Exceedances & Percentiles & AERMOD

Roland Stull
UBC
ATSC 595D
2024

Given the:

- turbulent, somewhat random nature of the boundary layer;
- chaotic, somewhat unpredictable nature of weather;
- statistical definition of air-quality observations and standards; and
- imperfect nature of air-quality models ...

Many air-quality standards ALLOW the actual observed concentration to **exceed** the published air-quality standard a small number of times without any penalty.

Two ways this are done is by:

- specifying the max **number** of **exceedances** that are allowed; or
- stating that the air-quality standard corresponds to a specified **percentile** level of concentration values.

Example from the US EPA:

Pollutant [links to historical tables of NAAQS reviews]	Primary/ Secondary	Averaging Time	Level	Form
Carbon Monoxide (CO)	primary	8 hours	9 ppm	Not to be exceeded more than once per year
		1 hour	35 ppm	
Lead (Pb)	primary and secondary	Rolling 3 month average	0.15 $\mu g/m^3$ (1)	Not to be exceeded
Nitrogen Dioxide (NO_2)	primary	1 hour	100 ppb	98th percentile of 1-hour daily maximum concentrations, averaged over 3 years
	primary and secondary	1 year	53 ppb (2)	Annual Mean
Ozone (O_3)	primary and secondary	8 hours	0.070 ppm (3)	Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years

https://www.epa.gov/criteria-air-pollutants/naaqs-table

Example from the US EPA:

(continued)

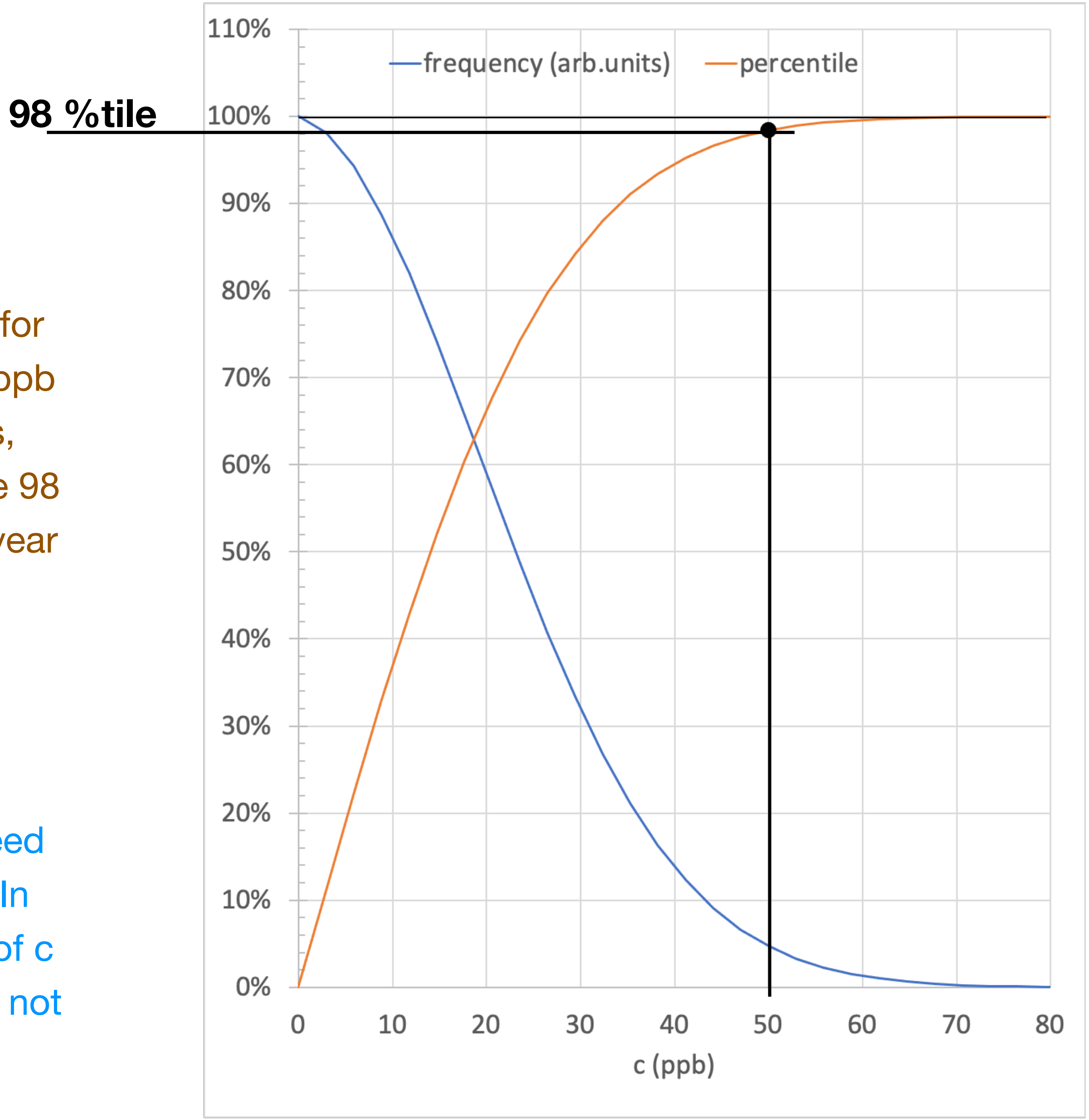
Pollutant [links to historical tables of NAAQS reviews]		Primary/ Secondary	Averaging Time	Level	Form
Particle Pollution (PM)	$PM_{2.5}$	primary	1 year	12.0 μg/m^3	annual mean, averaged over 3 years
		secondary	1 year	15.0 μg/m^3	annual mean, averaged over 3 years
		primary and secondary	24 hours	35 μg/m^3	98th percentile, averaged over 3 years
	PM_{10}	primary and secondary	24 hours	150 μg/m^3	Not to be exceeded more than once per year on average over 3 years
Sulfur Dioxide (SO_2)		primary	1 hour	75 ppb [(4)]	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		secondary	3 hours	0.5 ppm	Not to be exceeded more than once per year

https://www.epa.gov/criteria-air-pollutants/naaqs-table

Illustration
of percentile
exceedances

Suppose the Ambient Air Quality Standard (AAQS) for some pollutant is c = 50 ppb for 1-hour average values, not to be exceeded at the 98 percentile level over a 3-year period.

3 years = 26,280 hours. Thus, during that 3-year period, it is OK for c exceed 50 ppb up to 525 times. In this case, the max value of c during the exceedance is not specified.



Example from the Canadian Council of Ministers of the Environment (CCME)

Pollutant	Averaging Time	Numerical Value			Statistical Form
		2015	2020	2025	
Fine Particulate Matter ($PM_{2.5}$)	24-hour	28 µg/m^3	27 µg/m^3		The 3-year average of the annual 98th percentile of the daily 24-hour average concentrations
	Annual	10.0 µg/m^3	8.8 µg/m^3		The 3-year average of the annual average of the daily 24-hour average concentrations
Ozone (O_3)	8-hour	63 ppb	62 ppb	60 ppb	The 3-year average of the annual 4th highest of the daily maximum 8-hour average ozone concentrations
Nitrogen dioxide (NO_2)	1-hour	-	60 ppb	42 ppb	The 3-year average of the annual 98th percentile of the daily maximum 1-hour average concentrations
	Annual	-	17.0 ppb	12.0 ppb	The average over a single calendar year of all 1-hour average concentrations
Sulphur dioxide (SO_2)	1-hour	-	70 ppb	65 ppb	The 3-year average of the annual 99th percentile of the SO_2 daily maximum 1-hour average concentrations
	Annual	-	5.0 ppb	4.0 ppb	The average over a single calendar year of all 1-hour average SO_2 concentrations

https://ccme.ca/en/air-quality-report#slide-8

How AERMOD finds Max concentrations:

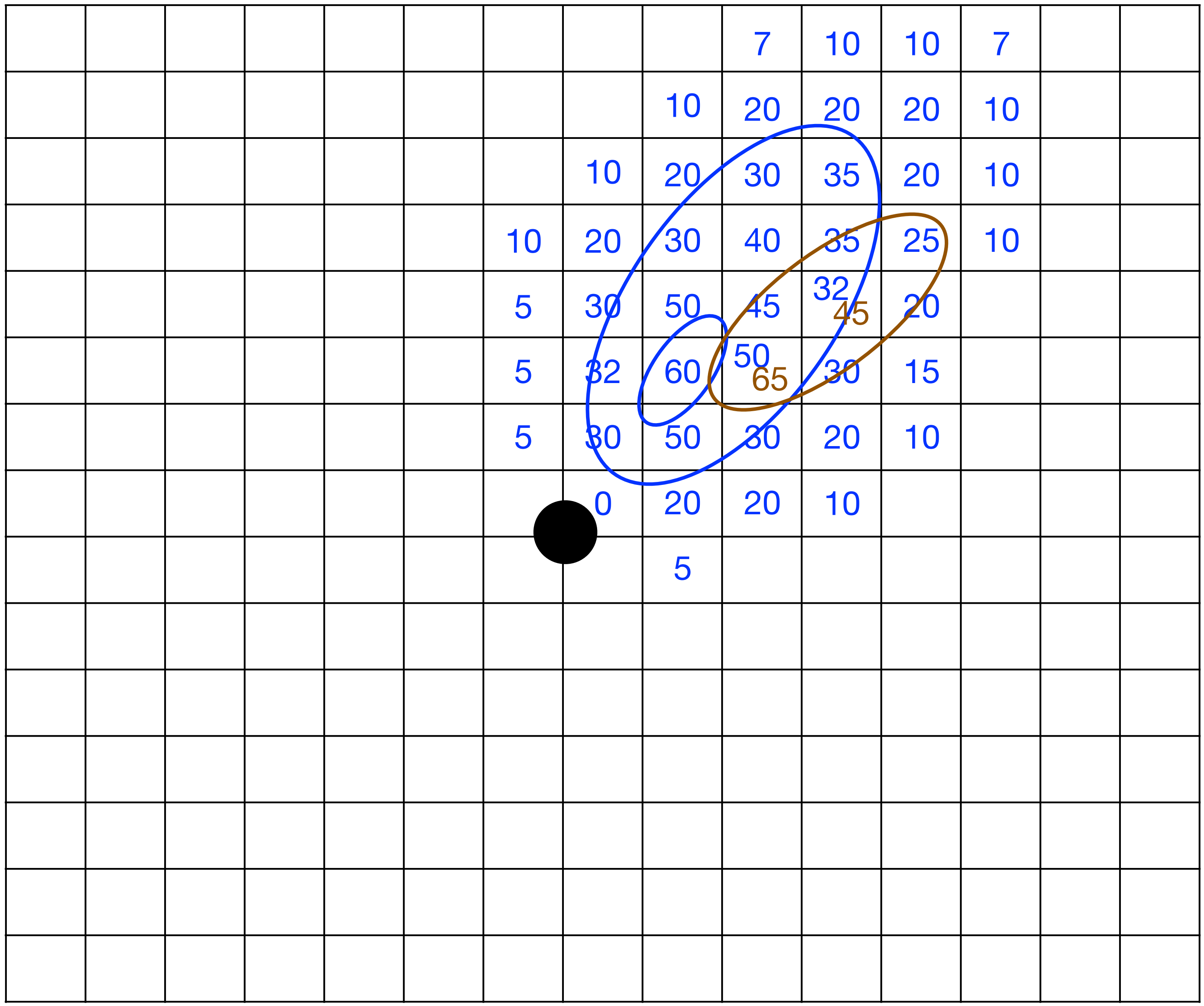
- Assume a receptor is located in each grid cell. This grid of many cells forms your set of receptors, each recording pollutant concentration.

- AERMOD uses Gaussian plume to find c in each grid cell for any one hour, and stores that c for each cell.

- Repeats for next hour with the new weather inputs. If the c value is greater than the stored c value, then the new value overwrites the old stored value for that cell.

- Repeats for every hour for 1 yr or for 3 years, updating the stored value only if the new concen. is greater.*

- End up with a gridded field of 1-hour-average c_max values over 1 or 3 years.



* can also save 2nd highest, 3rd highest, etc. in each cell.

Steps to find c_max:

To solve for c, you need sigma_y,z and M.

$$c = \frac{Q}{2\pi\sigma_y\sigma_z M}\cdot \exp\left[-0.5\cdot\left(\frac{y}{\sigma_y}\right)^2\right]\cdot \left\{\exp\left[-0.5\cdot\left(\frac{z-z_{CL}}{\sigma_z}\right)^2\right]+\exp\left[-0.5\cdot\left(\frac{z+z_{CL}}{\sigma_z}\right)^2\right]\right\} \quad \bullet(19.20)$$

To solve for sigma_y,z, you need sigma_v,w

$$\sigma_y^{\,2} = 2\cdot\sigma_v^{\,2}\cdot t_L^{\,2}\cdot\left[\frac{x}{M\cdot t_L}-1+\exp\left(-\frac{x}{M\cdot t_L}\right)\right] \quad \bullet(19.13a)$$

$$\sigma_z^{\,2} = 2\cdot\sigma_w^{\,2}\cdot t_L^{\,2}\cdot\left[\frac{x}{M\cdot t_L}-1+\exp\left(-\frac{x}{M\cdot t_L}\right)\right] \quad \bullet(19.13b)$$

To solve for sigma_v,w and M, you need u*, w*, zi, L, zo, etc.

$$M(z) = \frac{u_*}{k}\left[\ln\left(\frac{z}{z_o}\right)+6\frac{z}{L}\right] \quad \bullet(18.15)$$

$$\sigma_v = 1.6\cdot u_*\cdot[1-0.5\cdot(z/h)] \quad (18.25b)$$

$$\sigma_w = 1.25\cdot u_*\cdot[1-0.5\cdot(z/h)] \quad (18.25c)$$

To solve for u*, w*, L, etc., you need surface fluxes and BL depth.

$$w_* = \left[\frac{|g|\cdot z_i\cdot F_H}{T_v}\right]^{1/3} = \textbf{Deardorff velocity}\ (\text{m s}^{-1}) \quad (19.22)$$

$\approx 0.08\cdot w_B$, where w_B is the buoyancy velocity

$$u_*^{\,2} = C_D\cdot M_{10}^{\,2}$$

$$C_D = \frac{k^2}{\ln^2(z_R/z_o)} \quad (18.12)$$

To solve for surface fluxes and BL depth, you need meteorology including static stability & clouds, land-use, terrain, etc.

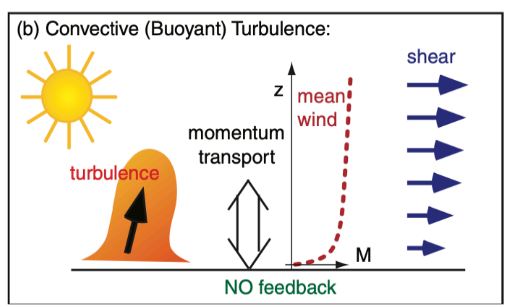


Figure 18.22

Table 19-2a. Pasquill-Gifford turbulence types for **Daytime**. *M* is wind speed at *z* = 10 m.

M (m s^{-1})	Insolation (incoming solar radiation) Strong	Moderate	Weak
< 2	A	A to B	B
2 to 3	A to B	B	C
3 to 4	B	B to C	C
4 to 6	C	C to D	D
> 6	C	D	D

AERMOD tech. manual starts from the bottom and works up.

To solve for c,
you need
sigma_y,z and M.

5

To solve for sigma_y,z, you
need sigma_v,w

4

To solve for sigma_v,w
and M, you need u*,
w*, zi, L, zo, etc.

3

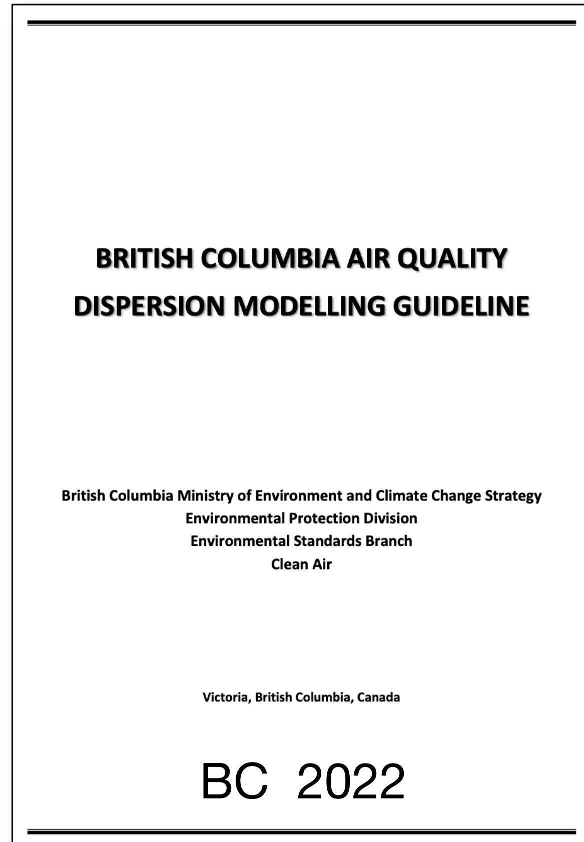
To solve for u*, w*, etc., you need
surface fluxes and BL depth.

2

To solve for surface fluxes and
BL depth, you need meteorology
including static stability &
clouds, land-use, terrain, etc.

1

Take advantage of guides & tips provided by ministries and agencies on how to get inputs to run dispersion models.



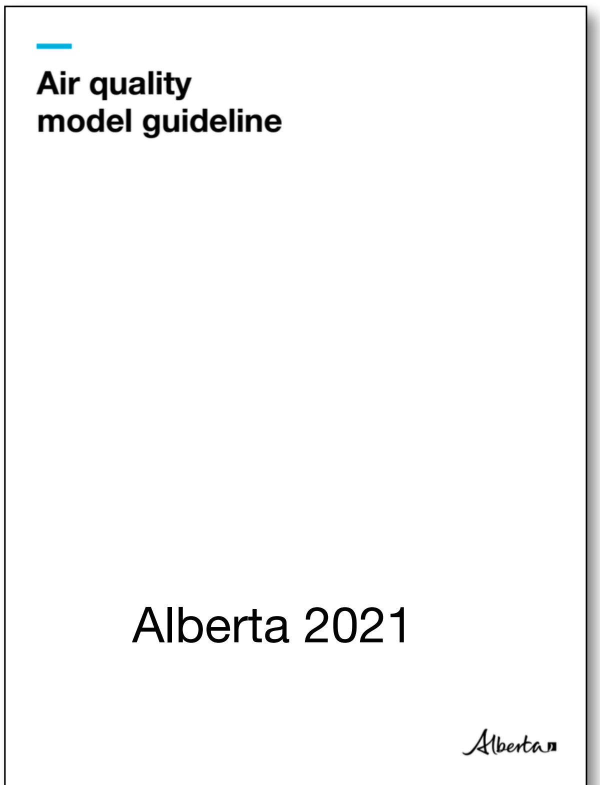
BRITISH COLUMBIA AIR QUALITY DISPERSION MODELLING GUIDELINE

British Columbia Ministry of Environment and Climate Change Strategy
Environmental Protection Division
Environmental Standards Branch
Clean Air

Victoria, British Columbia, Canada

BC 2022

https://www2.gov.bc.ca/assets/gov/environment/air-land-water/air/reports-pub/bc_dispersion_modelling_guideline.pdf



Air quality model guideline

Alberta 2021

Alberta

https://open.alberta.ca/dataset/cefcad38-6d49-4cce-98f7-23b1741f85b7/resource/b4ed8dc9-3850-4e5f-a618-42b29c4ba2d4/download/aep-aqmg-air-quality-model-guideline-2021-09.pdf

- the end -