AERMOD

Intro

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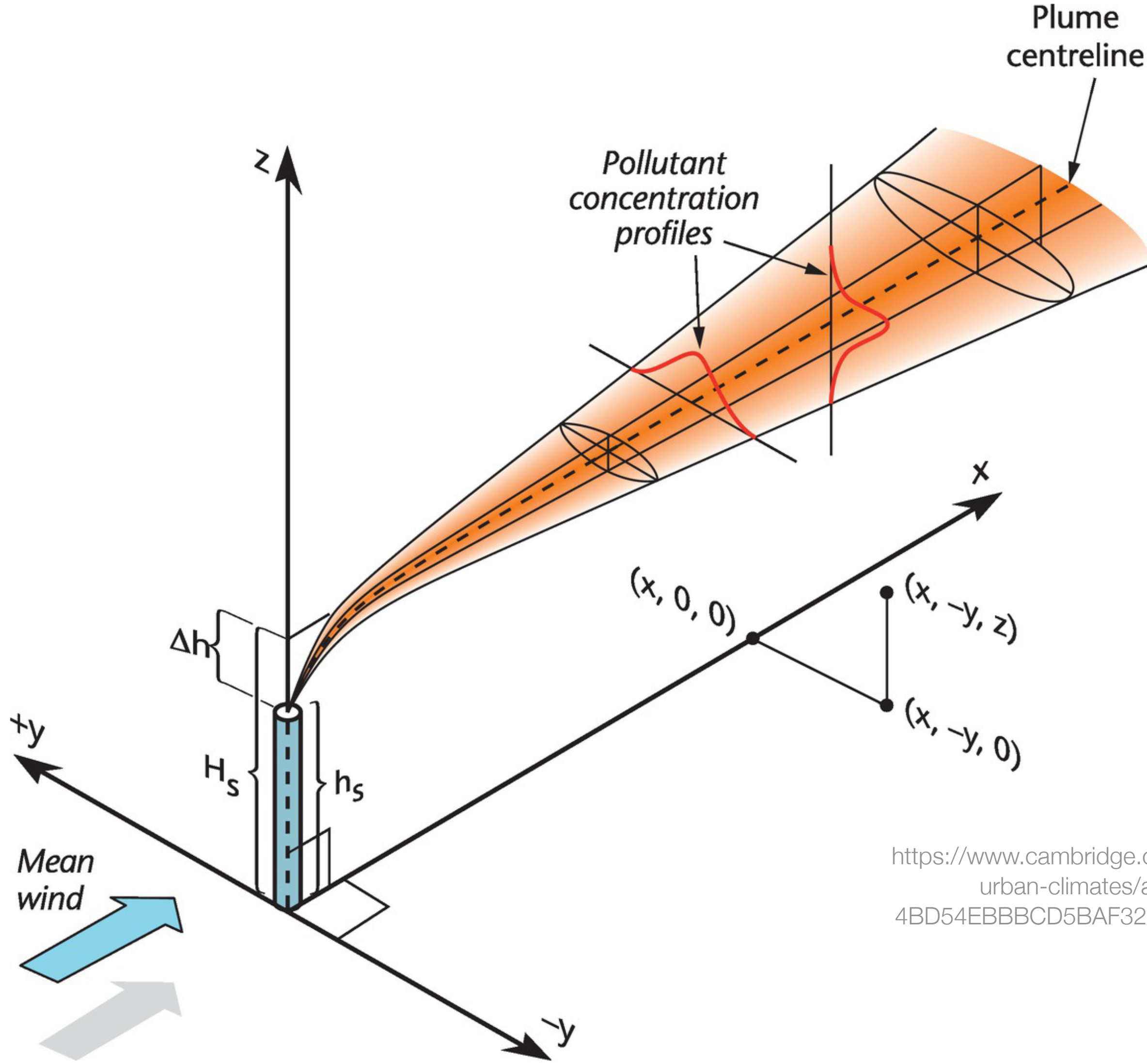
UBC
2024

AERMOD is a steady-state plume model

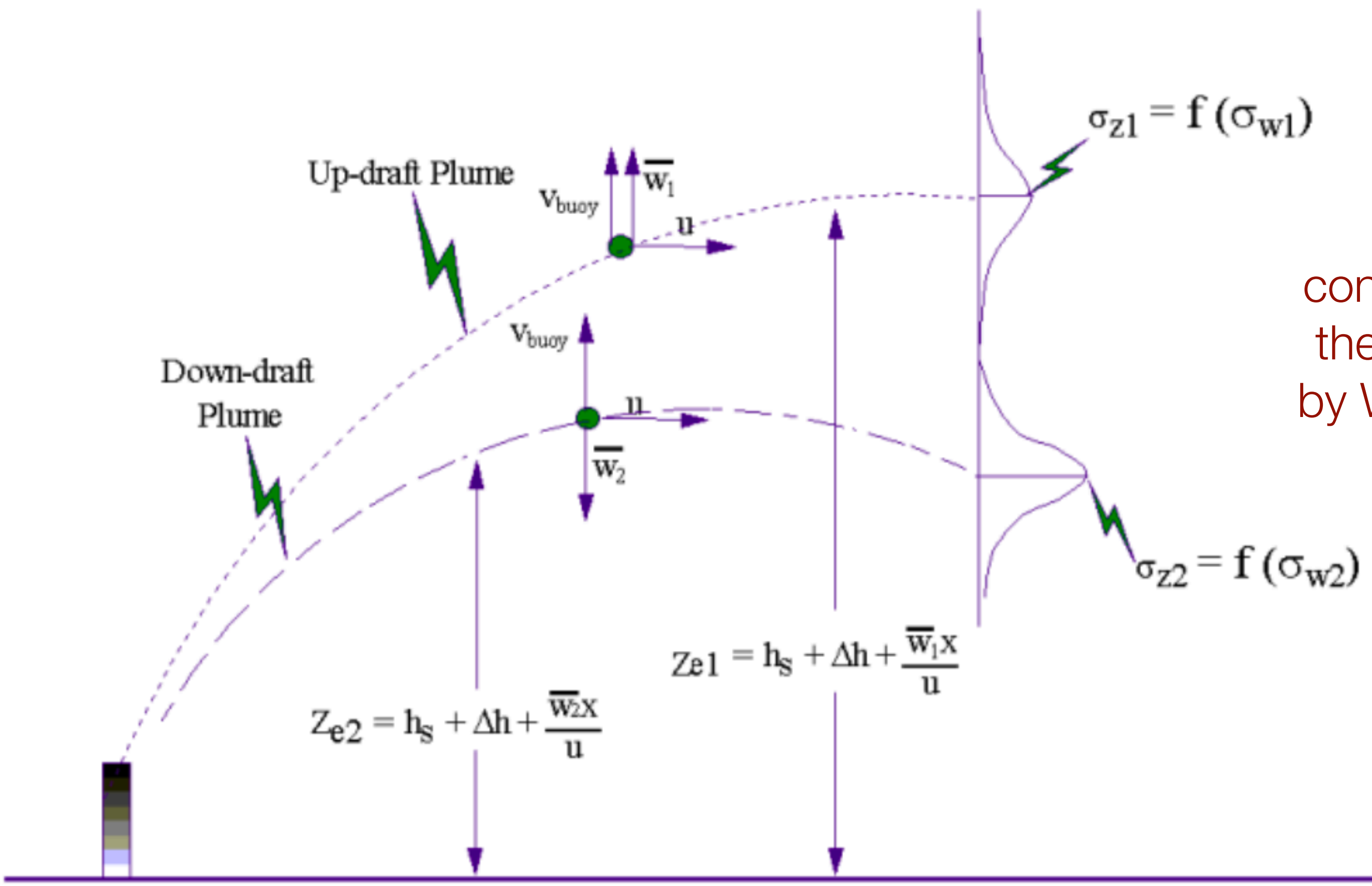
In the **stable boundary layer** (SBL), it assumes the concentration distribution to be Gaussian in both the vertical and horizontal.



https://www.cambridge.org/core/books/abs/urban-climates/air-pollution/4BD54EBBBCD5BAF32E275FA44667CE96

AERMOD is a steady-state plume model

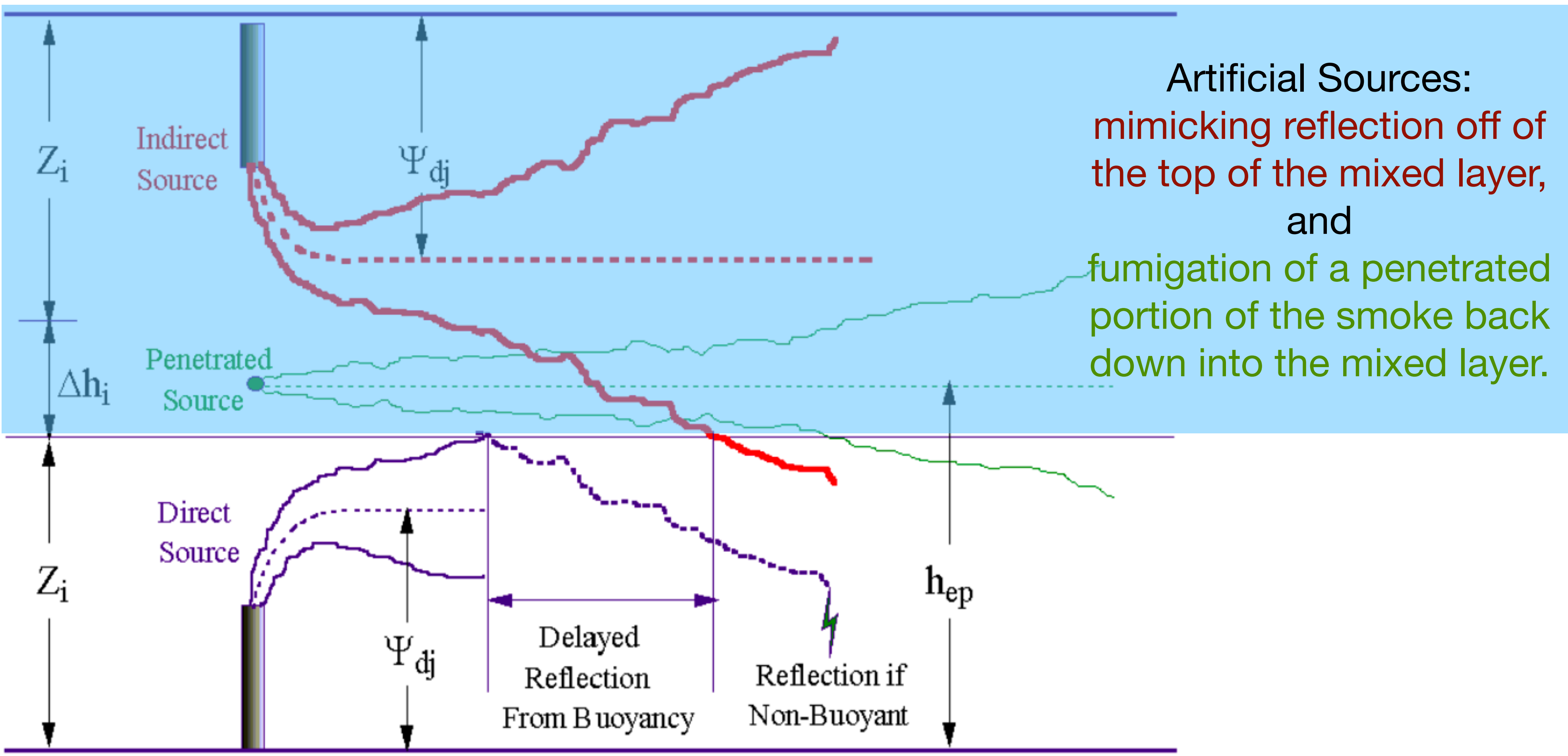
In the **convective boundary layer** (CBL), the horizontal distribution is also assumed to be Gaussian, but the vertical distribution is described with a bi-Gaussian probability density function (pdf).



This behavior of the concentration distributions in the CBL was demonstrated by Willis and Deardorff (1981) and Briggs (1993).

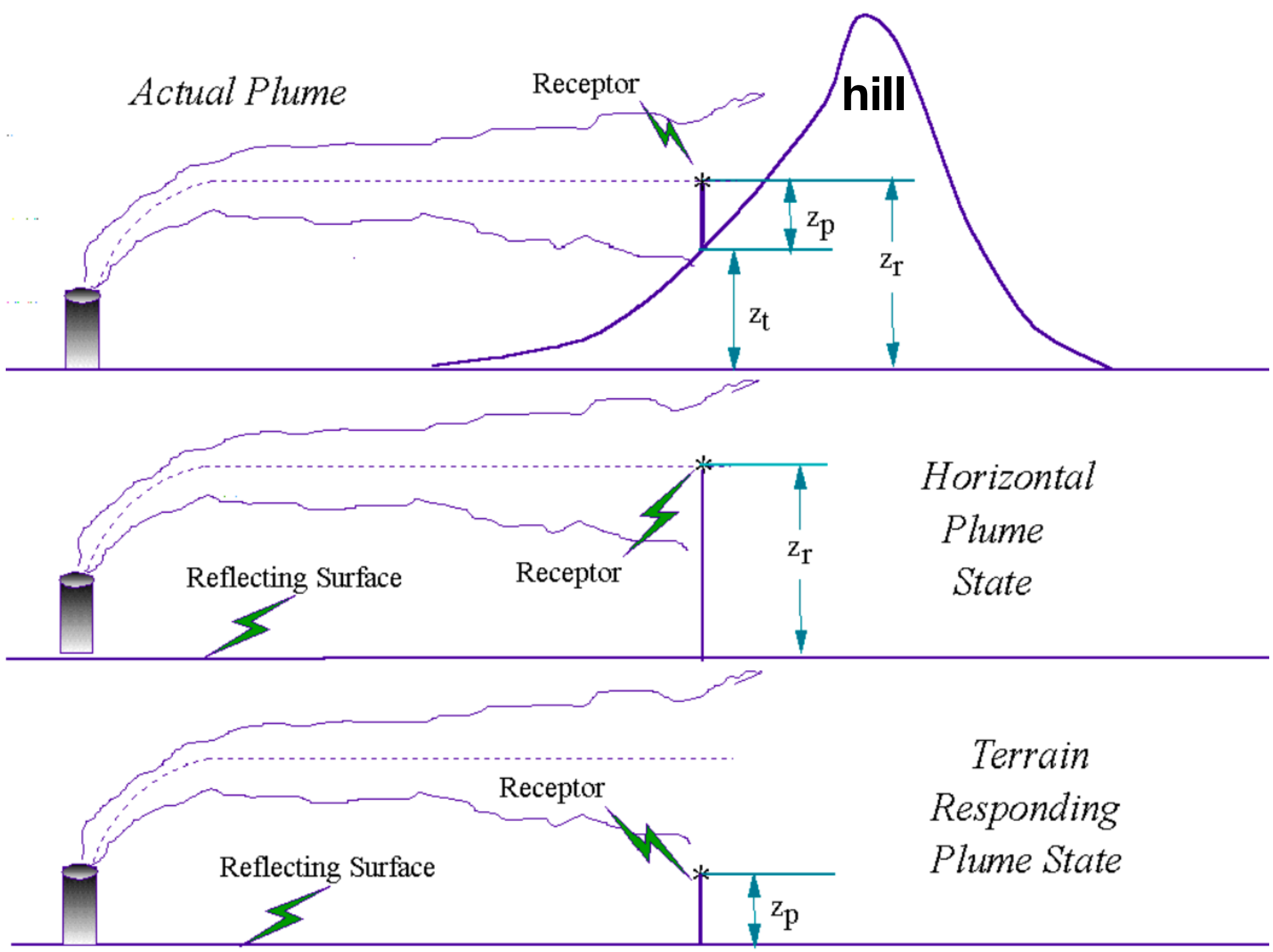
AERMOD is a steady-state plume model

Additionally, in the CBL, AERMOD treats "**plume lofting**," whereby a portion of plume mass, released from a buoyant source, rises to and remains near the top of the boundary layer before becoming mixed into the CBL. AERMOD also tracks any plume mass that **penetrates** the elevated stable layer, and then allows it to re-enter the boundary layer when and if appropriate.



AERMOD is a steady-state plume model

Using a relatively simple approach, AERMOD incorporates current concepts about flow and dispersion in complex terrain. Where appropriate, the plume is modeled as either impacting and/or following the terrain.

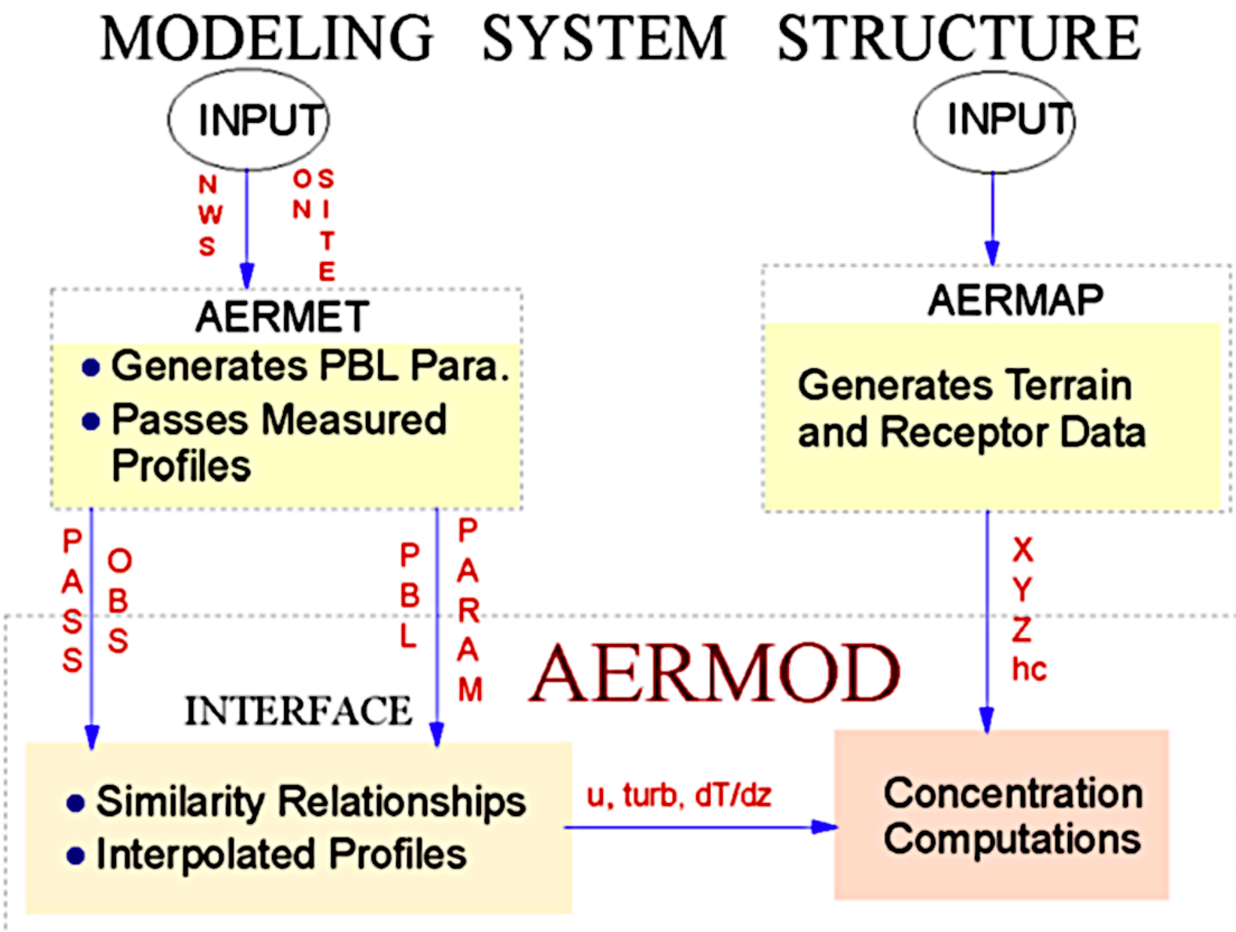


Portion of the plume that goes around the hill (assumes centerline at constant altitude MSL).

Portion of the plume that goes over the hill (assume centerline follows the local terrain slope).

AERMOD is a steady-state plume model

Can utilize routine Weather-Service weather observations and/or soundings.
Then applies boundary-layer similarity theory and scaling variables to calculate turbulence intensity, which is used to calculate the sigma_y and sigma_z dispersion values for the Gaussian plume.



CAUTION: All air-quality models are known to have large errors.

Therefore, all are designed to be "conservative" in the sense that they intentionally overestimate pollutant concentrations.

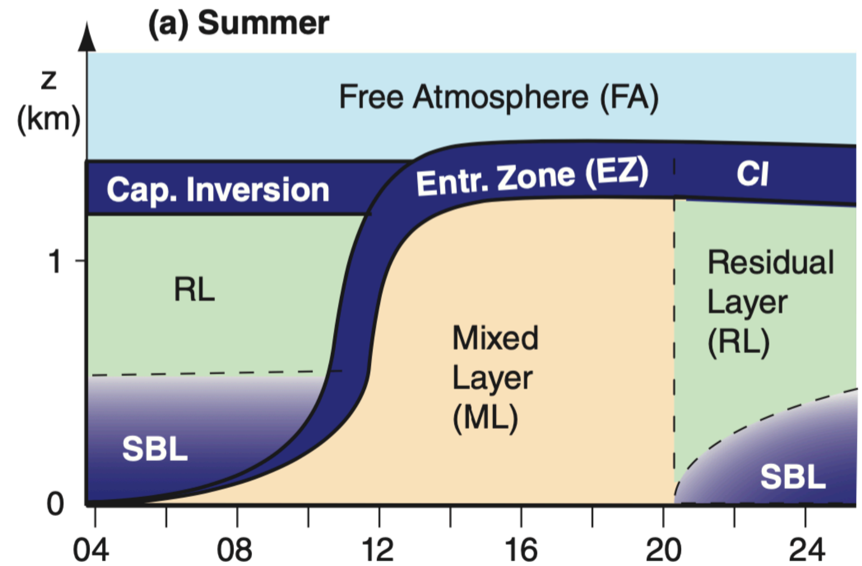
AERMET is the meteorological Pre-processor

Surface characteristics in the form of albedo, surface roughness, and Bowen ratio,

plus standard meteorological observations (wind speed, wind direction, temperature, and cloud cover), are input to AERMET.

AERMET then calculates the PBL parameters:

- friction velocity (u*),
- Monin-Obukhov length (L),
- convective (Deardorff) velocity scale (w*),
- temperature scale (θ*),
- mixing height (zi), and
- surface heat flux (H).



(Aside: Bowen Ratio)

3.6.2. The Bowen Ratio

Define a **Bowen ratio**, *B*, as surface sensible-heat flux divided by surface latent-heat flux:

$$B = \frac{\mathbb{F}_H}{\mathbb{F}_E} = \frac{F_H}{F_E} \qquad (3.56)$$

Typical values are: 10 for arid locations, 5 for semi-arid locations, 0.5 over drier savanna, 0.2 over moist farmland, and 0.1 over oceans and lakes.

can write the Bowen ratio as:

$$B = \gamma \cdot \frac{\Delta\theta}{\Delta r} \qquad (3.57)$$

for a **psychrometric constant** defined as $\gamma = C_p/L_v = 0.4\ (g_{water\ vapor}/kg_{air})\cdot K^{-1}$.

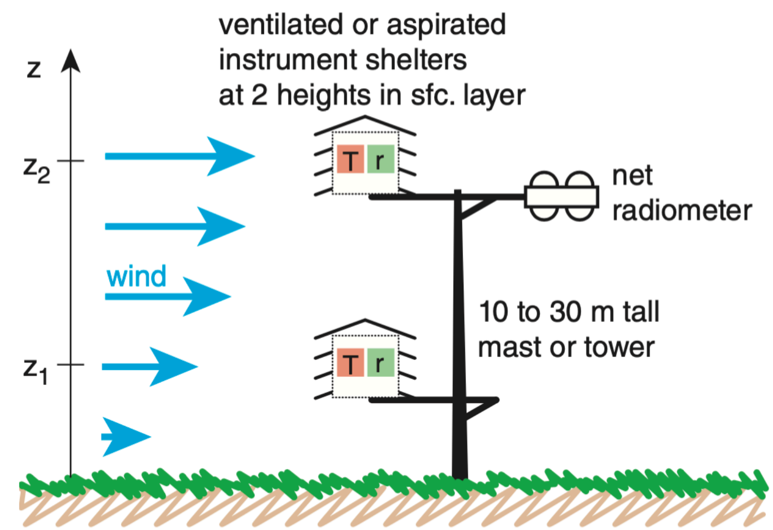


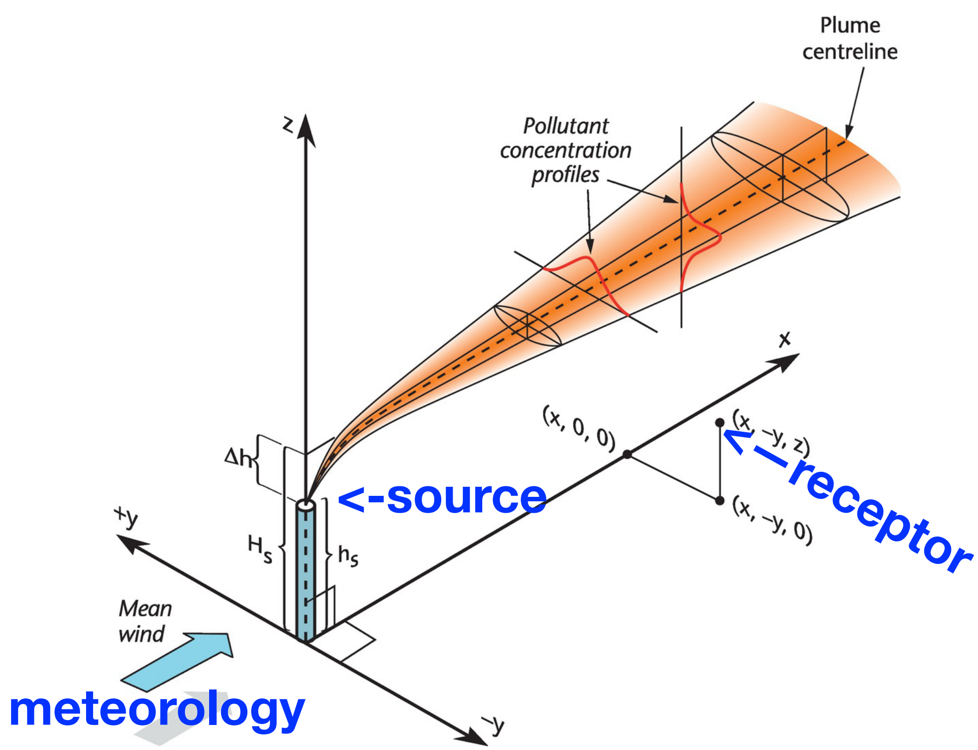
Figure 3.11
Field set-up for getting surface effective sensible and latent heat fluxes using the Bowen-ratio method. (T, r) are (thermometers, hygrometers) that are shielded from sunlight using ventilated instrument shelters. The net radiometer measures $\mathbb{F}^*$.

$$F_H = \frac{-0.9 \cdot F^*}{\frac{\Delta r}{\gamma \cdot \Delta\theta} + 1} \qquad F_E = \frac{-0.9 \cdot F^*}{\frac{\gamma \cdot \Delta\theta}{\Delta r} + 1}$$

where F* is net radiation, r is mixing ratio, and theta is potential temperature.

Input

CO	CONTROL
SO	SOURCE
RE	RECEPTORS
ME	METEOROLOGY
OU	OUTPUT




```
** To run the example, copy the AERTEST.INP file to AERMOD.INP and type:
**
**    AERMOD
**
** The results for this example problem are provided in file AERMOD.OUT.

CO STARTING
   TITLEONE A Simple Example Problem for the AERMOD Model with PRIME
   MODELOPT  CONC   FLAT
   AVERTIME  1  3  8  24  PERIOD
   POLLUTID  SO2
   RUNORNOT  RUN
   EVENTFIL  aertest_evt.inp
   ERRORFIL  ERRORS.OUT
CO FINISHED

SO STARTING
   ELEVUNIT  METERS
   LOCATION  STACK1  POINT  0.0   0.0   0.0

** Point Source       QS     HS     TS    VS    DS
** Parameters:       ----   ----   ----  ----   ---
   SRCPARAM  STACK1  500.0   65.00  425.  15.0   5.

SO BUILDHGT  STACK1    36*50.
SO BUILDWID  STACK1   62.26   72.64   80.80   86.51   89.59   89.95
SO BUILDWID  STACK1   87.58   82.54   75.00   82.54   87.58   89.95
SO BUILDWID  STACK1   89.59   86.51   80.80   72.64   62.26   50.00
SO BUILDWID  STACK1   62.26   72.64   80.80   86.51   89.59   89.95
SO BUILDWID  STACK1   87.58   82.54   75.00   82.54   87.58   89.95
SO BUILDWID  STACK1   89.59   86.51   80.80   72.64   62.26   50.00
SO BUILDLEN  STACK1   82.54   87.58   89.95   89.59   86.51   80.80
SO BUILDLEN  STACK1   72.64   62.26   50.00   62.26   72.64   80.80
SO BUILDLEN  STACK1   86.51   89.59   89.95   87.58   82.54   75.00
SO BUILDLEN  STACK1   82.54   87.58   89.95   89.59   86.51   80.80
SO BUILDLEN  STACK1   72.64   62.26   50.00   62.26   72.64   80.80
SO BUILDLEN  STACK1   86.51   89.59   89.95   87.58   82.54   75.00
SO XBADJ     STACK1  -47.35  -55.76  -62.48  -67.29  -70.07  -70.71
SO XBADJ     STACK1  -69.21  -65.60  -60.00  -65.60  -69.21  -70.71
SO XBADJ     STACK1  -70.07  -67.29  -62.48  -55.76  -47.35  -37.50
SO XBADJ     STACK1  -35.19  -31.82  -27.48  -22.30  -16.44  -10.09
SO XBADJ     STACK1   -3.43    3.34   10.00    3.34   -3.43  -10.09
SO XBADJ     STACK1  -16.44  -22.30  -27.48  -31.82  -35.19  -37.50
SO YBADJ     STACK1   34.47   32.89   30.31   26.81   22.50   17.50
SO YBADJ     STACK1   11.97    6.08    0.00   -6.08  -11.97  -17.50
SO YBADJ     STACK1  -22.50  -26.81  -30.31  -32.89  -34.47  -35.00
SO YBADJ     STACK1  -34.47  -32.89  -30.31  -26.81  -22.50  -17.50
SO YBADJ     STACK1  -11.97   -6.08    0.00    6.08   11.97   17.50
SO YBADJ     STACK1   22.50   26.81   30.31   32.89   34.47   35.00

   SRCGROUP  ALL
SO FINISHED

RE STARTING
RE GRIDPOLR POL1 STA
           ORIG STACK1
           DIST 175. 350. 500. 1000.
           GDIR 36 10 10
RE GRIDPOLR POL1 END
RE FINISHED

ME STARTING
   SURFFILE  AERMET2.SFC
   PROFFILE  AERMET2.PFL
   SURFDATA  14735  1988  ALBANY,NY
   UAIRDATA  14735  1988  ALBANY,NY
   SITEDATA  99999  1988  HUDSON
   PROFBASE  0.0  METERS
ME FINISHED

OU STARTING
   RECTABLE  ALLAVE  FIRST-THIRD
   MAXTABLE  ALLAVE  50
   SUMMFILE  AERTEST.SUM
OU FINISHED
```

Input

- What do the following mean:
  - CONC , FLAT
  - AVERTIME 1 3 8 24 PERIOD
- What output files will be produced?

```
** To run the example, copy the AERTEST.INP file to AERMOD.INP and type:
**
**    AERMOD
**
** The results for this example problem are provided in file AERMOD.OUT.

CO STARTING
   TITLEONE A Simple Example Problem for the AERMOD Model with PRIME
   MODELOPT  CONC   FLAT
   AVERTIME  1  3  8  24  PERIOD
   POLLUTID  SO2
   RUNORNOT  RUN
   EVENTFIL  aertest_evt.inp
   ERRORFIL  ERRORS.OUT
CO FINISHED
```

Input

- What do the following mean:
  - ELEVUNIT METERS
  - LOCATION STACK1 POINT 0.0 0.0 0.0
  - QS, HS, TS, VS, DS (and their units)
  - SRCGROUP ALL
- Next, info about building downwash.

```
SO STARTING
   ELEVUNIT  METERS
   LOCATION  STACK1  POINT  0.0   0.0   0.0

** Point Source       QS      HS      TS     VS     DS
** Parameters:       ----     ----    ----   ----   ---
   SRCPARAM  STACK1  500.0   65.00  425.   15.0    5.

SO BUILDHGT  STACK1    36*50.
SO BUILDWID  STACK1    62.26   72.64   80.80   86.51   89.59   89.95
SO BUILDWID  STACK1    87.58   82.54   75.00   82.54   87.58   89.95
SO BUILDWID  STACK1    89.59   86.51   80.80   72.64   62.26   50.00
SO BUILDWID  STACK1    62.26   72.64   80.80   86.51   89.59   89.95
SO BUILDWID  STACK1    87.58   82.54   75.00   82.54   87.58   89.95
SO BUILDWID  STACK1    89.59   86.51   80.80   72.64   62.26   50.00
SO BUILDLEN  STACK1    82.54   87.58   89.95   89.59   86.51   80.80
SO BUILDLEN  STACK1    72.64   62.26   50.00   62.26   72.64   80.80
SO BUILDLEN  STACK1    86.51   89.59   89.95   87.58   82.54   75.00
SO BUILDLEN  STACK1    82.54   87.58   89.95   89.59   86.51   80.80
SO BUILDLEN  STACK1    72.64   62.26   50.00   62.26   72.64   80.80
SO BUILDLEN  STACK1    86.51   89.59   89.95   87.58   82.54   75.00
SO XBADJ     STACK1  -47.35  -55.76  -62.48  -67.29  -70.07  -70.71
SO XBADJ     STACK1  -69.21  -65.60  -60.00  -65.60  -69.21  -70.71
SO XBADJ     STACK1  -70.07  -67.29  -62.48  -55.76  -47.35  -37.50
SO XBADJ     STACK1  -35.19  -31.82  -27.48  -22.30  -16.44  -10.09
SO XBADJ     STACK1   -3.43    3.34   10.00    3.34   -3.43  -10.09
SO XBADJ     STACK1  -16.44  -22.30  -27.48  -31.82  -35.19  -37.50
SO YBADJ     STACK1   34.47   32.89   30.31   26.81   22.50   17.50
SO YBADJ     STACK1   11.97    6.08    0.00   -6.08  -11.97  -17.50
SO YBADJ     STACK1  -22.50  -26.81  -30.31  -32.89  -34.47  -35.00
SO YBADJ     STACK1  -34.47  -32.89  -30.31  -26.81  -22.50  -17.50
SO YBADJ     STACK1  -11.97   -6.08    0.00    6.08   11.97   17.50
SO YBADJ     STACK1   22.50   26.81   30.31   32.89   34.47   35.00

   SRCGROUP  ALL
SO FINISHED
```

Building Downwash

Saathoff et al.

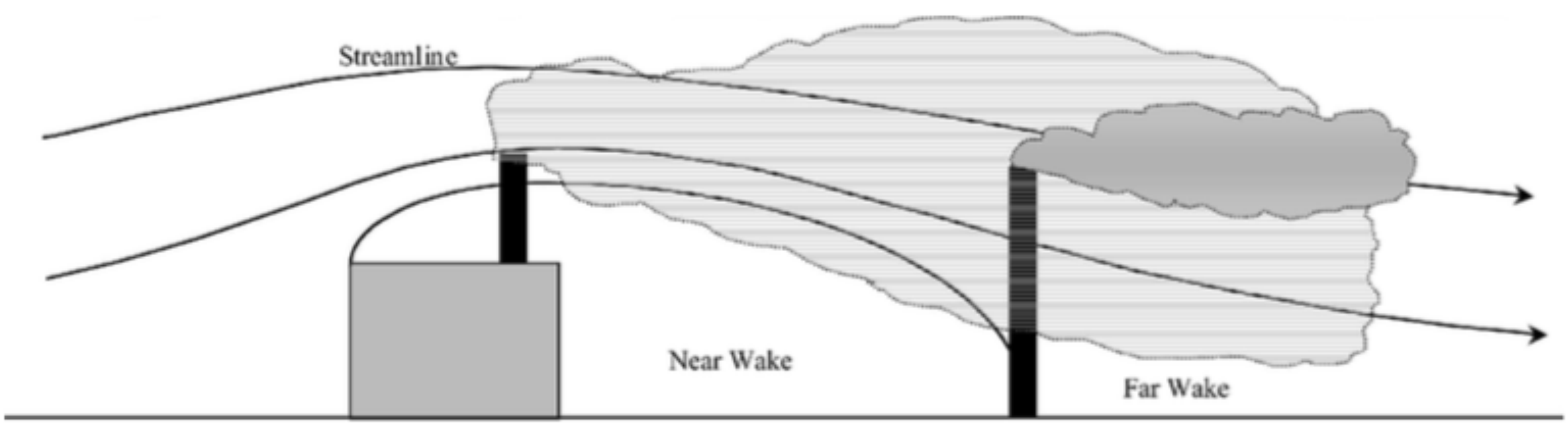


Figure 1. Schematic representation of two identical emission sources showing the dependence of plume dispersion on stack proximity to a structure. Reproduced with permission from Schulman et al.[8] Copyright 2000 A&WMA, *Journal of Air & Waste Management Association.*

Building Downwash

Figure 1. From Schulman[3] showing a comparison of streamlines predicted by the PRIME model with thorse observd in wind tunnel simulation of a cubic building.

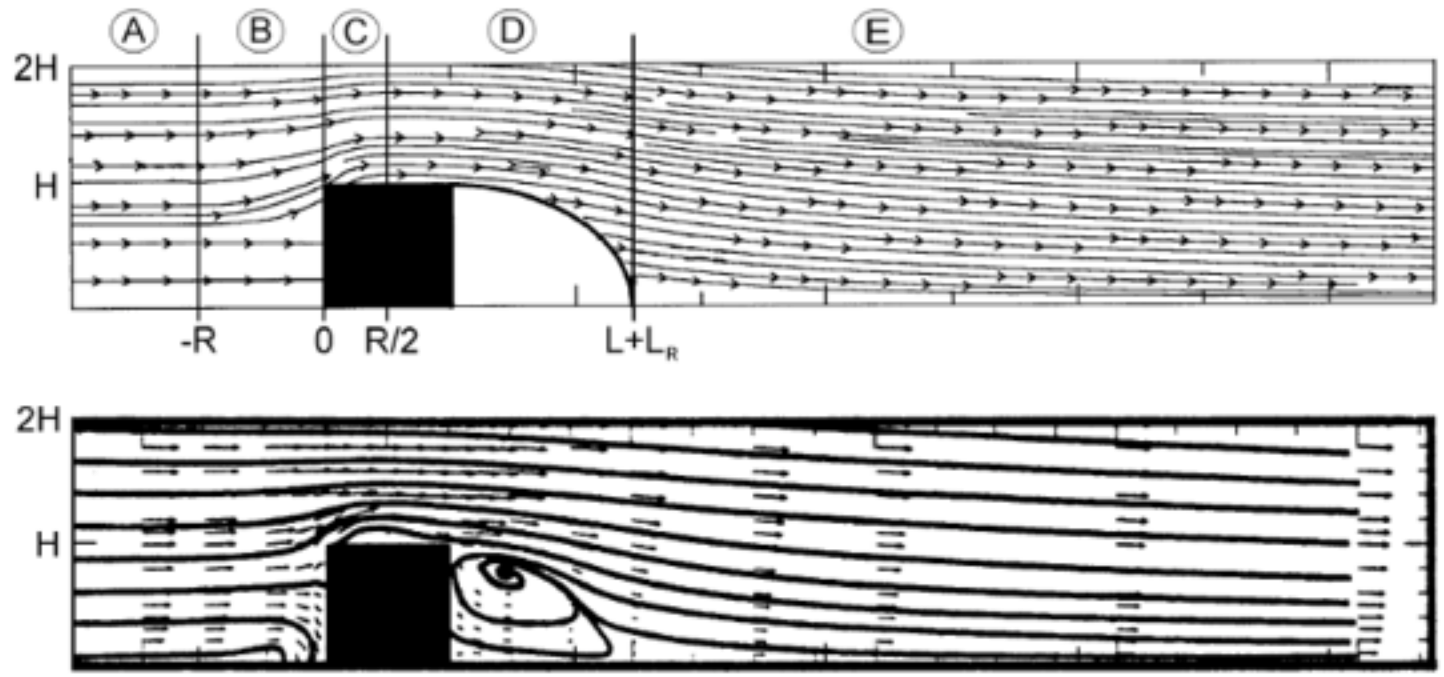
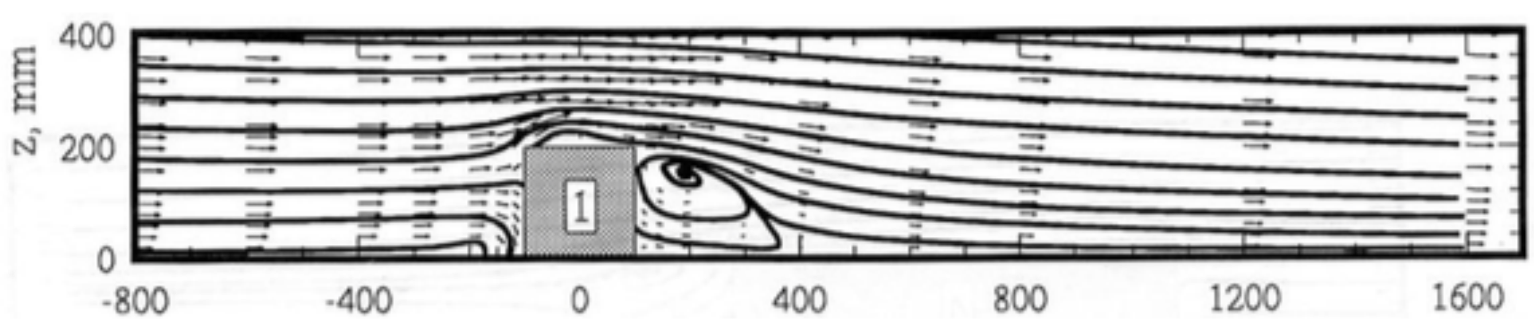
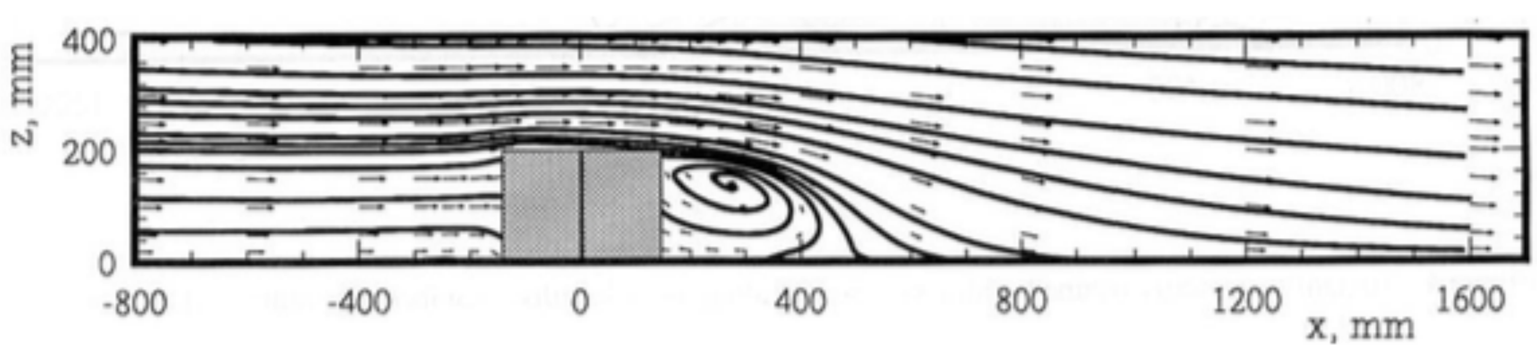


Figure 7: Streamline patterns around cubical buildings; a) wind perpendicular to leading wall; b) cube rotated 45 degrees, so the wind approaches the leading corner. (Snyder and Lawson, 1994)

a)

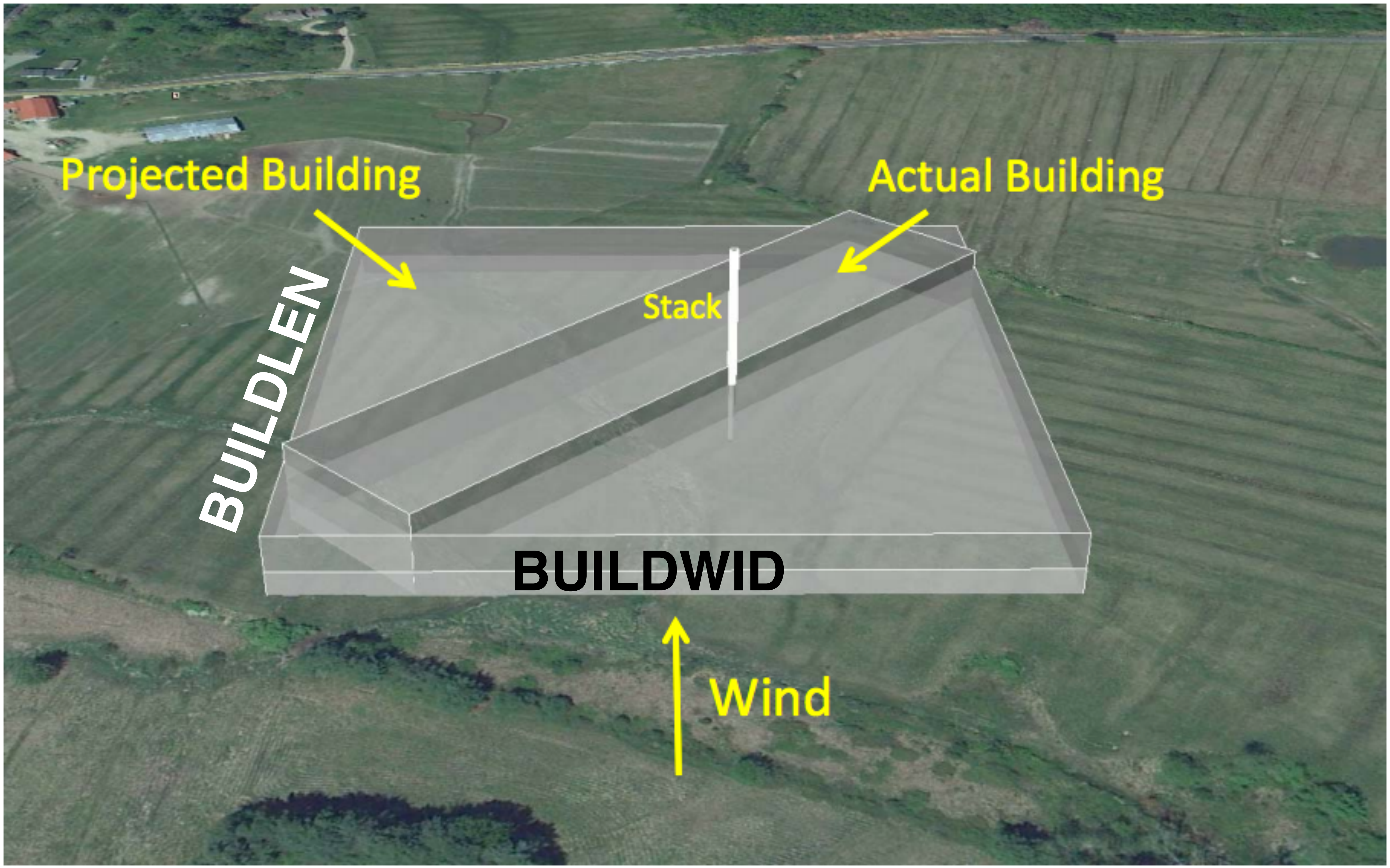


b)



http://www.cppwind.com/wp-content/uploads/2014/01/AWMA2012-Petersen-Paper-387-Downwash-Problems.pdf

“PROJECTED” BUILDING, USED IN AERMOD



http://www3.epa.gov/scram001/10thmodconf/presentations/3-3-EPA10thConferenceAQModeling-BuildingDownwash_SchulmanScire.pdf

Input

- Definitions:
  - BUILDHGT = building height [36 heights, one for each 10° flow vector starting with wind blowing **toward** 10° (with respect to true north), and going clockwise every 10°. E.g., 10, 20, 30, … 350, 360]
  - BUIILDWID = width of the "projected" bldg, every 10°, starting with the 10° vector.
  - BUIILDLEN = length of the "projected" bldg, every 10°

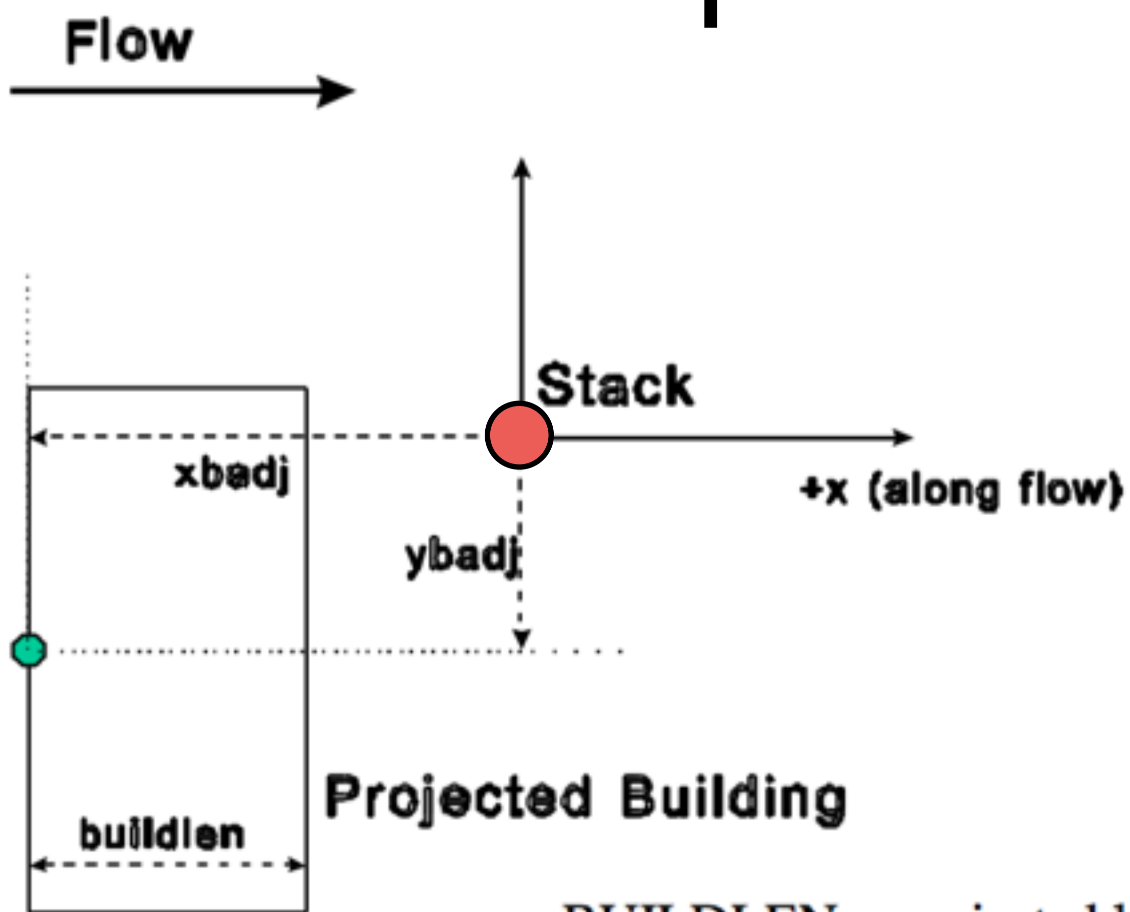
```
SO STARTING
   ELEVUNIT  METERS
   LOCATION  STACK1  POINT  0.0   0.0   0.0

** Point Source        QS      HS      TS     VS     DS
** Parameters:        ----     ----   ----   ----   ---
   SRCPARAM  STACK1  500.0   65.00  425.   15.0   5.

SO BUILDHGT  STACK1    36*50.
SO BUILDWID  STACK1    62.26   72.64   80.80   86.51   89.59   89.95
SO BUILDWID  STACK1    87.58   82.54   75.00   82.54   87.58   89.95
SO BUILDWID  STACK1    89.59   86.51   80.80   72.64   62.26   50.00
SO BUILDWID  STACK1    62.26   72.64   80.80   86.51   89.59   89.95
SO BUILDWID  STACK1    87.58   82.54   75.00   82.54   87.58   89.95
SO BUILDWID  STACK1    89.59   86.51   80.80   72.64   62.26   50.00
SO BUILDLEN  STACK1    82.54   87.58   89.95   89.59   86.51   80.80
SO BUILDLEN  STACK1    72.64   62.26   50.00   62.26   72.64   80.80
SO BUILDLEN  STACK1    86.51   89.59   89.95   87.58   82.54   75.00
SO BUILDLEN  STACK1    82.54   87.58   89.95   89.59   86.51   80.80
SO BUILDLEN  STACK1    72.64   62.26   50.00   62.26   72.64   80.80
SO BUILDLEN  STACK1    86.51   89.59   89.95   87.58   82.54   75.00
SO XBADJ     STACK1  -47.35  -55.76  -62.48  -67.29  -70.07  -70.71
SO XBADJ     STACK1  -69.21  -65.60  -60.00  -65.60  -69.21  -70.71
SO XBADJ     STACK1  -70.07  -67.29  -62.48  -55.76  -47.35  -37.50
SO XBADJ     STACK1  -35.19  -31.82  -27.48  -22.30  -16.44  -10.09
SO XBADJ     STACK1   -3.43    3.34   10.00    3.34   -3.43  -10.09
SO XBADJ     STACK1  -16.44  -22.30  -27.48  -31.82  -35.19  -37.50
SO YBADJ     STACK1   34.47   32.89   30.31   26.81   22.50   17.50
SO YBADJ     STACK1   11.97    6.08    0.00   -6.08  -11.97  -17.50
SO YBADJ     STACK1  -22.50  -26.81  -30.31  -32.89  -34.47  -35.00
SO YBADJ     STACK1  -34.47  -32.89  -30.31  -26.81  -22.50  -17.50
SO YBADJ     STACK1  -11.97   -6.08    0.00    6.08   11.97   17.50
SO YBADJ     STACK1   22.50   26.81   30.31   32.89   34.47   35.00

   SRCGROUP  ALL
SO FINISHED
```

Input




```
SO BUILDLEN  STACK1    86.51   89.59   89.95   87.58   82.54   75.00
SO XBADJ     STACK1   -47.35  -55.76  -62.48  -67.29  -70.07  -70.71
SO XBADJ     STACK1   -69.21  -65.60  -60.00  -65.60  -69.21  -70.71
SO XBADJ     STACK1   -70.07  -67.29  -62.48  -55.76  -47.35  -37.50
SO XBADJ     STACK1   -35.19  -31.82  -27.48  -22.30  -16.44  -10.09
SO XBADJ     STACK1    -3.43    3.34   10.00    3.34   -3.43  -10.09
SO XBADJ     STACK1   -16.44  -22.30  -27.48  -31.82  -35.19  -37.50
SO YBADJ     STACK1    34.47   32.89   30.31   26.81   22.50   17.50
SO YBADJ     STACK1    11.97    6.08    0.00   -6.08  -11.97  -17.50
SO YBADJ     STACK1   -22.50  -26.81  -30.31  -32.89  -34.47  -35.00
SO YBADJ     STACK1   -34.47  -32.89  -30.31  -26.81  -22.50  -17.50
SO YBADJ     STACK1   -11.97   -6.08    0.00    6.08   11.97   17.50
SO YBADJ     STACK1    22.50   26.81   30.31   32.89   34.47   35.00

   SRCGROUP  ALL
SO FINISHED
```

BUILDLEN	projected length of the building along the flow
XBADJ	along-flow distance from the stack to the center of the upwind face of the projected building
YBADJ	across-flow distance from the stack to the center of the upwind face of the projected building

BPIP is a pre-processor that takes actual building dimensions and figures out projected bldg length, width, xbadj, and ybadj.
Get BPIP-PRIME from EPA web page:
http://www3.epa.gov/ttn/scram/dispersion_related.htm

BPIP Input

The test case addresses the following configuration (see Figure 3):

Building Dimensions (L,W,H)	75, 50, 50 (m)
Building Orientation	Long side aligns N-S
Stack Height	65 (m)
Stack Location1	10 m East of Center of East Wall

The input file for BPIP contains the following information:

```
'PRIME test case'
'ST'
'METERS'  1.0
'UTMN'   0.0
   1
'unit1 '          1   0.0
         4    50.00
   0.0      0.0
   0.0     75.0
  50.0     75.0
  50.0      0.0
   1
'unit1'        .00      65.00       60.    37.5
```

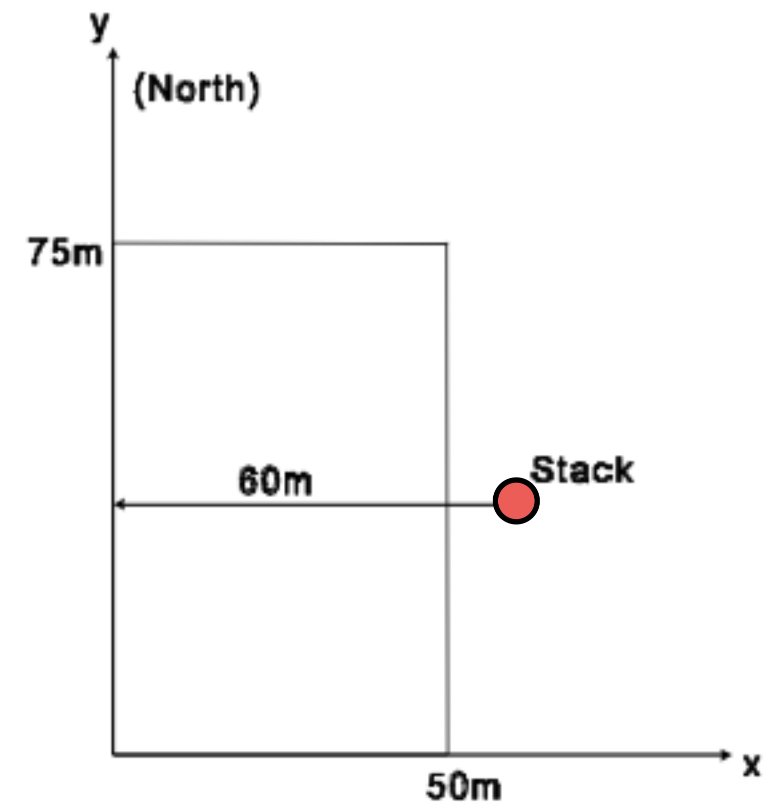


Figure 3. Building/stack configuration for test case.

BPIP output

The test case addresses the following configuration (see Figure

Building Dimensions (L,W,H)75, 50, 50 (m)	
Building Orientation	Long side aligns N-S
Stack Height	65 (m)
Stack Location1	10 m East of Center of East Wall

```
PRIME test case

BPIP output is in meters

SO BUILDHGT Unit 1   50.00   50.00   50.00   50.00   50.00   50.00
SO BUILDHGT Unit 1   50.00   50.00   50.00   50.00   50.00   50.00
SO BUILDHGT Unit 1   50.00   50.00   50.00   50.00   50.00   50.00
SO BUILDHGT Unit 1   50.00   50.00   50.00   50.00   50.00   50.00
SO BUILDHGT Unit 1   50.00   50.00   50.00   50.00   50.00   50.00
SO BUILDHGT Unit 1   50.00   50.00   50.00   50.00   50.00   50.00
SO BUILDWID Unit 1   62.26   72.64   80.80   86.51   89.59   89.95
SO BUILDWID Unit 1   87.58   82.54   75.00   82.54   87.58   89.95
SO BUILDWID Unit 1   89.59   86.51   80.80   72.64   62.26   50.00
SO BUILDWID Unit 1   62.26   72.64   80.80   86.51   89.59   89.95
SO BUILDWID Unit 1   87.58   82.54   75.00   82.54   87.58   89.95
SO BUILDWID Unit 1   89.59   86.51   80.80   72.64   62.26   50.00
SO BUILDLEN Unit 1   82.54   87.58   89.95   89.59   86.51   80.80
SO BUILDLEN Unit 1   72.64   62.26   50.00   62.26   72.64   80.80
SO BUILDLEN Unit 1   86.51   89.59   89.95   87.58   82.54   75.00
SO BUILDLEN Unit 1   82.54   87.58   89.95   89.59   86.51   80.80
SO BUILDLEN Unit 1   72.64   62.26   50.00   62.26   72.64   80.80
SO BUILDLEN Unit 1   86.51   89.59   89.95   87.58   82.54   75.00
SO XBADJ    Unit 1  -47.35  -55.76  -62.48  -67.29  -70.07  -70.71
SO XBADJ    Unit 1  -69.21  -65.60  -60.00  -65.60  -69.21  -70.71
SO XBADJ    Unit 1  -70.07  -67.29  -62.48  -55.76  -47.35  -37.50
SO XBADJ    Unit 1  -35.19  -31.82  -27.48  -22.30  -16.44  -10.09
SO XBADJ    Unit 1   -3.43    3.34   10.00    3.34   -3.43  -10.09
SO XBADJ    Unit 1  -16.44  -22.30  -27.48  -31.82  -35.19  -37.50
SO YBADJ    Unit 1   34.47   32.89   30.31   26.81   22.50   17.50
SO YBADJ    Unit 1   11.97    6.08    0.00   -6.08  -11.97  -17.50
SO YBADJ    Unit 1  -22.50  -26.81  -30.31  -32.89  -34.47  -35.00
SO YBADJ    Unit 1  -34.47  -32.89  -30.31  -26.81  -22.50  -17.50
SO YBADJ    Unit 1  -11.97   -6.08    0.00    6.08   11.97   17.50
SO YBADJ    Unit 1   22.50   26.81   30.31   32.89   34.47   35.00
```

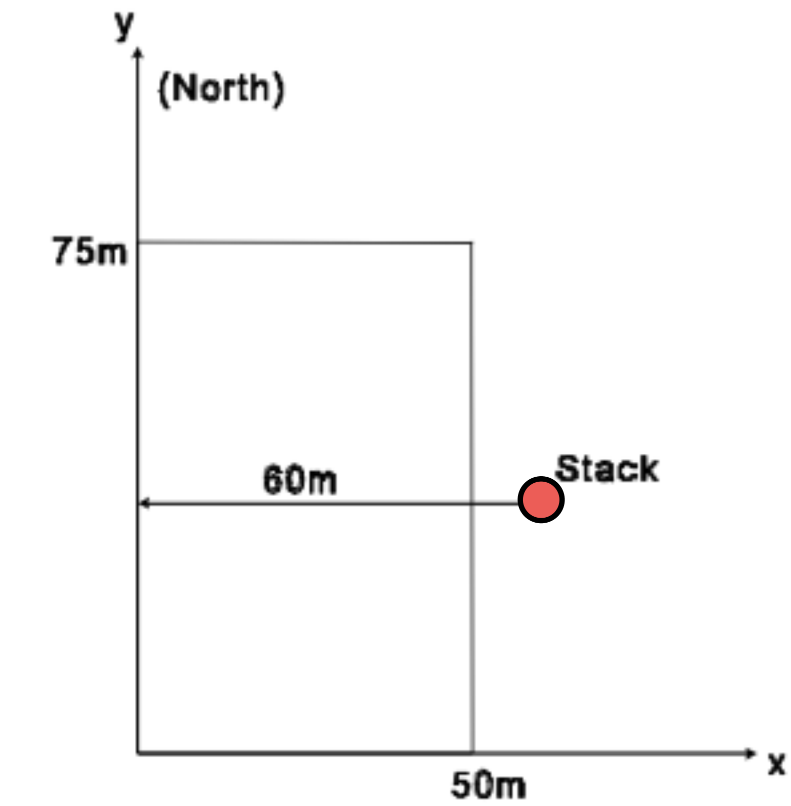
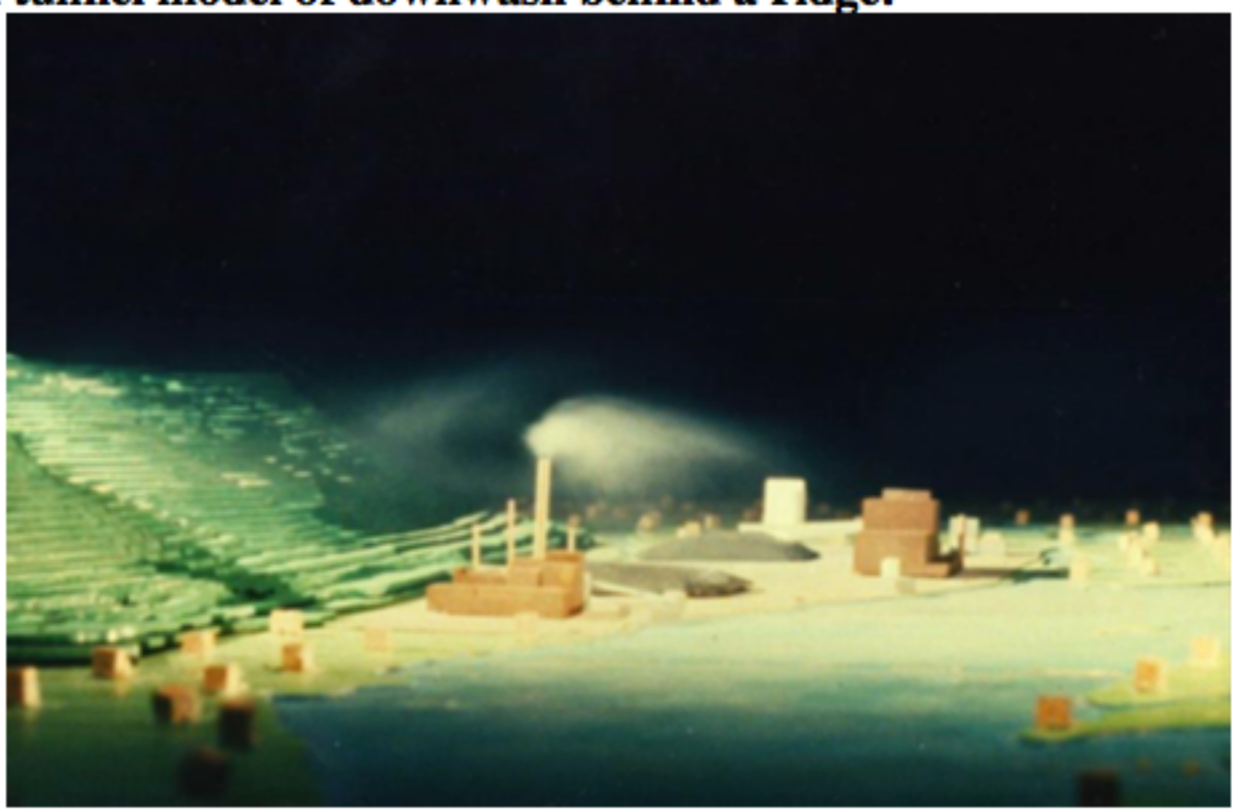


Figure 3. Building/stack configuration for test case.

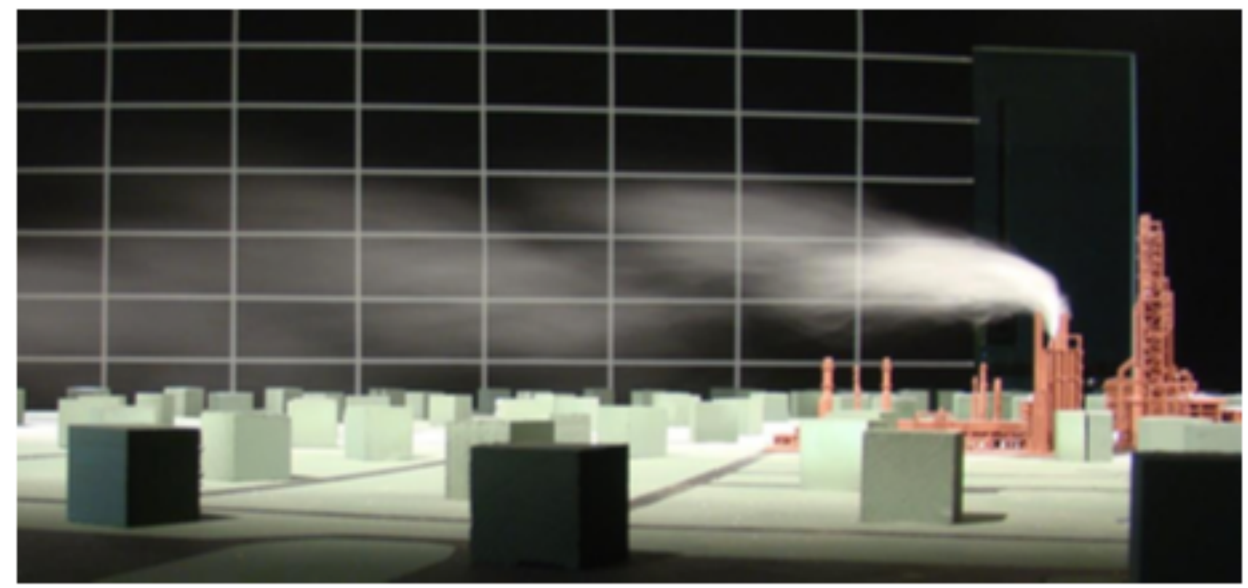
Other Downwash Issues

Terrain Downwash

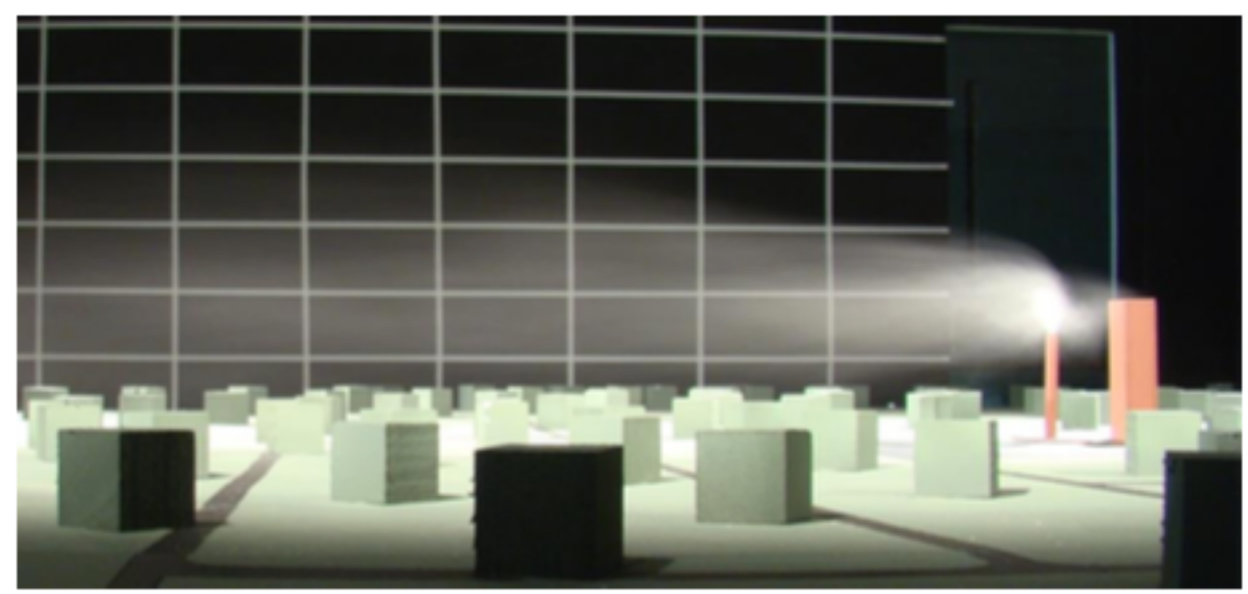
wind tunnel model of downwash behind a ridge.



Downwash behind open structures vs. solid buildings



b)



c)

Observed v. Predicted Q-Q Plots – 1977 (1-hr Average SO_2 Concentrations)

from R. Peterson, CPP