Lawrence Livermore National Laboratory

Turbulence and Concentration Averaging Times in Plume Models: HotSpot, EPIcode and NARAC

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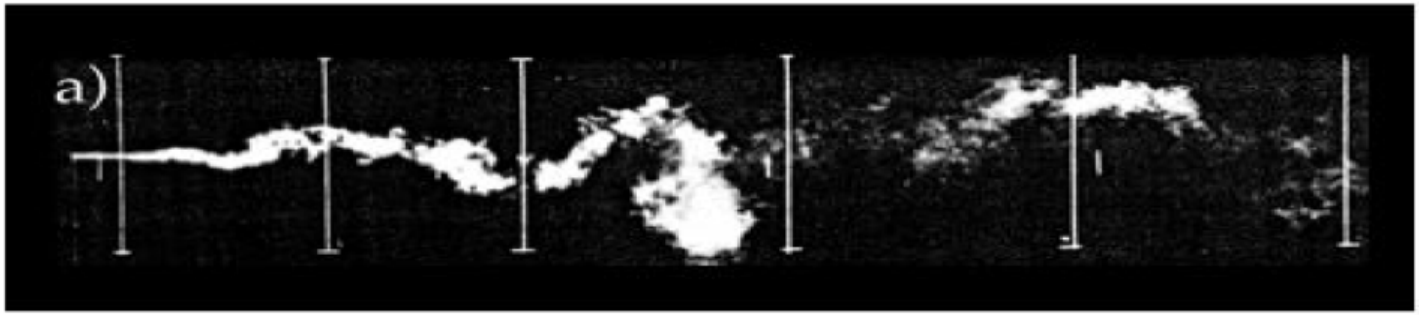
Outline of, and Questions Addressed by, this Presentation

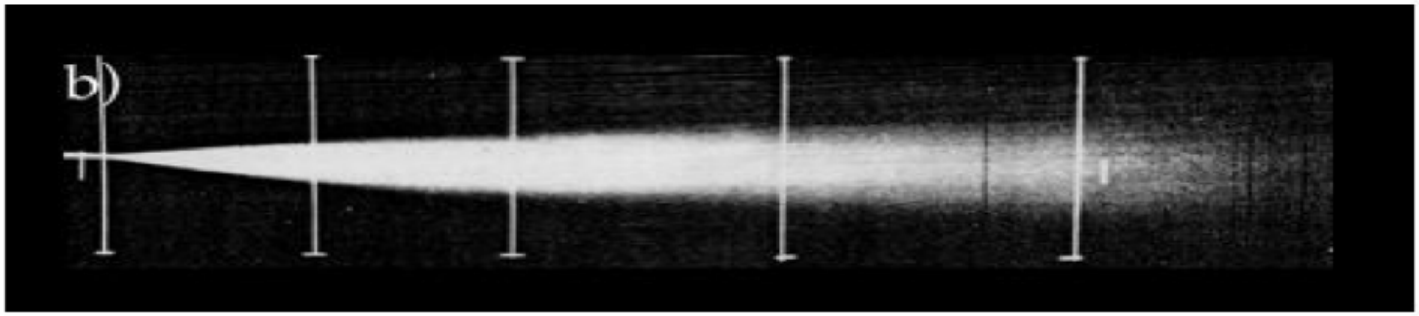
- How does averaging or sampling time affect air concentrations from atmospheric releases?
- How do plume models account for different averaging/sampling times?
- How can I change the sampling/averaging time in a plume model?
- What factors should I consider when selecting the averaging/sampling time for a plume model?
- How do different plume models determine averaging time?

Longer Averaging Times Result in Wider, More Dilute Plumes

Instantaneous plume showing random nature of turbulent eddies



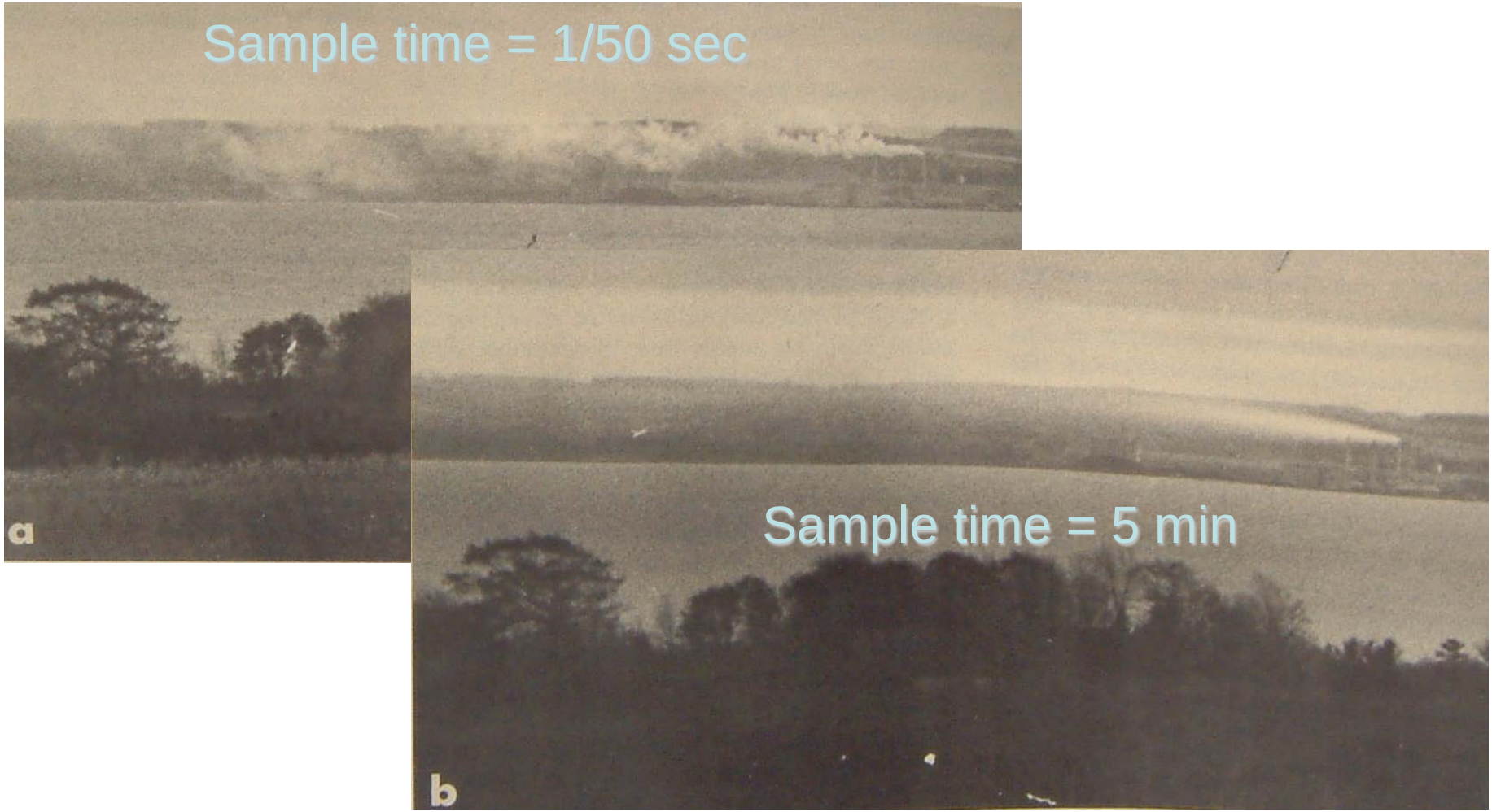
Ensemble-average plume (long-time exposure)



Photographs of a short- and long-time exposure of a smoke plume in a wind tunnel

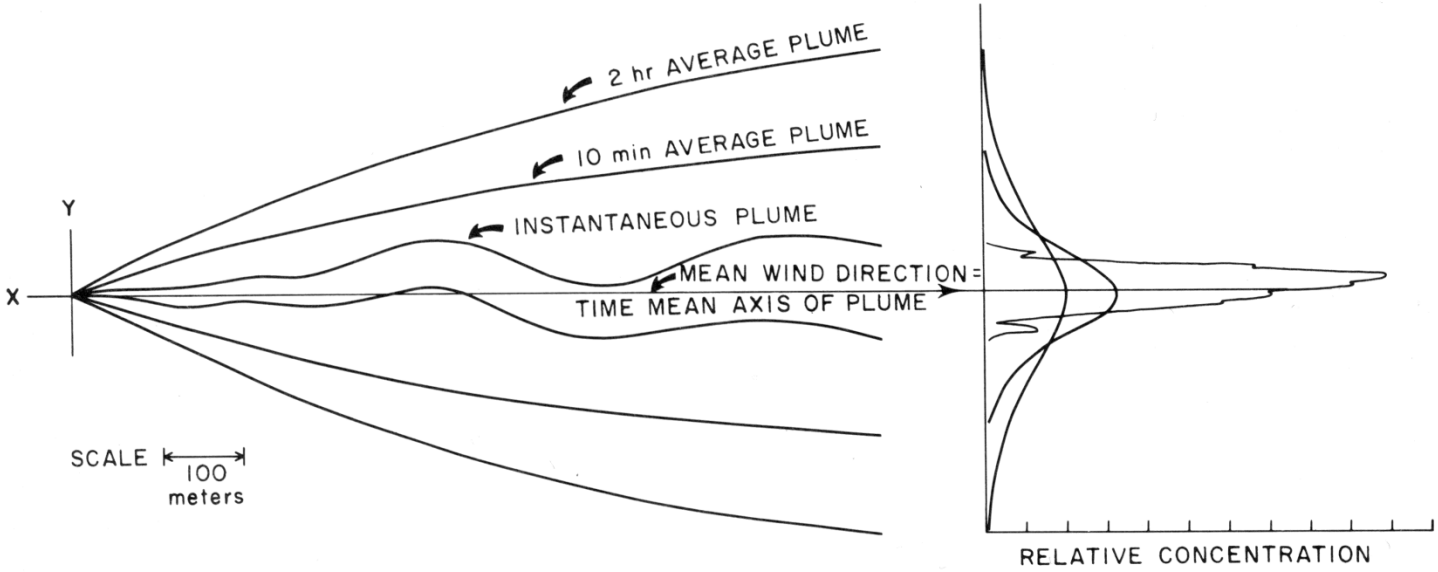
(U.S. EPA Fluid Modeling Facility).

Longer Averaging Times Result in Wider, More Dilute Plumes



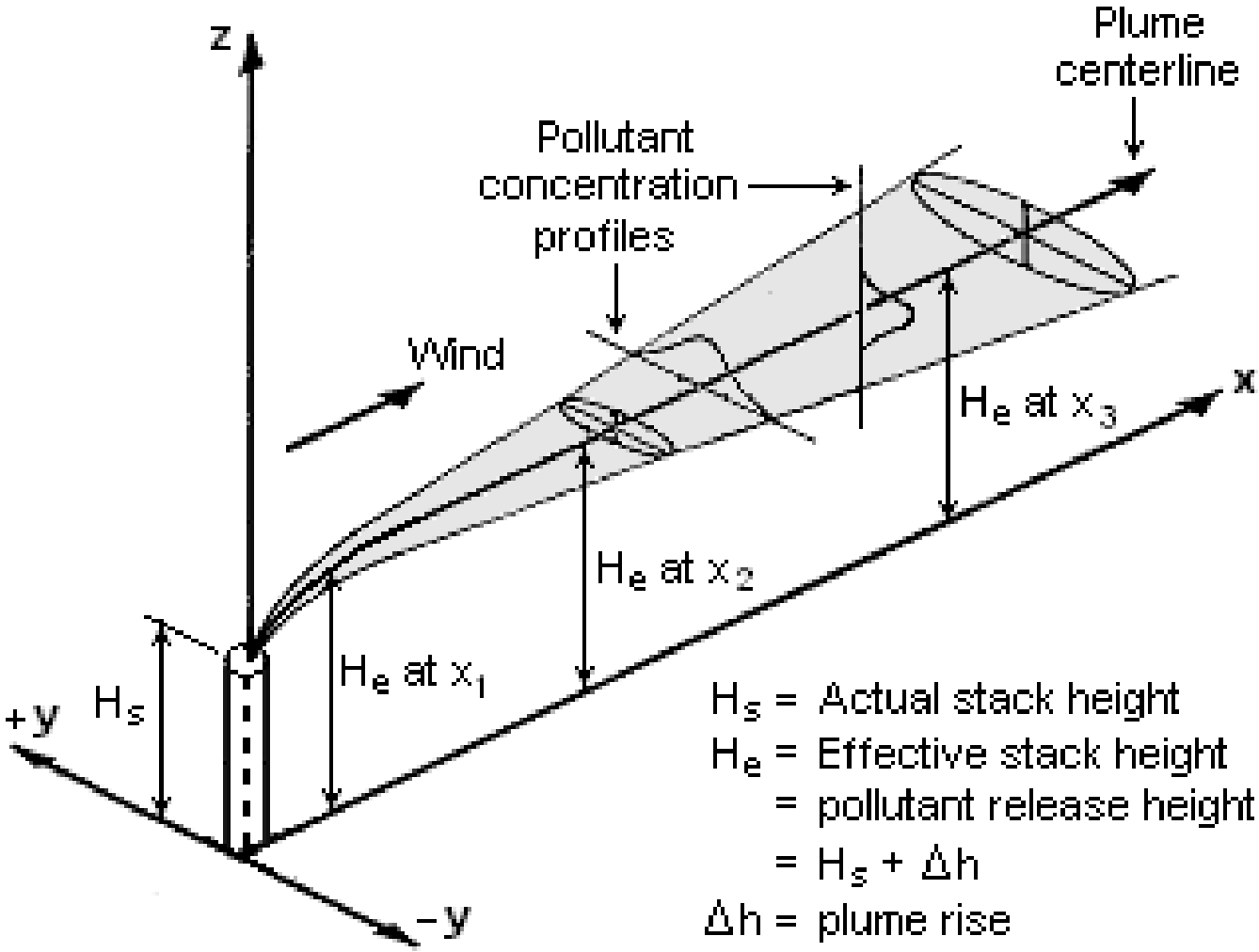
Instantaneous versus Time-Averaged Plumes

- Horizontal concentration distribution become wider, and peak concentrations become lower, for longer sampling/averaging time due to longer period wind fluctuations, or “meandering” of the <u>horizontal</u> wind direction



(Slade, 1970).

Plume Model Coordinates



H_s = Actual stack height
H_e = Effective stack height
= pollutant release height
= $H_s + \Delta h$
Δh = plume rise

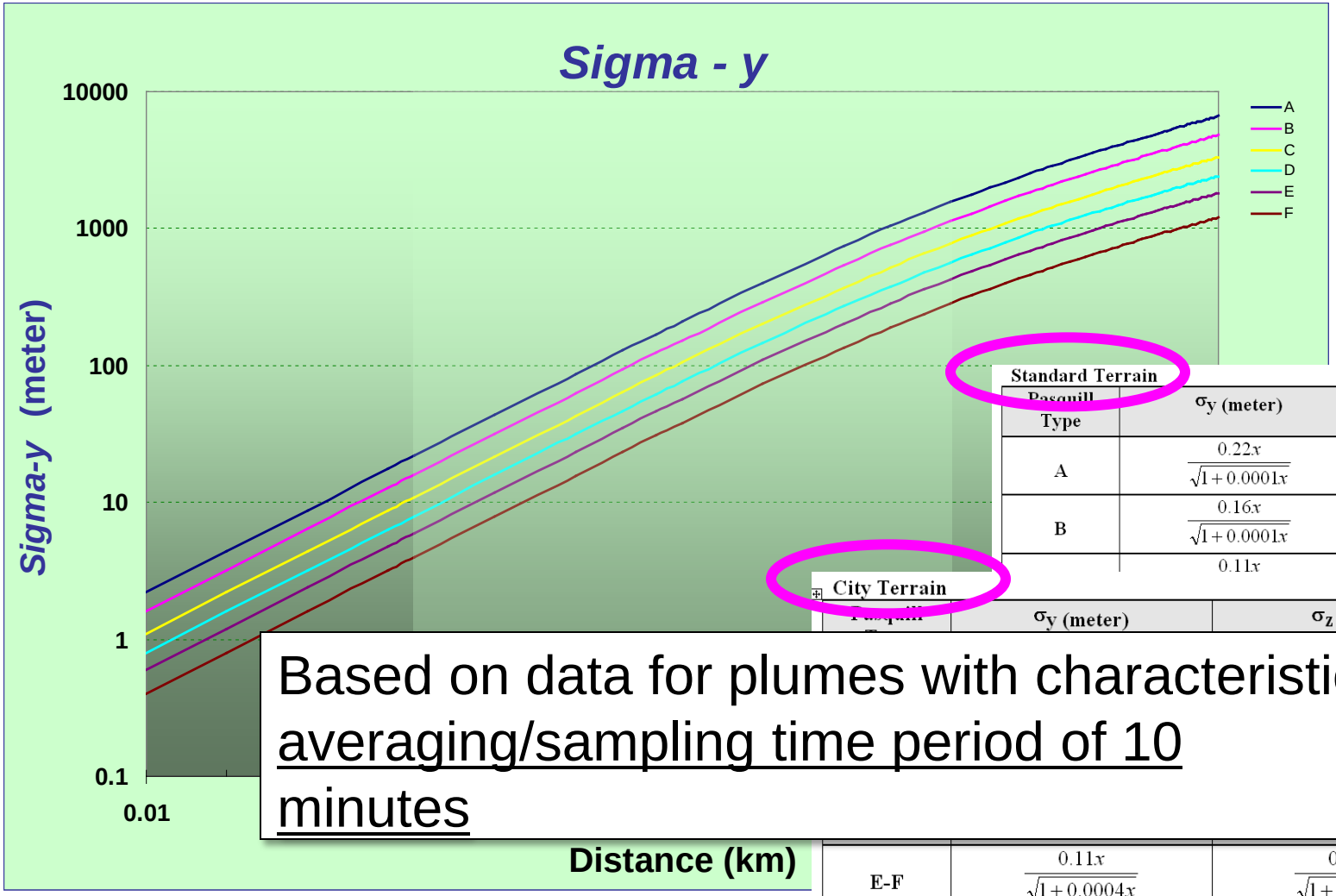
Gaussian Plume Model

Assuming a uniform mean wind, no settling, no deposition, no trapping by inversion and neglecting dispersion in the streamwise direction, the time-integrated mean concentration (e.g, Ci-s/m^3) is given by

$$C(x,y,z)=\frac{Q_T}{2\pi u\sigma_y\sigma_z}\exp\left(-\frac{y^2}{2\sigma_y^2}\right)\left\{\exp\left(-\frac{(z-H_e)^2}{2\sigma_z^2}\right)+\exp\left(-\frac{(z+H_e)^2}{2\sigma_z^2}\right)\right\}$$

where $\sigma_y(x)$ and $\sigma_z(x)$ are the Gaussian plume spread parameters that depend on atmospheric turbulence stability class, time-integrated concentration is $C(x,y,z)$, u is average wind speed, Q_T is total mass or activity emitted from the source, (e.g. Ci), and H_e is the height of the source.

Gaussian Plume Models (HotSpot, EPIcode) Have Options for Plume Spread Parameters that are Based on a 10 min Sampling/Averaging Time



Standard Terrain

Pasquill Type	σ_y (meter)	σ_z (meter)
A	$\frac{0.22x}{\sqrt{1+0.0001x}}$	$0.20x$
B	$\frac{0.16x}{\sqrt{1+0.0001x}}$	$0.12x$
	$0.11x$	$0.080x$

City Terrain

Pasquill Type	σ_y (meter)	σ_z (meter)
E-F	$\frac{0.11x}{\sqrt{1+0.0004x}}$	$\frac{0.08x}{\sqrt{1+0.0015x}}$

x = downwind distance, meter.

Based on data for plumes with characteristic <u>averaging/sampling time period of 10 minutes</u>

HotSpot and *EPIcode* AveragingTime Correction for Horizontal Plume Spread

$$\sigma'_y = \sigma_y \left[\frac{t}{10} \right]^{0.2} ,$$

where—

σ_y = 10-min standard deviation of the concentration distribution.

σ_y' = Standard deviation for averaging time, *t*.

Effect of averaging time on time integrated air concentration and Committed Effective Dose (CED)

Sample time (min)	Relative CED
0.1	2.51
1	1.58
10	**1.00**
60	0.70
120	0.61

Reference for 0.2 Power Law Relationship for Sigma-y Versus Sampling/Averaging Time

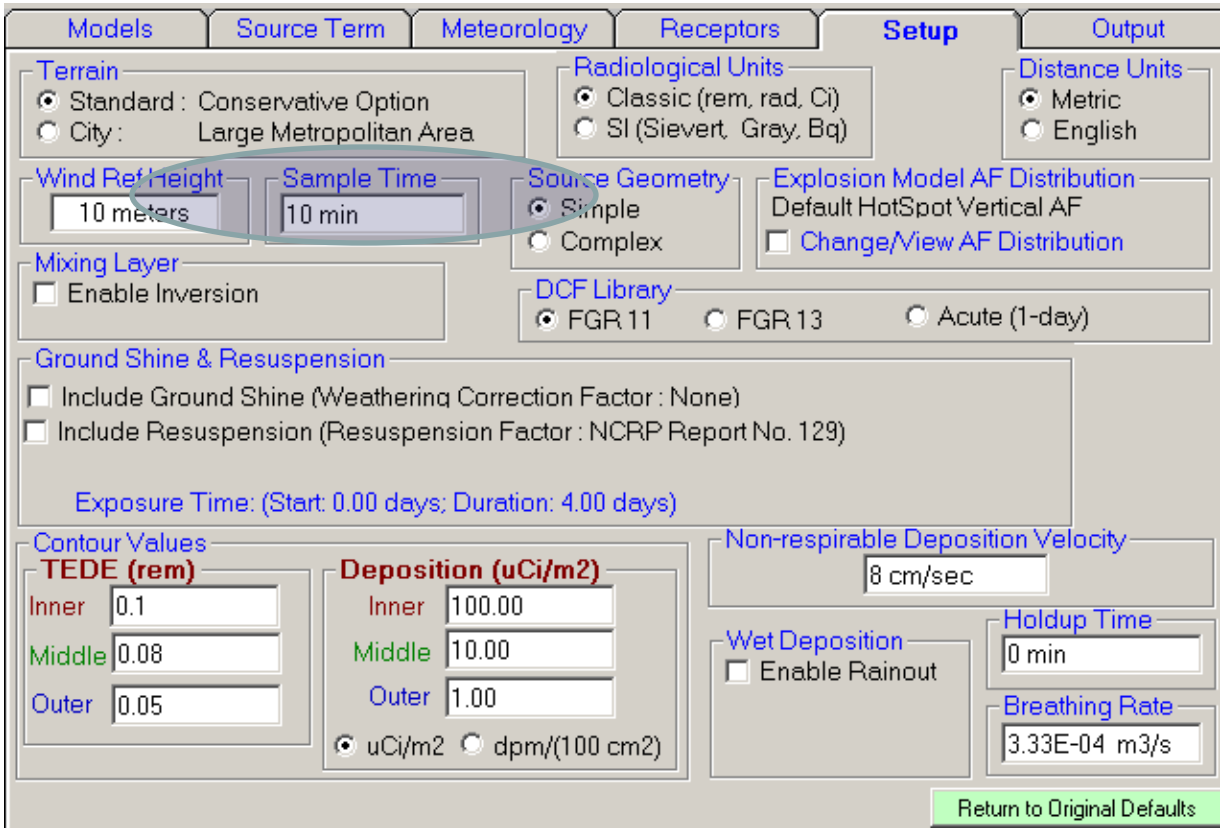
References

Cramer, H.E., G.M. DeSanto, P. Morgenstern, R.K. Dumbauld, R.N. Swanson, 1964: *Meteorological Prediction Techniques and Data System*, Technical Report No. 64-3-G, Geophysics Corporation of America, Bedford, MA. (Available from the Defense Technical Information Center, Ft. Belvoir, VA).

Slade, D.H. (ed.) 1968: *Meteorology and Atomic Energy*, U.S. Atomic Energy Commission

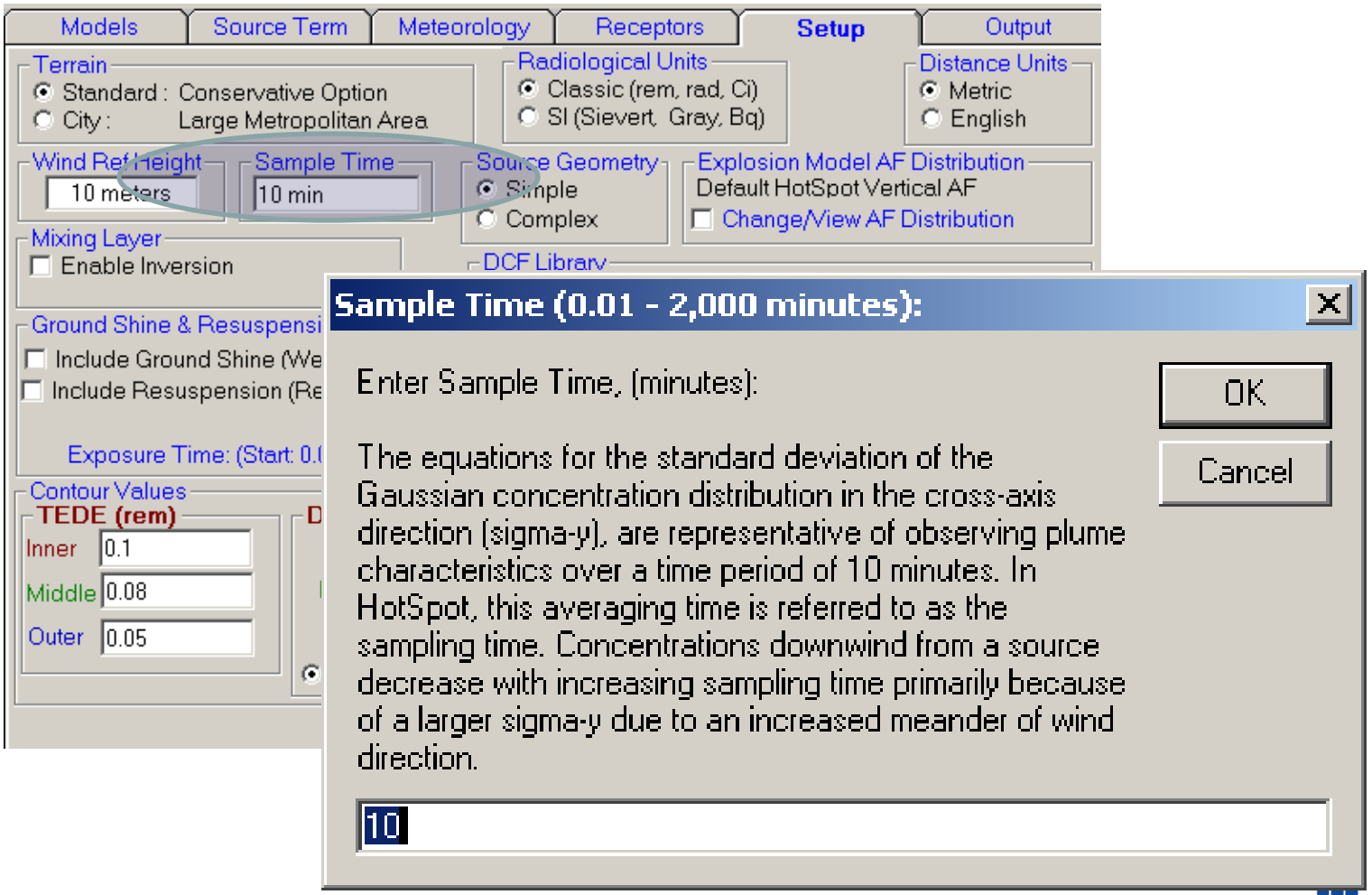
Hanna, S., Briggs, G., Hosker, Jr., R., *Handbook on Atmospheric Diffusion*, DOE/TIC 11223 (DE82002045), prepared for the Office of Health and Environmental Research, Office of Energy Research, U.S. Department of Energy, 1982.

HotSpot Allows Users to Change Sample Time from Default of 10 min



In HotSpot and EPI*code*, concentration averaging time is referred to as the *Sample Time*.

HotSpot Allows Users to Change Sample Time from Default of 10 min



Factors to Consider When Selecting Sample/Averaging Time in a Plume Model

- Sample/averaging time should be the desired exposure time to the receptor of interest, i.e., the time a human is exposed to the puff or plume
- Sample/averaging time should not be greater than the cloud passage time, that is, the total time it takes for a plume or puff to pass the receptor is the maximum exposure time
- For toxic chemical health effects that are concentration dependent, the sample/averaging time should be small enough to represent peak concentration

  Emergency Management Guide (EMG), DOE G 151.1-2: states that the highest time-weighted average concentration predicted or measured for any 15-minute period should be used. For exposure periods of less than 15 minutes, a shorter time period may be used (the exposure duration)
- For plume models using multiple meteorological data times, the sample/averaging time should not be greater that the meteorological data averaging time period

How do different plume models determine sampling/averaging time?

- Hotpot (radiological releases)
  - Defaults Sample Time to 10 min
    (60 min for General Resuspension and Plutonium Resuspension models)
  - User can input different *Sample Time*
- EPI code (chemical releases)
  - For a Continuous Release model, the default sample time is 10 minutes.
  - For the Term Release, Fire Release, Liquid Spill, and Explosive Release models, EPIcode computes the sample time using the *release duration* and *cloud passage time*, but never exceeding the *Maximum Sample Time*
- NARAC ADAPT/LODI models
  - Turbulent velocity variances in the models are adjusted using averaging time
  - Averaging time value is adjusted so it is <u>not greater than</u> the *release duration,* and <u>not greater than</u> the desired *exposure time* for the concentration output
  - The value must <u>not be less</u> than the *minimum averaging time* value of 15 min
  - NARAC software automatically sets (for sites with frequent meteorological tower data feeds), or analysts manually adjust, sample/averaging time so that it is <u>not greater than</u> the input *meteorological data averaging time period*