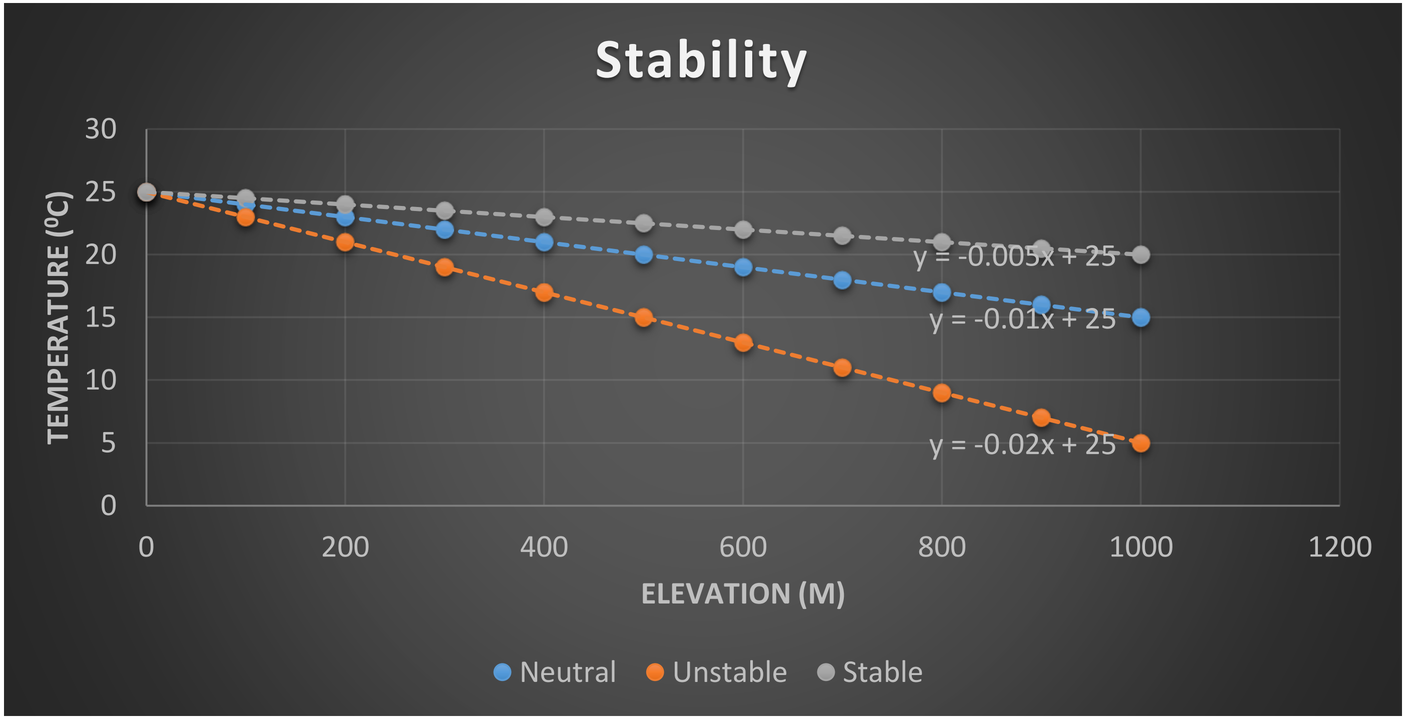
Condition of the Atmosphere

Dry Adiabatic Lapse Rate~ $-1^{0}C/100m$

Elevation (m)	Temperature (^{0}C)		
	Case 1	Case 2	Case 3
0	25	25	25
100	24	23	24.5
200	23	21	24
300	22	19	23.5
400	21	17	23
500	20	15	22.5
600	19	13	22
700	18	11	21.5
800	17	9	21
900	16	7	20.5
1000	15	5	20



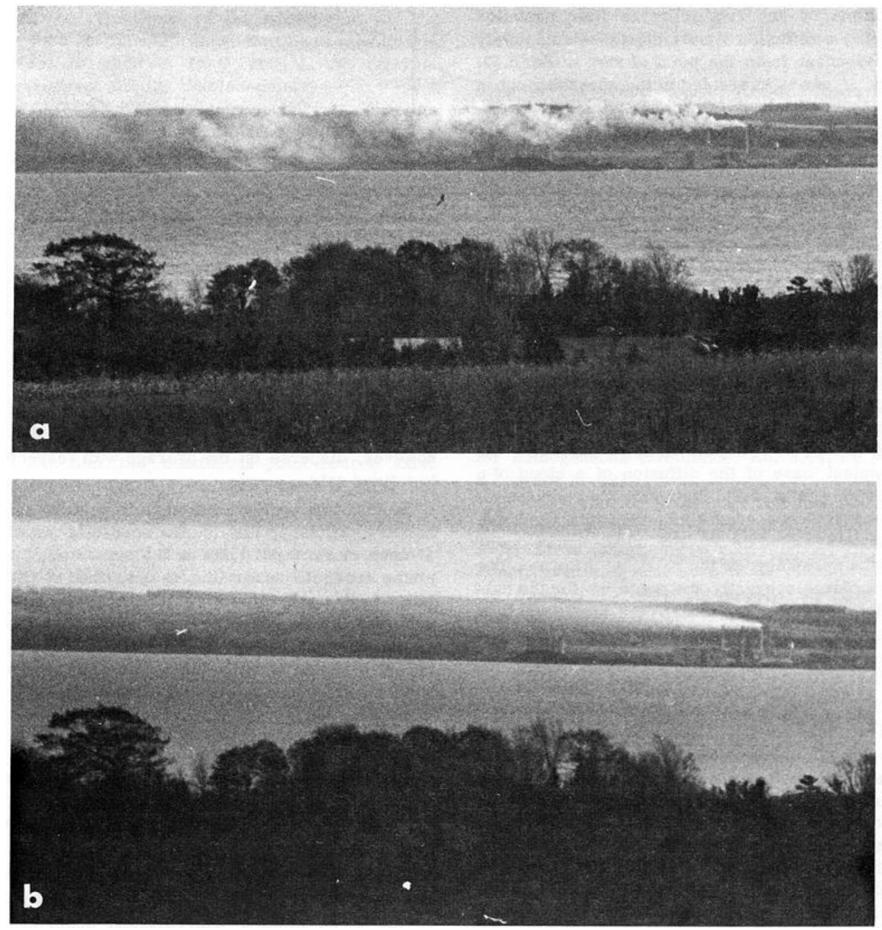
Plume from Stacks

GAUSSIAN DISPERSION MODELING

Instantaneous and Time-averaged Plume

- At any given time, the plume looks rather turbulent and does not have a well defined shape

- However, under steady wind condition and averaged over sufficient time, the plume shows well defined shape



Plume photographs (a) instantaneous 1/50s exposure,
(b) 5-min time exposure (Slade, 1968) – Walton J.C. (2008)

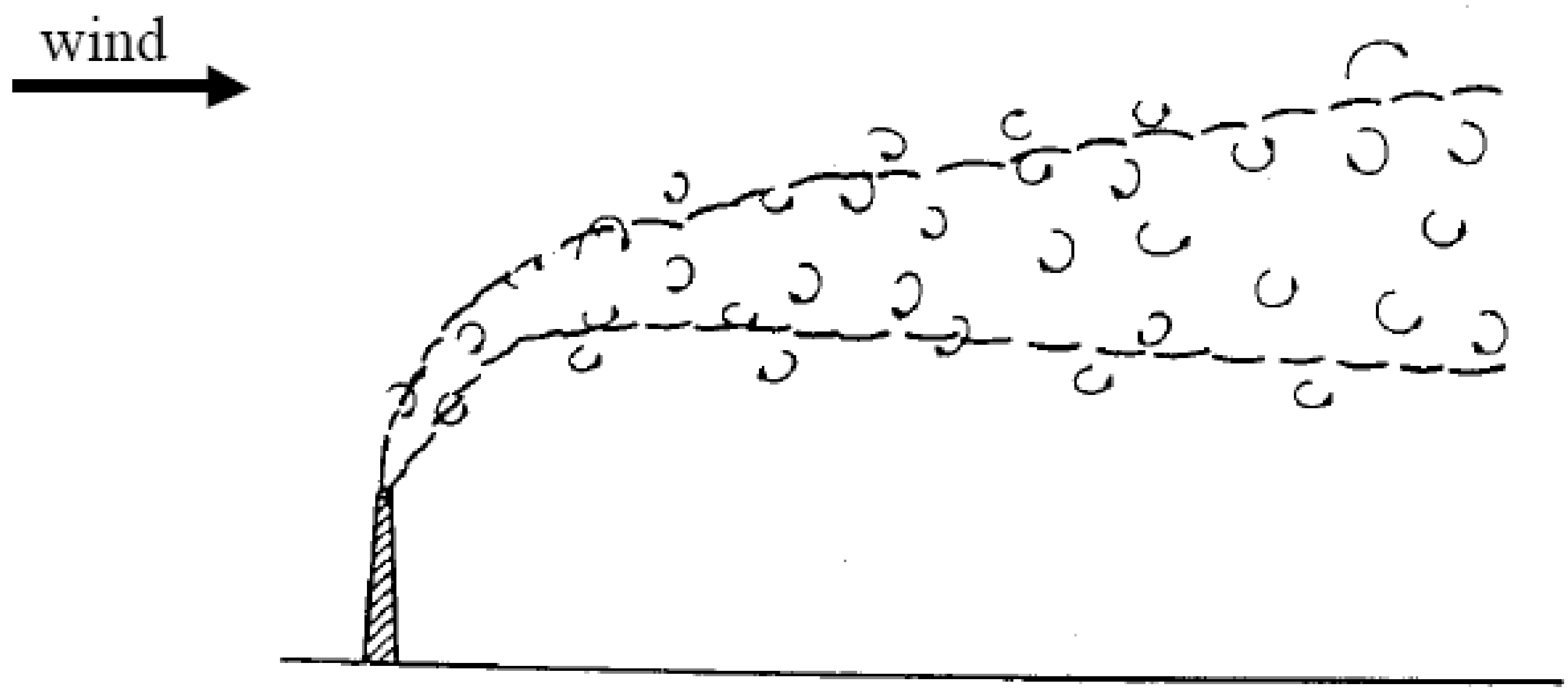
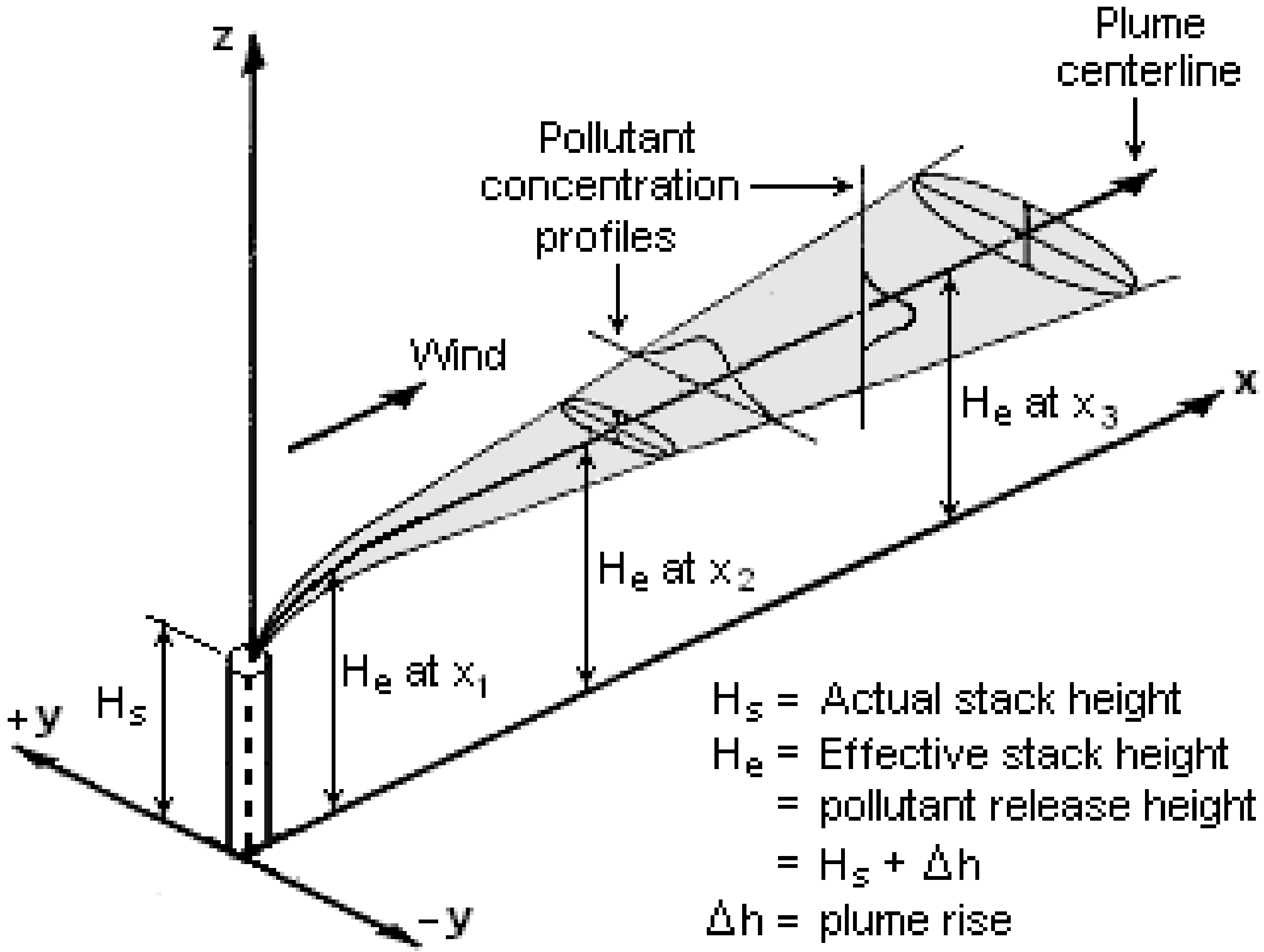


Fig 4-3, p.44 in Martin et al

Pollutant Concentration Profile

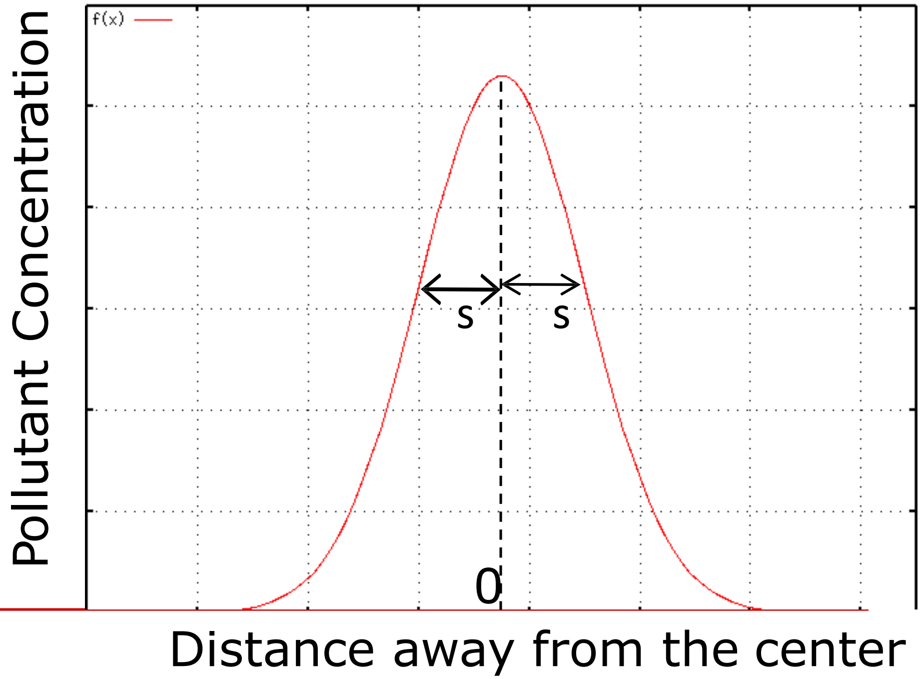


Gaussian Distribution of Pollutant Concentration

- Time-averaged pollutant concentration follows Gaussian distribution:

$$C(y) \propto \frac{1}{s\sqrt{2\pi}} \exp\left(-\frac{y^2}{2\sigma^2}\right)$$

s : Plume spread



More about Sy and Sz

- Called “plume spread parameter”
- Function of downwind distance (x)
  - The further downwind, the greater the spread parameter values
- Function of atmospheric stability
  - The more unstable the larger the parameter values
- S_z usually smaller than S_y

Gaussian Dispersion Equation to Estimate Surface Concentrations

$$C(x, y, 0) = \frac{E}{2\pi\, S_y S_z\, U} \exp\left(-\frac{y^2}{2S_y^2}\right) \exp\left(-\frac{H_e^2}{2S_z^2}\right)$$

E= Emission rate of the pollutant from the stack (g/s)

S_y and S_z are plume spread parameters

U= Wind speed (m/s)

H_e=Height of the plume central line (m)

The Pasquill Stability Classes

Stability class	Definition	Stability class	Definition
A	very unstable	D	neutral
B	unstable	E	slightly stable
C	slightly unstable	F	stable

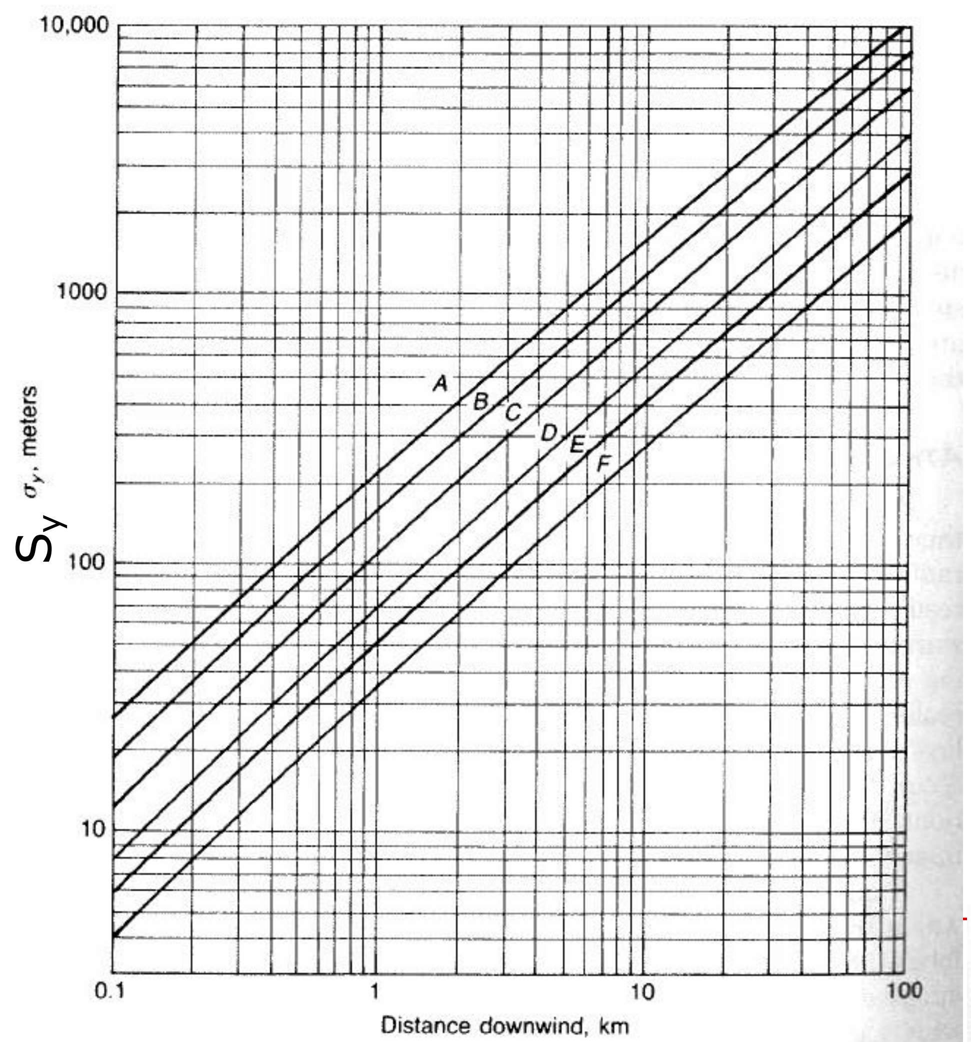
Meteorological Conditions Define the Pasquill Stability Classes

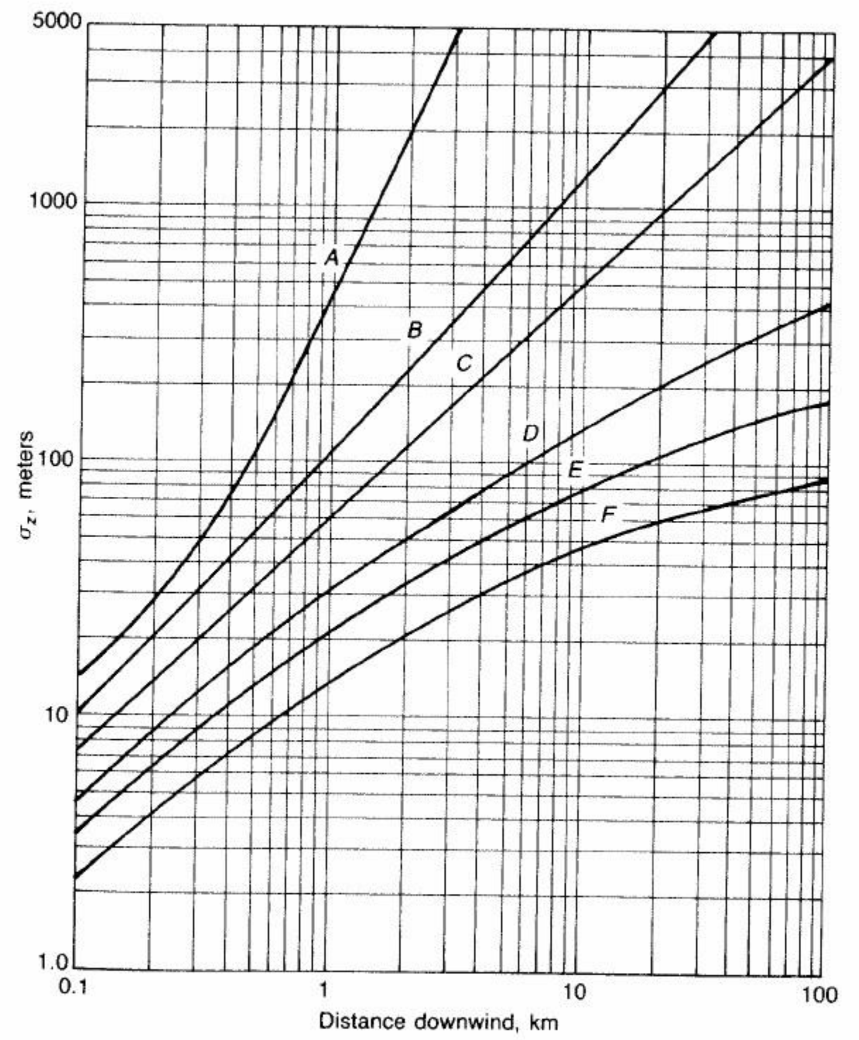
Surface wind speed		Daytime incoming solar radiation			Nighttime cloud cover	
m/s	mi/h	Strong	Moderate	Slight	> 50%	< 50%
< 2	< 5	A	A – B	B	E	F
2 – 3	5 – 7	A – B	B	C	E	F
3 – 5	7 – 11	B	B – C	C	D	E
5 – 6	11 – 13	C	C – D	D	D	D
> 6	> 13	C	D	D	D	D
Note: Class D applies to heavily overcast skies, at any wind speed day or night						

Determine Solar Radiation Strength

- As a rule of thumb
  - Strong: Solar intensity > 700 W/m^2
  - Moderate: Solar intensity > 350 W/m^2
  - Slight: Solar intensity > 100 W/m^2
  - Solar intensity < 100 W/m^2 but still day hours → neutral

S_y, S_z Charts


10,000
1000
100
10
S_y σ_y, meters
A
B
C
D
E
F
0.1
1
10
100
Distance downwind, km


5000
1000
100
10
1.0
σ_z, meters
A
B
C
D
E
F
0.1
1
10
100
Distance downwind, km

Equations to Estimate S_y and S_z

$$S_y = a \times x^{0.894}$$

$$S_z = c \times x^d + f$$

a, c, d, f are parameters. They are functions of stability classes and distance downwind (x). NOTE: 'x' should be in units of **km.**

		x<1km			x>1km		
Stability	a	c	d	f	c	d	f
A	213	440.8	1.941	9.27	459.7	2.094	-9.6
B	156	106.6	1.149	3.3	108.2	1.098	2
C	104	61	0.911	0	61	0.911	0
D	68	33.2	0.725	-1.7	44.5	0.516	-13
E	50.5	22.8	0.678	-1.3	55.4	0.305	-34
F	34	14.35	0.74	-0.35	62.6	0.18	-48.6

Example Problem

Given:

- *E=127 g/s*
- *x=850 m*
- *y=0*
- *H_e=101 m*
- *U=4.5 m/s*
- *Strong solar radiation*

$$C(x, y, 0) = \frac{E}{2\pi\, S_y S_z\, U} \exp\left(-\frac{y^2}{2S_y^2}\right) \exp\left(-\frac{H_e^2}{2S_z^2}\right)$$

Step 1

Estimate Plume Spread parameters

Surface wind speed		Daytime incoming solar radiation			Nighttime cloud cover	
m/s	mi/h	Strong	Moderate	Slight	> 50%	< 50%
< 2	< 5	A	A – B	B	E	F
2 – 3	5 – 7	A – B	B	C	E	F
3 – 5	7 – 11	B	B – C	C	D	E
5 – 6	11 – 13	C	C – D	D	D	D
> 6	> 13	C	D	D	D	D
Note: Class D applies to heavily overcast skies, at any wind speed day or night						

$S_y = a \times x^{0.894}$

S_y =*134.9 m*

$S_z = c \times x^d + f$

S_z =91.7 m

Stability	a	x<1km c	d	f	x>1km c	d	f
A	213	440.8	1.941	9.27	459.7	2.094	-9.6
B	***156***	***106.6***	***1.149***	***3.3***	108.2	1.098	2
C	104	61	0.911	0	61	0.911	0
D	68	33.2	0.725	-1.7	44.5	0.516	-13
E	50.5	22.8	0.678	-1.3	55.4	0.305	-34
F	34	14.35	0.74	-0.35	62.6	0.18	-48.6

Step 2

Estimate Surface Concentration using Gaussian Dispersion Equation

$$C(x, y, 0) = \frac{E}{2\pi\, S_y S_z\, U} \exp\left(-\frac{y^2}{2S_y^2}\right) \exp\left(-\frac{H_e^2}{2S_z^2}\right)$$

C=424 $\mu g/m^3$