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Innovative Techniques for the AERMOD System

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Overview of Topics

- Temporal Scale of Bowen Ratios in AERMET
- Urban Characteristics of Highly Industrial Areas Using Thermal Satellite Data
- AERMOD Debugging

Growth of the Convective Mixed Layer

- In situations with tall stacks in simple terrain, peak ambient concentrations are often observed when the rising convective mixing height reaches a stable plume aloft and mixes it to the ground.
- Therefore, a critical performance criterion of any steady-state air dispersion model (i.e., AERMOD) is to be able to accurately estimate the rate of growth of the convective mixed layer during the daytime hours.
- In general, AERMET has a limited temporal resolution of surface moisture (monthly, seasonal, annual).

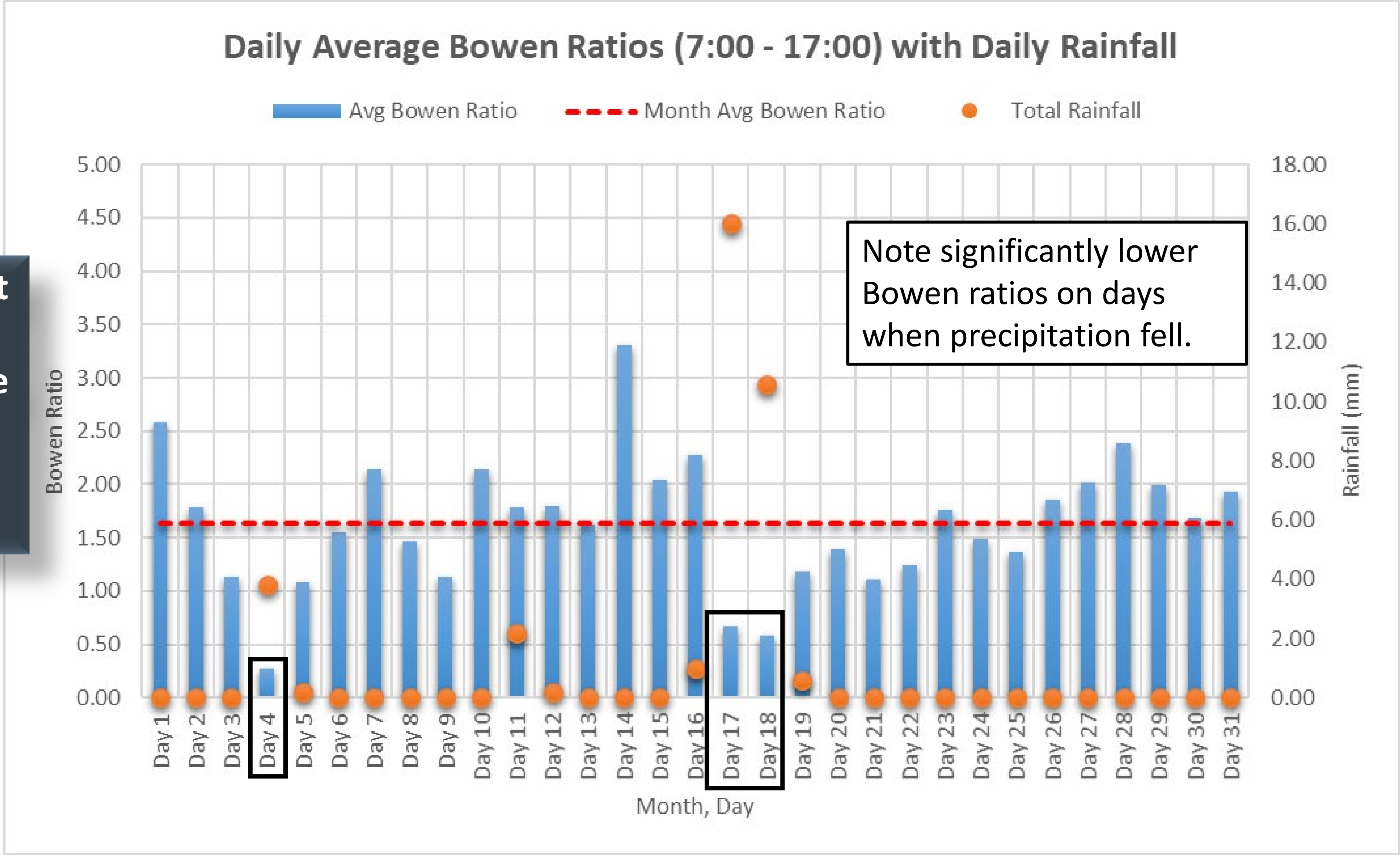
AERMET Stage 3

- There are 3 surface characteristic parameters used in the final stage of AERMET (Stage 3):
  - Roughness
  - Albedo
  - Bowen Ratio (ratio between sensible and latent heat fluxes)

- The Bowen Ratio parameter is sensitive to daily fluctuations, yet AERMET’s most refined temporal scale is monthly.

Daily Average Bowen Ratios with Daily Rainfall: Summer Month

Sensible & Latent heat fluxes were measured on-site using fast-response instruments.



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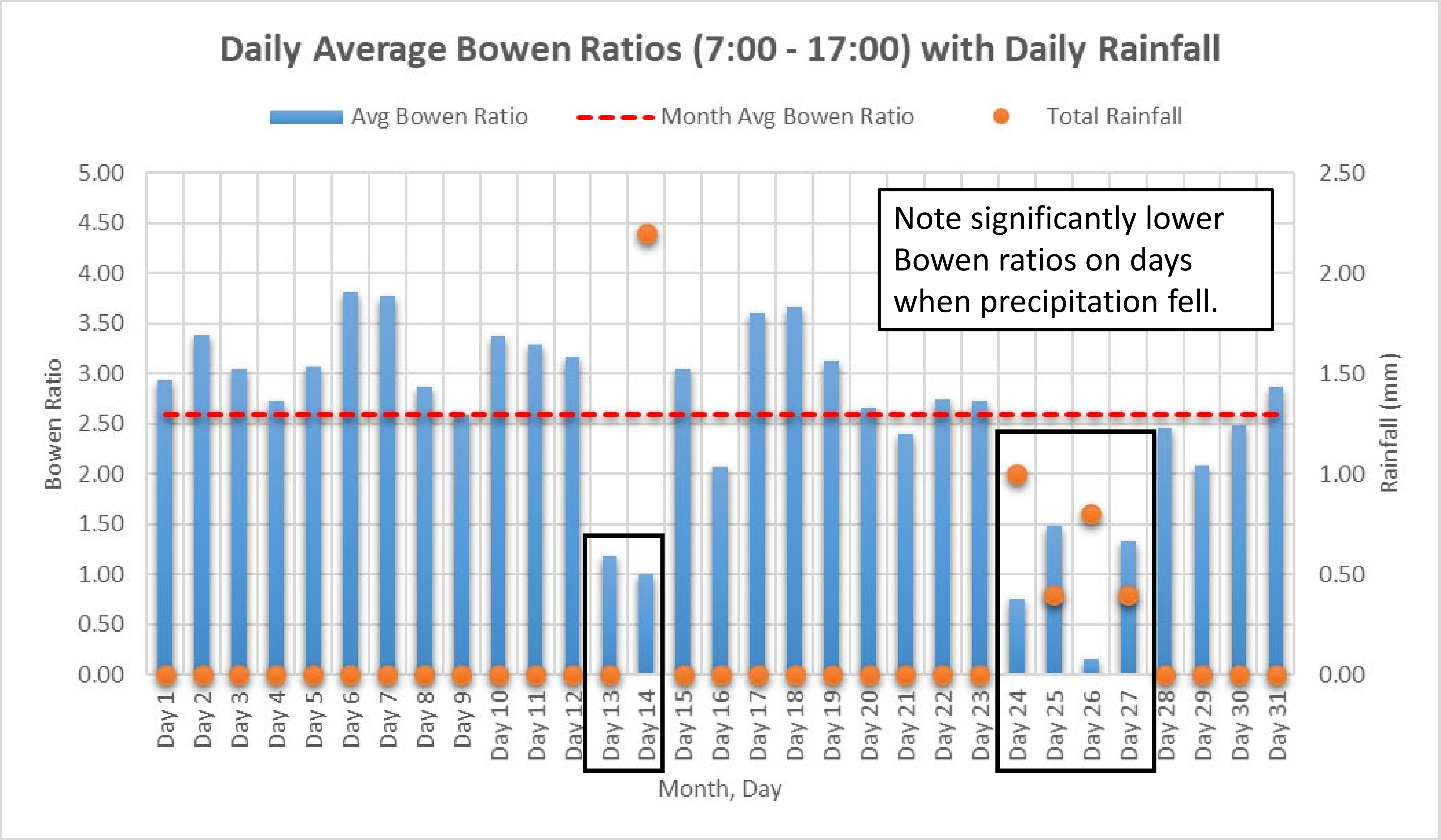
Daily Average Bowen Ratios with Daily Rainfall: Autumn Month



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Key Findings & Recommendation

– Recent findings using research-grade databases indicate AERMET's skill in estimating the magnitude of the convective mixed layer can improve (along with the timing of the inversion breakup) by a daily selection for the moisture characterization.

– Appendix E.2 of AERMET user manual (August 2019) describes a 5-day vs. 30-year average rainfall procedure to develop sub-monthly time periods.

– Encourage EPA to consider adding the capability of AERMET to accept and process daily Bowen Ratios.
  - This could also occur in tandem with an update to AERSURFACE tool to compute daily Bowen Ratios, which would streamline the process.

Urban Dispersion Characteristics in Highly Industrialized Areas

- Anthropogenic heat releases can cause urban heat island effects, as noted by Irwin (1978) in an internal EPA memo
- An “urban heat island” prevents the boundary layer from becoming stable at night
- Emission sources in highly industrialized areas with significant heat releases may be better characterized with urban dispersion than rural dispersion
- Facilities that operate 24/7 that could cause these heat effects may include:

Metal processing such as aluminum smelters or steel mills	Oil and gas refineries	Taconite processing facilities	Pulp and paper mills

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Determining the Equivalent Population

– AERMOD, has an urban model option that parameterizes the nocturnal boundary layer using a population input variable

– The AERMOD urban formulation uses a relationship between the urban-rural temperature difference ($\Delta T_{u\text{-}r}$) and the equivalent population (P):

$$\Delta T_{u\text{-}r} = \Delta T_{max} \, [0.1 \, \ln(P/P_o) + 1.0],$$

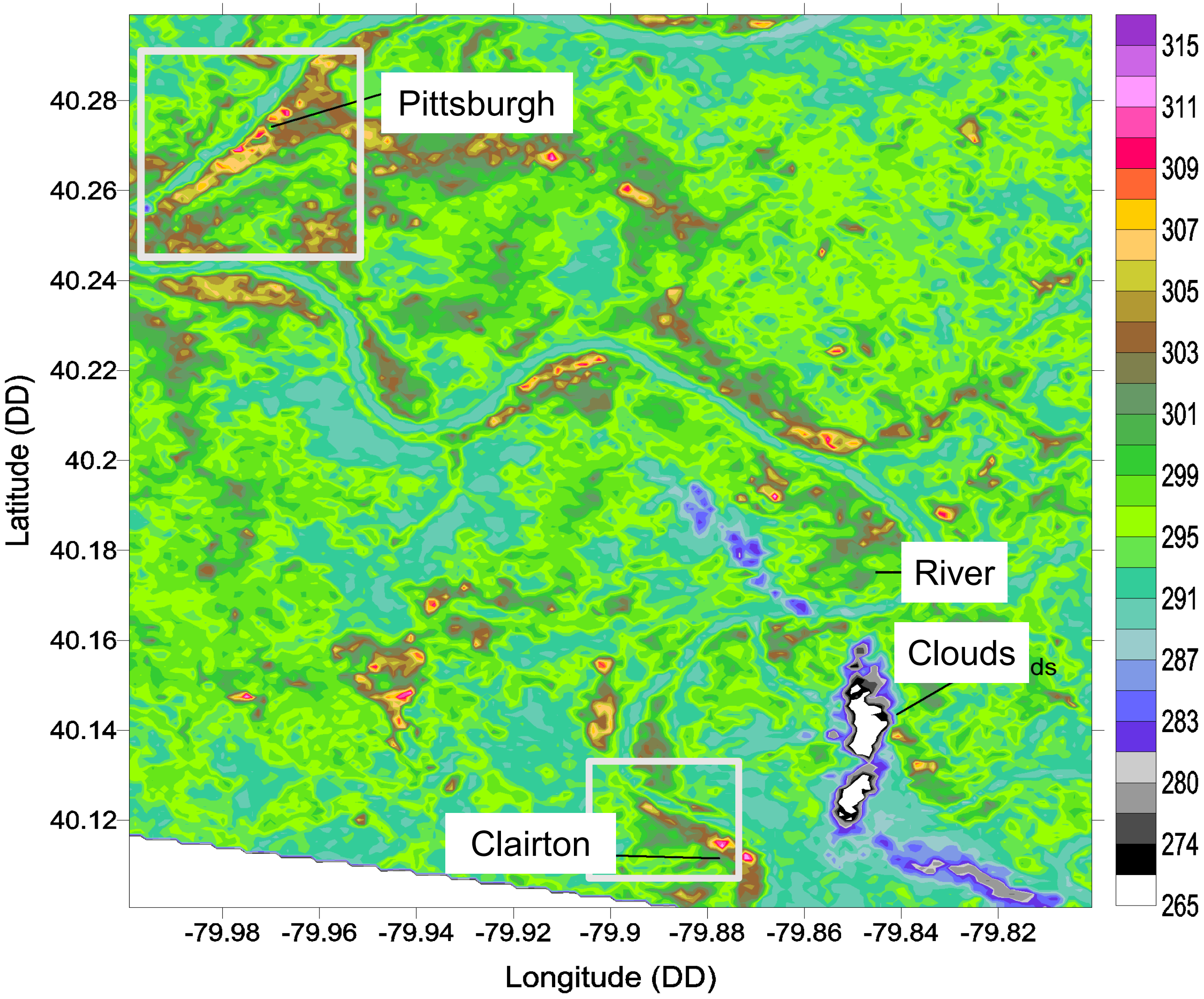
where $\Delta T_{max} = 12^{\circ}C$ and $P_o = 2{,}000{,}000$

– Urban-rural temperature difference can be measured for industrial complexes with satellite imagery

– Estimating surface temperature from satellite imagery can inform the application of this urban characterization technique

AERMOD Formulation: https://www3.epa.gov/ttn/scram/models/aermod/aermod_mfed.pdf

Quantifying a Heat Release



Brightness temperature from ASTER band 14 June 21, 2004 for 1100 LST

- Satellite imagery can provide a method of comparing urban-like area heat signatures to its cooler rural surroundings

- A highly industrial area in Clairton, PA, home to a steel and coke mill, is as “hot” as downtown Pittsburgh, according to satellite-derived surface temperature

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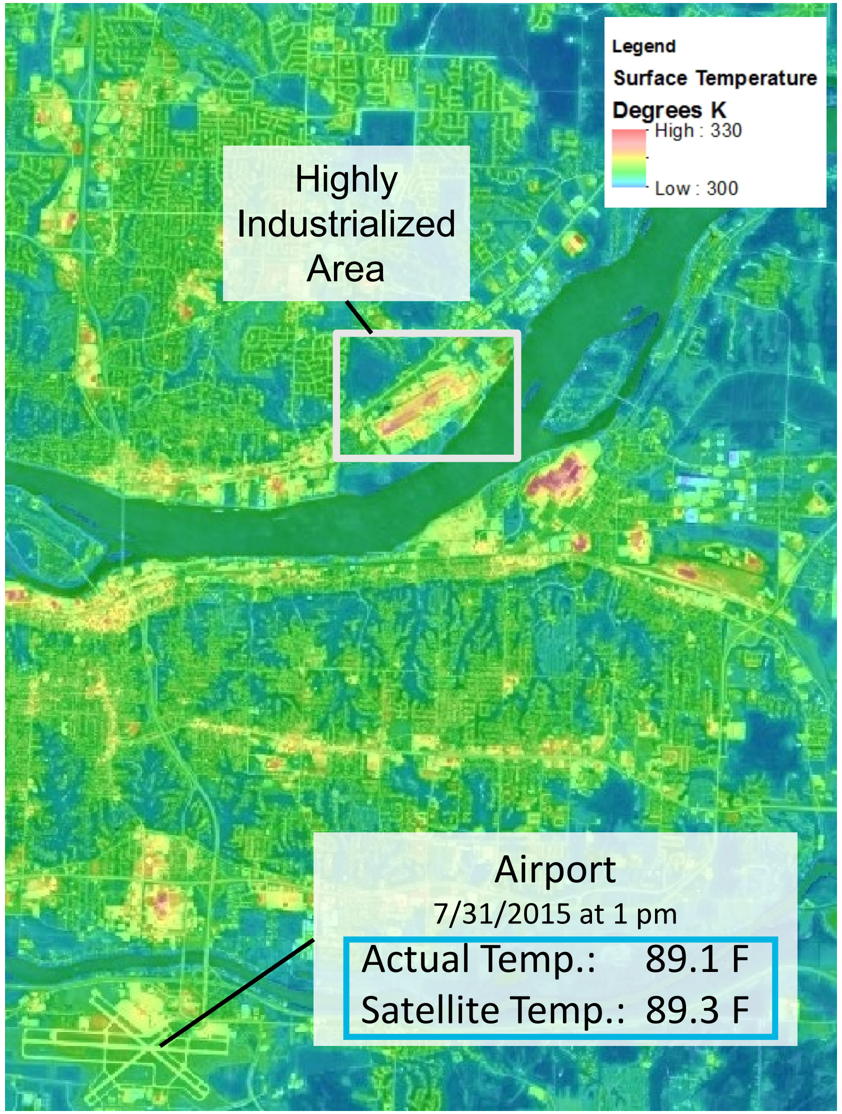
Accuracy of Satellite-derived Surface Temperature



- Satellite-derived surface temperatures can be quite accurate
- 90 to 100 meter spatial resolution images can reliably detect surface temperature perturbations as small as 1-2 K
- The industrial source shown here is located near an airport
- These temperatures obtained by satellite are nearly identical to the airport's meteorological station

Paine et al. (2016). Source characterization refinements for routine modeling applications. Available at: https://www.sciencedirect.com/science/article/pii/S1352231016300036

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Key Messages & Recommendation

- Highly industrialized areas (HIAs), operating 24/7, in unpopulated areas can create an urban heat island effect.
- Urban characterization of these HIAs in AERMOD has been shown to improve model performance when compared with monitored concentrations.
- An equivalent population can be estimated by satellite data.
- The latest updates to the Guideline on Air Quality Models (Appendix W) have allowed for this procedure with appropriate documentation.
- This source characterization technique can be used without the need for an alternative model approval – we commend EPA's acceptance of this approach and encourage extension to other source characterization techniques (e.g. AERLIFT, LIFTOFF, AERMOIST).

Enhancements to AERMOD

Techniques funded by EPRI include:

DISTANCE-DEBUG

Printing of a debug file for determining several plume dispersion properties including whether plume could reach peak impacted receptor within 1-hour.

HRBINARY

Allows for the import of AERMOD unformatted 1-hour binary output from a separate model run so that it can be added to the current run.

DISTANCE-DEBUG: Example Output

Meteorological Conditions

Mechanical & Convective Mixing Heights

OBSERVED MET CONDITIONS FOR: YYMMDDHH: 14030510	USTAR (m/s)	WSTAR (m/s)	OBULEN (m)	URB_OBULEN (m)	ZIMECH (m)	ZICONV (m)	ZI_URB (m)	SFCZ0 (m)	THSTAR (K)
	0.14	0.45	-17.20	N.A.	119.00	256.00	N.A.	0.0500	-9.990

Sources & Receptor

Maximum Hourly Concentrations by Source

POINT SOURCES:

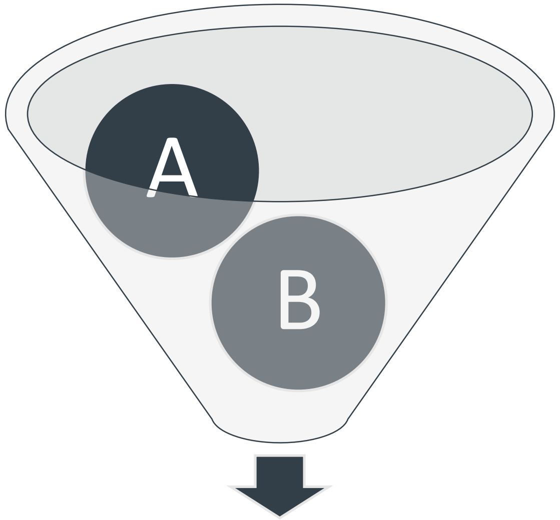
SOURCE ID	RCPT NO.	FINAL PLUME HT. (m)	DIST. FINAL PL.HT (m)	WDIR FINAL HT. (deg)	Effect. WSPD (m/s)	<------ DISTANCE 3600* ueff (m/s)	TO RECEPT (m) ----->	PLUME TYPE	MEAND. FRAC.	PART. PEN. FRAC.	EFFECT. SIGMA_V (m/s)	EFFECT. SIGMA_W (m/s)	HOURLY CONC. (µg/m3)
P 50	6833	353.6	1284.7	84.	1.918	6905.4	3441.5	PEN	0.181	0.889	0.500	0.213	105.954
P 51	6866	355.9	1284.7	84.	1.918	6906.1	3655.7	PEN	0.184	0.898	0.500	0.211	120.389

Final Effective Plume Height & Distance From Coherent Portion of the Dominant Plume Type

Dominant Plume Type

HRBINARY

Two Separate AERMOD Runs



Final Combined Statistical Output

Requirements

1. Identical Receptor File
2. Meteorology Covering Same Time Period
3. Identical Downwash (BPIP output) for all Sources
4. Same Modeling Period
5. 1-hour Binary Files
6. ALL Source Group

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Summary of Topics

Incorporation of Daily Bowen Ratios in AERMET

Using Thermal Satellite Data to Show Urban Characteristics of Highly Industrial Areas & Obtain An Equivalent Population

DISTANCE-DEBUG & HRBINARY

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Thank You