AERMOD Low Wind Speed Panel: Review of Charge Questions

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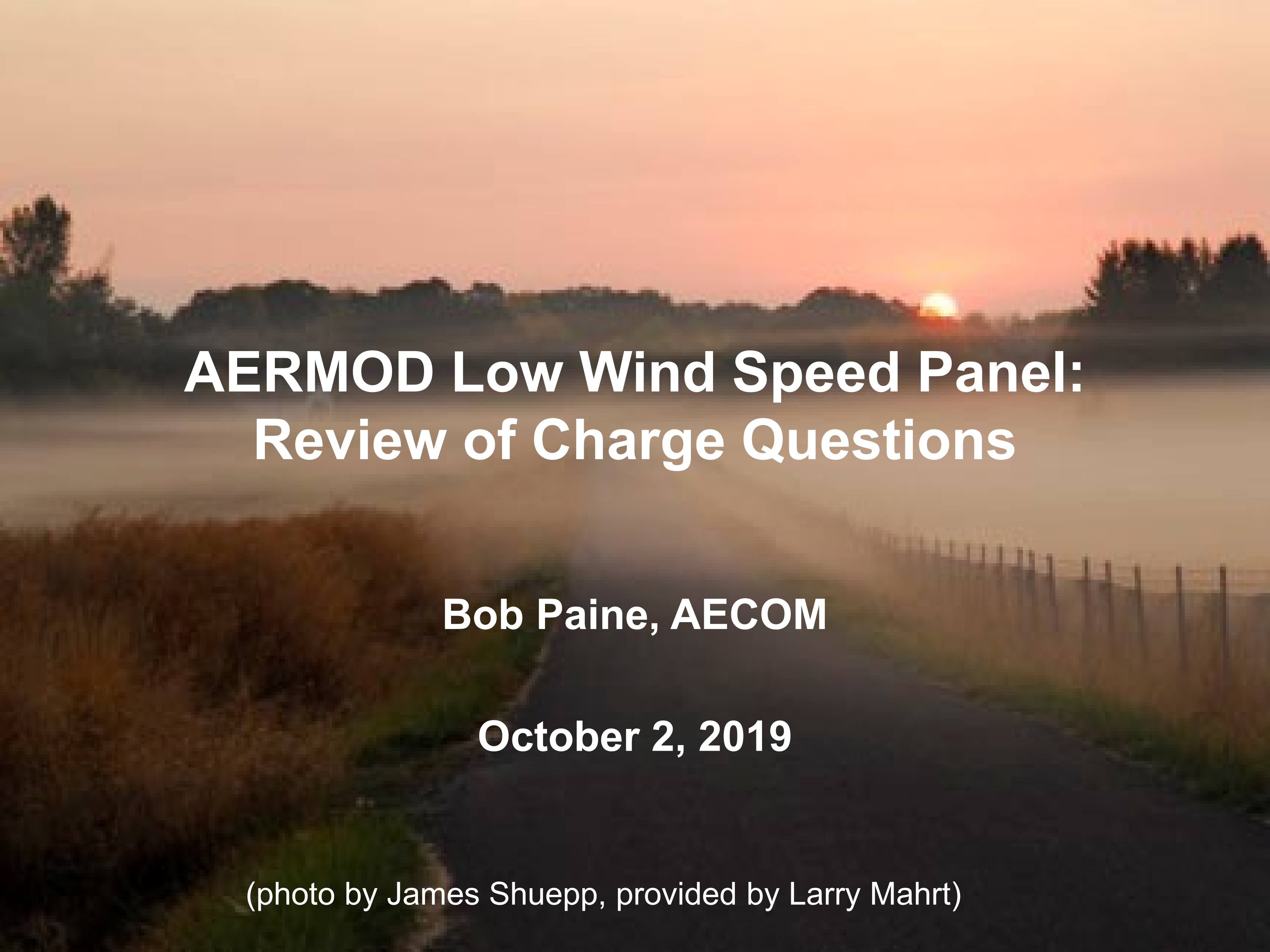
October 2, 2019



(photo by James Shuepp, provided by Larry Mahrt)

Outline of Presentation: Charge Questions

- Provide experiences using ADJ_U* option.
- Comment on EPA's strategy for LOW_WIND components of minimum wind speed, minimum sigma-v, and maximum meander factor.
- Should there be other changes considered for AERMOD for the LOW_WIND components, or for low wind speed conditions in general?
- What databases should be used for evaluation of low wind conditions?

Review of Challenges in Low Wind Speeds

- In low wind conditions, dilution wind speeds are low and therefore high concentrations are possible.
- For steady-state models, wind speed variability during low wind conditions challenges assumption of a straight plume that can travel 50 km in one hour.
- Challenges with low wind conditions:
  - Plumes don't go very far in 1 hour
  - Winds are likely not steady for the full hour, so the "coherent" plume is combined with a "pancake" plume in a weighted fashion in AERMOD
  - Parameterization of plume spreading in AERMOD may be underestimated in low winds, even with observed turbulence
- Challenge for steady-state models: avoid predictions of extremely high concentrations (can happen with a combination of low winds and low turbulence) by using a reasonable minimum for dilution wind speed and turbulence.

ADJ_U* Option Overview

- This option adjusts friction velocity (U*) in low wind speed (< 1-2 m/s) conditions to cover conditions where similarity theory does not work – corrects original formulation of AERMOD that was not thoroughly tested.
- Adjustment with larger values of U* will result in more mechanical turbulence, higher mechanical mixing heights, and a higher effective wind speed – lower predicted concentrations in these low wind conditions.
- EPA decided in its implementation to not combine ADJ_U* and observed turbulence; user selects one or the other.
- Low wind speed issues are also present in convective conditions, so I provide comments on this as well.
- Comments will cover cases both with and without available turbulence measurements.

ADJ_U* Option Without Turbulence Input

- In convective conditions, we see little difference with ADJ_U* because convective-related turbulence dominates over mechanical turbulence in low winds.
- In high winds, there is no “low wind” U* adjustment.
- In low wind/stable conditions, the higher U* results in larger parameterized turbulence values in both the vertical and the horizontal, and a higher mechanical mixing height.
- This usually results in lower concentrations in stable conditions vs. not using ADJ_U* (if no turbulence input).

ADJ_U* Option With Turbulence Input

- In convective conditions, the *parameterized* turbulence works well, so not using turbulence data in convective conditions with ADJ_U* does not cause a problem.
- In fact, use of observed turbulence data in convective conditions seems to result in overpredictions because the plume spreading as formulated with use of turbulence data appears to be too low.
- Conversely, in low wind speed stable conditions with complex terrain, the use of turbulence data improves the model performance vs. not using it, even when using ADJ_U* because the plume spreading is more accurate.
- The turbulence data seems to more properly account for actual wind fluctuations in stable conditions, especially with full hourly turbulence averages that include the wind direction shifts.

LOW_WIND Option Components

- Minimum sigma-v: this is one of the more important variables because the horizontal plume spreading is directly related to this parameter.
- Many researchers (e.g., several papers by Hanna) mention a minimum sigma-v value of 0.5 m/s; we had good results with this value for a field study on Laurel Ridge in PA – submitted to and currently under review by EPA Region 3.
- Minimum wind speed: this has to be reconciled with the instrument starting threshold; should not be too low (0.5 m/s seems like a good choice).
- Maximum meander: this relates to how the weighting function works between the coherent and pancake plume, but there are other parameters to consider here (more about this below) – in general, I would recommend keeping 0.95 as a default.

LOW_WIND Components – what to add?

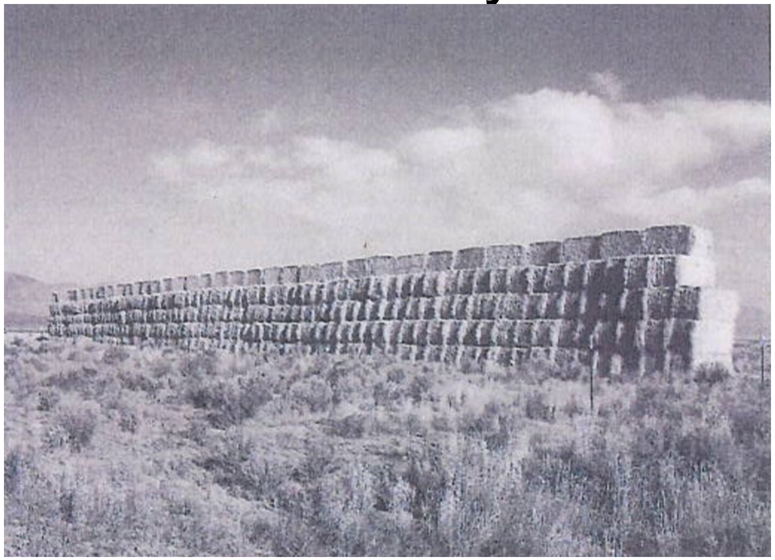
- Consider a minimum sigma-w option: parameterized value is often as low as 0.02 m/s above the mechanical mixing height, but many observations are well above 0.1 m/s
- For example, SCICHEM default uses minimum sigma-v as 0.5 m/s and minimum sigma-w as 0.1 m/s
- AERMOD is very sensitive to the weighting scheme between the coherent plume and the pancake plume because the coherent plume concentration can easily be an order of magnitude higher than the pancake plume concentration
- LOWWIND3 adjusted the random scaling time parameter ("BIGT", now 24 hours) to increase the pancake plume weight; but this adjustment was then removed for LOW_WIND
- The time scaling parameter should be added for LOW_WIND meander – more discussion on the next slide

LOW_WIND Issues – Research Findings

- Anfossi, D., D. Oettl, G. Degrazia, A. Goulart. 2005. An analysis of sonic anemometer observations in low wind speed conditions. *Boundary Layer Meteorology*, 114, 179–203.
- Slow mesoscale motions (wind fluctuations with periods of 20-30 minutes) exist under all meteorological conditions
- As the small-scale turbulence decreases with low wind speeds, these low frequency mesoscale motions become the most important factor for the total variance
- When the wind speed decreases below a certain threshold value (about 1.5 m/s), it is no longer possible to define a precise mean wind direction, and the wind direction oscillates with periods of the order of 30 minutes (well below 24 hours!)
- The slow mesoscale motions set a lower limit for the horizontal wind variance component

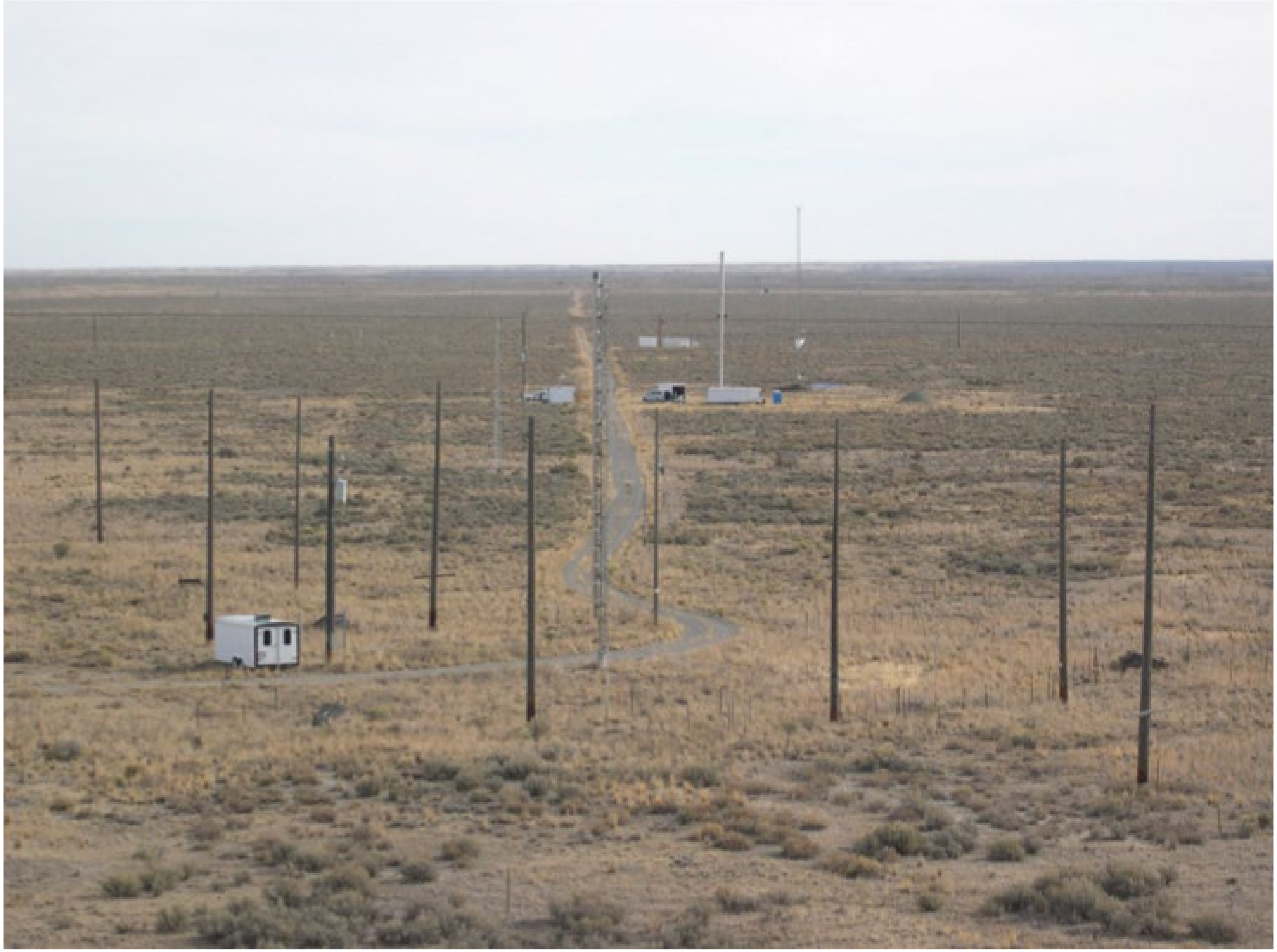
Recent NOAA Idaho Falls Research

- 2008 study for roadside barriers had a surprise – the plume spreading was much larger than expected from theory developed from older experiments
- This led to new experiments to update Project Prairie Grass
- Project Sagebrush occurred in two phases and involved 2-hour tracer releases vs. only a few minutes



- Low-level tracer releases with sampling at 100, 200, 400, 800 m, out to 3200 m in Phase 1
- 5 releases in Phase 1 (2013: daytime), 8 releases in Phase 2 (2016: 4 day, 4 night); many involving low wind speeds
- Inclusion of this database should be considered for low wind model evaluation

Project Sagebrush – View of Sampling Area



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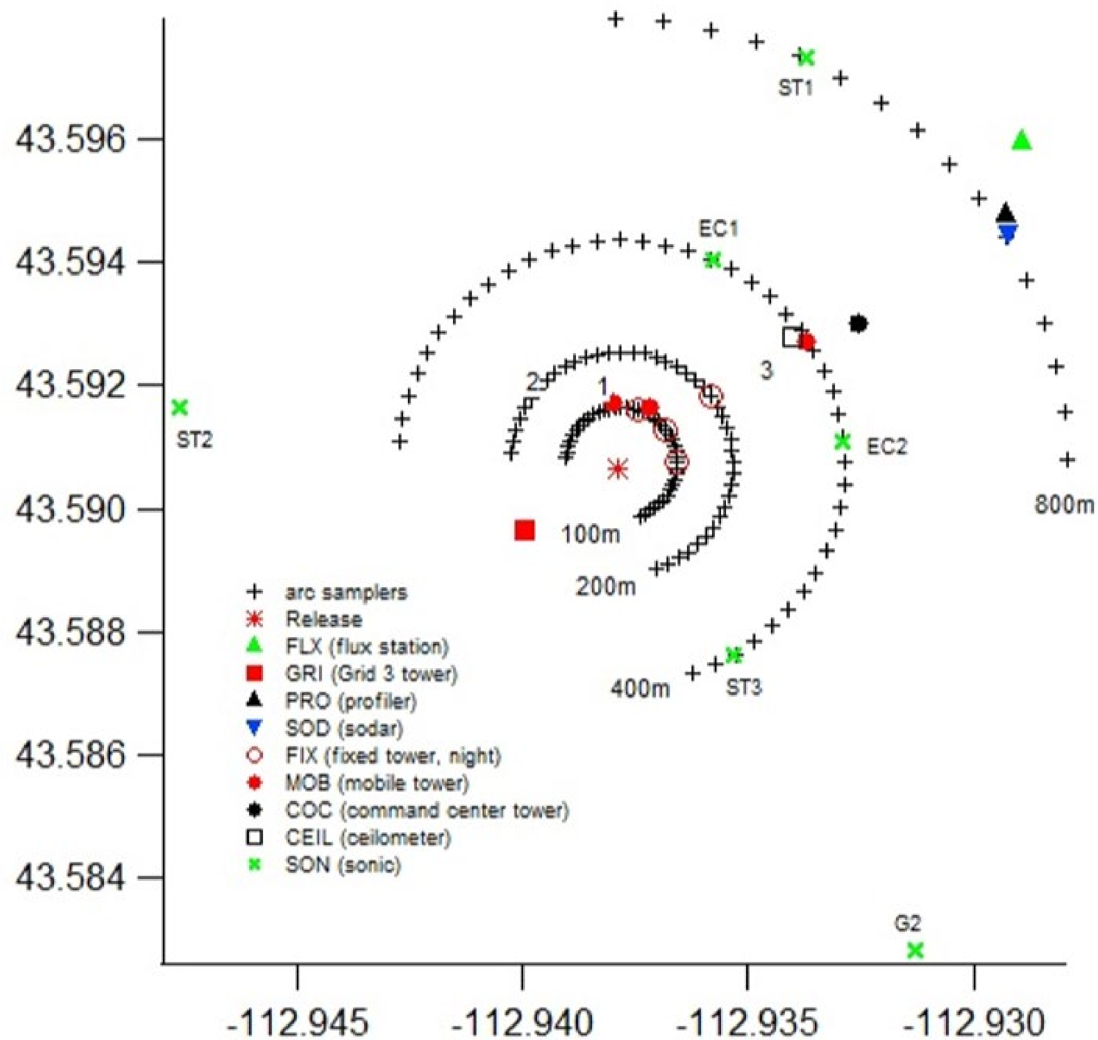
Project Sagebrush – Layout for Phase 2



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Low Wind Evaluation Databases to Consider

- Low-level releases:
  - Project Sagebrush (2013 and 2016: 13 trials of SF_6 tracer releases)
  - Three Mile Island (1972: 5 trials of SF_6 tracer releases)
  - Idaho Falls (1974: 11 days of SF_6 releases)
  - Oak Ridge (1974: 11 days of SF_6 releases)

- Elevated releases:
  - Lovett (1988 – 1 full year with 9 monitors, most of them on high terrain)
  - Tracy (1984 – 14 days of SF_6 releases from tall stack, mostly at night)
  - Hogback Ridge (1982 – 11 days of SF_6 releases from crane toward 2-D ridge)
  - Cinder Cone Butte (1980 – 18 days of SF_6 releases from crane toward Gaussian-shaped hill, Idaho)
  - Bull Run (1982 – 38 days of SF_6 releases from tall stack)
  - Kincaid (1980-1981 – 16 weeks of SF_6 releases from tall stack)
  - Laurel Ridge, PA (1990-1991 – full year of SO_2 releases from area power plants, 4 monitors)

Low Wind Modeling Issues – Other Considerations

- For turbulence data processing, use the full hour (not four 15-minute periods) to capture the wind fluctuations
- The current form of the parameterization for sigma-y and sigma-z computed from sigma-v and sigma-w may underestimate the dispersion, especially during the daytime
- There are issues to be presented tomorrow regarding the treatment of the penetrated plume component during low-wind speed convective conditions – this is a low-wind issue for convective conditions
- For evaluation of tracer databases (due to limited number of trials), the wind direction given to AERMOD should be derived from the *known location* of the peak monitored impact, not from the observed wind direction

Conclusions

- ADJ_U* option has made a difference for low wind speed, stable conditions
- In convective conditions, formulation of plume sigmas using observed turbulence needs reconsideration; AERMOD works better without turbulence in daytime conditions
- …and there is a problem with the penetrated plume – more on that tomorrow
- AERMOD LOW_WIND updates could consist of one or more of: a) adjustment of meander fraction (“BIGT”), b) adjust the minimum sigma-v and sigma-w values
- Evaluations should take advantage of tracer and full-year databases already in existence