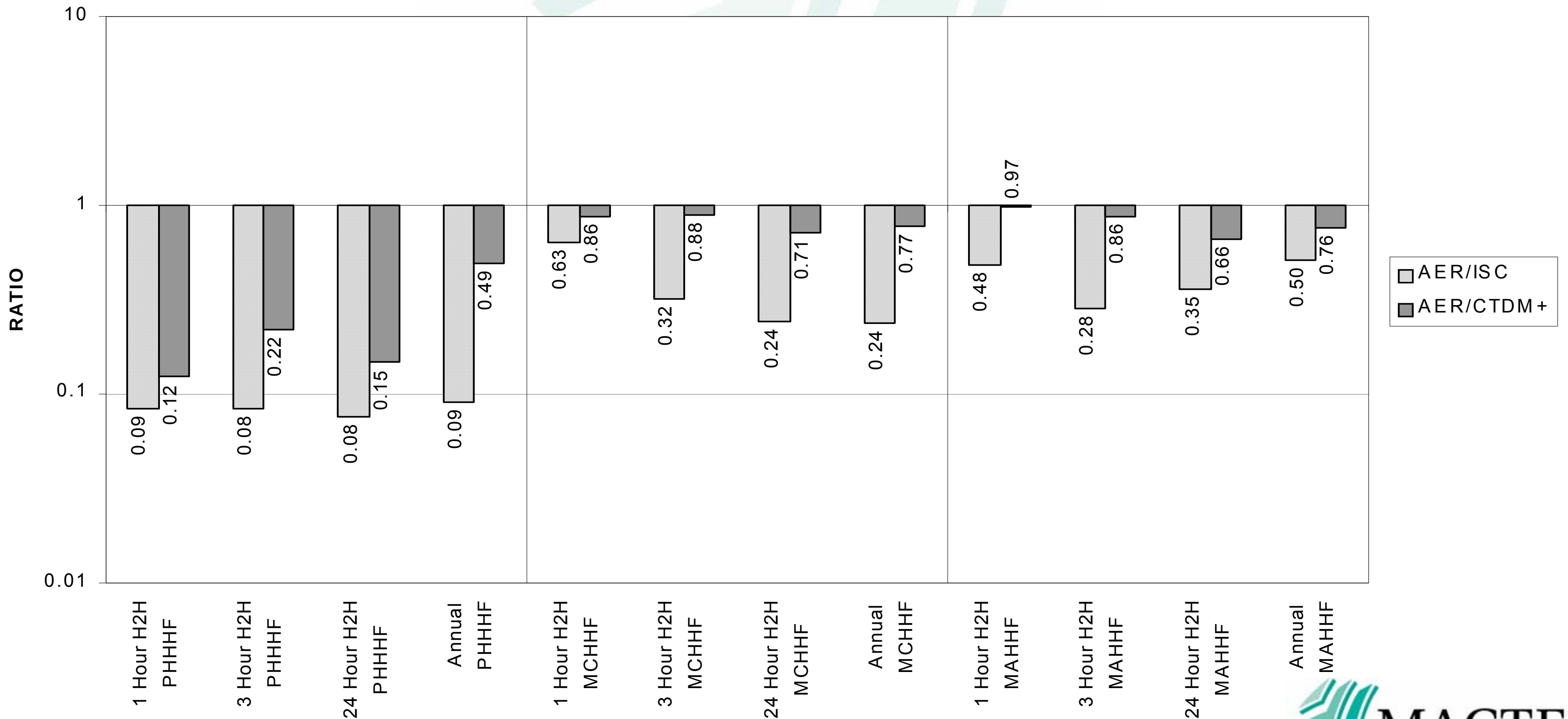


AERMOD Consequence Analysis



AERMOD Consequence Analysis

FIGURE 4-18.
RATIOS OF HIGH-SECOND HIGH (PLUS HIGH ANNUAL) CONCENTRATIONS
AERMOD TO ISCST3(COMPLEX1) AND CTDMPLUS
COMPLEX TERRAIN
HIGH STACK, HIGH BUOYANCY, HILL FAR FROM SOURCE



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Additional AERMOD Features

- Non-regulatory Options for Modeling NO to NO_2 Conversion
  - Plume Volume Molar Ratio Method (**PVMRM**)
  - Ozone Limiting Method (**OLM**)
- Dry and Wet **Deposition** of Gases and Particles for Multimedia Risk Assessment Applications
- Still to Come…
  - **AERSCREEN**: Screening tool based on AERMOD for use without observed meteorological data
  - **AERSURFACE**: Processes land-use data to estimate surface characteristics (Albedo, Bowen Ratio, and Surface Roughness)

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AERSCREEN Screening Model

- AERSCREEN Screening Model Consists of Two Components:
  - **MAKEMET** program generates matrix of meteorological conditions (.sfc and .pfl files) based on user-specified surface characteristics and temperature range
  - **ASCREEN** program provides command-prompt interface to AERMOD in SCREEN mode; incorporates MAKEMET, BPIPPRM and AERMAP; no area source option yet
- MAKEMET-generated Data used to Estimate Worst-case 1-hr Concentrations
- Scaling Factors for 3-, 8-, 24-hr and Annual Averages part of ASCREEN – Still Being Evaluated

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AERSCREEN Screening Model

- Significant Testing To Date Shows Good Results
- Recent Testing Performed for Rugged Terrain Settings, with and without Building Downwash
- Options for Applications with Terrain and Downwash Still Being Evaluated
- Alpha Version Submitted to Regional Modelers on April 25, 2006; Comments Requested By Mid-May
- Beta Release As Soon As Possible After Regional/State Modelers Workshop in May

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AERSURFACE Tool

- Tool Designed to Assist With Estimating Surface Characteristics for AERMET
- Existing Program Uses GEO.DAT File For Land Use Data
- New Version Being Designed:
  - Will use higher resolution NLCD data directly, bypassing MAKEGEO
  - More detailed Land Use category breakdown
  - More flexible options for domain size and direction sectors
- Draft Tool Expected by Fall 2006

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Other New or Pending Features

- Bulk Richardson Number Option in AERMET (04300), Uses Low-level (10-2m) ΔT in lieu of Cloud Cover
- Options for Capped and Horizontal Releases
  - EPA Model Clearinghouse procedure not applicable for PRIME downwash algorithm
- Additional Options for Varying Emissions by Month, Hour-of-Day and Day-of-Week (MHRDOW & MHRDOW7)
- Multiple Urban Areas in Single Model Run
- Updated Processing for PM-2.5 Standard
- MM5-to-AERMOD Tool Under Development

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AERMOD Limitations

- AERMOD is a Steady-State, Straight-Line Plume Model
  - Assumes uniform atmosphere across domain for each hour
  - Limited to near-field (< 50km) impact assessments
- AERMOD Applies to Continuous Releases – May Not Apply for Emergency Response
- AERMOD Does Not Address Multi-pollutant Photochemical Transformations (e.g. Ozone)

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AERMOD Potential Pitfalls

- Small Urban Areas with Tall Stacks
- Urban Option with Urban Meteorological Data
- No Horizontal Meander for Area Sources
- Very Low Roughness with Light Winds
- Excessive Model Runtimes
- AERMAP Terrain Data Format Limitations

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AERMOD Potential Pitfalls

- Surface Heterogeneity and Meteorological Data Representativeness
- Model Clearinghouse Procedure for Capped/Horizontal Releases with PRIME
- Area Sources in Terrain – Not Well-tested; Possible Issues with Sloped Terrain
- BPIPPRM Issues – Prior BPIP Logic for Selecting Controlling Structure May Not Be Appropriate for PRIME

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Important Points to Remember

- Many AERMOD Inputs are Same/Similar to ISCST3
- Biggest Challenge Will Likely Be Met Data Processing
  - Unfamiliar data formats
  - AERMET requires full upper air soundings
  - **Specification of surface characteristics**
- Coordination with Regulatory Agency on Key Issues
  - Modeling protocol may be needed
- New Boundary Layer Modeling Concepts in AERMOD
  - Similarity parameters – u_*, w_* and L – important for QA and interpretation of results

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Questions

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