Modeling In-Canopy Dispersion of Pheromones Using a Puff Model

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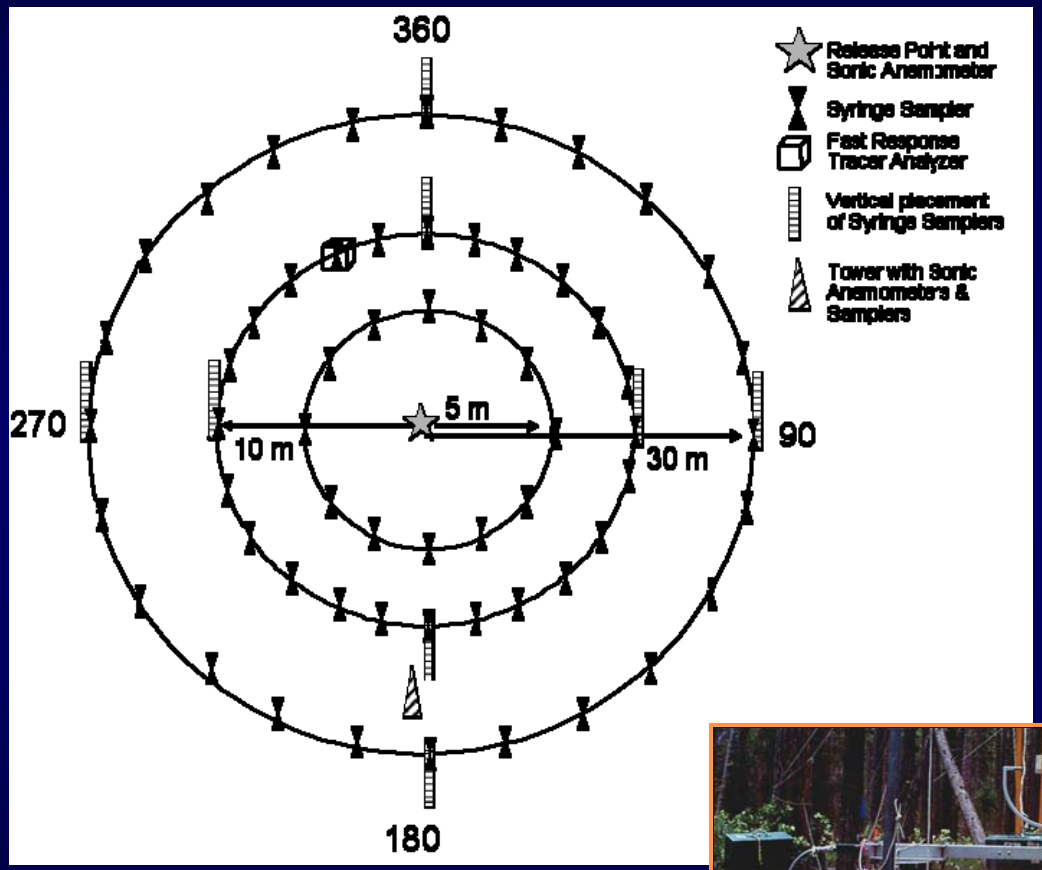
Overall Goal: Simulate Pheromone Dispersion

- Improve our ability to simulate tracer gas movement and spread under a forest canopy
  - Instantaneous puff dispersion model

Objective: Simulate pheromone concentration fluctuations on all temporal scales

- Simulate time averaged and instantaneous concentrations
  - Evaluate the model using SF_6 data collected during recent surrogate pheromone transport studies
    (Thistle et al., 2004)
    - Lodgepole pine site, Montana, July 2000
    - Ponderosa pine site, Oregon, June 2001

Surrogate Pheromone Transport Studies

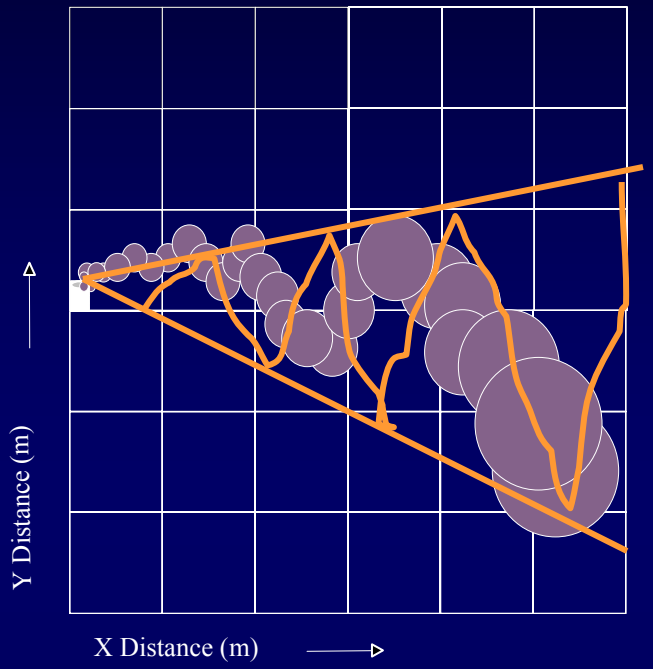


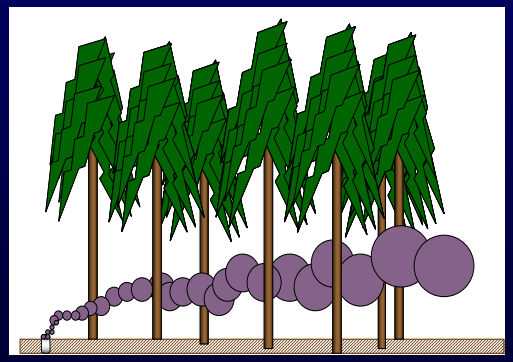
Description of Model

- Lagrangian
- Three-dimensional
- Instantaneous puff dispersion model
- Derived from meandering plume model
  (Peterson et al., 1990)
- Simulates pheromone plume transport and dispersion

- Produces output at different temporal scales
  - Time-averaged pheromone concentrations for the entire domain or at specified receptors
  - Instantaneous pheromone concentrations at a specified receptor

Puff Release





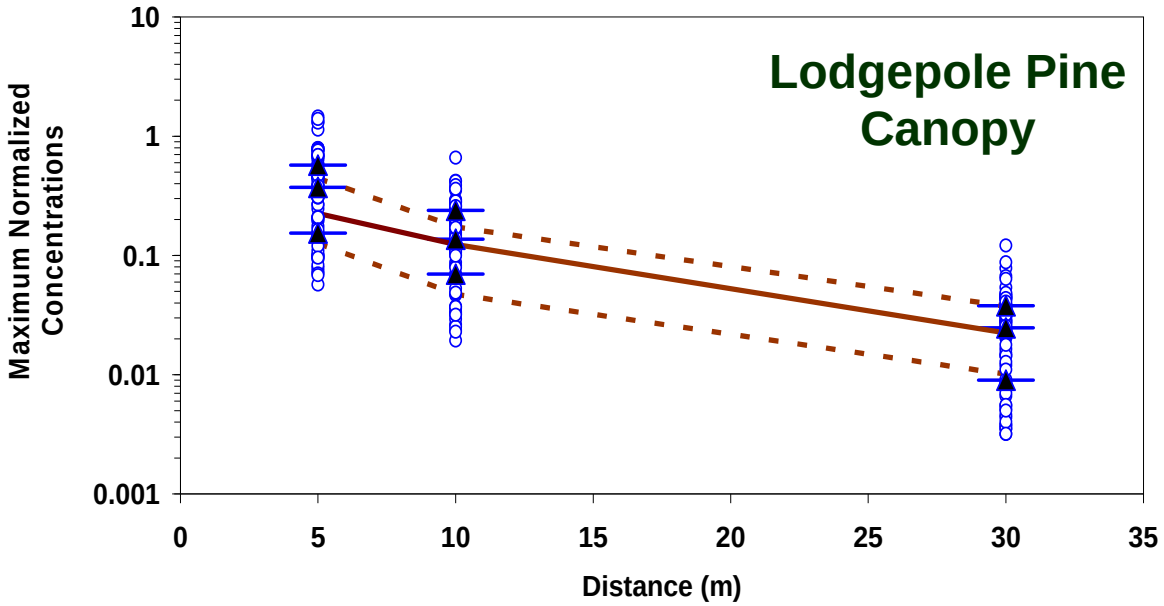
- 1 puff released every 1 s
  - Advected downwind using sonic data as input
    - u, v, and w wind components
- Spread of puff is assumed Gaussian
  - Calculated from turbulence data
  - Isotropic in the horizontal
- 30 minute simulation time
- Domain
  - 66 m X 66 m X 10 m
  - 0.5 m X 0.5 m X 0.5 m (grid size)

The Model: Guassian Puff Equation

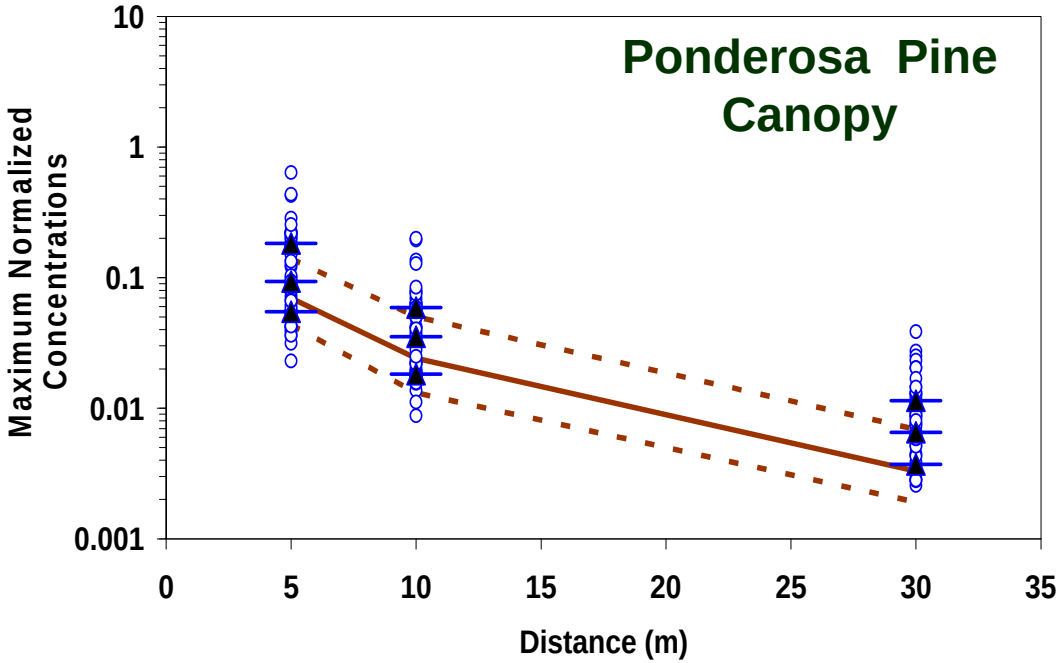
$$C_i = \sum_{P=1}^{N} C_{ip} \quad \text{where,}$$

$$C_{ip} = \frac{\dot{m}}{2\,\sigma_z \sigma_r^2\, \pi\sqrt{2\pi}} \times \left[\exp\left(-0.5\left(\frac{r}{\sigma_r}\right)^2\right)\right] \times \left[\exp\left(-0.5\left(\frac{z+H}{\sigma_z}\right)^2\right) + \exp\left(-0.5\left(\frac{z-H}{\sigma_z}\right)^2\right)\right]$$

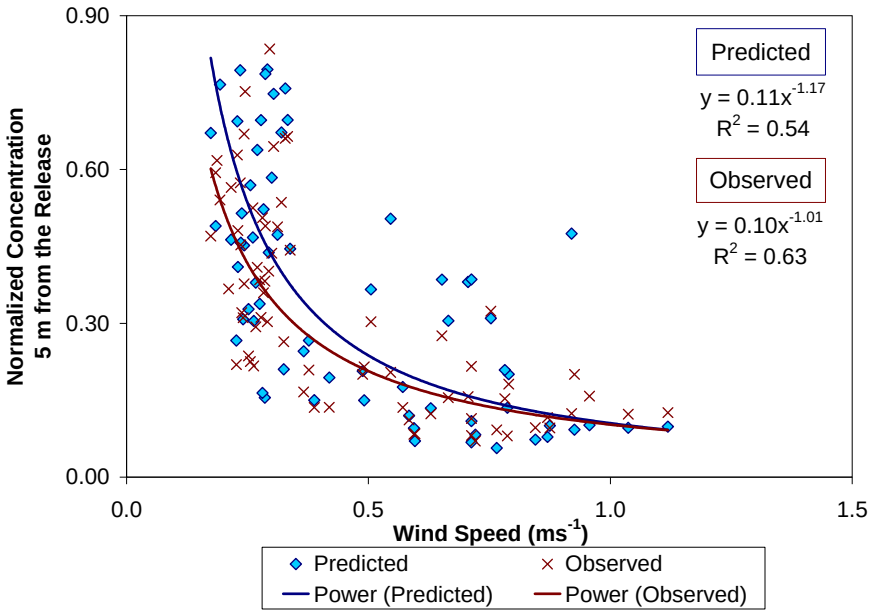
- $\dot{m}$ = mass (μg) released every second
- r = radial distance from the center of each puff to a specific receptor point (m)
- z = height from the surface to the receptor (m)
- H = release height (m)
- σ_r = horizontal dispersion coefficient of the puff
- σ_z = vertical dispersion coefficient of the puff
- N = number of puffs released



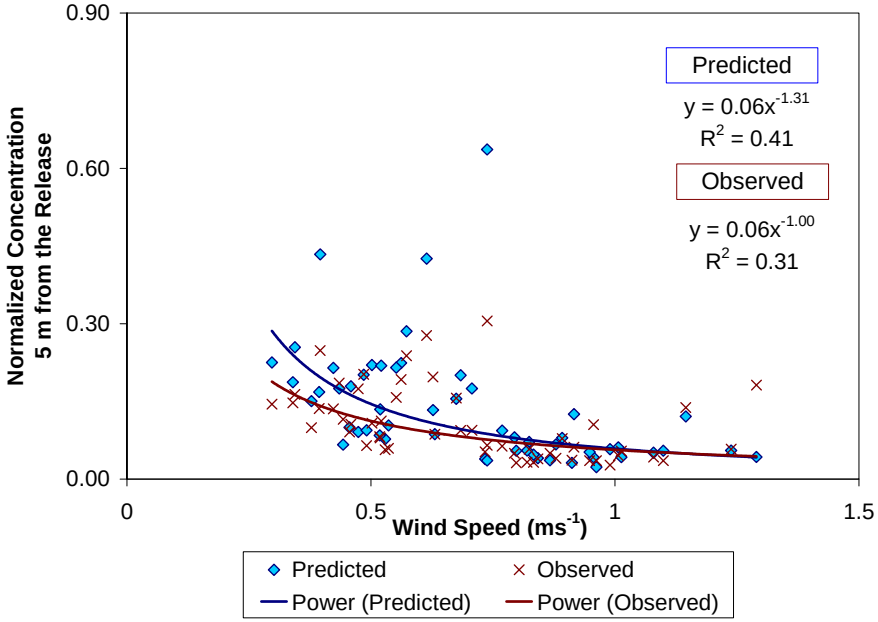
Time Averaged Concentrations and Distance



Time Averaged Concentrations and Wind Speed

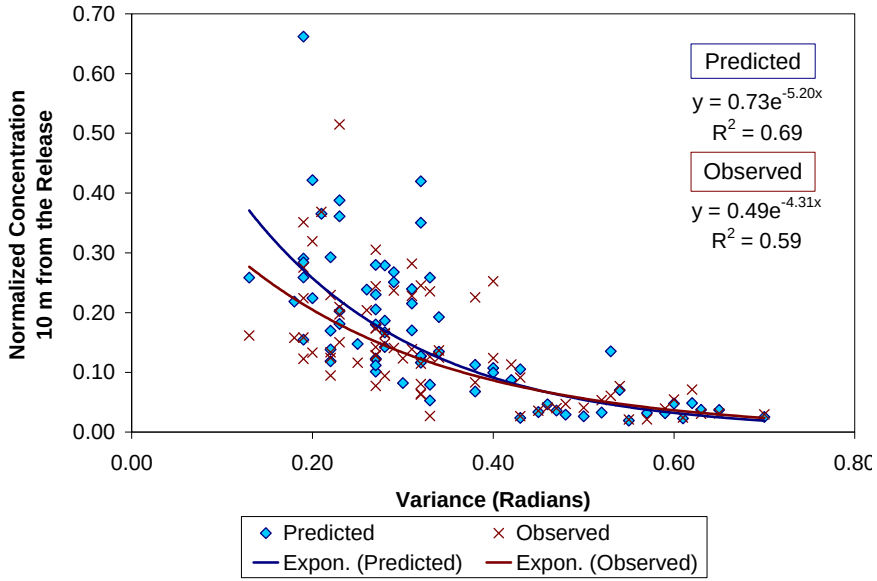


Lodgepole Pine Canopy

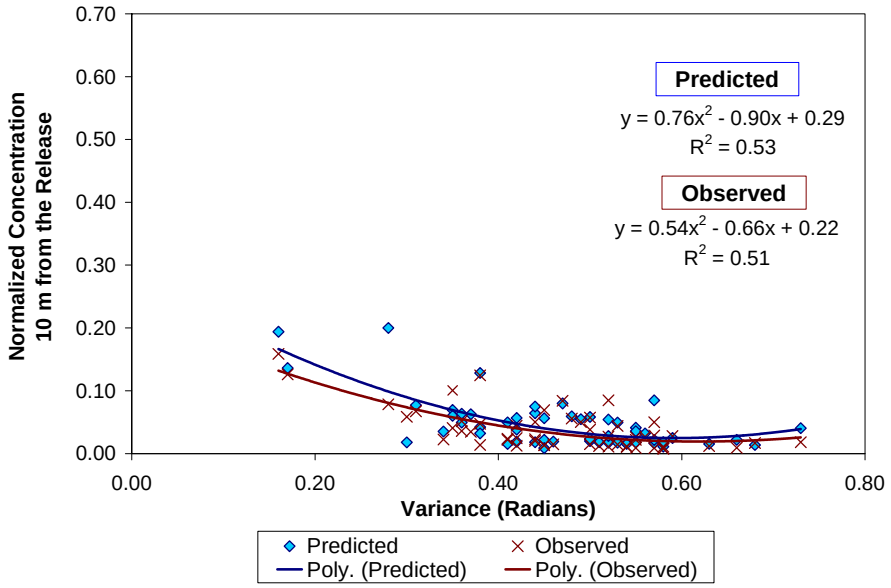


Ponderosa Pine Canopy

Time Averaged Concentrations and Wind Variance



Lodgepole Pine Canopy



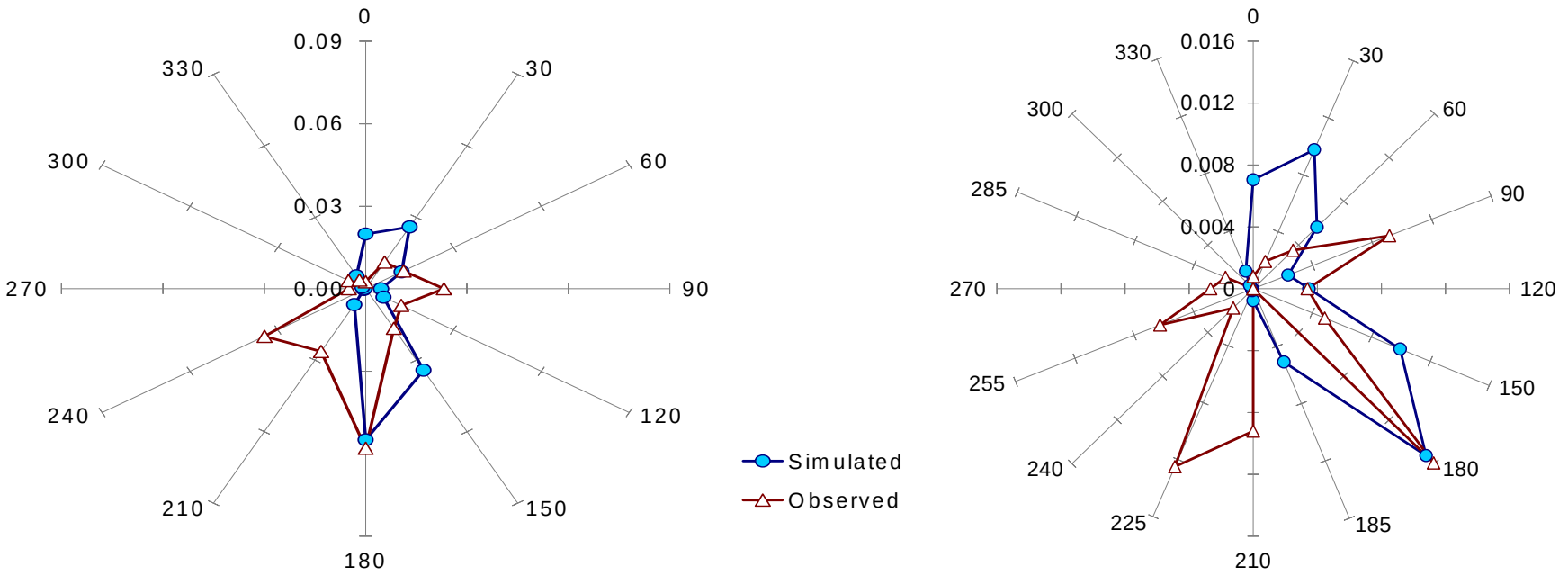
Ponderosa Pine Canopy

Time Averaged Concentration Shape

Ponderosa Pine Canopy: June 21, 2001 at 1:00 p.m.

5 m from the Source

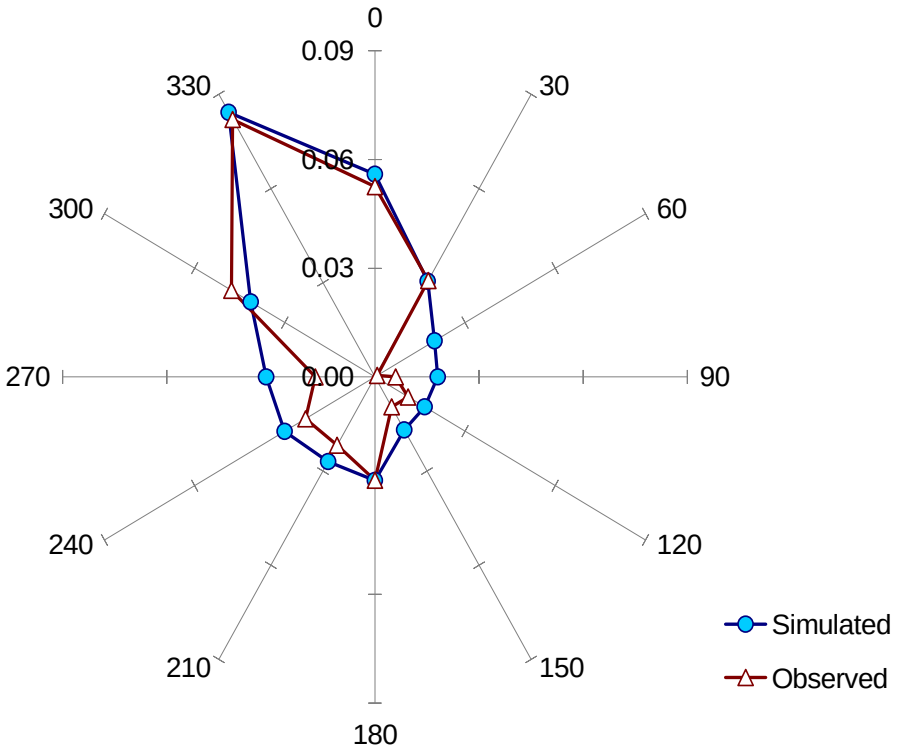
10 m from the Source



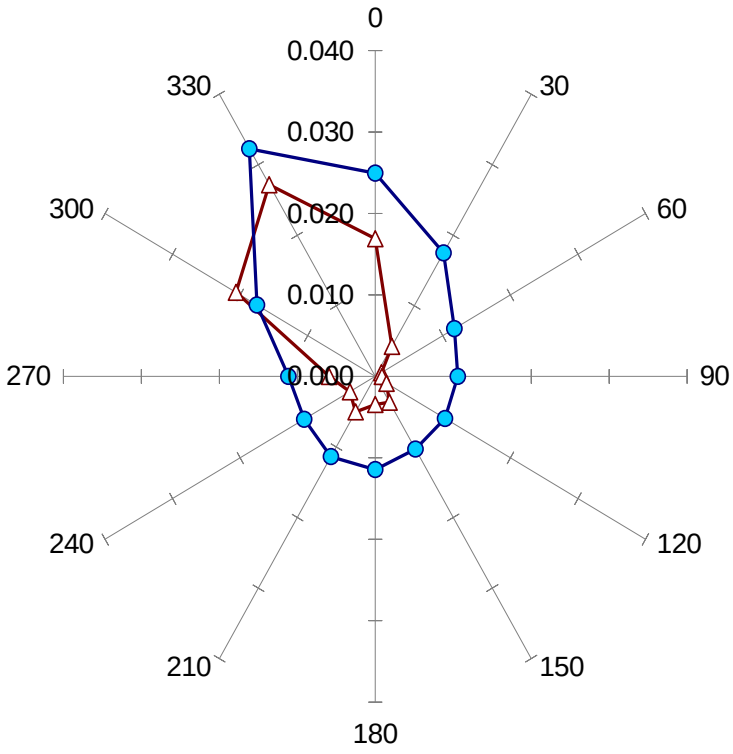
Time Averaged Concentration Shape

Ponderosa Pine Canopy: June 25, 2001 at 4:00 p.m.

5 m from the Source

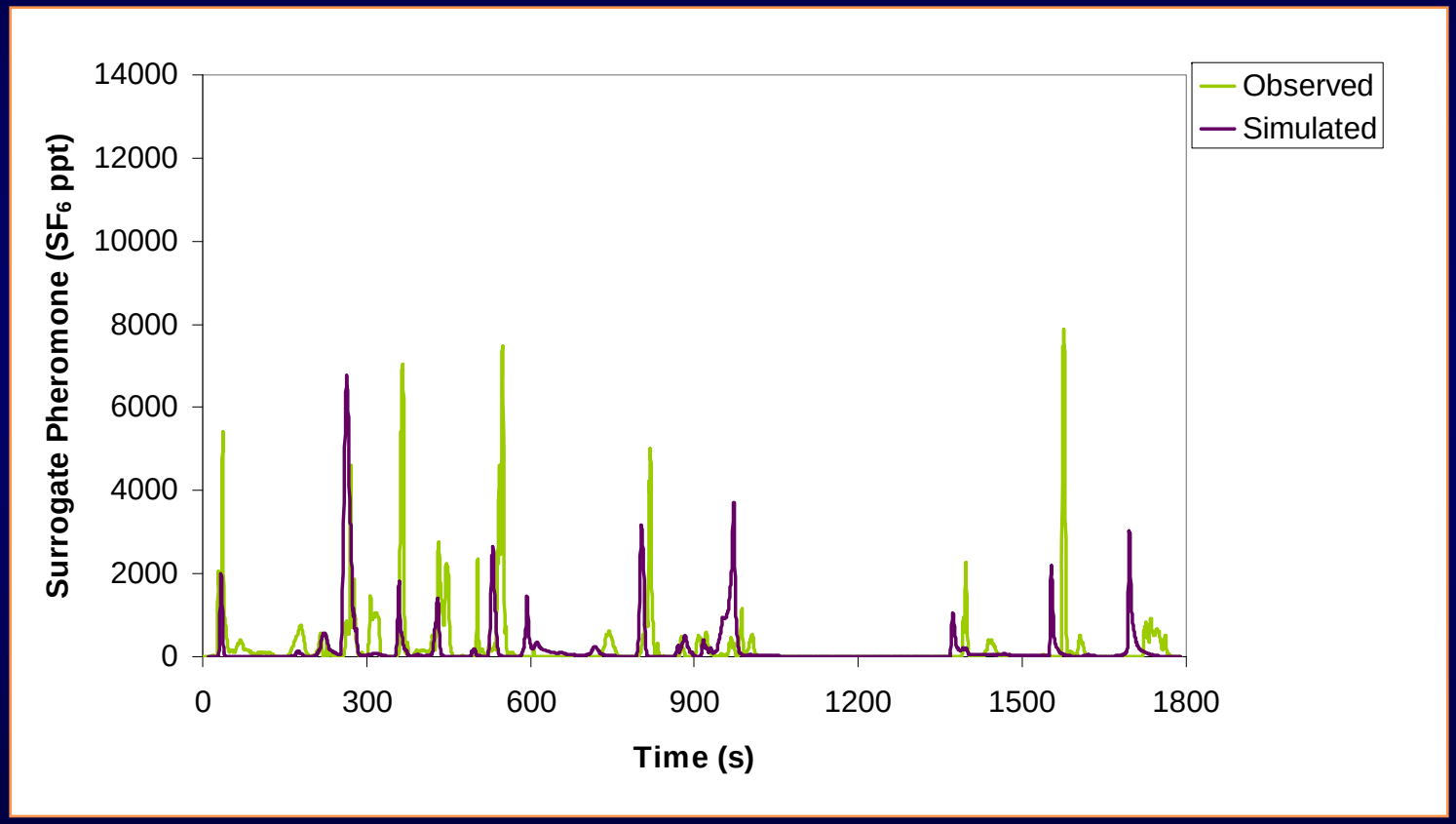


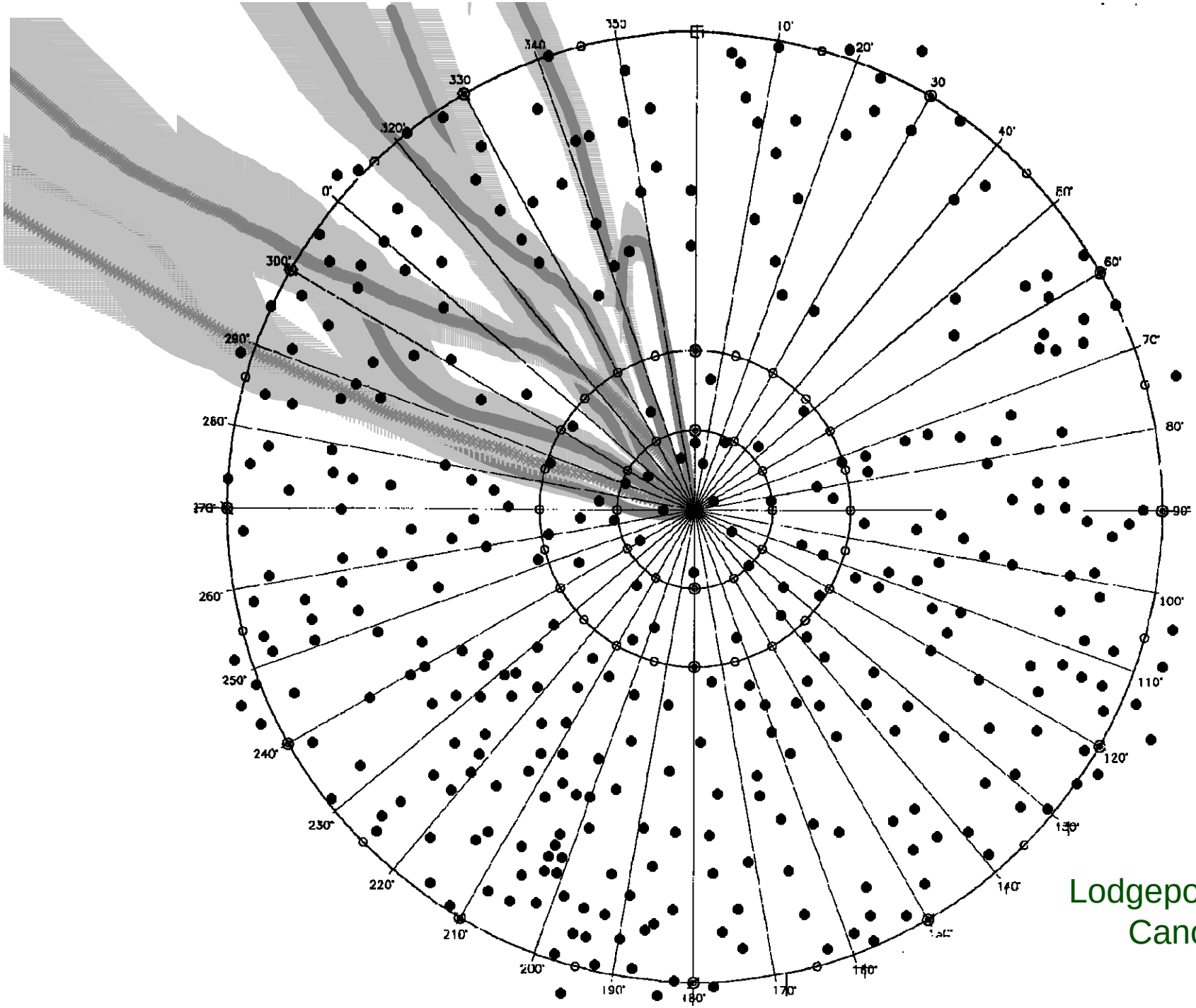
10 m from the Source



Instantaneous Concentrations

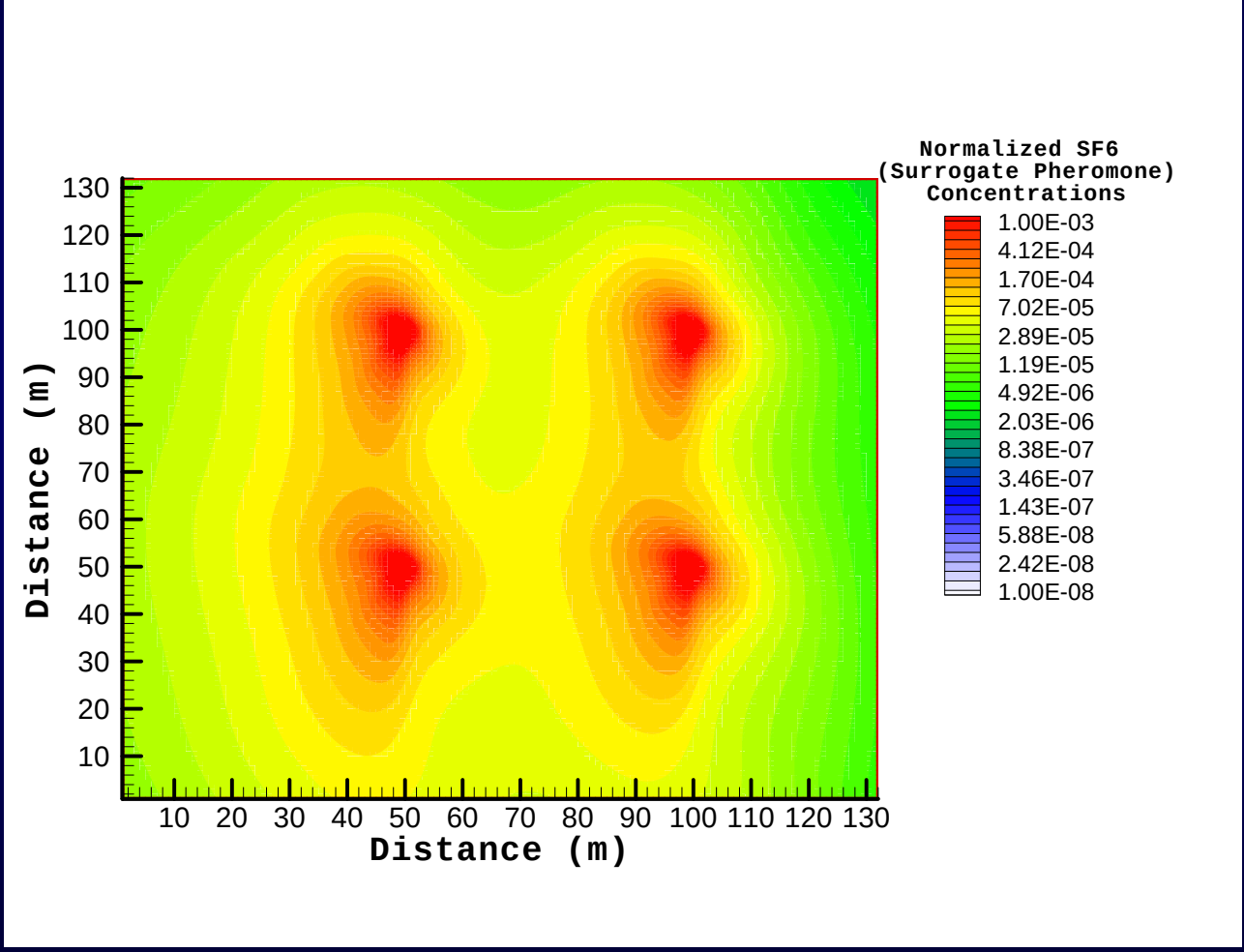
Lodgepole Pine Site: July 24, 2000, 10:30 a.m.



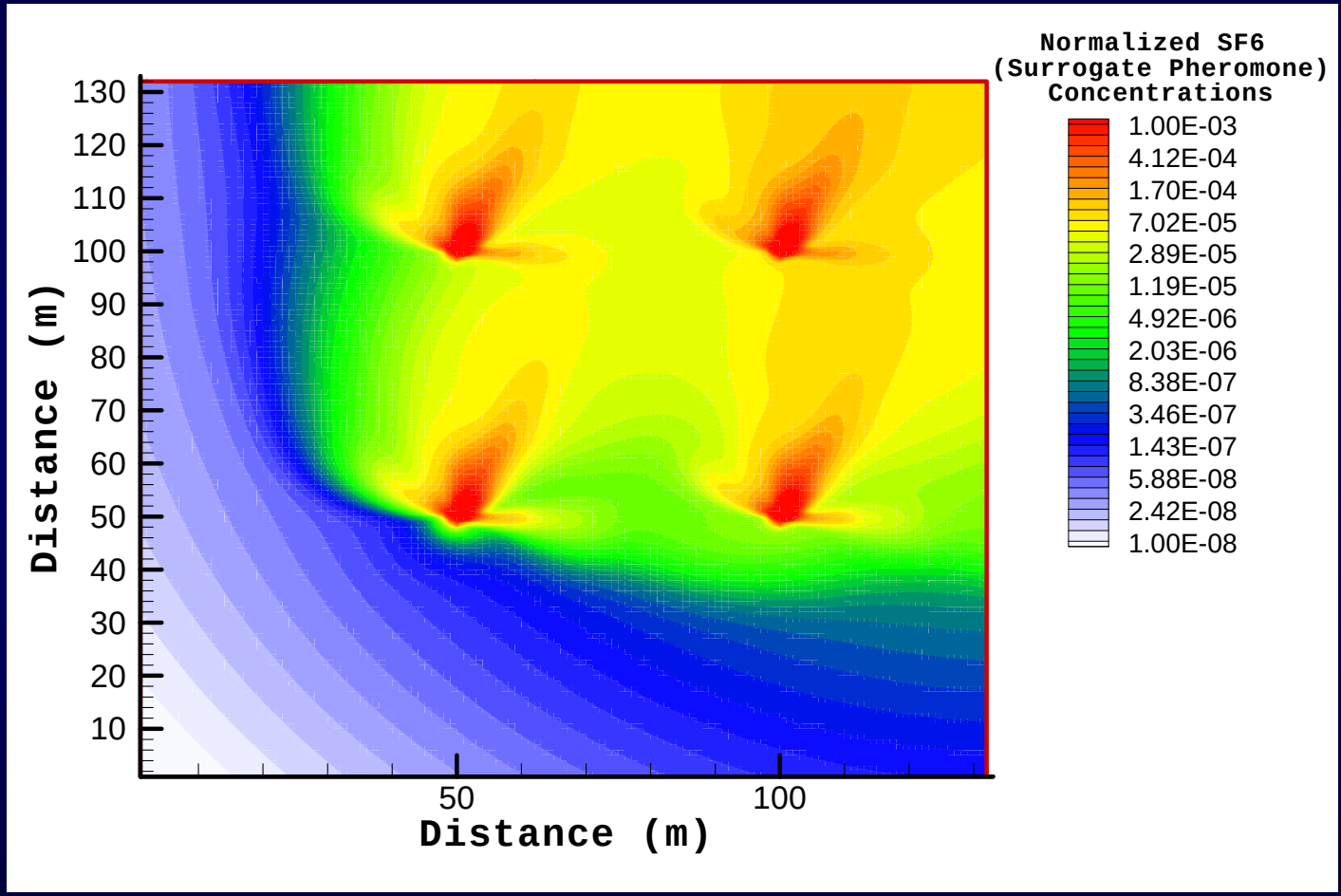


Lodgepole Pine Canopy

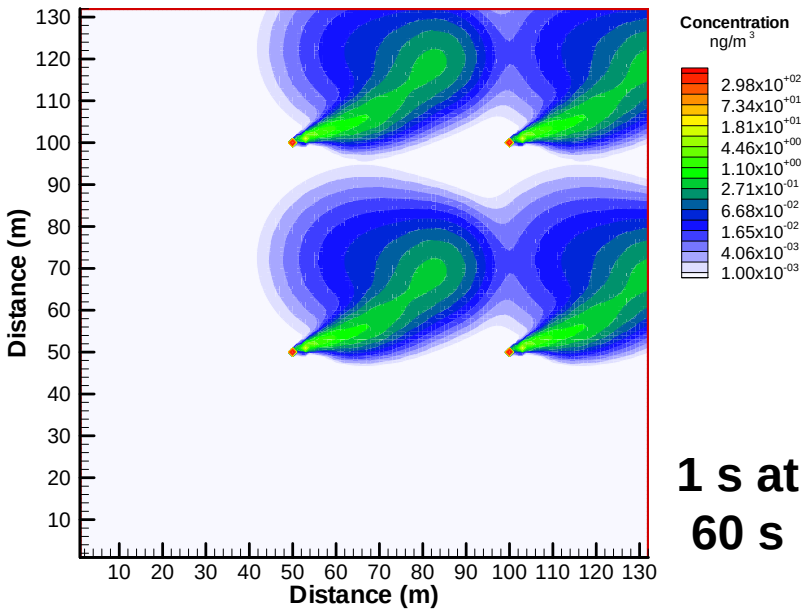
Application ~ Four Sources: Lodgepole Pine



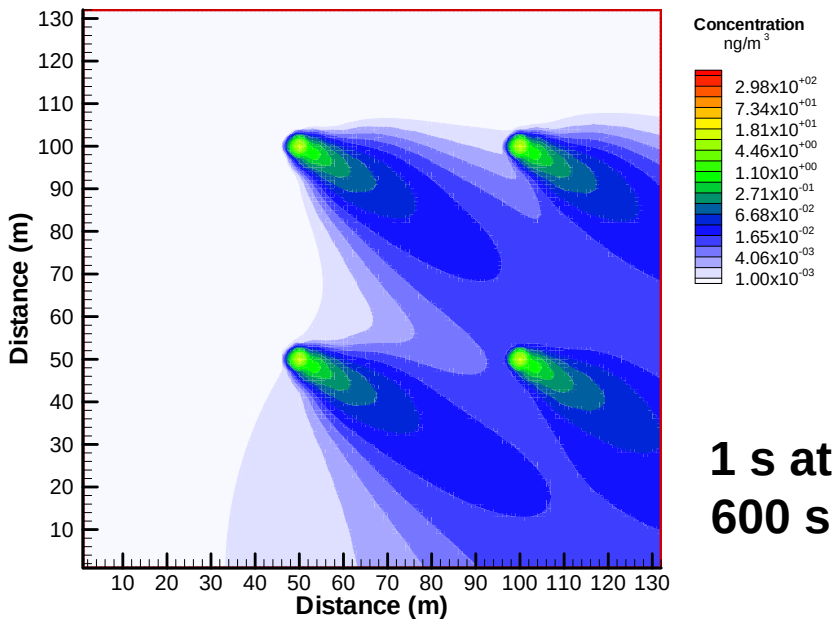
Application ~ Four Sources: Ponderosa Pine



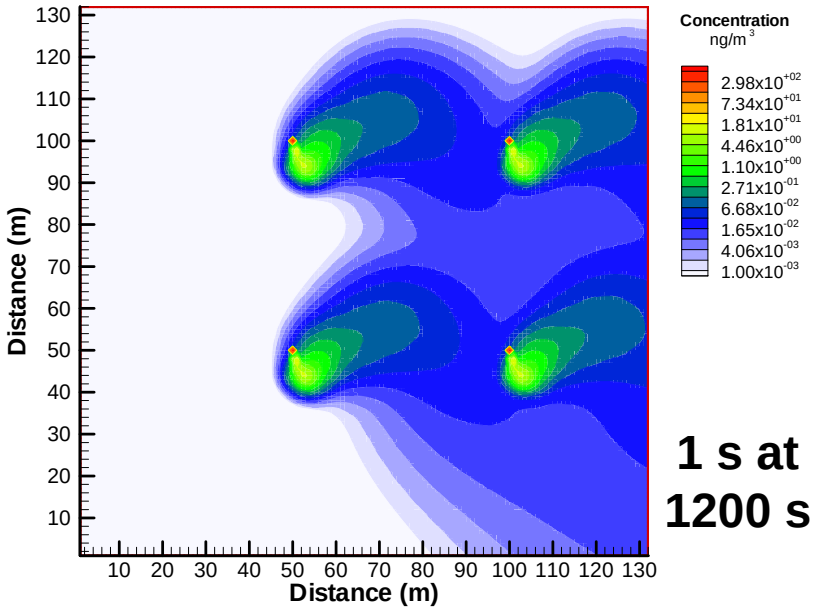
Results: Instantaneous Concentrations



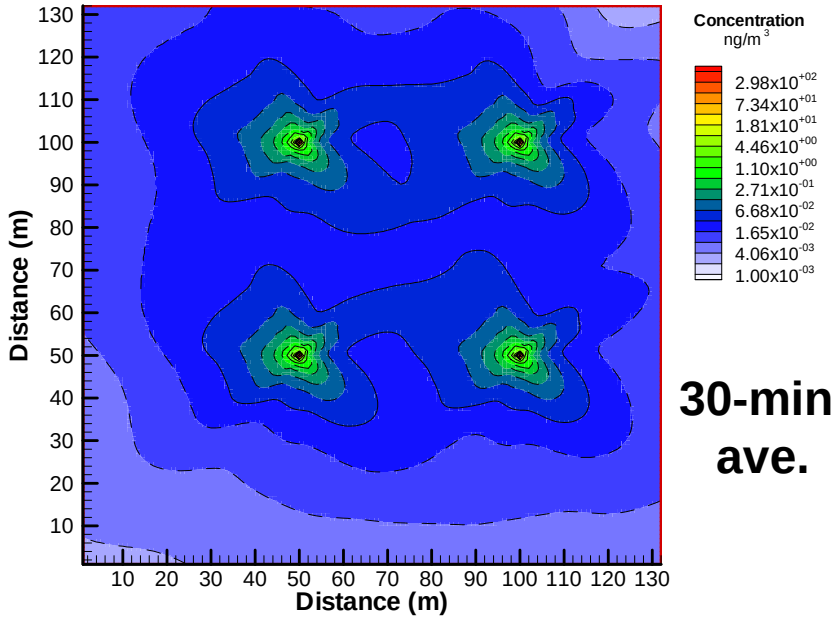
1 s at 60 s



1 s at 600 s



1 s at 1200 s



30-min. ave.

Application: Threshold Response

$$\chi_{Ph} = \frac{\chi_{SF_6}}{Q_{SF_6}} \times Q_{Ph}$$

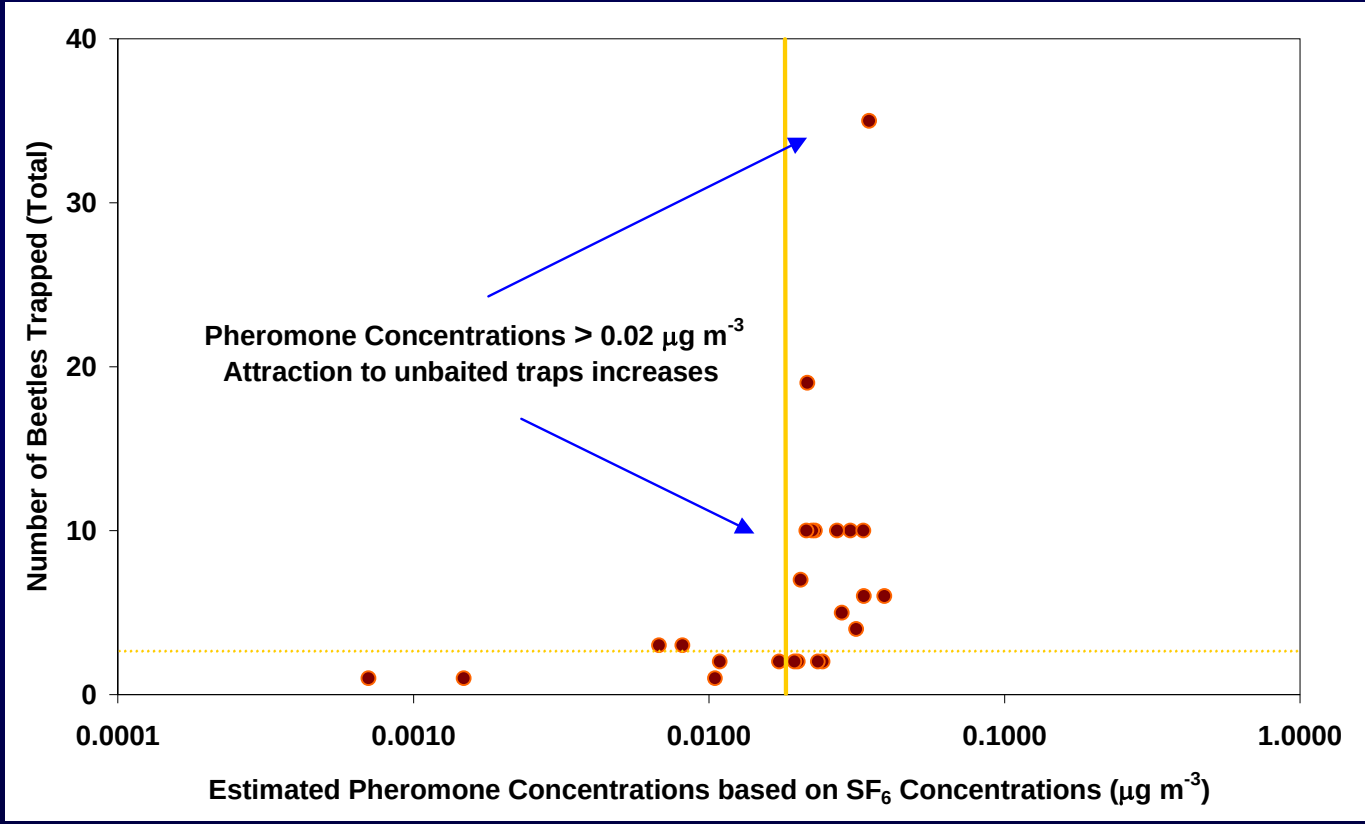
χ_{Ph} = Estimated Pheromone concentration

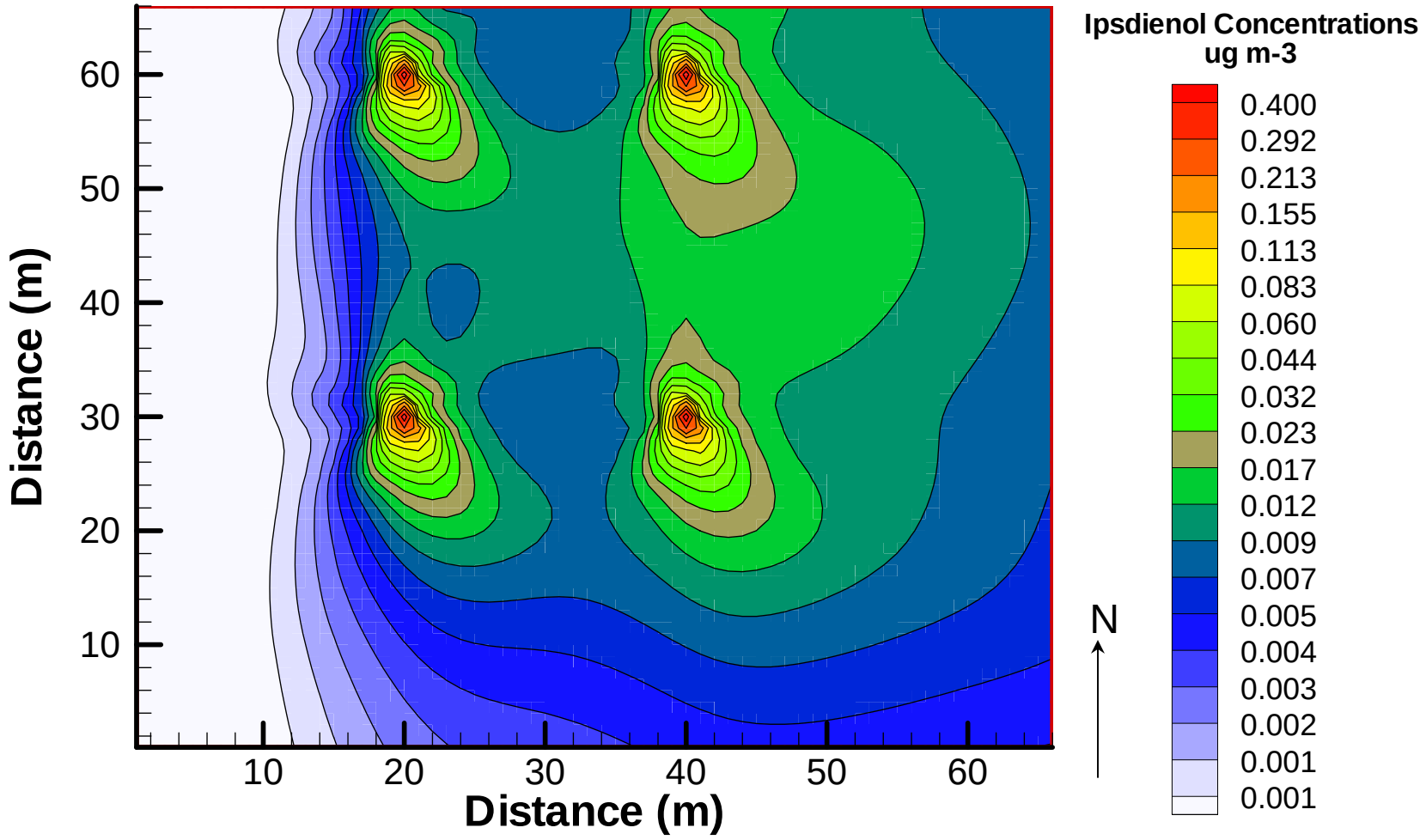
χ_{SF6} = Measured SF_6 concentration

Q_{SF6} = SF_6 release rate

Q_{Ph} = Pheromone release rate

Application: Threshold Response





Hypothetical Application: Ponderosa Pine

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We thank Mike Huey, Wes Throop, Robert Beckley, Patricia Skyler, and Erik Lamb for their support in the field.

	Lodgepole Pine Site			Ponderosa Pine Site		
	5 m	10 m	30 m	5 m	10 m	30 m
Mean Bias (sm^{-3})	0.10	0.02	0.00	0.03	0.01	0.00
Mean Error (sm^{-3})	0.14	0.05	0.01	0.05	0.01	0.01
Fractional Bias (%)	17	10	-16	15	21	47
Fractional Error (%)	35	33	52	39	38	69
Fa^2 (%)	83	90	65	87	85	53

Results: Time Averaged Concentrations

- To determine if SF_6 is a suitable surrogate pheromone
  - By correlating SF_6 concentrations to *I. pini* trap catch
  - But first: Evaluate flight behavior of *I. pini*
    - Determine peak flight

Objective: Evaluation of SF_6 as a surrogate pheromone