Contract No:

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An Improved Method for Calculating the Lagrangian Time Scale in an Emergency Response Plume Dispersion Model

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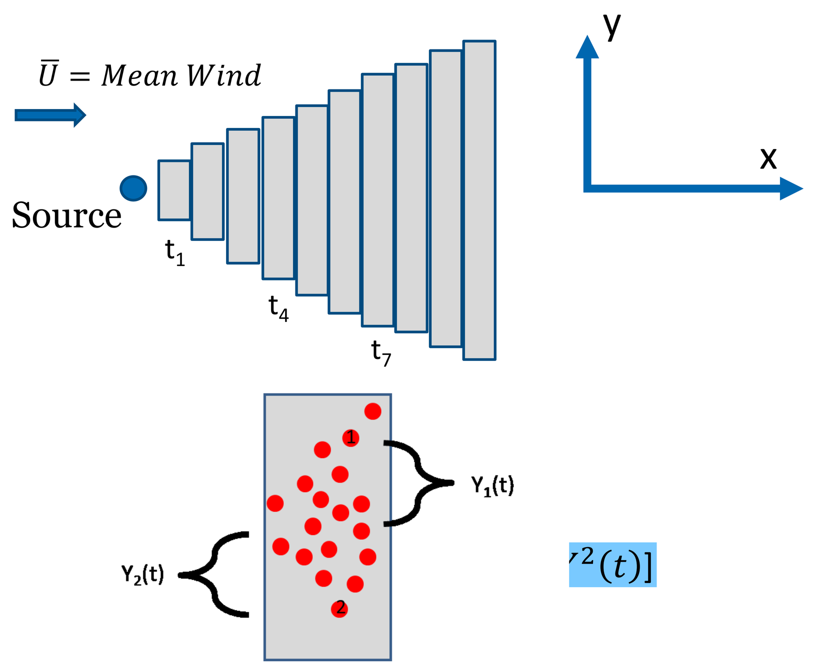
The Atmospheric Technologies Group (ATG) at the Savannah River National Laboratory in South Carolina is charged with consequence assessment in the event of the accidental airborne release of hazardous material. To accomplish this in a timely manner, ATG has developed the Puff-Plume software tool – a Gaussian model that can quickly provide expected surface concentration values and deposition values (if relevant) based on the estimated source term, the current (and forecasted) winds and turbulence, and the boundary layer stability.

To estimate the rate at which the contaminants will disperse vertically and crosswise to the wind direction, the model currently makes use of high-frequency wind measurements and several empirical approximations for stability characterization. A more explicit representation originally proposed by Taylor, however, characterizes the lateral dispersion of a Gaussian plume as a function of wind variability and the Lagrangian time scale. The latter can be calculated as either i) a function of the turbulent length scale, or as ii) a function of the Eulerian timescale (itself a function of the autocorrelation of the lateral wind fluctuations). Using both methods, we are revising the Puff-Plume model to conform to Taylor's theory of dispersion, thereby making greater use of observed turbulence data in place of the currently parameterized values.

The new version of Puff-Plume has been validated against i) data from a field campaign, conducted in the vicinity of the Savannah River Site, in which a tracer was released and monitored as it traveled downwind, and ii) data from a high-resolution mesoscale simulation coupled to a dispersion model. We will discuss the results, and how the model is used in the context of emergency response.



Roberts and Webster, 2003

$$\frac{1}{2}\frac{d}{dt}[Y^2(t)] = [v'^2]\int_0^\infty R_\xi d\xi$$

v' = fluctuations of wind perpendicular to the mean wind

R_ξ = Lagged autocorrelation of v'

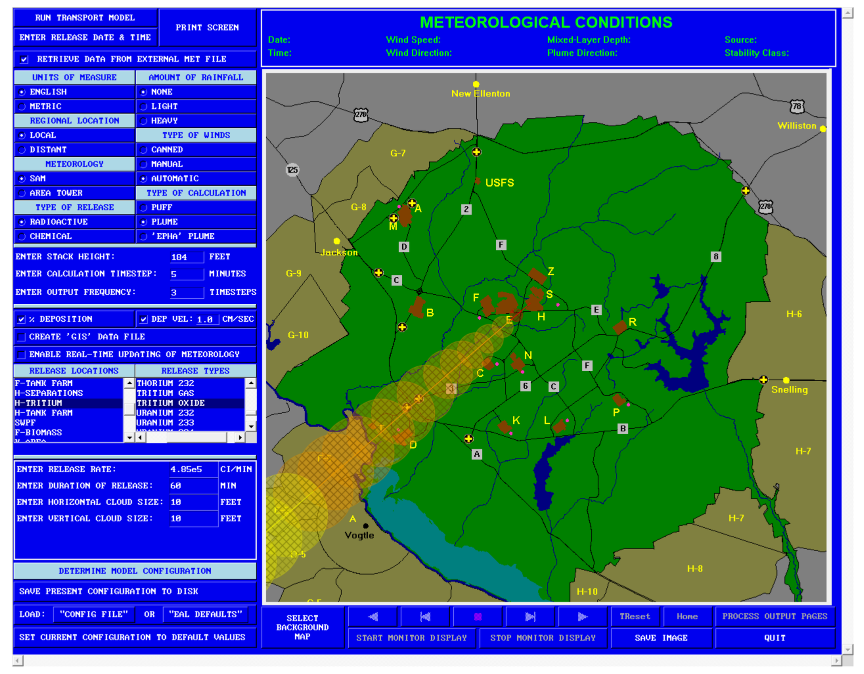
$$T_E = \int_0^\infty R_\xi d\xi \quad T_L = C\frac{\overline{U}}{\sigma_v}T_E$$

$$[Y^2(t)] = 2[v'^2]T_L t + constant$$

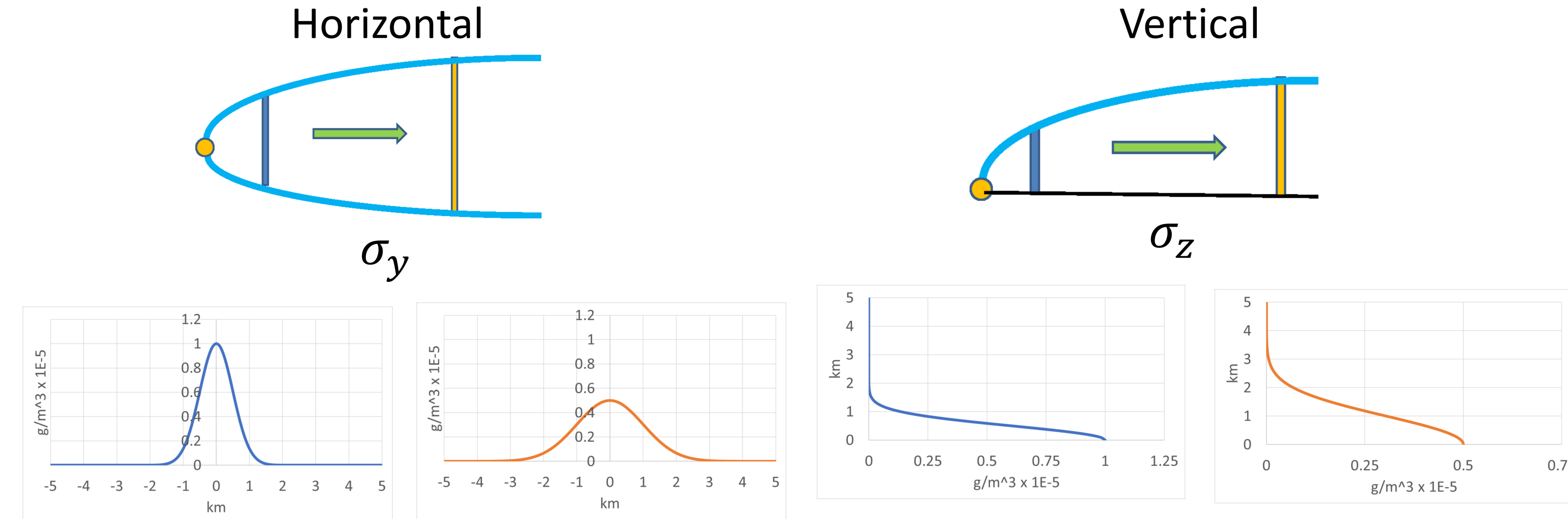
$$\sigma^2_{y,t+1} = \sigma^2_{y,t} + 2[v'^2]T_L\Delta t$$

Taylor, 1922

Puff-Plume Gaussian Dispersion Model



Gaussian Plume Model



Plume width (σ_y) and height (σ_z) increase with downwind distance/time.

Puff-Plume Algorithm

$$\sigma_y = \sigma_a x f(x)$$

$$\sigma_z = f(x, stability)$$

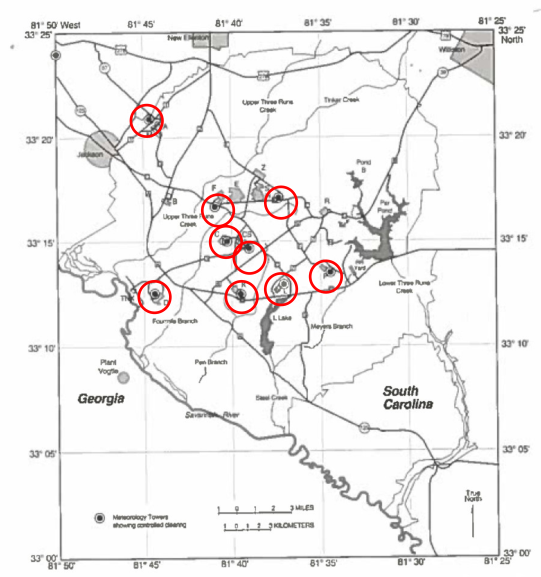
σ_a = Standard deviation of fluctuations of horizontal wind direction

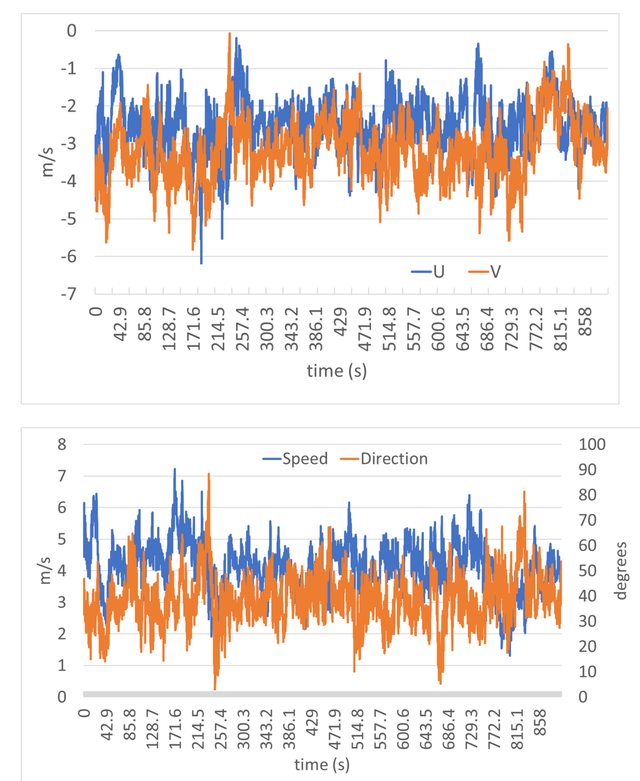
x=downwind distance

Goal

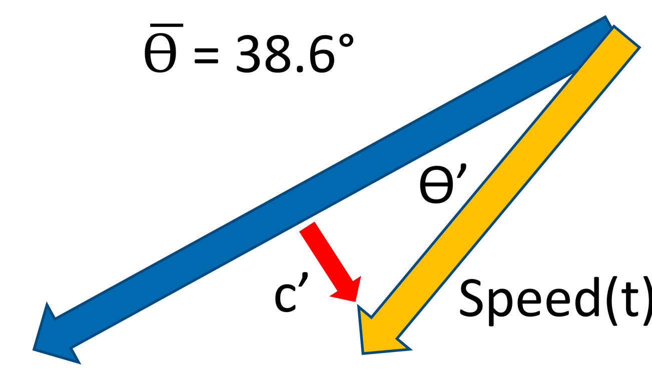
Use 10Hz sonic data to get new values for the puff/plume spread in the Puff-Plume model

10Hz Sonic Anemometer Locations at SRS

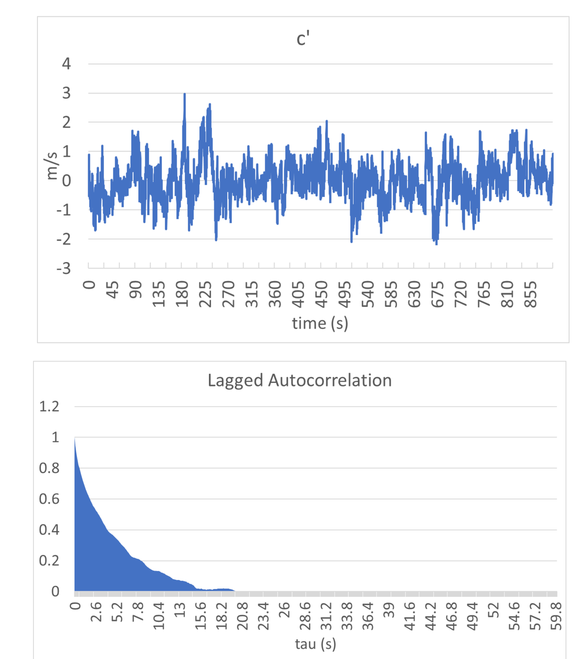




1. Record wind components, convert to speed and direction.



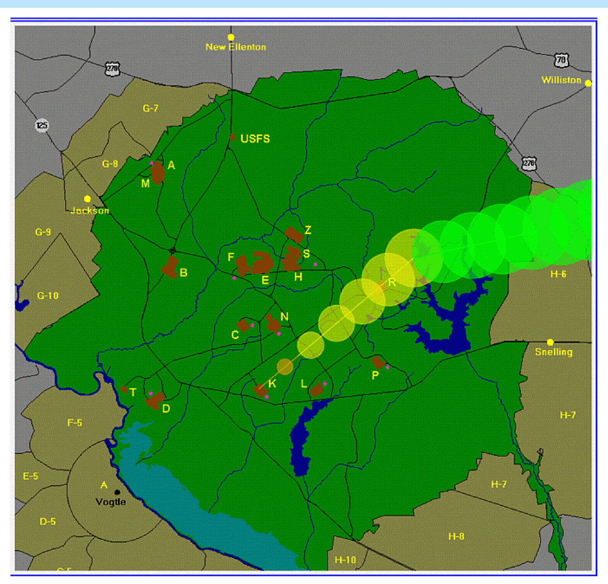
2. Calculate time series of wind fluctuations (c') perpendicular to the mean wind direction ($\overline{\Theta}$).

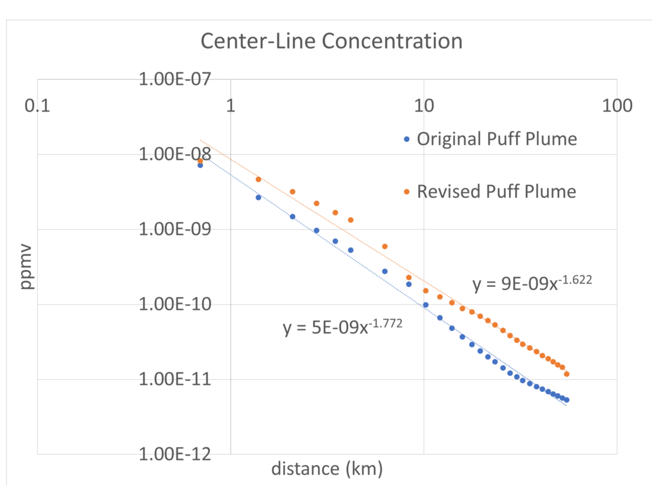


	Azimuthal	Elevation
$[c'^2]$ (m^2/s^2)	.454	.266
T_E (s)	4.55	3.06
T_L (s)	16.45	14.46
$d[\sigma^2]/dt$ (m^2/s)	14.93	7.71

3. Solve for $[c'^2]$ T_L (s) and $d[\sigma^2]/dt$.

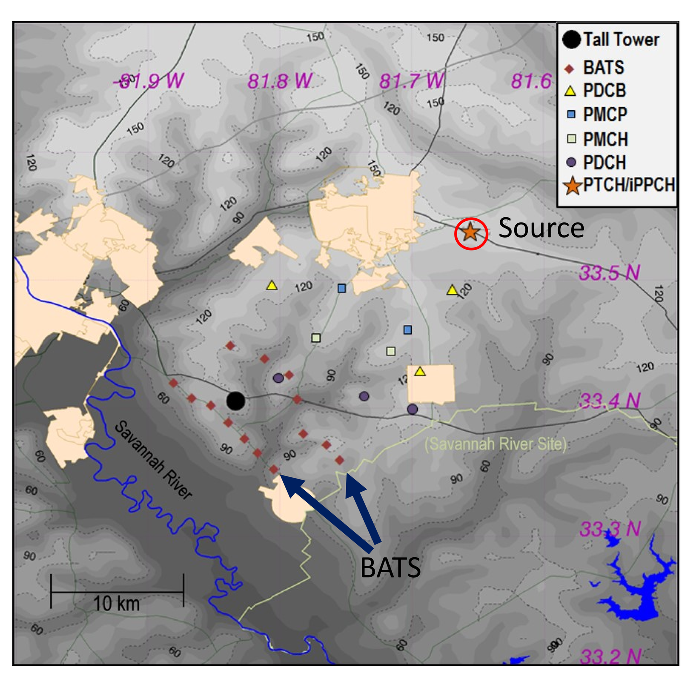
- START TIME OF THE RELEASE IS 08:00 EST 12-NOV-19
- INITIAL CLOUD SIZE: HEIGHT IS 10 FT; WIDTH IS 10 FT
- RADIOACTIVE RELEASE--ISOTOPE IS PU-238
- SOURCE TERM IS 2.60E-02 CI/MIN
- LENGTH OF RELEASE FOR PLUME IS 20 MINUTES
- RELEASE HEIGHT IS 1.0 FT
- RELEASE LOCATION AT SRS, K AREA.



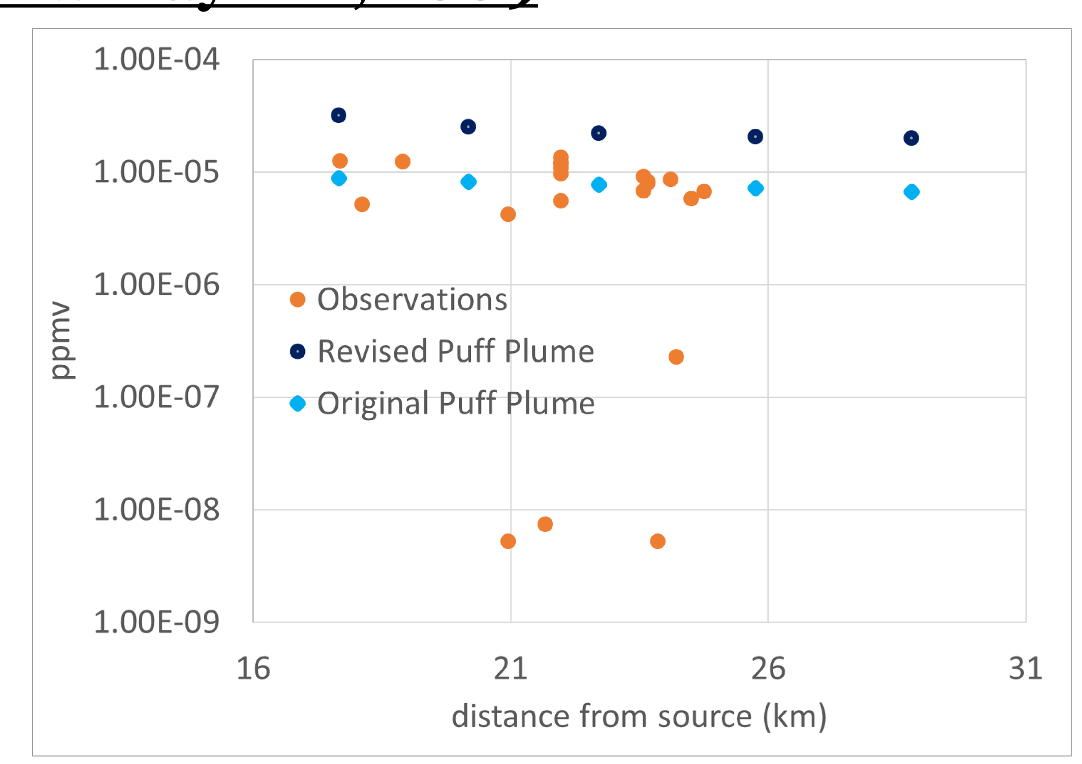


	Old	New
Dose at 1.4km	182 mrem	317 mrem
Dose at 6.27km	18.8 mrem	40.4 mrem
Dose at 10.2km	6.73 mrem	10.4 mrem

Tracer Release Experiment: May 12th, 2009



- Release from 2:00am EDT to 6:00am EDT
- Perflourocarbon PTCH
- .53 g/hour
- Monitored at 15 BATS stations
- Run Puff-Plume with sonic data from that night
- Compare simulated plume center-line concentration to BATS maxima



Conclusions

- The Atmospheric Technologies Group at SRNL is revising its Gaussian Puff-Plume model by applying Taylor's theorem of dispersion.
- 10Hz data from a series of sonic anemometers located onsite are used to calculate an explicit rate of plume spread
- We will continue to run tests before incorporating the new model into our site's Emergency Response Organization

SRNL is a U.S. Department of Energy National Laboratory operated by Savannah River Nuclear Solutions.

Roberts, P. and D. Webster 2003: Turbulent diffusion. Environmental Fluid Mechanics: Theories and Applications.

Taylor, G. I., 1922: Diffusion by Continuous Movements, *Proceedings of the London Mathematical Society*, **s2-20**, 196-212