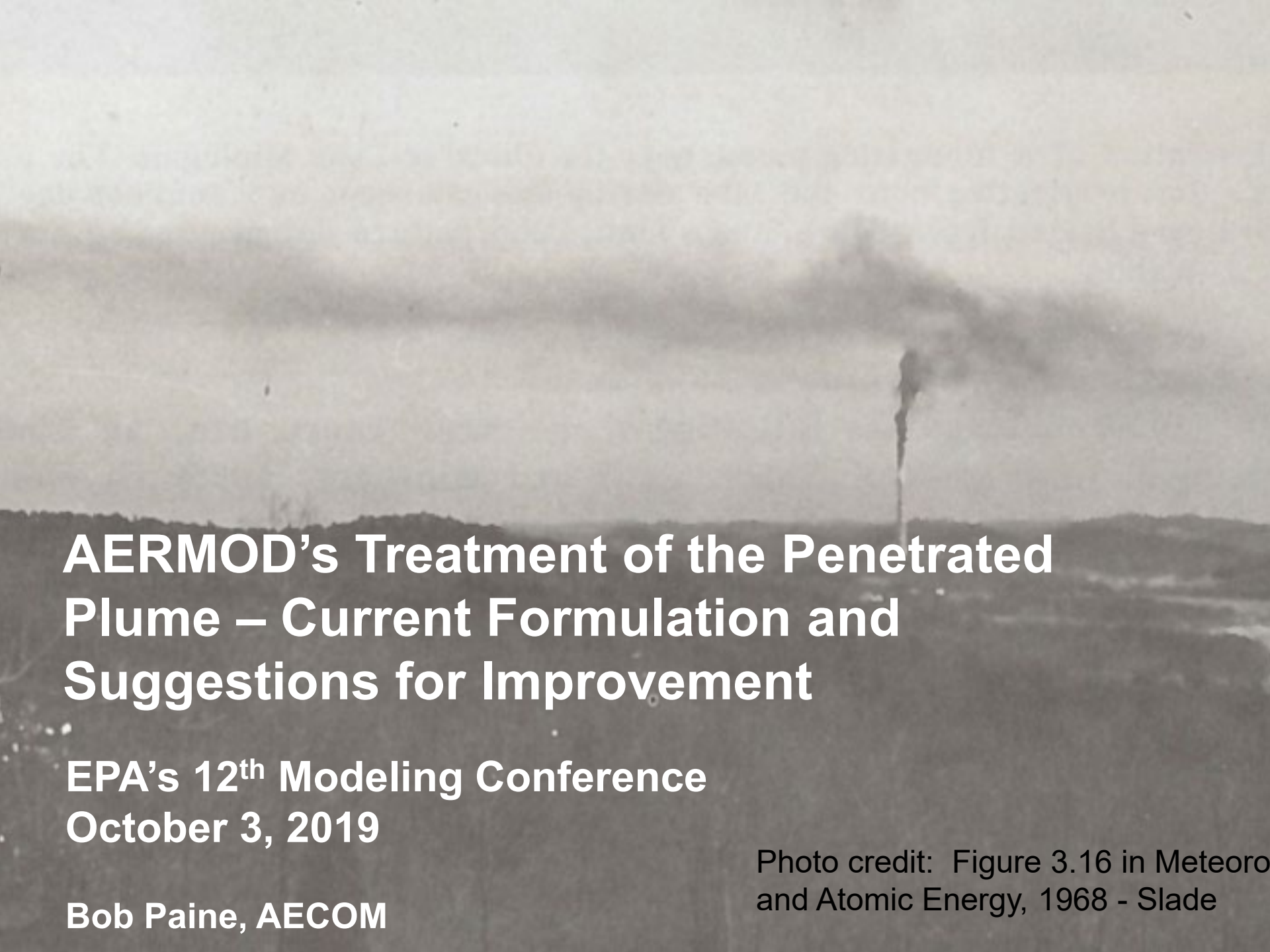


AERMOD's Treatment of the Penetrated Plume – Current Formulation and Suggestions for Improvement

EPA's 12th Modeling Conference
October 3, 2019

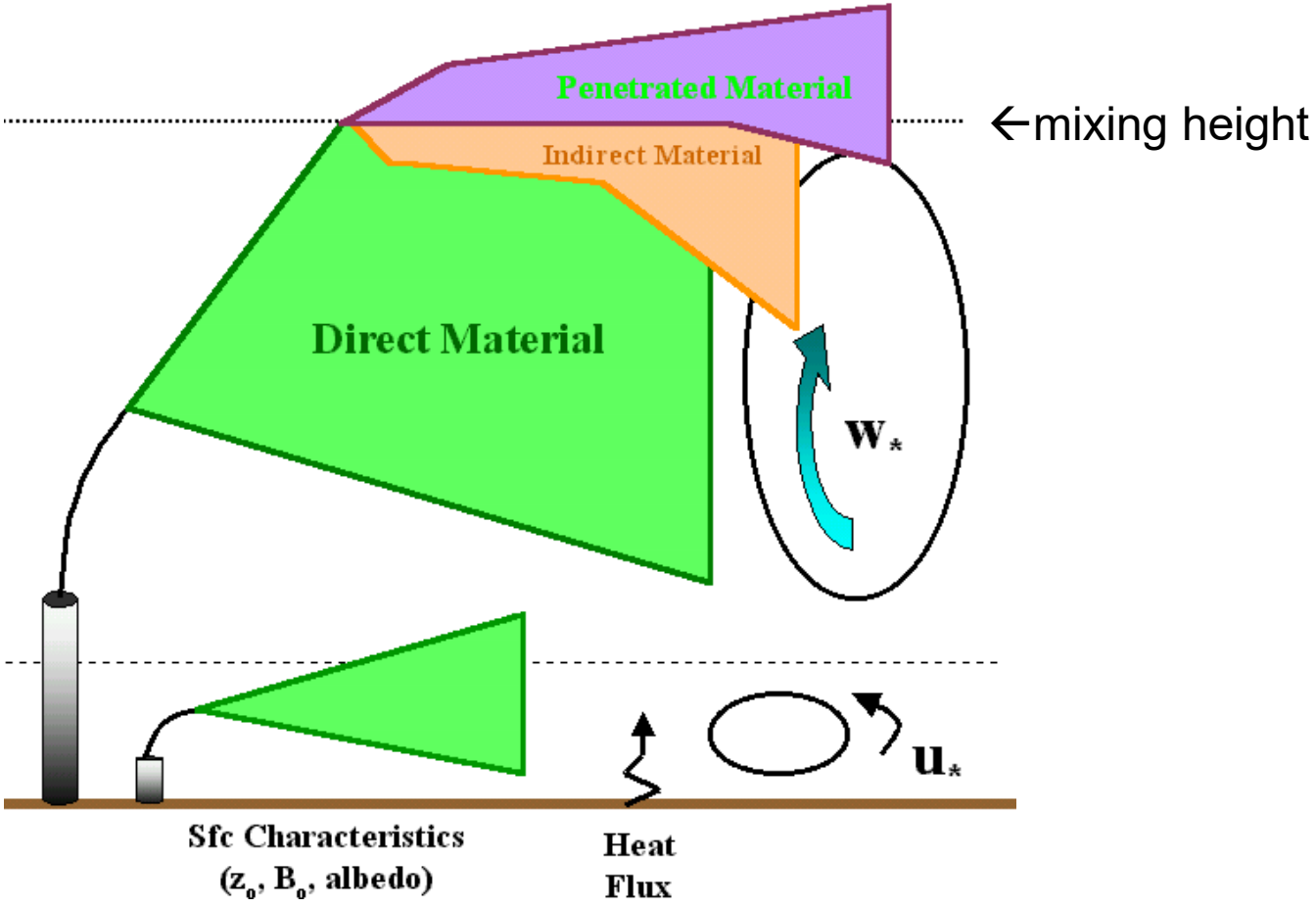
Bob Paine, AECOM

Photo credit: Figure 3.16 in Meteoro
and Atomic Energy, 1968 - Slade

Outline of Presentation

- What is the “penetrated plume”?
- History of penetrated plume treatment
- Current issue in AERMOD
- Field study findings
- Suggested approach for addressing this issue

AERMOD's 3-Plume Treatment in Convective Conditions



AERMOD's Treatment of Vertical Turbulence in Convective Conditions

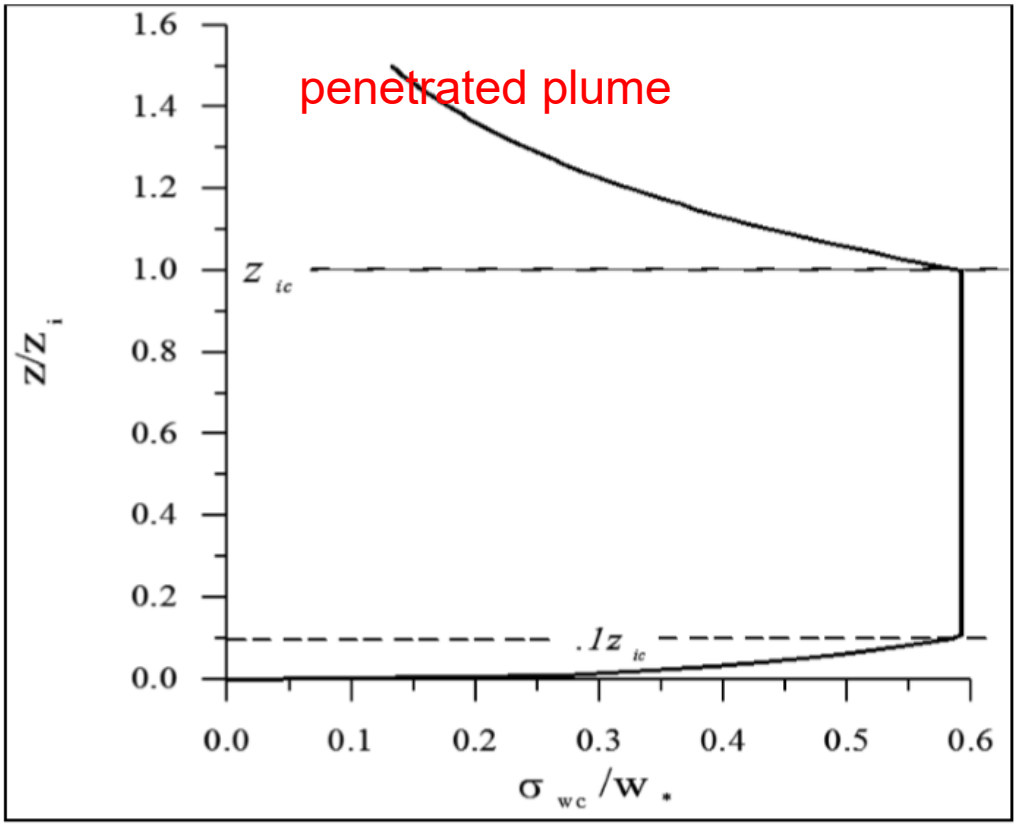


Figure 5. Convective portion of the vertical turbulence in the CBL

Evidence of a Problem with the Penetrated Plume Behavior

- Many modeling runs using AERMOD show a counterintuitive result in that the penetrated plume mixes to the ground rapidly and results in the highest concentration during the daytime
- This happens quite early in the morning, while observations show peak convective concentrations later in the day when (and after) the mixing height intercepts the penetrated plume
- The predecessor to AERMOD, ISCST3, predicted zero ground-level concentrations in this case
- We would expect minimal mixing of the penetrated plume to the ground before it is intercepted by the mixed layer

How Do We Know the Penetrated Plume is Causing This Issue? Answer: Debug Output

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

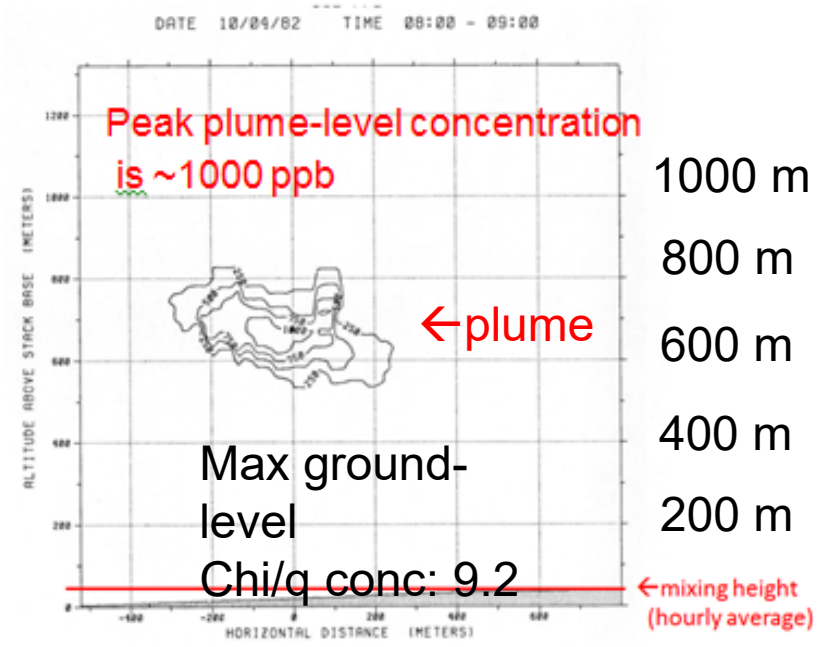
POINT SOURCES:

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

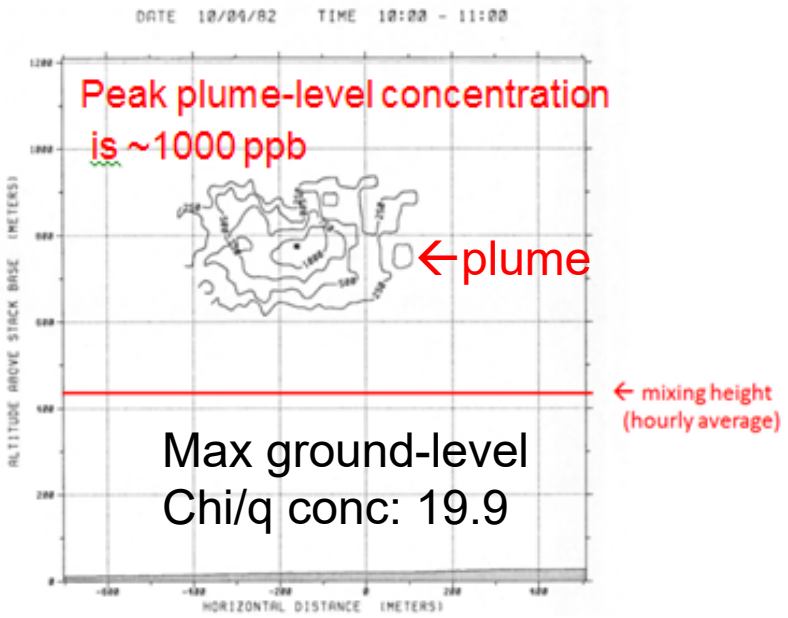
This output comes from the “DISTANCE DEBUG” output; initially distributed at the EPRI web site:
http://sourceforge.net/projects/epri-dispersion/

Lidar Images from Typical Day – Bull Run 1982 Field Study

Bull Run Lidar Plume Scan: 8-9 AM

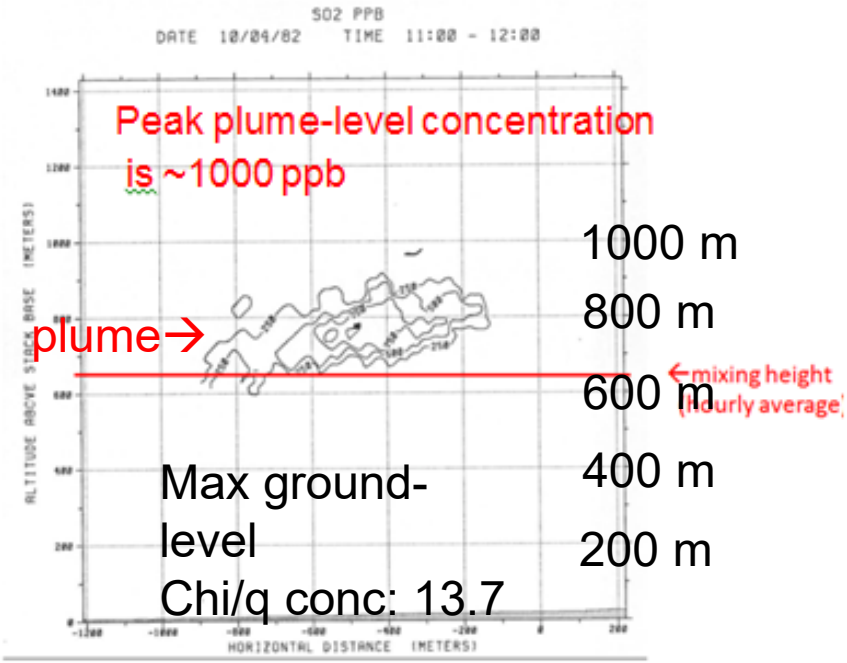


Bull Run Lidar Plume Scan: 10-11 AM

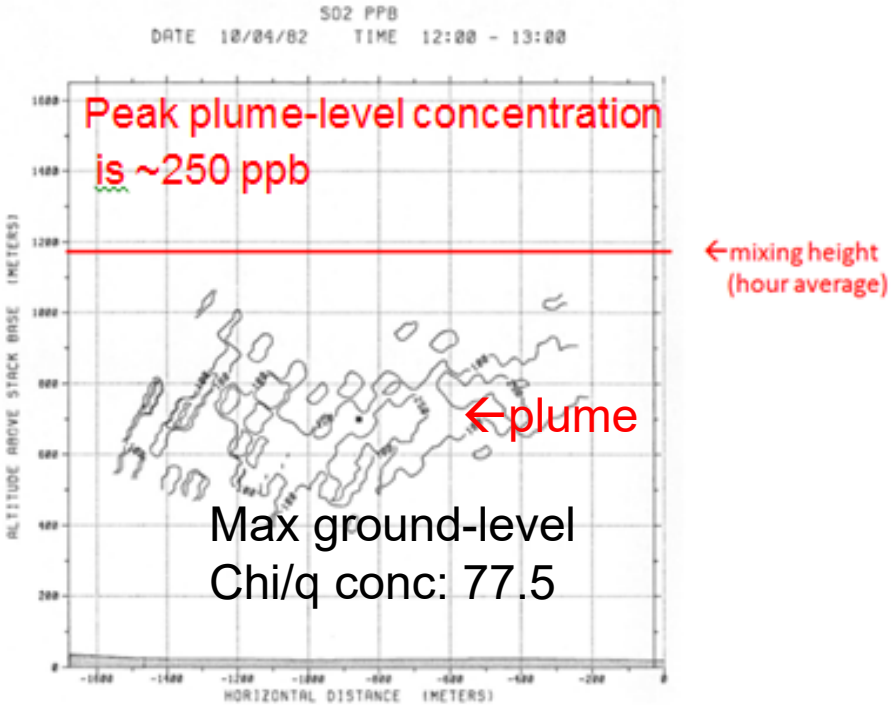


Lidar Images from Typical Day – Bull Run 1982 Field Study

Bull Run Lidar Plume Scan: 11 AM - noon



Bull Run Lidar Plume Scan: noon – 1 PM



Review of Penetrated Plume Issue in AERMOD That Needs to be Fixed

- LIDAR data from research-grade field studies (e.g., Bull Run) show that the penetrated plume stays in the stable layer aloft until the mixing height captures the plume
- AERMOD shows high impacts from the penetrated plume too early in the day and on too many hours - this shows up in several ongoing studies
- AERMOD overestimates the turbulence assigned to the penetrated plume by averaging the “effective” values between the plume height and the ground
- This is inappropriate because the penetrated plume does not reach the ground until the convective mixing height reaches the plume, and the turbulence levels below the mixing lid can be much higher than those at plume level

Suggested Approach for the Bug Fix: "PENMOD"

- The current AERMOD treatment can be viewed as a formulation "bug" that needs to be fixed
- Approach is also discussed by Weil et al., 1997. "A PDF Dispersion Model for Buoyant Plumes in the Convective Boundary Layer". *J. Appl. Met.* 36. 982-1003.
- Fix: compute the effective values for dispersion for the penetrated plume *at the plume level in the stable layer aloft* until the mixing height reaches the plume
- To do this, AERMOD could be modified to *look ahead* to the next hour's mixing height to see if it rises above the height of the current hour's penetrated plume
- If not, then take the effective parameters from the current plume level; do not average to the ground
- If the mixing height rises to capture the plume, then mix the plume to the ground for that portion of the hour