REFORMULATION OF DISPERSION EQUATIONS FOR NEAR SURFACE RELEASES

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Reformulation motivated by development of a dispersion model for roadway emissions-adverse health effects established

OUTLINE

- Old Equations
- Formulation
- Comparison with Data
- New Formulation
- Performance
- Conclusions
- Sagebrush Project

Vertical Plume Spread

AERMOD uses plume spreads derived from Prairie Grass Experiment conducted in 1956. Based on asymptotic behavior of K(z) and wind speed, U.

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$$U\frac{d\sigma_z^2}{dx} \sim K\left(\sigma_z\right)$$

$$\bar{C}^y \sim \frac{Q}{\sigma_z U}$$

$$\sigma_z U \sim u_* x \qquad \text{Neutral}$$

$$\sim u_* \frac{x^2}{|L|} \qquad \text{Unstable}$$

$$\sim u_* L^{1/3} x^{2/3} \qquad \text{Stable}$$

Vertical Plume Spread

Prairie Grass Data:
http://envs.au.dk/en/knowledge/air/models/background/omlprairie/excelprairie/

$$\sigma_z = \sqrt{\frac{2}{\pi}} \frac{u_* x}{U} \left(1 + 0.7 \frac{x}{L}\right)^{-\frac{1}{3}} \quad for\ L > 0$$

and

$$\sigma_z = \sqrt{\frac{2}{\pi}} \frac{u_* x}{U} \left(1 + 0.006 \left(\frac{x}{|L|}\right)^2\right)^{\frac{1}{2}} \quad for\ L < 0.$$

Horizontal Plume Spread

AERMOD uses plume spreads derived from Prairie Grass Experiment conducted in 1956

$$\sigma_y = \frac{\sigma_v x}{U}\left(1 + 78X\right)^{-0.3}$$

where

$$X = \frac{\sigma_v x}{U z_i}$$

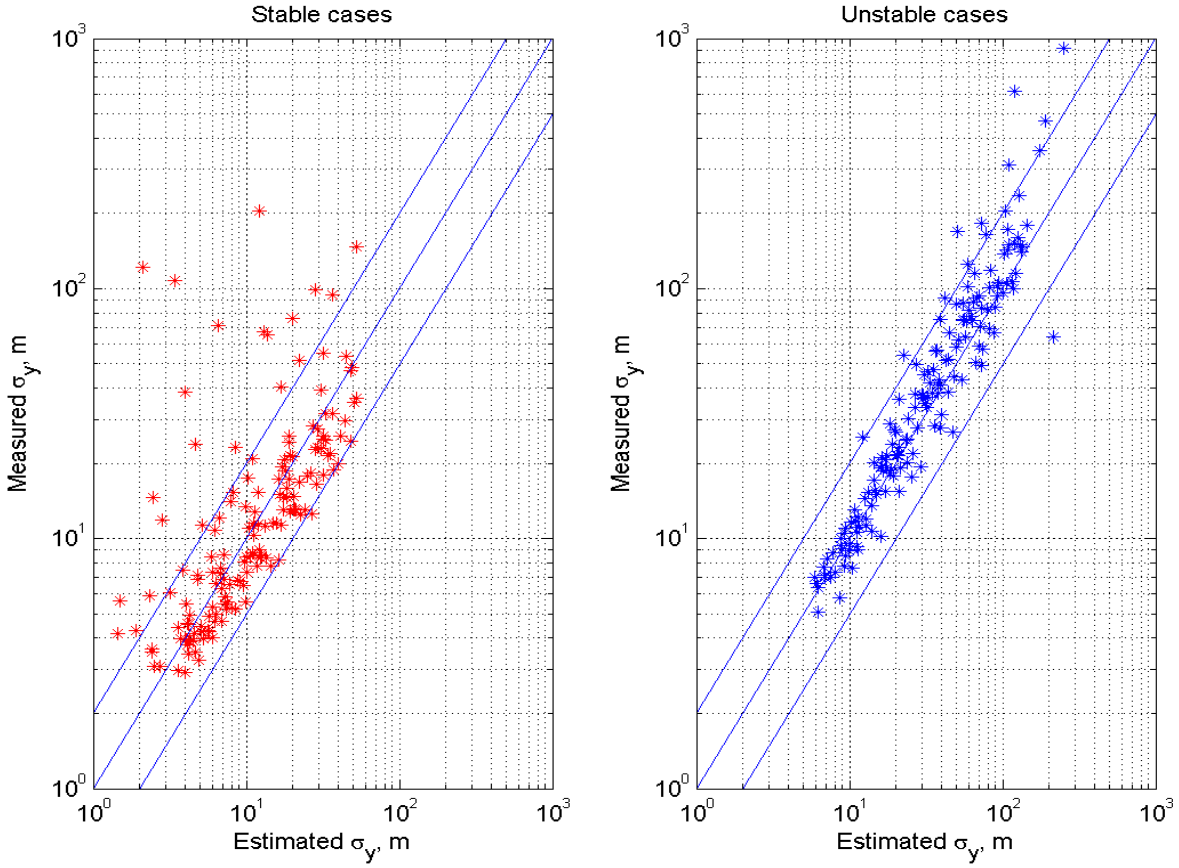
Which Wind Speed?

Solved iteratively

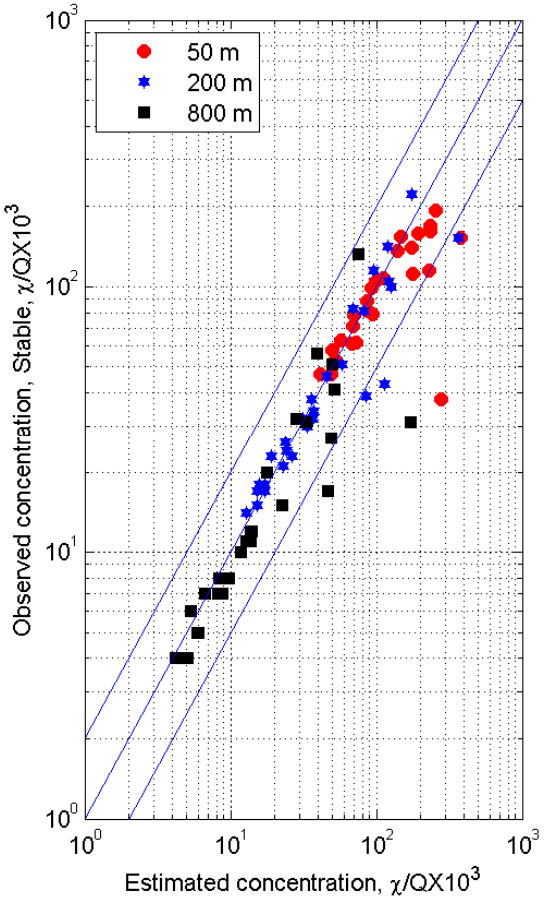
$$\sigma_z = f\left(x, u_*, L, U(\bar{z})\right)$$

$$\frac{\bar{z}}{\sigma_z} = \sqrt{\frac{2}{\pi}} exp\left[-\frac{1}{2}\left(\frac{z_s}{\sigma_z}\right)^2\right] + erf\left(\frac{z_s}{\sqrt{2}\sigma_z}\right)$$

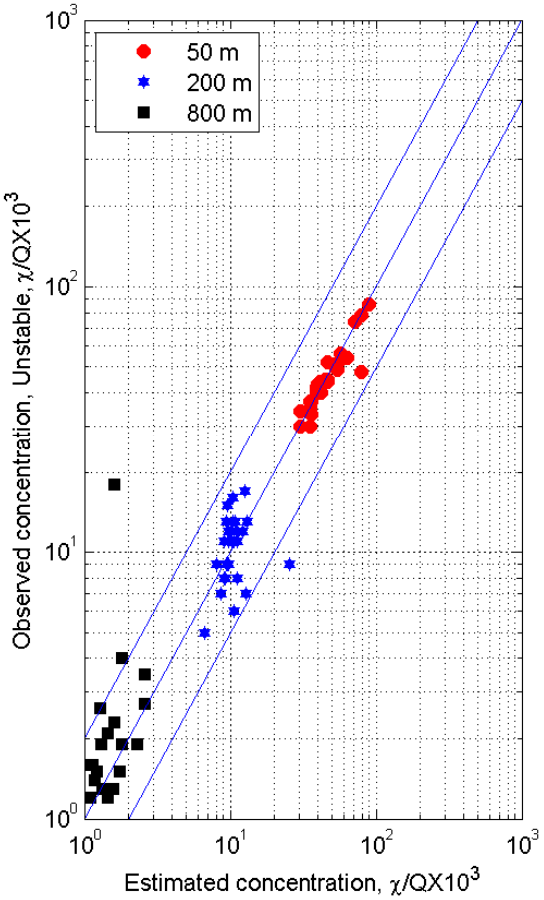
Horizontal Spread (Old Equations)



Comparison with PG Observations

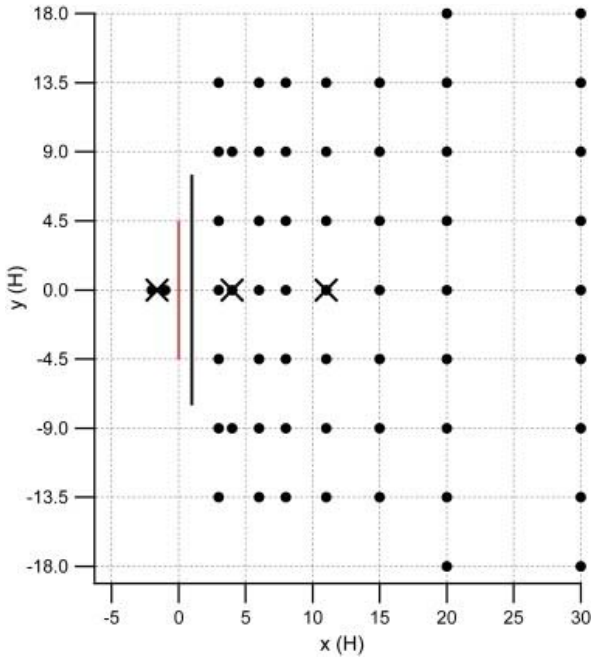


Stable



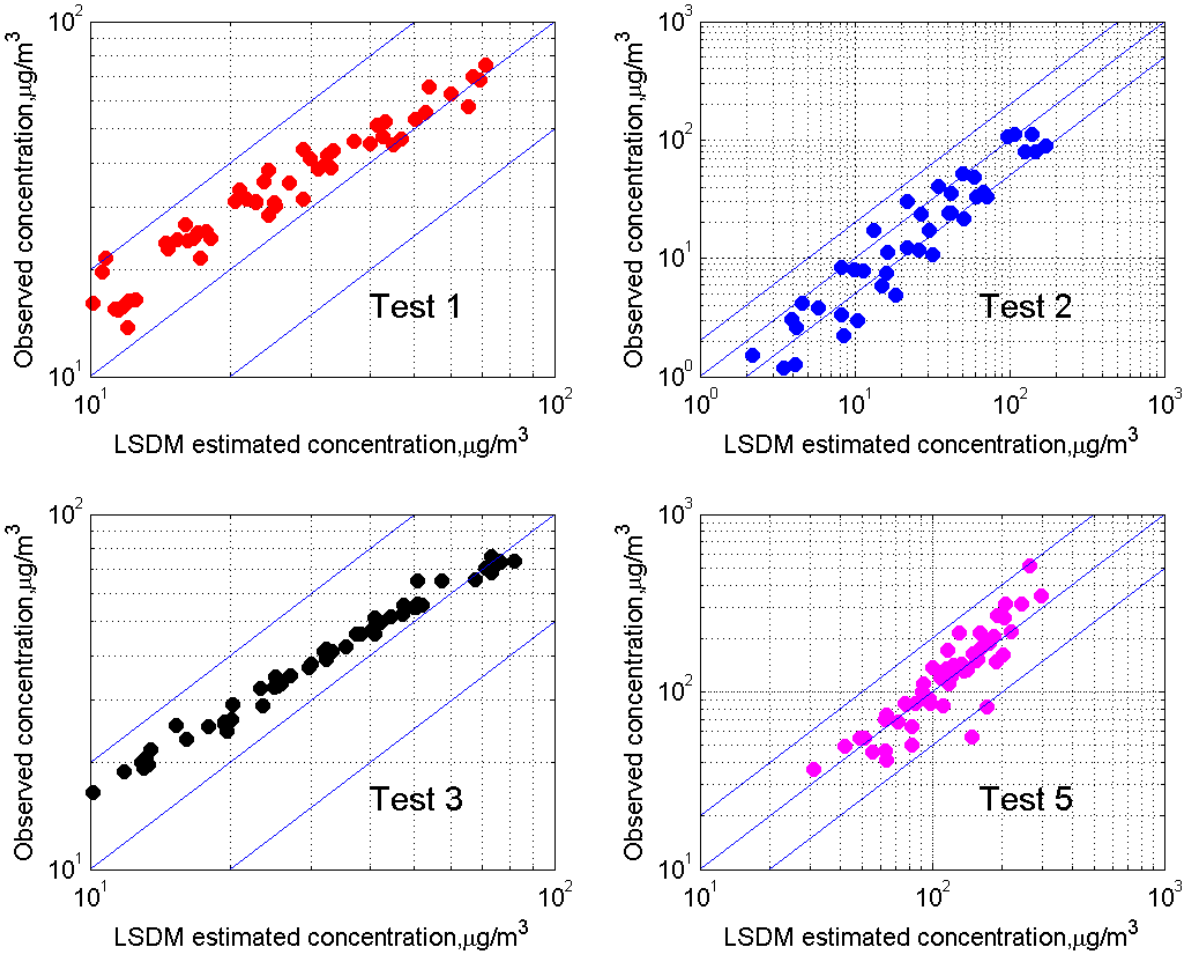
Unstable

Idaho Falls Experiment -2008



- Two 54 m line sources of SF_6 , one behind barrier and the other in open terrain
- 5 tests, lasting 3 hours each broken up into 15 minute segments
- 4 cases: neutral, slightly stable, very stable, very unstable

Comparison using PG curves



1: Neutral
2: Very unstable
3: Slightly stable
5: Very stable

Modified Vertical Plume Spread

$$U\sigma_z \frac{d\sigma_z}{dx} \sim K(\sigma_z)$$

$$\sigma_z \sim \frac{u_* x}{U(\sigma_z)} \qquad \text{Neutral}$$

$$\sigma_z \sim \left(\frac{u_*}{U}\right)^2 \frac{x^2}{|L|} \qquad \text{Unstable}$$

$$\sigma_z \sim L^{2/3} x^{1/3} \qquad \text{Stable}$$

Horizontal Plume Spread

$$\frac{d\sigma_y}{dx} \sim \frac{\sigma_v}{U} = \frac{\sigma_v}{u_*}\left(\frac{u_*}{U}\right)$$

Eckman, 1994

$$\sigma_y \sim \frac{\sigma_v}{u_*}\sigma_z \qquad \textit{Neutral}$$

$$\sigma_y \sim \frac{\sigma_v}{u_*}\left(\sigma_z |L|\right)^{1/2} \qquad \textit{Unstable}$$

$$\sigma_y \sim \frac{\sigma_v}{u_*}\frac{\sigma_z^2}{L} \qquad \textit{Stable}$$

Reformulation

Stable Conditions

$$\sigma_z = 0.64 \frac{u_*}{U} x \left(1 + 3 \frac{u_*}{U} \left(\frac{x}{L} \right)^{2/3} \right)^{-1}$$

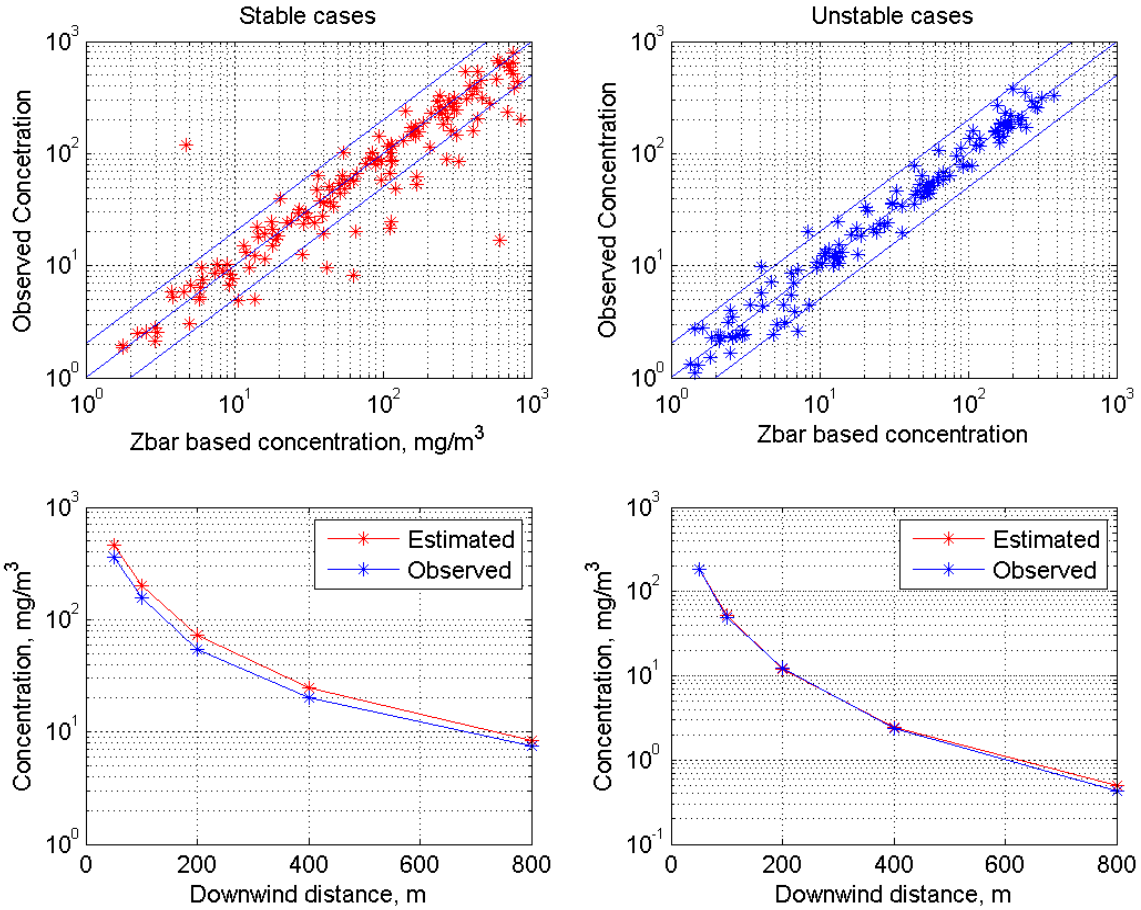
$$\sigma_y = 1.6 \frac{\sigma_v}{u_*} \sigma_z \left(1 + 1.5 \frac{\sigma_z}{L} \right)$$

Unstable Conditions

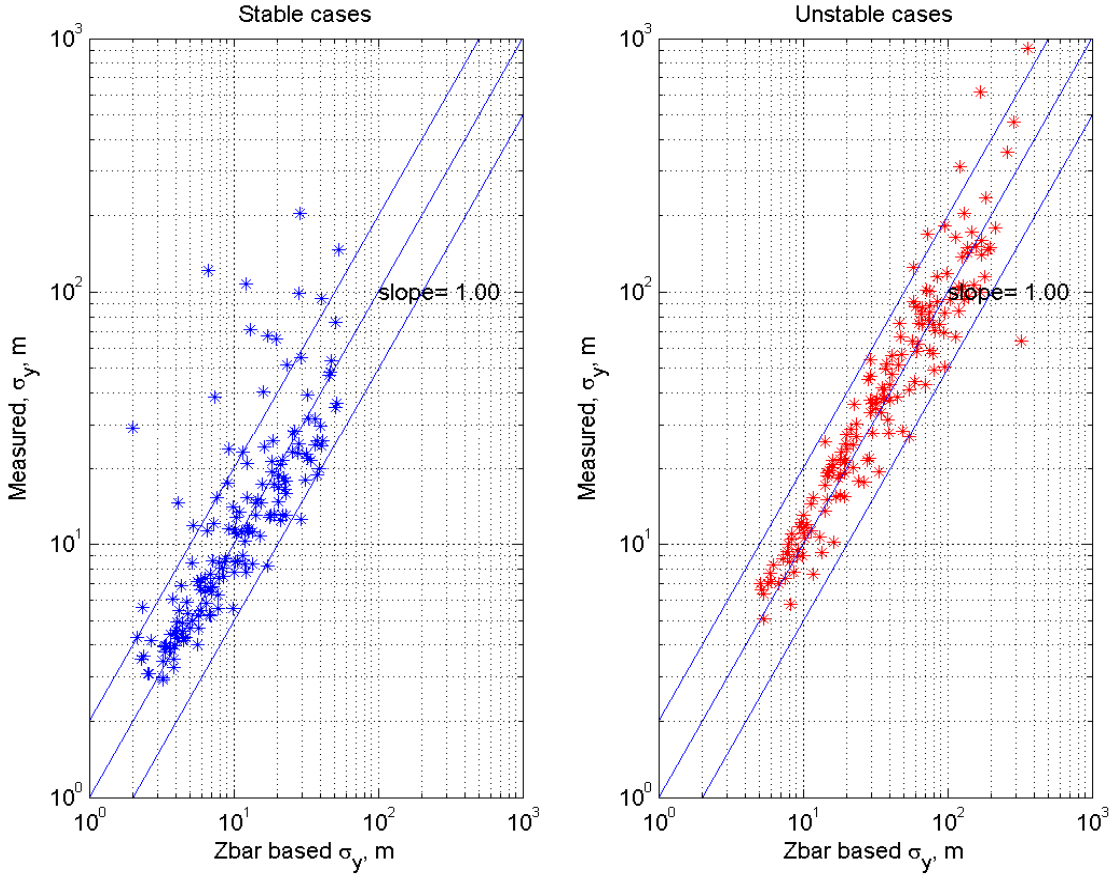
$$\sigma_z = 0.64 \frac{u_*}{U} x \left(1 + 1.5 \left(\frac{u_*}{U} \frac{x}{|L|} \right) \right)$$

$$\sigma_y = 1.6 \frac{\sigma_v}{u_*} \sigma_z \left(1 + 0.5 \frac{\sigma_z}{|L|} \right)^{-1/2}$$

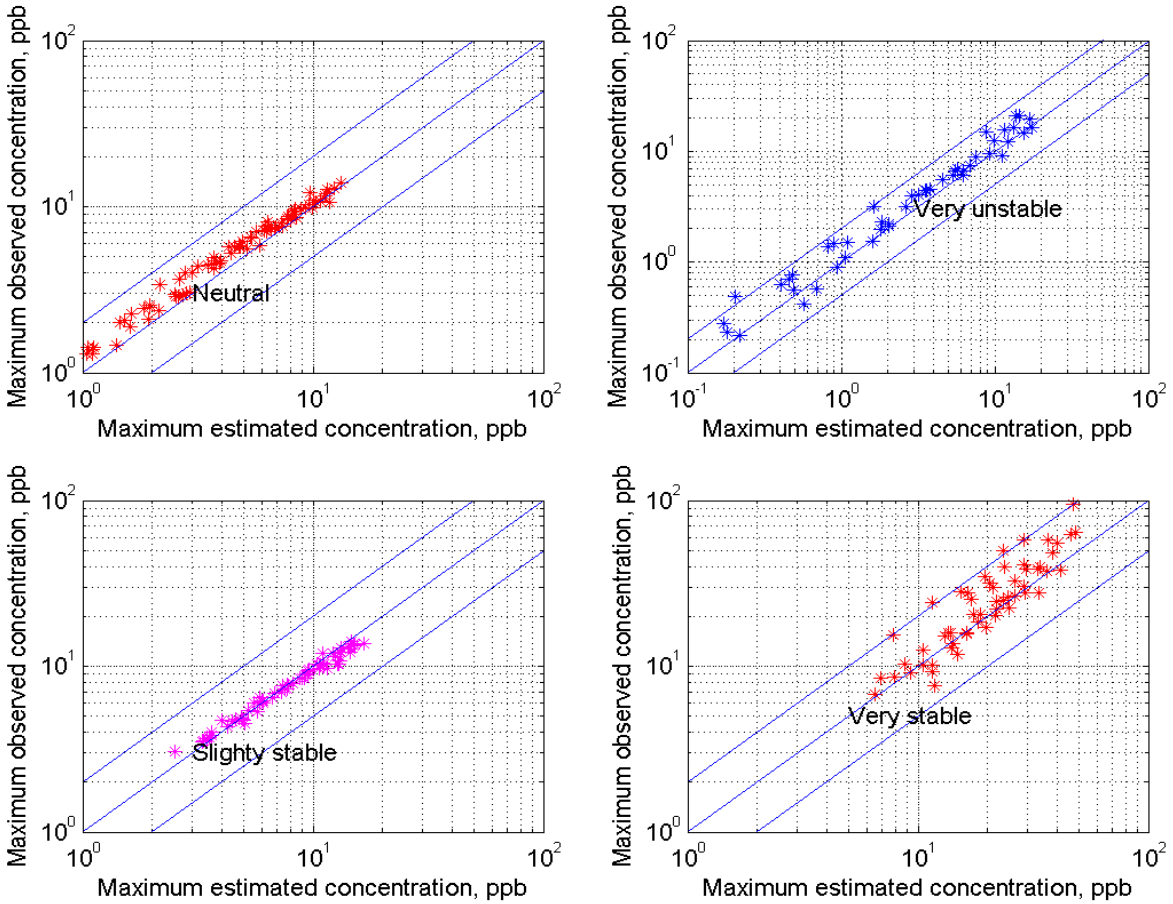
Prairie Grass Data



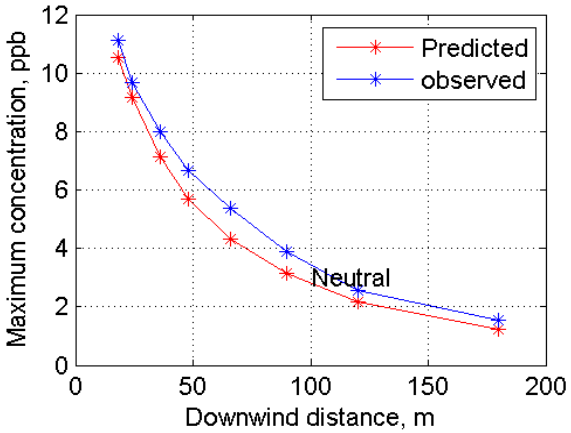
Horizontal Spread
Prairie Grass Data

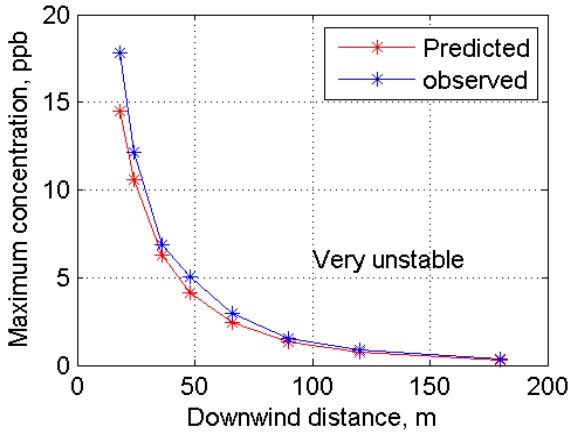


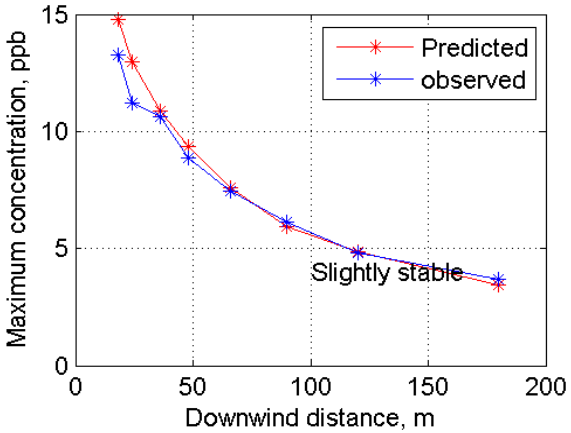
Concentrations
Idaho Falls Data

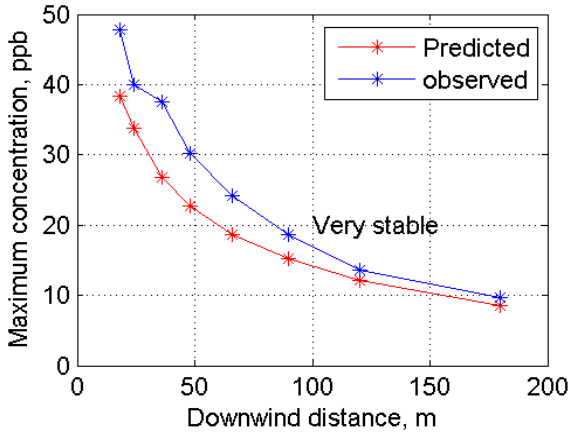


Spatial Gradients
Idaho Falls Data







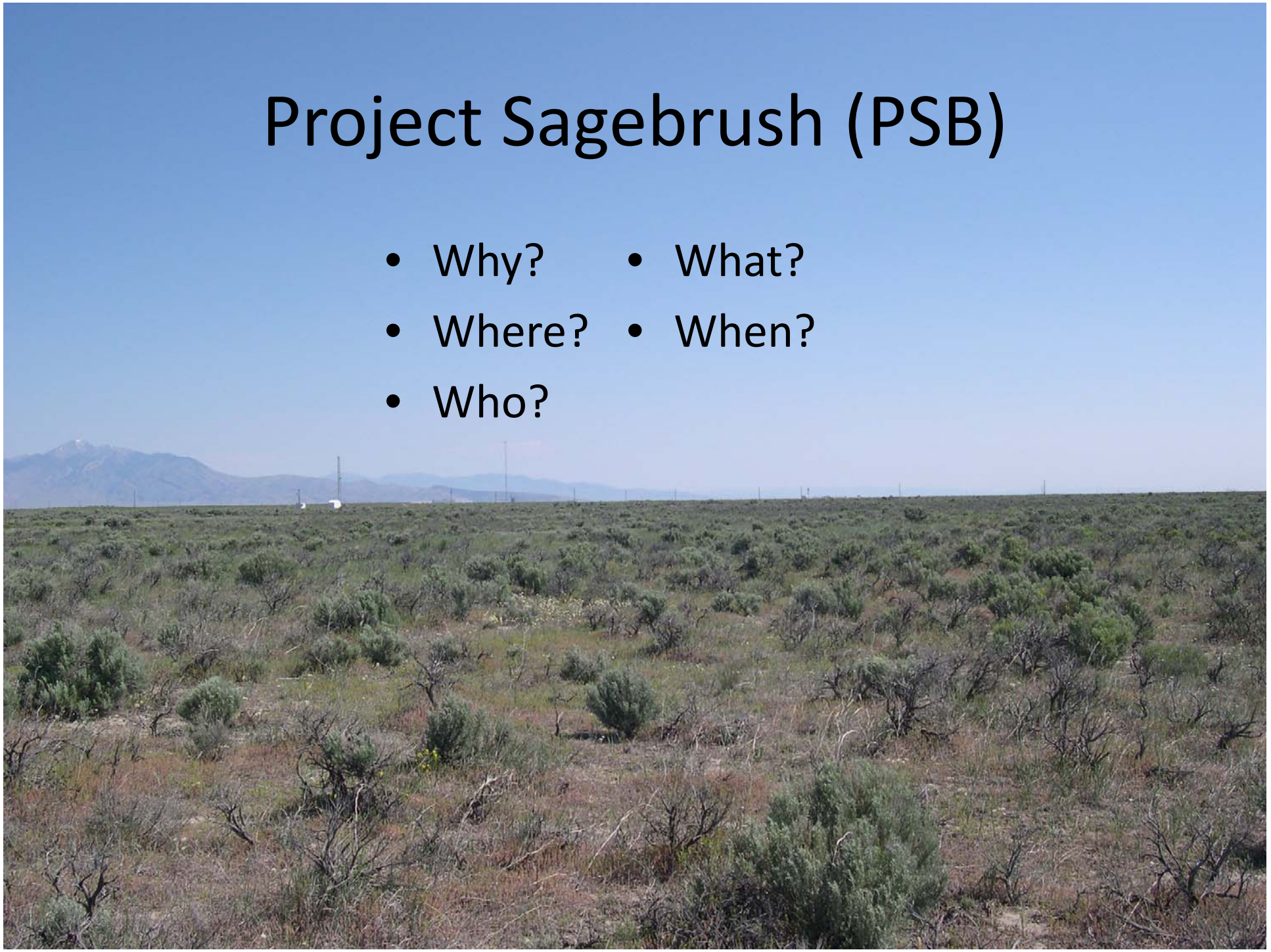


Conclusions

- Reformulations are consistent with theory
- Describes data from both Prairie Grass and Idaho Falls
- Plume spreads and wind speed are coupled and thus need to be consistent with each other

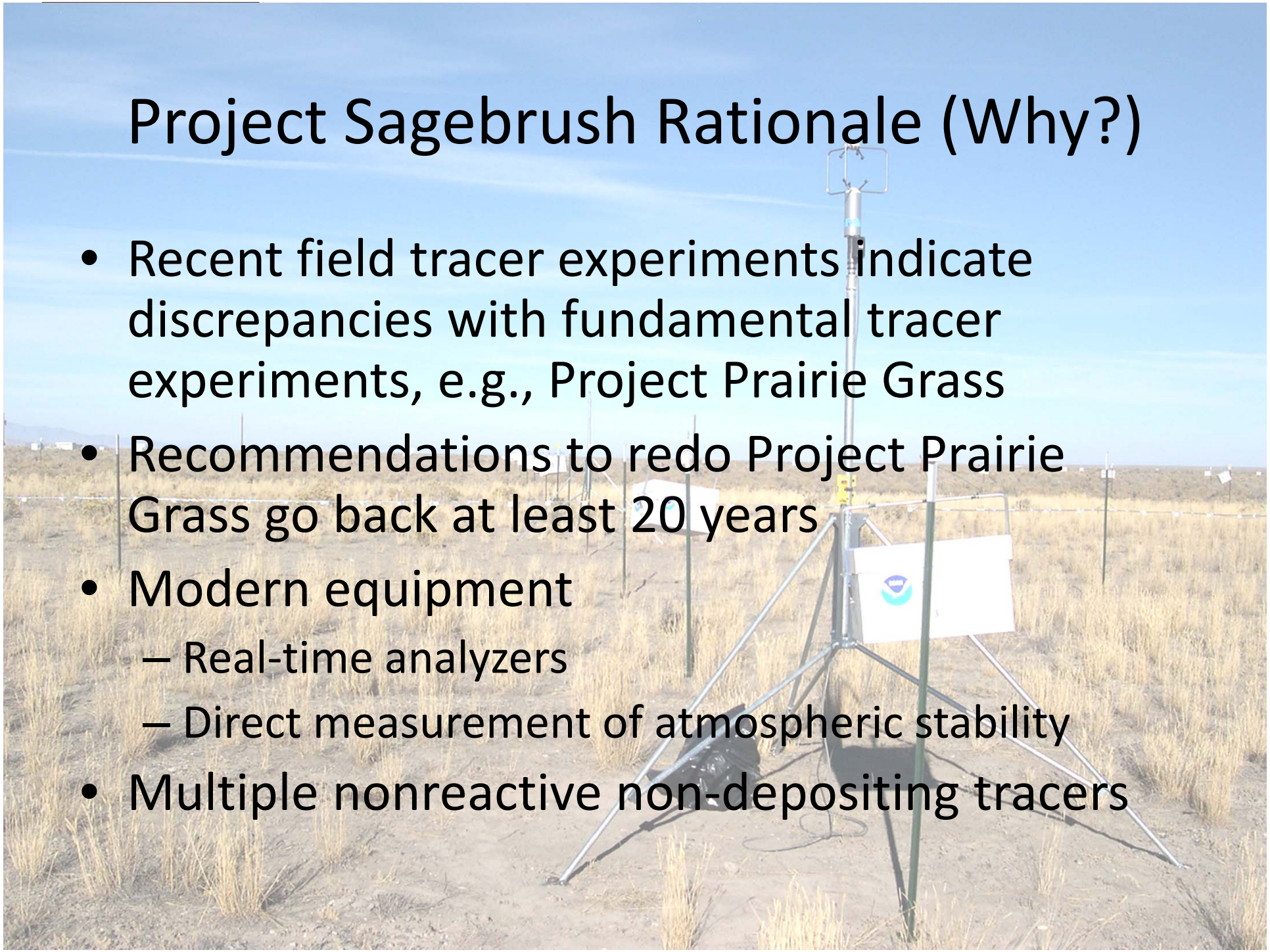
Project Sagebrush (PSB)

- Why?
- Where?
- Who?
- What?
- When?



Project Sagebrush Rationale (Why?)

- Recent field tracer experiments indicate discrepancies with fundamental tracer experiments, e.g., Project Prairie Grass
- Recommendations to redo Project Prairie Grass go back at least 20 years
- Modern equipment
  - Real-time analyzers
  - Direct measurement of atmospheric stability
- Multiple nonreactive non-depositing tracers



Project Prairie Grass and Project Sagebrush Comparison (What?)

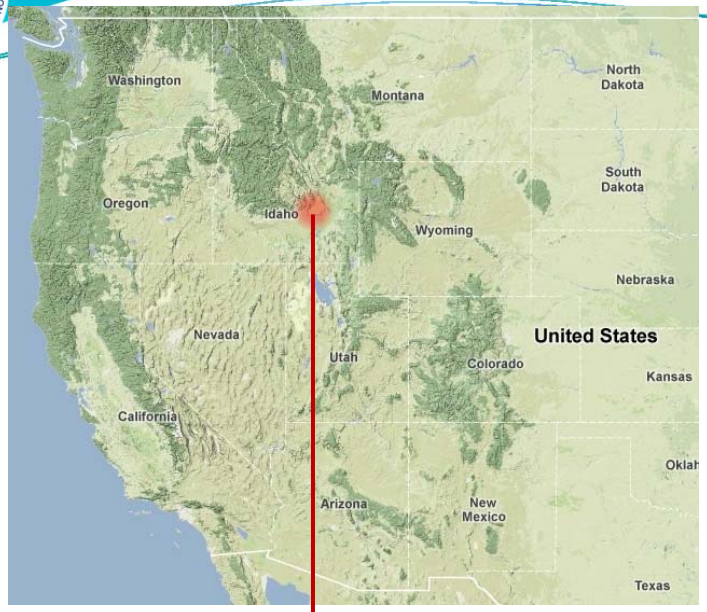
Project Prairie Grass

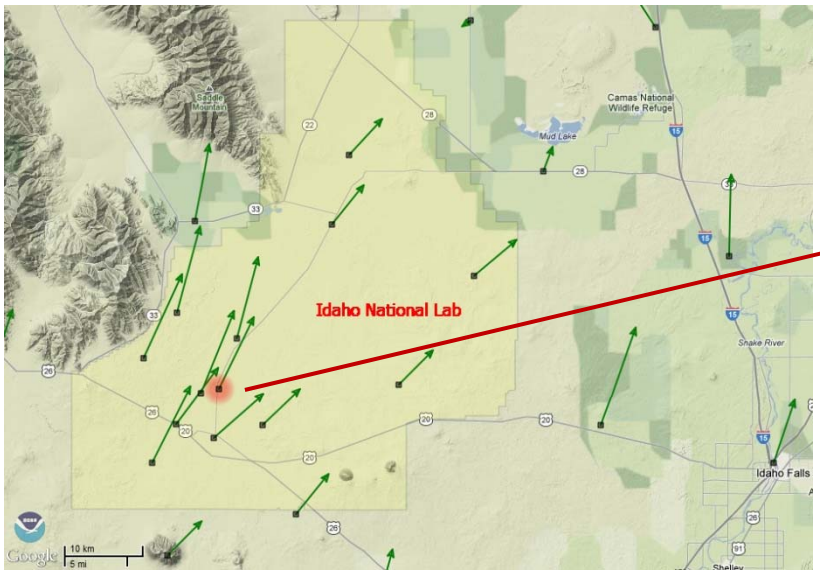
- Number of experiments: 70
- Time of year: summer
- Single tracer: SO_2
- Release type: point
- Samplers: 600; 10 minutes
- Domain: to 800 m
  - 50, 100, 200, 400, 800 m
- Vertical: 6-17.5m towers on 100 m arc
- Met. instruments: cup and vanes

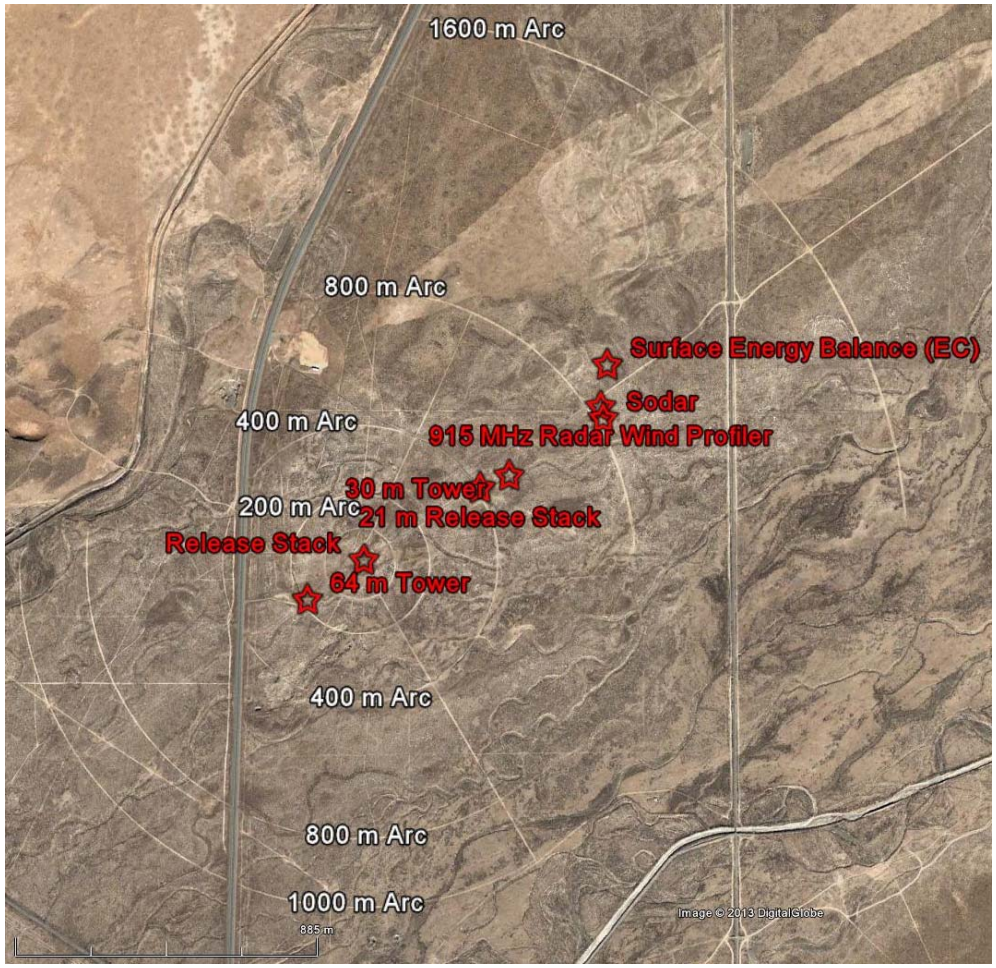
Project Sagebrush

- Number of experiments: multiple seasons, multiple years
- Multiple Tracers: SF_6, PDCB, PMCH, m-PDCH
- Release type: point, line, stack
- Samplers: 135 bag samplers (12 bags each); 5-999 minutes; and 10 real-time analyzers
- Domain: to 1600 m and more
  - 25, 50, 100, 200, 400, 800, 1600 m, +m
- Vertical: aircraft and towers
- Met. instruments: 3-d sonic anemometers, fast response IRGA

NOAA/INL Tracer Test Facility (Where?)







PSB Participants (Who?)

Kirk Clawson - NOAA Federal
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- Field Deployment Collaborators
  - NOAA ARL Field Research Division
  - NOAA ARL Atmospheric Turbulence and Diffusion Division
  - University of Tennessee Space Institute
- Data Analysis Collaborators
  - U.S. Environmental Protection Agency
  - University of California-Riverside
- Additional Collaborators Are Invited to Participate