GAUSSIAN DISPERSION MODELS

AERMOD: THEORY AND PRACTICE

UFES

Tutor: M.Eng Davi de Ferreyro Monticelli
e-mail: davimonticelli@gmail.com

Professor: Dra. Jane Meri Santos

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AERMOD MODEL

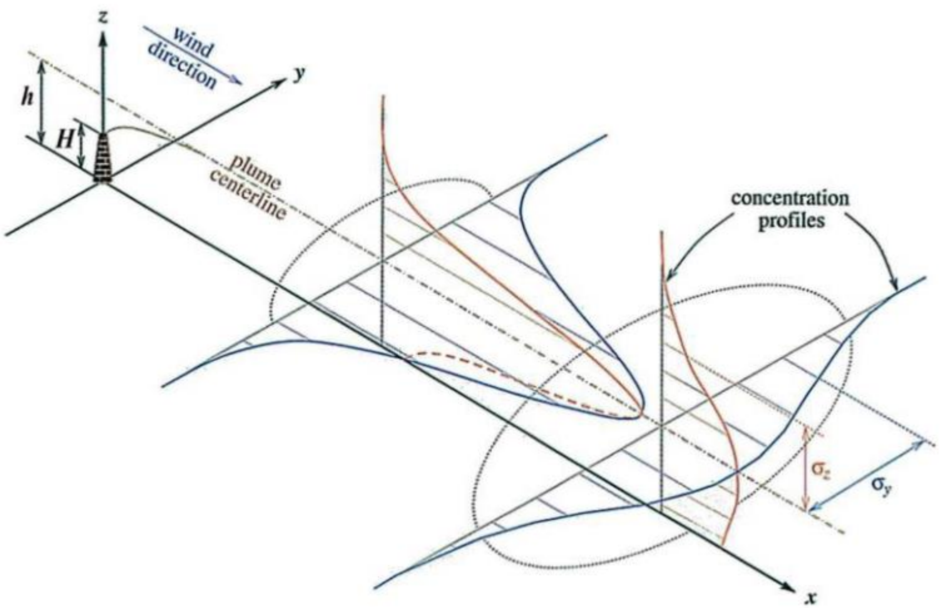
- **A**MS/**E**PA **R**egulatory **Mod**el (**A.E.R.M.O.D**)

- "A steady-state plume model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain" (USEPA)

What does this mean?

AERMOD MODEL

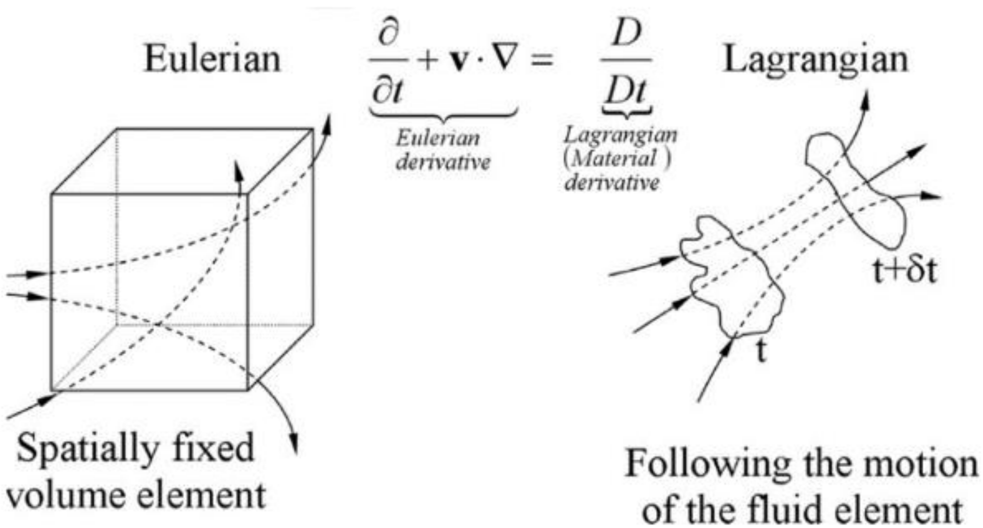
- "A steady-state **plume** model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain" (USEPA)



Source: (DOURADO, 2013).

AERMOD MODEL

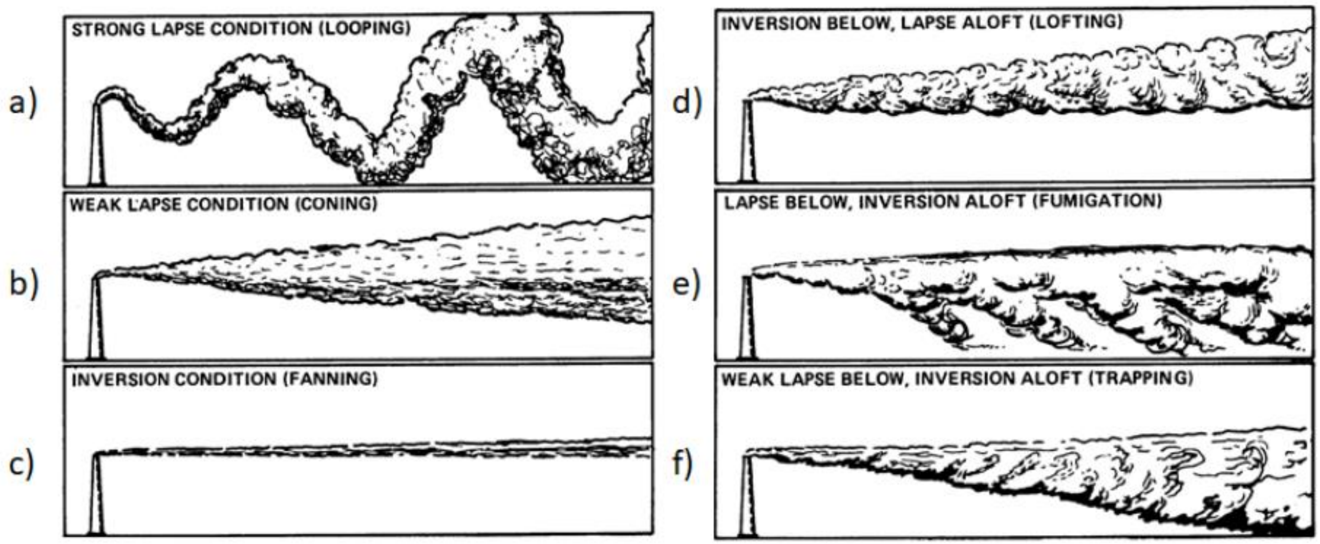
- "A **steady-state** plume **model** that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain" (USEPA)



Source: ResearchGate

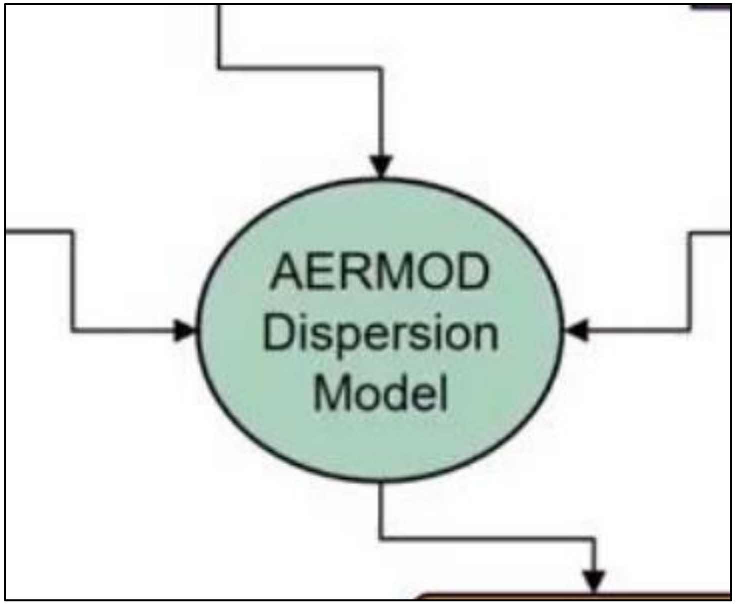
MODELO AERMOD

- "A steady-state plume model that incorporates air dispersion based on **planetary boundary layer turbulence structure and scaling concepts**, including treatment of both surface and elevated sources, and both simple and complex terrain" (USEPA)



Source: (BOUBEL et. al, 1994).

PROCESSOR



GAUSSIAN PLUME DISPERSION MODEL

SOURCES TREATMENT

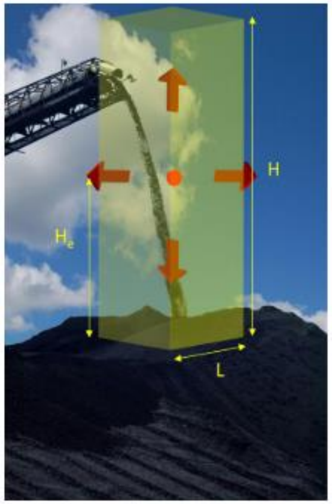
- Estimate the ambient concentrations and/or deposition fluxes using information of emission sources, meteorology and terrain.

- **Possible sources to be modeled:**

POINT

AREA

VOLUMETRIC



POLIGONS

What about traffic lanes?

SOURCES TREATMENT

- AERMOD is ***not*** a dispersion model specifically develop for modeling traffic emissions (like RLINE or CALINE4). However, with some adaptation it could do the job:

1) Treat the emissions as discrete packages of volume sources in sequence and equally spaced

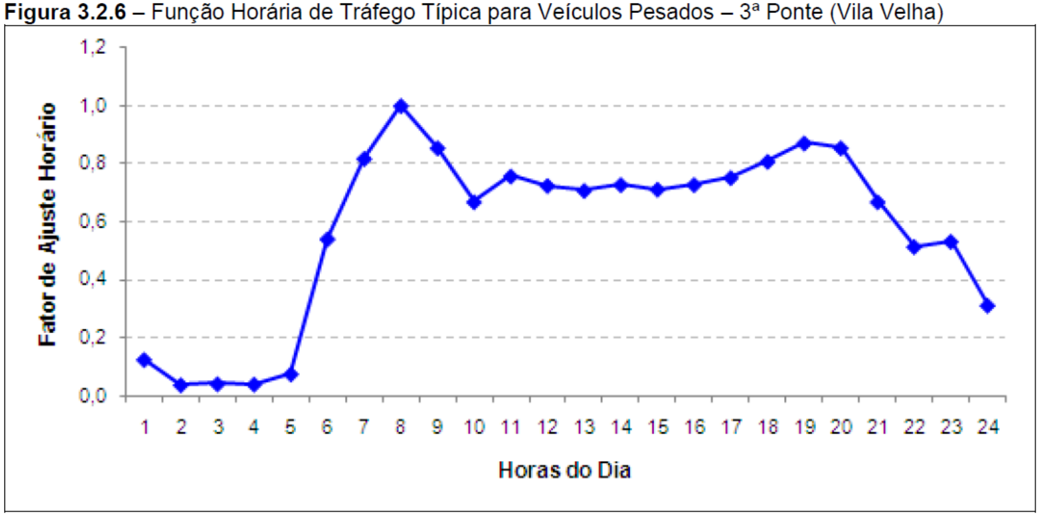
2) Treat as emissions from area sources (thus must be divided by the road area).

ROAD SOURCES

Different roads have different emission distribution of particulate matter!

Emission varies during the day/night due to traffic flow!

Figura 3.2.6 – Função Horária de Tráfego Típica para Veículos Pesados – 3ª Ponte (Vila Velha)



(IEMA, 2010)

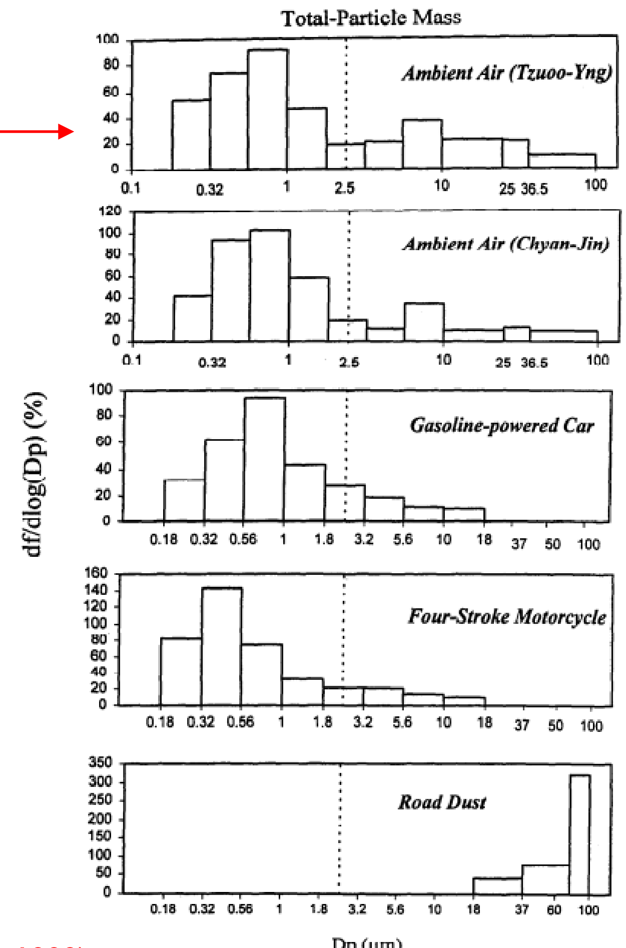
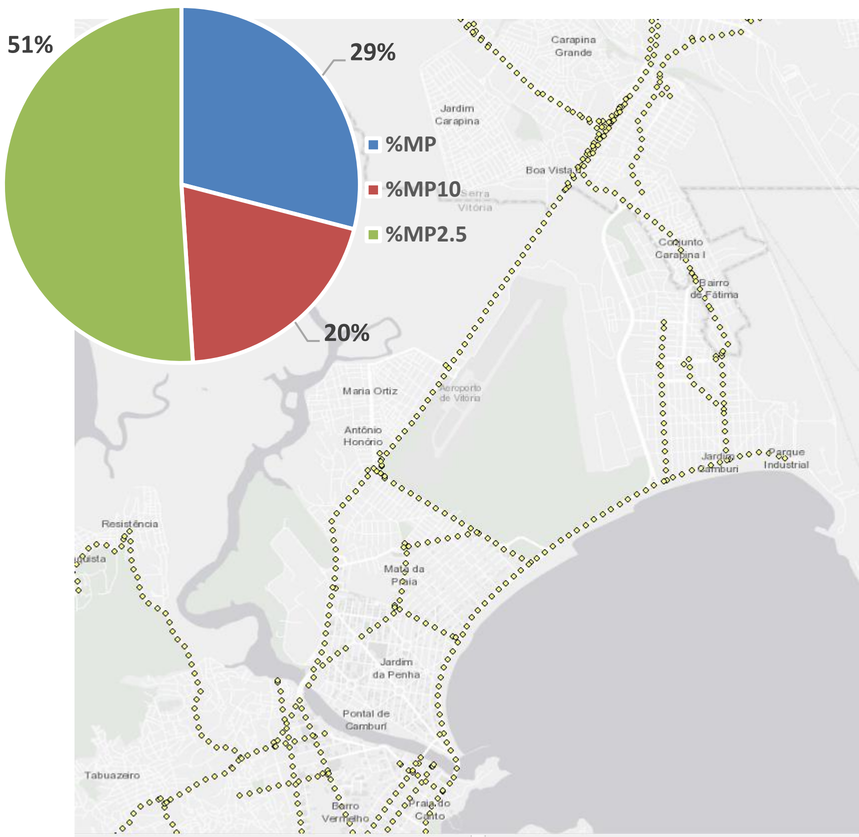


Fig. 1. Size distribution of total-particle mass.

(Yang et al. 1999)

ROAD SOURCES



"Volume Package" approach

Recommendation:
(Haul Road Workgroup Project)

1. Used when the receptor is outside the exclusion zone;

   i. Zone = (2.15 x Sigma-Y) + 1;
   ii. Plume height (H) = 1.7 x Vehicle height;
   iii. Emission height (h) = 0.5 x H;
   iv. Plume lateral size (L) =
      a. Vehicles width + 6 meters (single lane)
      b. Lane width + 6 meters (double lane)
   v. Sigma-Z = H / 2.15;
   vi. Sigma-Y = H / 2.15;
   vii. Emission in g/s

ROAD SOURCES

Area source approach

Reccomendation:
(Haul Road Workgroup Project)

II. Used when the receptor is inside the exclusion zone;

i. Zone = (2.15 x Sigma-Y) + 1;
ii. Plume height (H) = 1.7 x Vehicle height;
iii. Emission height (h) = 0.5 x H;
iv. Plume lateral size (L) =
   a. Vehicles width + 6 meters (single lane)
   b. Lane width + 6 meters (double lane)
v. Sigma-Z = H / 2.15;
vi. Size (length) = road size (length);
vii. Emission in $g/s/m^2$

SOURCES CHARACTERIZATION

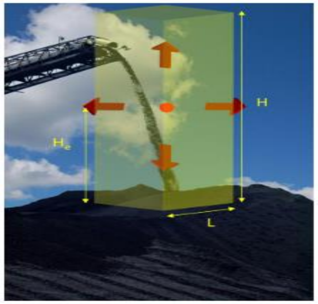
- **INPUTS**

AERMOD		
Point sources	• Emission rate (g/s); • Emission height (m); • Emission temperature (K); • Emission velocity (m/s); • Stack diameter (m) • Coordinates (UTM)	
Area sources	• Emission rate ($g/s.m^2$); • Emission height (m); • Length (m); • Width (m); • Rotation angle to prevalent wind (optional); • Initial vertical dimension of plume (optional) • Coordinates (UTM)	

Source: (USEPA, 2004).

SOURCES CHARACTERIZATION

- **INPUTS**

AERMOD		
Volume sources	• Emission rate (g/s); • Heigh of the center of the plume (m) • Plume initial lateral dimension (m); • Plume initial vertical dimension (m); • Coordinates	
Poligon sources	• Emission rate (g/s.m²); • Emission height (m); • Number of corners; • Plume initial lateral dimension (m) (optional)	

Source: (USEPA, 2004).

PROCESSOR: AERMOD

▪ EMISSIONS TREATMENT

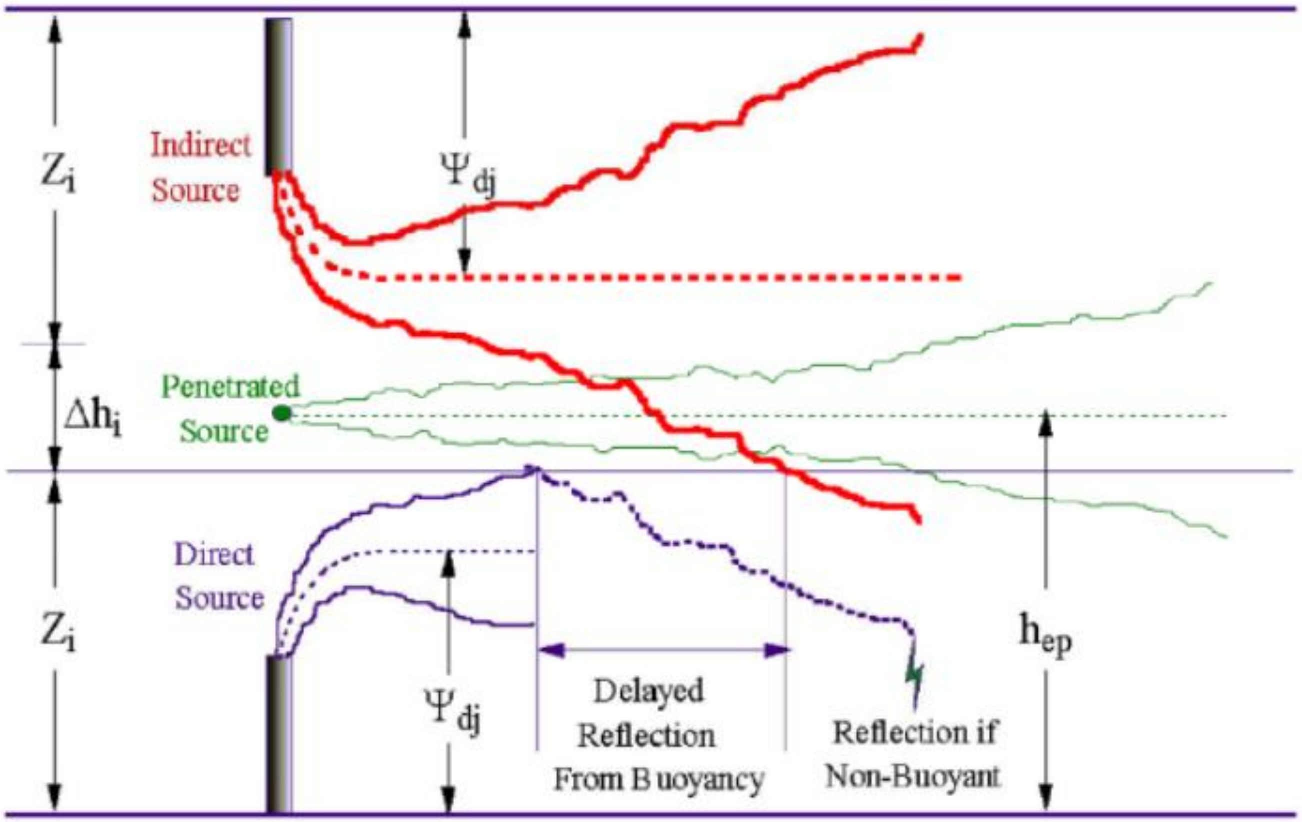
AERMOD	
Direct sources	• $C_d(x,y,z) = \frac{Qf_p}{\sqrt{2\pi u}} F_y \sum_{f=1}^{2} \sum_{m=0}^{\infty} \frac{\lambda_f}{\sigma_{zj}} \left[\exp\left(-\frac{(z-\Psi_{dj}-2mz_i)^2}{2\sigma_{zj}^2}\right) + \exp\left(-\frac{(z+\Psi_{dj}+2mz_i)^2}{2\sigma_{zj}^2}\right)\right.$
Penetrated sources	• $C_d(x,y,z) = \frac{Q(1-f_p)}{\sqrt{2\pi u}} F_y \sum_{f=1}^{2} \sum_{m=0}^{\infty} \frac{\lambda_f}{\sigma_{zj}} \left[\exp\left(-\frac{(z-\Psi_{dj}-2mz_i)^2}{2\sigma_{zj}^2}\right) + \exp\left(-\frac{(z+\Psi_{dj}+2mz_i)^2}{2\sigma_{zj}^2}\right)\right.$
Indirect sources	• $C_d(x,y,z) = \frac{Qf_p}{\sqrt{2\pi u\sigma_{zp}}} F_y \sum_{f=1}^{2} \sum_{m=-\infty}^{\infty} \frac{\lambda_f}{\sigma_{zj}} \left[\exp\left(-\frac{(z-\Psi_{dj}-2mz_i)^2}{2\sigma_{zj}^2}\right) + \exp\left(-\frac{(z+\Psi_{dj}+2mz_{ieff})^2}{2\sigma_{zp}^2}\right)\right.$

*$Cd(x, y, z)$ is the concentration due to a direct source at distance (x,y,z); Q = stack emission strength; u = wind velocity; λf = distribution coefficient; ψdj = difference height between source base and plume centreline; fp = fraction of emitted contaminant (by the source) that stays in the CBL (0<fp<1); zi = height above the reflected surface in a stable layer; σzp = total vertical dispersion of penetrated force; hep = plume height that penetrate beyond the CBL.

Source: (USEPA, 2016).

PROCESSOR: AERMOD

- **EMISSIONS TREATMENT**



Source: (USEPA, 2016).

PROCESSOR: AERMOD

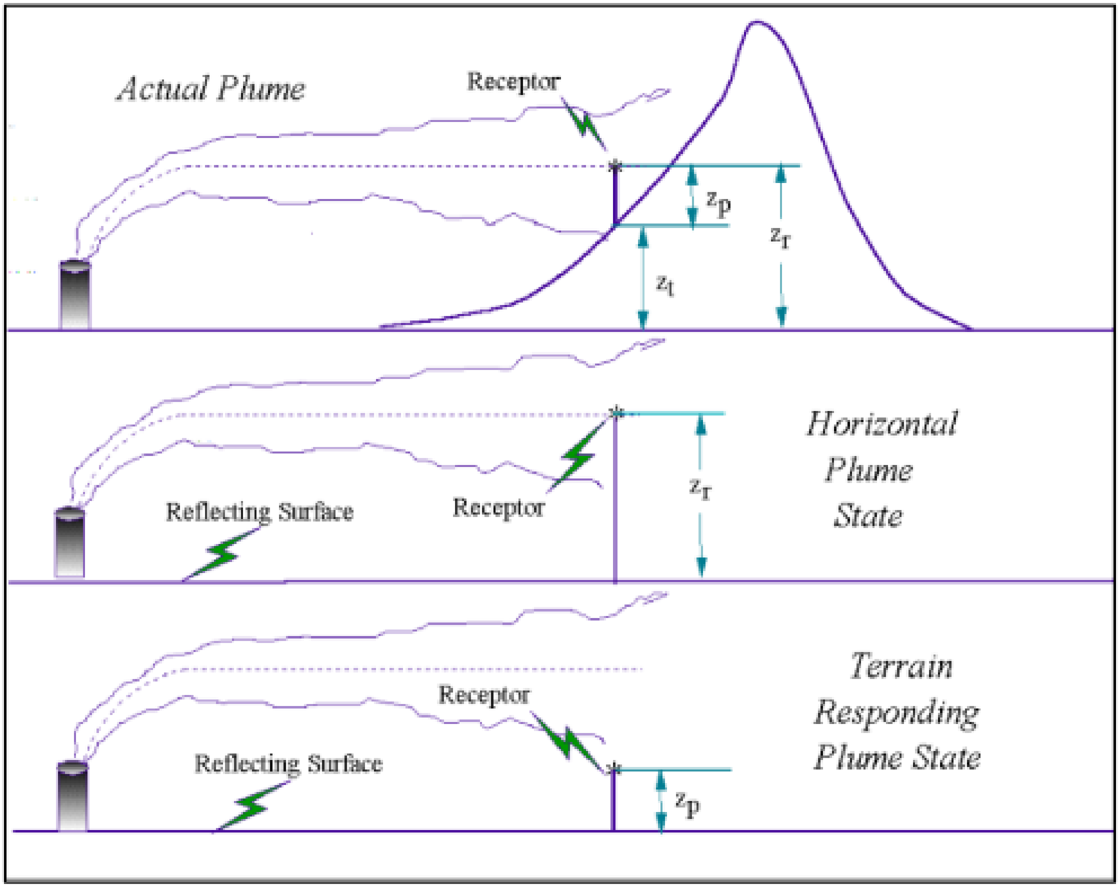
- **EMISSIONS TREATMENT**

AERMOD	
Complex terrain and atmospheric stability	• $C_T\{x_r, y_r, z_r\} = f.C_{c,s}\{x_r, y_r, z_r\} + (1-f)C_{c,s}\{x_r, y_r, z_p\}$
	where $C_T\{x_r, y_r, z_r\}$ is the total concentration $C_{c,s}\{x_r, y_r, z_r\}$ is the contribution from the horizontal plume state (subscripts c and s refer to convective and stable conditions, respectively), $C_{c,s}\{x_r, y_r, z_p\}$ is the contribution from terrain-following state, f is the plume state weighting function, $\{x_r, y_r, z_r\}$ is the coordinate representation of a receptor (with zr defined relative to stack base elevation) zp = zr - zt is the height of a receptor above local ground, and zt is the terrain height at a receptor.

Source: (USEPA, 2016).

PROCESSOR: AERMOD

- **EMISSIONS TREATMENT**



Source: (USEPA, 2016).

PROCESSOR: AERMOD

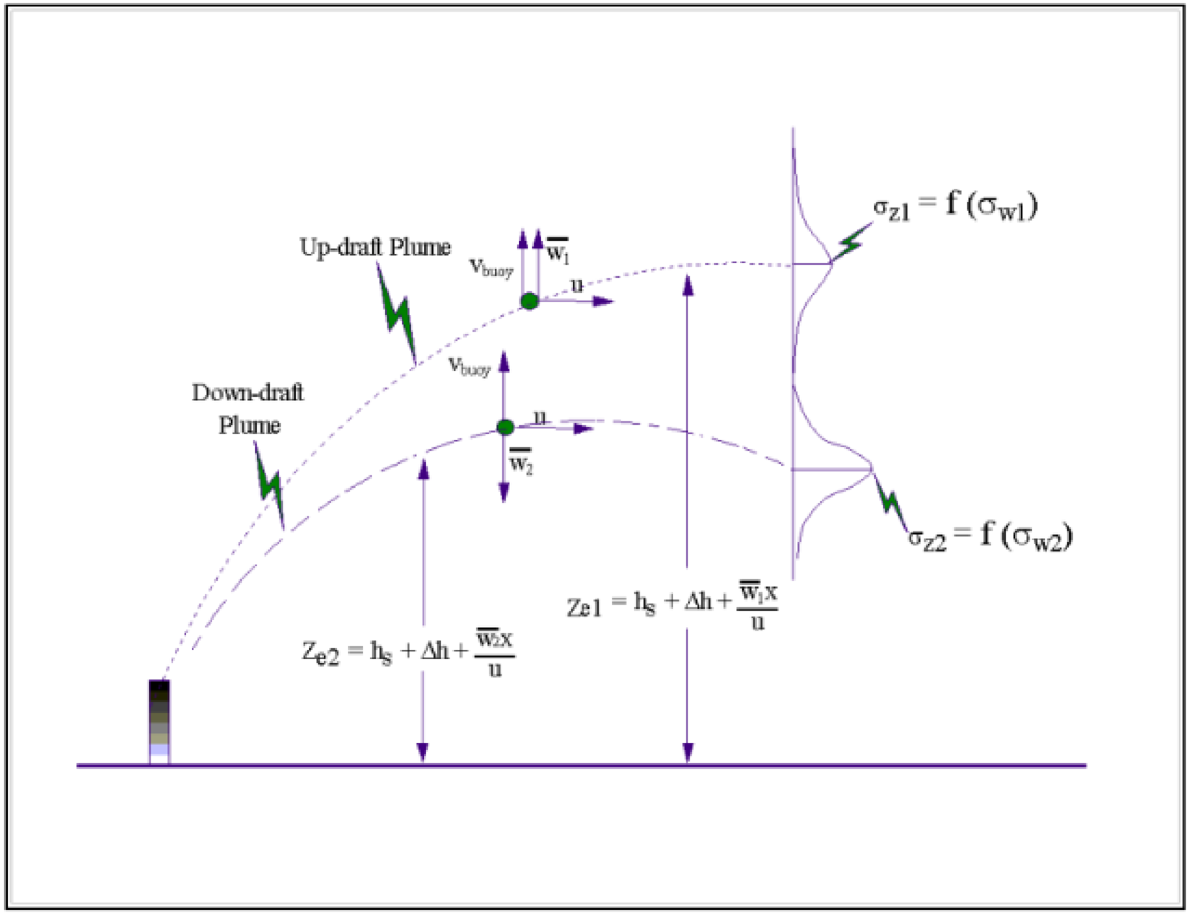
- **EMISSIONS TREATMENT**

AERMOD	
Bi-Gaussian distribution	• $p_w = \frac{\lambda_1}{\sqrt{2\pi\sigma_{w1}}} \exp\left(-\frac{(w-\overline{w}_1)^2}{2\sigma_{w1}^2}\right) + \frac{\lambda_2}{\sqrt{2\pi\sigma_{w2}}} \exp\left(-\frac{(w-\overline{w}_2)^2}{2\sigma_{w2}^2}\right)$
	where λ1 and λ2 are weighting coefficients for the two distributions with λ1 + λ2 = 1(the subscripts 1 and 2 refer to the updraft and downdraft distributions, respectively). The parameters of the pdf (w1, w2, σw1, σw2, λ1, λ2) are functions of σw (the "total" or overall root mean square vertical turbulent velocity), the vertical velocity skewness S = wwww σw ^ 3 (where w^3 is the third moment of w. An expanded discussion of the pdf parameters is given in Weil et al. (1997).

Source: (USEPA, 2016).

PROCESSOR: AERMOD

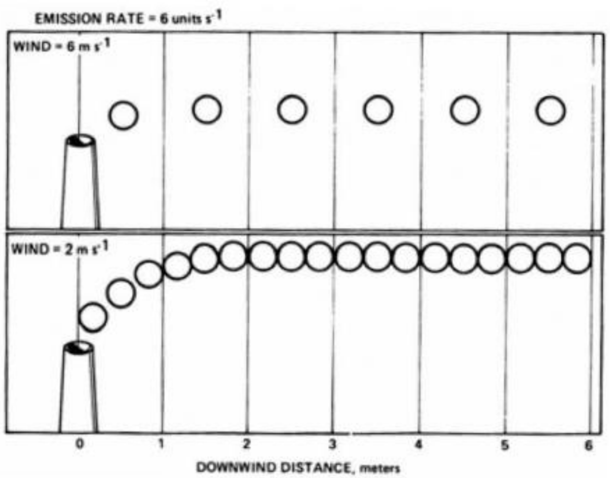
- **EMISSIONS TREATMENT**



Source: (USEPA, 2016).

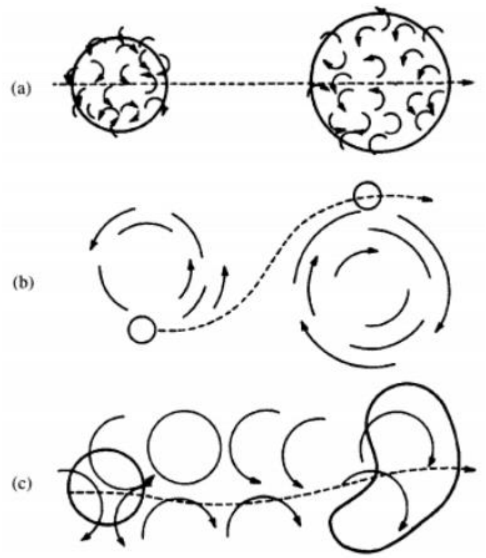
CHALLENGES TO THE GAUSSIAN MODEL

Low wind speeds:



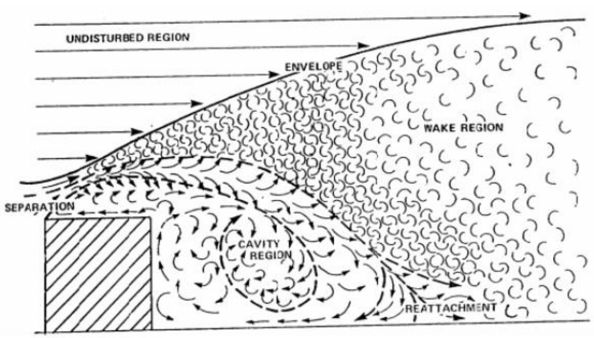
Source: (BOUBEL et. al, 1994).

Turbulence:



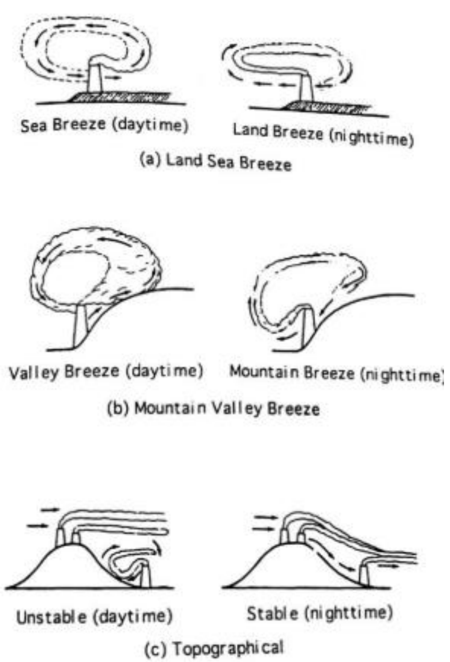
Source: SEINFELD and PANDIS (2006).

Obstacles:



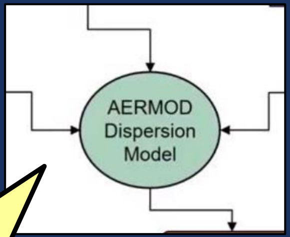
Source: (EPA, 1985).

Topography:



Source: (ARYA, 1999).

PROCESOR: AERMOD



Basic functions

AERMOD.INP: PART I

CO STARTING
CO TITLEONE Dry Deposition **Title**
CO MODELOPT BETA CONC DDEP ELEV NODRYDPLT NOWETDPLT **Modeling options**
CO AVERTIME MONTH **Averaging period**
CO POLLUTID TPM **Pollutant to be modeled**
CO RUNORNOT RUN
CO EVENTFIL CONTRIB SOCONT
CO SAVEFILE SAVED 1 **Salve the run as backup in case of being out of energy suddenly**
CO DEBUGOPT DEPOS
CO ERRORFIL ERROS.OUT **File that may describe modeling errors, if any**
CO FINISHED

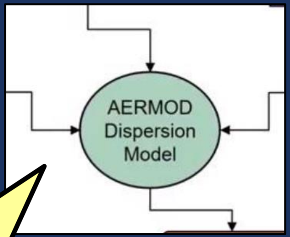
Command lines

SO STARTING
** Point Source NAME Type X(m) Y(m) Elev (m)
** ---
SO LOCATION S01 POINT 366147.00 7760400.00 10.00
(...)
** AreaPoly Source NAME Type X(m) Y(m) Elev (m)
** AreaVert Source Xv(1) Y(1) ...
** ---
SO LOCATION S02 AREAPOLY 365325.53 7759545.85 2.00
(...)
** Volume Source NAME Type X(m) Y(m) Elev (m)
** ---
SO LOCATION S08 VOLUME 357987.00 7749107.00 3.00
(...)

Input of sources location
(Area source is the center of it or the first corner)

Sources attribution

PROCESSOR: AERMOD



Basic functions

AERMOD.INP: PART II

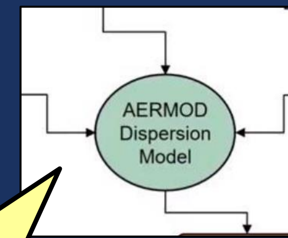
```
** Point Sources
**                ID  ES(g/s) HS(m)   TS(K)   VS(m/s)    DS(m)
** Parameters:----------------------------------------------
SO SRCPARAM  S01    0.53   3.00    298.15   2.00   1.00
(...)
** AreaPoly Sources
**                ID  ES(g/s.m2) HS(m)  Nv)
** Parameters:----------------------------------------------
SO SRCPARAM  S02   0.0000006  2   9
(...)
** Volume Sources
**                ID    ES(g/s) HS(m)  Synit(m)   Sznit(m)
** Parameters:----------------------------------------------
SO SRCPARAM   S08     0.07     5.00     1.12     2.33
(...)
** AreaVert
SO AREAVERT  S02   365325.53  7759545.85  365321.07  7759559.71  365375.25  7759648.57  365354.14
7759667.79  365320.16  7759670.88  365247.20  7759581.78  365182.71  7759476.57  365209.96  7759472.22
365254.60  7759437.94
(...)
SO SRCGROUP  ALL
SO FINISHED
```

Command used to group sources for posterior analysis

Sources input (vary by type of source)

Sources attribution

PROCESSOR: AERMOD



Basic functions

AERMOD.INP: PART III

RE STARTING
RE INCLUDED AERMAP.ROU **AERMAP output for receptors**
RE DISCCART 369917.00 7766305.00 26
RE DISCCART 368945.00 7762315.00 35
RE DISCCART 367429.00 7760371.00 05
RE DISCCART 365266.00 7753279.00 03 **Discrete receptors coordinates**
RE DISCCART 360857.00 7752450.00 08
RE DISCCART 362532.00 7749346.00 04
RE DISCCART 365354.00 7750721.00 05
RE DISCCART 353697.00 7749998.00 18
RE DISCCART 366107.00 7753649.00 36
RE DISCCART 366640.00 7753590.00 05
RE FINISHED

Receptors attribution

ME STARTING
ME SURFFILE EAS_2009.SFC **Output files from AERMET**
ME PROFFILE EAS_2009.PFL
ME SURFDATA 00013 2009
ME UAIRDATA 00083649 2009 **Meteorological stations information**
ME PROFBASE 4 METERS
ME FINISHED

Meteorological variables attribution

OU STARTING
OU RECTABLE ALLAVE FIRST SECOND **Complete description of options in the User Guide**
OU MAXTABLE ALLAVE 50
OU POSTFILE MONTH ALL PLOT MONTHAVERG.PLT **← Good for plotting concentration fields**
OU FINISHED
** Concentration is in micrograms/m³ e deposition flux in g/m²

Output options

EXAMPLE SO_2

What should I consider?

In a modeling domain of 50km x 50km only a small fraction (~2%) of SO2 is converted in sulfates.

(Gibson et al. , 2013)

For the coastal region of Tokyo – Japan, the conversion of SO2 into SO42- was 0.18 during summer time and 0.03 during winter

(Miyakawa et al. , 2013)

```
CO STARTING
CO TITLEONE "SO2_IN_RMGV"
CO MODELOPT DFAULT
CO AVERTIME 1 24 ANNUAL
CO POLLUTID SO2
CO RUNORNOT RUN
CO SAVEFILE SAVED 1
CO ERRORFIL ERROS.OUT
CO FINISHED
```

Average time for the majority of air quality guidelines for SO2

The "DFAULT" option in AERMOD assumes a Half-life of 4 hours for SO2 modeled in na urban environment;

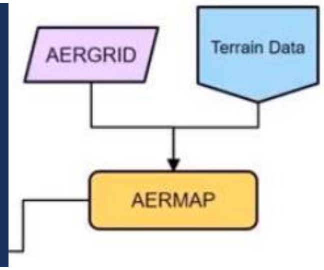
"POLLUTID SO2" activates a special treatemtn based on the maximum hourly mean concentrations of the stuy period;

Mandatory reading: *Section 3.2.15 - AERMOD User's Guide*

AERMAP

- What about the terrain pre-processor?

PRE-PROCESSOR: AERMAP

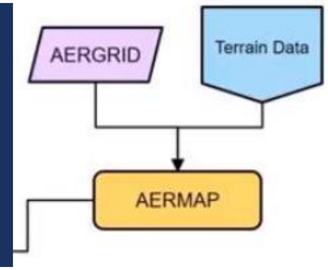


AERMAP	
Input	**Output**
• Terrain file (.DEM); • Receptors location (discrete or grid) (UTM X and UTM Y); • Sources location (UTM X and UTM Y).	• Height (topographic) of receptors; • Height (topographic) of sources; • Modeling GRID

It can be ignored if a “flat” terrain condition is desired

Source: (USEPA, 2004).

PRE-PROCESSORS: AERMAP



AERMAP.INP :

Command lines

CO STARTING
TITLEONE Dry Deposition — **Title 1**
TERRHGTS EXTRACT — **Extract input file information**
DATATYPE DEM — **Type of input file**
DATAFILE S21W41.DEM — **Input file name**
DOMAINXY 342781.00 7735094.00 -24 392781.00 7785094.00 -24 — **Domain size and UTM zone**
ANCHORXY 0.0 0.0 0.0 0.0 -24 3 — **UTM Greenwich, UTM zone, Hour shift from UTC**
DEBUGOPT RECEPTOR — **Debug receptors**
RUNORNOT RUN
CO FINISHED

Sources attribution

SO STARTING
LOCATION S01 POINT 366147.00 7760400.00
LOCATION S03 POINT 357974.00 7750147.00
Sources location
(….)
SO FINISHED

Receptors attribution

RE STARTING
GRIDCART TESTE1 STA
XYINC 342781.00 100 500.00 7735112.00 100 500.00
TESTE1 END
RE FINISHED

Grid initial point (lower-left corner), spacing and number of points in each Direction (square)

Output options

OU STARTING
RECEPTOR AERMAP.ROU — **Output file with receptors information**
SOURCLOC AERMAP.SOU — **Output file with sources information**
DEBUGREC RECELV
OU FINISHED

THANK YOU!

Next:

Feedback

- Any relevant feedback for my next presentations

Questions

- Was something unclear?

References

- AERMOD Model Formulation and Evaluation (US EPA)
- AERMET User's Guide (US EPA)

In case a question comes up later:
davimonticelli@gmail.com or daviubc1@student.ubc.ca

OBRIGADO!