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Representative Meteorological Data for AERMOD: A Case Study of WRF-Extracted Data Versus Nearby Airport Data

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The Typical Approach

- Typical met data for near-field air dispersion modeling:
  - Closest airport station to facility being modeled
  - Purpose-built “on-site” stations located at or near the facility
- Large error if distance from actual location is too great
- Large error if conditions change rapidly with distance (e.g. complex terrain)

The New Alternative

- New option: mesoscale meteorological data (WRF)
  - Long history in weather forecasting and regional AQ modeling (CALPUFF, CAMx, CMAQ)
- Potential to eliminate distance-based error
- Downside: forecast error is much greater than observational error
- In practice, which has less error?
  - Somewhat distant observed met station
  - Mesoscale model-derived met data

Objectives

- Evaluate model accuracy using:
  - Observed data that isn't in the perfect spot (typical)
  - Model-derived data
  - On-site data (approximate "truth")
- Consider differing regulatory guidance (land use, ADJ_U*, etc.)
- Two cases:
  - Simple terrain (Gulf Coast)
  - Complex terrain (Rocky Mountains)

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Methods

- An on-site met station is used as "truth"
- Evaluate met data itself
  - A moderately distant airport station
  - The closest grid cell of a WRF model run
- Evaluate AERMOD model results using each data source (site specific "truth", distant airport, and WRF)

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Simple Terrain Case Study

- Source location/on-site "truth": Wallisville Road air quality monitor location near Houston, TX (AQS: 48-201-0617)
- NWS airport met data taken from George Bush Intercontinental (KIAH)
- WRF dataset extracted from the nearest gridpoint of a 12 km resolution national WRF simulation obtained from US EPA
- Data from January-December 2007 was used

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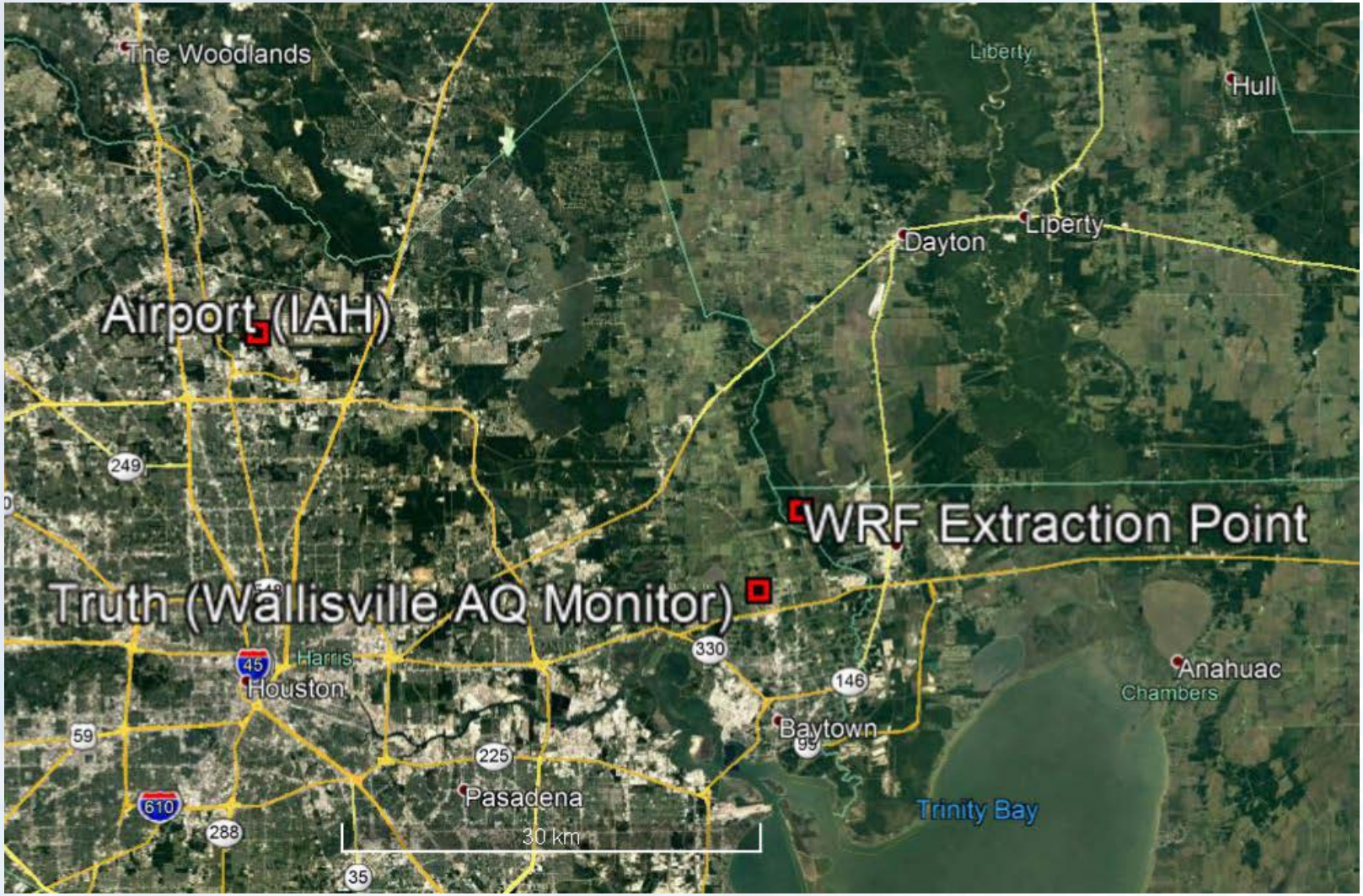
Methods



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Complex Terrain Case Study

- Wamsutter, WY air quality monitor location (AQS: 56-037-0200) was used as source location
  - Onsite data from the monitor was used as "true" met conditions at the site
- NWS airport met data was taken from the Rock Springs, Wyoming Airport (KRKS)
- WRF dataset extracted from the nearest gridpoint of a 12 km resolution national WRF simulation obtained from US EPA
- Data from January-December 2008 was used

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Methods

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Meteorological Data Processing

- Data processed according to latest U.S. EPA regulations/guidance/recommendations
- All data processed using AERMET
- WRF: extracted to point data files using U.S. EPA's MMIF tool, then processed through AERMET
- Airport data: uses 1-minute wind data (AERMINUTE)
- 0.5 m/s calm wind threshold for all datasets
- Land use:
  - 1992 NLCD (via AERSURFACE) used for airport and on-site data
  - Land use data from WRF (via MMIF) used for WRF data

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Meteorological Data Processing: ADJ_U* Option in AERMET

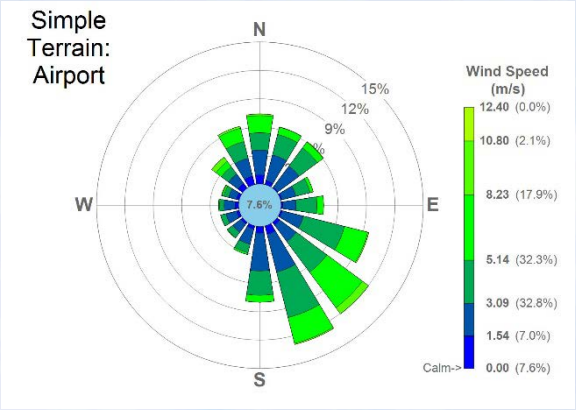
- Intended to offset AERMOD's tendency to over-predict concentrations from near-ground sources under stable, low wind conditions
  - Applied to the airport and WRF met datasets in accordance with US EPA guidance
  - Not applied to the "truth" datasets
    - The onsite stations used as "truth" include hourly σ_θ (standard deviation of horizontal wind direction) data
    - US EPA guidance on use of ADJ_U* recommends that it not be used if direct measurements of turbulence are available

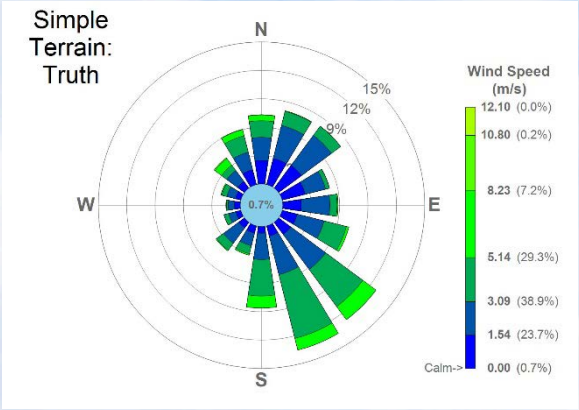
AERMOD Simulations

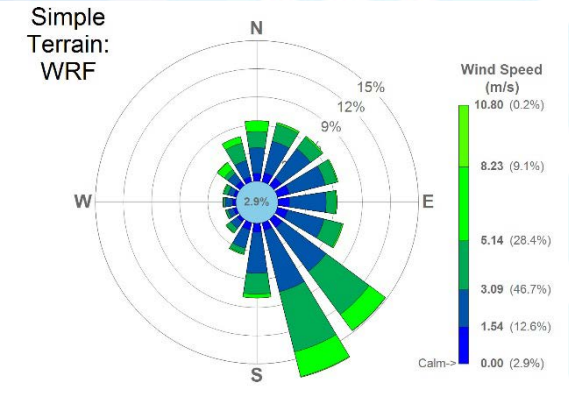
- Two different sources were modeled
  - Ground-level volume source
  - 35-meter stack source
- Terrain data incorporated with AERMAP
- No building downwash
- AERMOD simulations were carried out for a one-year period
- Regulatory default settings were used
- Maximum 1-hr, 24-hr, and annual concentrations modeled

Results: Met Data Comparison

Simple Terrain Case







- Wind Direction:
  - Modest differences between all datasets
  - Increased frequency of prevailing SSE/SE wind pattern in WRF dataset
- Wind Speeds:
  - Low winds underestimated by both (moreso by Airport than WRF)
  - High winds overrepresented by Airport
  - Land use?

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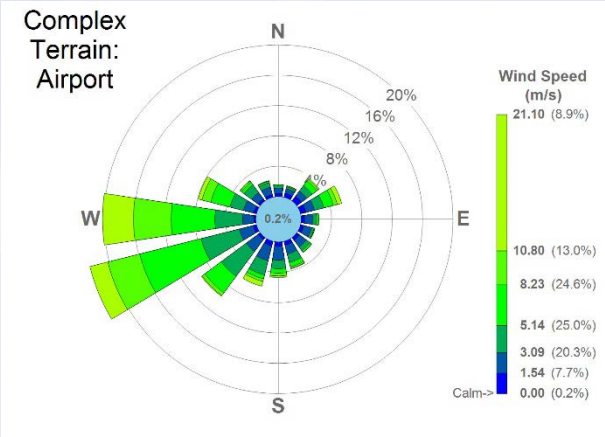
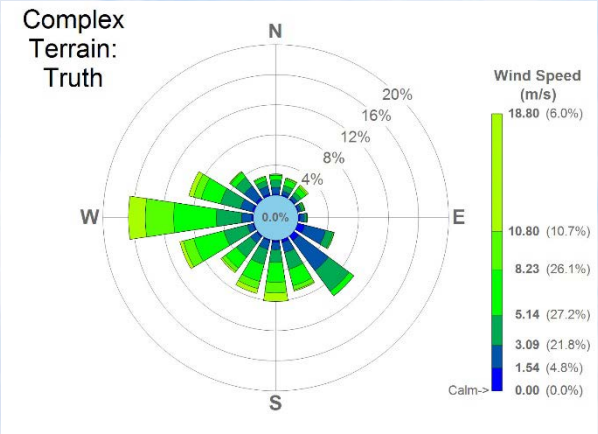
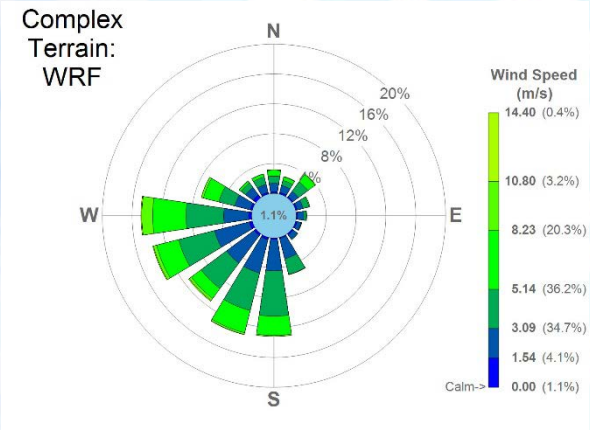
Results: Met Data Comparison

Complex Terrain Case







- Wind Direction:
  - Major differences between all datasets
- Wind speeds:
  - High winds overrepresented in Airport, underrepresented in WRF
  - Average Airport wind speeds were higher than average WRF or Truth wind speeds
  - Land use? (or just local variation…)

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Comparison of AERMOD Results

Maximum Annual Concentration				
Source Group	Simple Terrain		Complex Terrain	
	Airport	WRF	Airport	WRF
Tall Stack	1.34	1.67	1.28	0.80
Ground Level	0.52	0.45	0.50	0.39
Maximum 1-Hour Concentration				
Source Group	Simple Terrain		Complex Terrain	
	Airport	WRF	Airport	WRF
Tall Stack	0.85	1.29	0.85	1.21
Ground Level	0.14	0.16	0.21	0.29
Maximum 24-Hour Concentration				
Source Group	Simple Terrain		Complex Terrain	
	Airport	WRF	Airport	WRF
Tall Stack	1.37	1.70	0.86	1.10
Ground Level	0.37	0.42	0.24	0.22

Summary of max ground-level 1-hour, 24-hour, and annual average concentrations, normalized so "Truth" concentration is 1.00

- Ground-level source: large, consistent under-prediction (more on this later)
- Tall stack source: better performance
- Airport and WRF results broadly comparable
- WRF results more conservative in most cases
  - Exception: Annual maximum concentrations

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Comparison of AERMOD Results

Normalized Bias (1-Hour Concentrations)				
Source Group	Simple Terrain		Complex Terrain	
	Airport	WRF	Airport	WRF
Tall Stack	-20%	30%	2%	-12%
Ground Level	-81%	-63%	-45%	-35%
Normalized RMSE (1-Hour Concentrations)				
Source Group	Simple Terrain		Complex Terrain	
	Airport	WRF	Airport	WRF
Tall Stack	34%	49%	47%	38%
Ground Level	124%	110%	126%	119%

Bias and RMSE, normalized based on the average "Truth" concentration.

- Broadly similar performance in most cases
- Both the Airport and WRF datasets showed:
  - a consistent under-prediction bias for the ground level source
  - lower bias for the tall stack source
- Normalized RMSE for the WRF dataset was lower than for the Airport dataset with the exception of the simple terrain, tall stack case.

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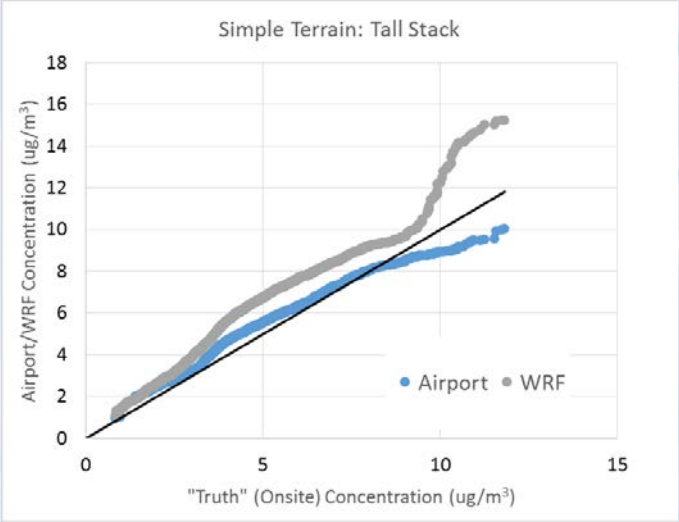
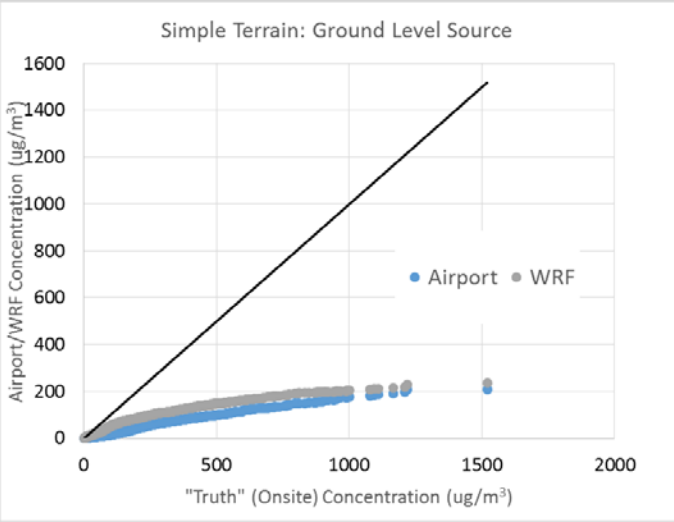
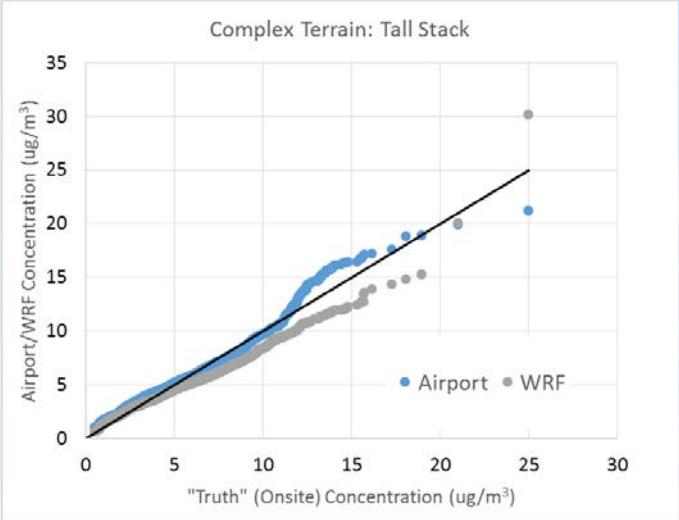
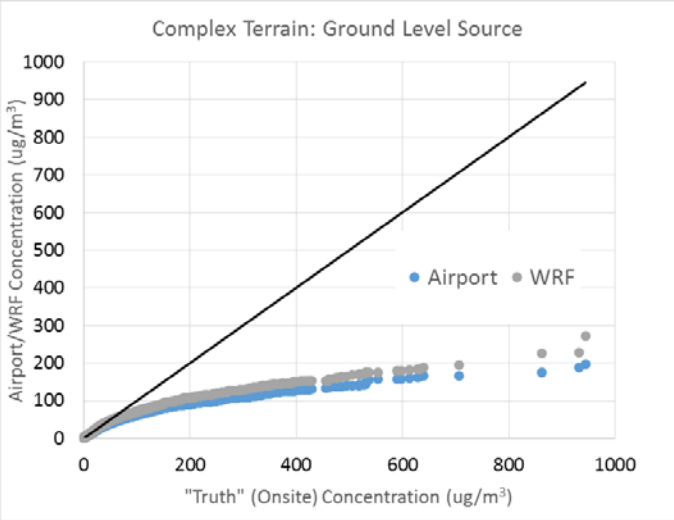
Comparison of AERMOD Results









Q-Q plots for 1-hour concentrations resulting from a tall stack and ground level source in the simple and complex terrain cases

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Conclusions: WRF-Derived Met Data vs Traditional Airport Data

- Wind speed and direction: broadly similar
  - Both struggle with wind patterns in complex terrain (12 km WRF resolution?)
  - Low wind speeds underweighted by Airport data (flat, open land use), better represented by WRF
- AERMOD model performance: broadly similar
  - Performance of Airport vs. WRF data varied among source, type, averaging period, and assessment metric
  - Broadly similar error, bias, etc. (more cases needed to draw a broader conclusion)
  - Findings support use of WRF in near-field dispersion modeling when no representative observation site is available. Similar conclusions to U.S. EPA evaluation of mesoscale models
    - https://www3.epa.gov/ttn/scram/appendix_w/2016/MMIF_Evaluation_TSD.pdf

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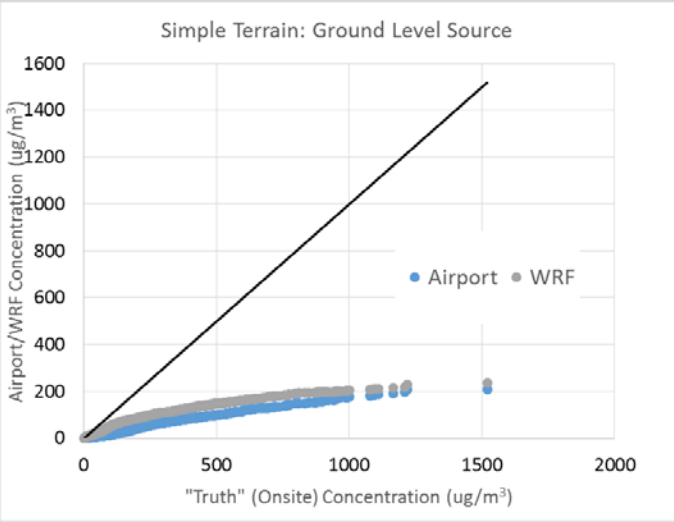
Conclusions: Applicability of ADJ_U* to Onsite Met Datasets

- Ground-level source produced much lower concentrations with WRF and Airport data than with on-site "truth" data
- WRF and Airport data used ADJ_U* AERMET option;
- On-site "truth" did not



Conclusions: Applicability of ADJ_U* to Onsite Met Datasets

- U.S. EPA ADJ_U* guidance:
  - Use for Airport data
  - Use for WRF data
  - Use for on-site stations with no direct turbulence measurement
  - Do NOT use for on-site stations with direct turbulence measurements (turbulence measurements should eliminate the need for a manual U* adjustment)
- This case: on-site station collects *some* turbulence data (σ_θ)
- Conclusion:
  - Either ADJ_U* should be used when σ_θ is only available turbulence data, or
  - Use of ADJ_U* with airport and WRF data is wrong
    - Conclusion contrary to extensive ADJ_U* validation studies

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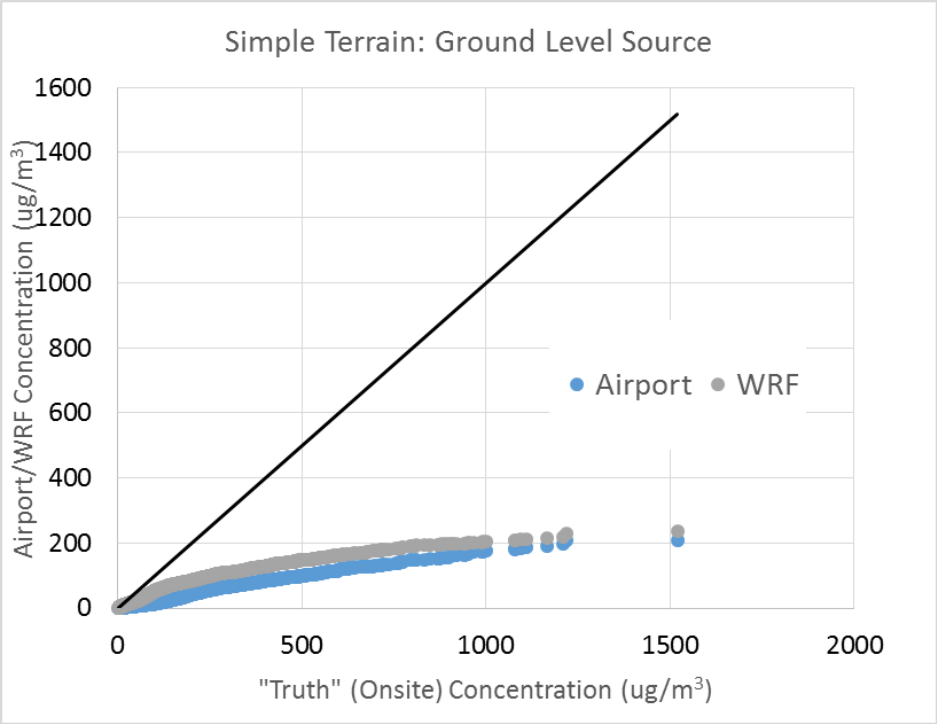
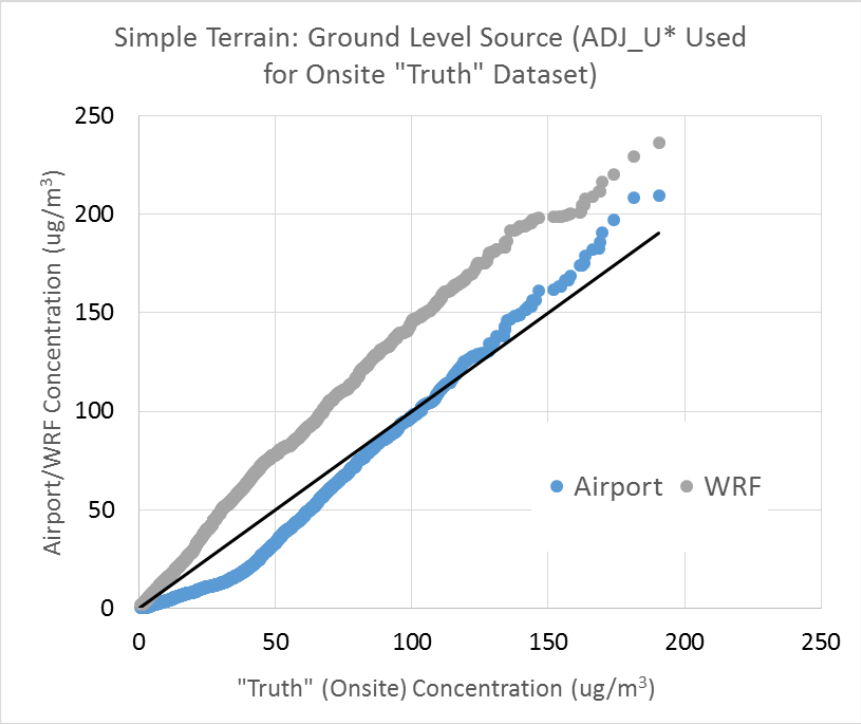
Conclusions: Applicability of ADJ_U* to Onsite Met Datasets

- ADJ_U* should be applied to on-site met data if σ_θ is the only available turbulence data (very common)
- With this change, all three AERMOD met data options produce broadly consistent results





Q-Q plots for 1-hour concentrations resulting from a ground-level source in the simple terrain case, with ADJ_U* not applied to the onsite ("Truth") meteorological dataset (left) and with ADJ_U* applied (right)

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Questions?

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