Organization of Course

INTRODUCTION

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**HYSPLIT Theory and Practice**

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6. Concentrations / Deposition

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Overall Project Issues & Examples

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"Hands On"
HYSPLIT Modeling
Exercise #1

Running and Mapping
a Single Back-Trajectory using the
Graphical User Interface (GUI)

First, delete all files from "c:\hysplit4\working"
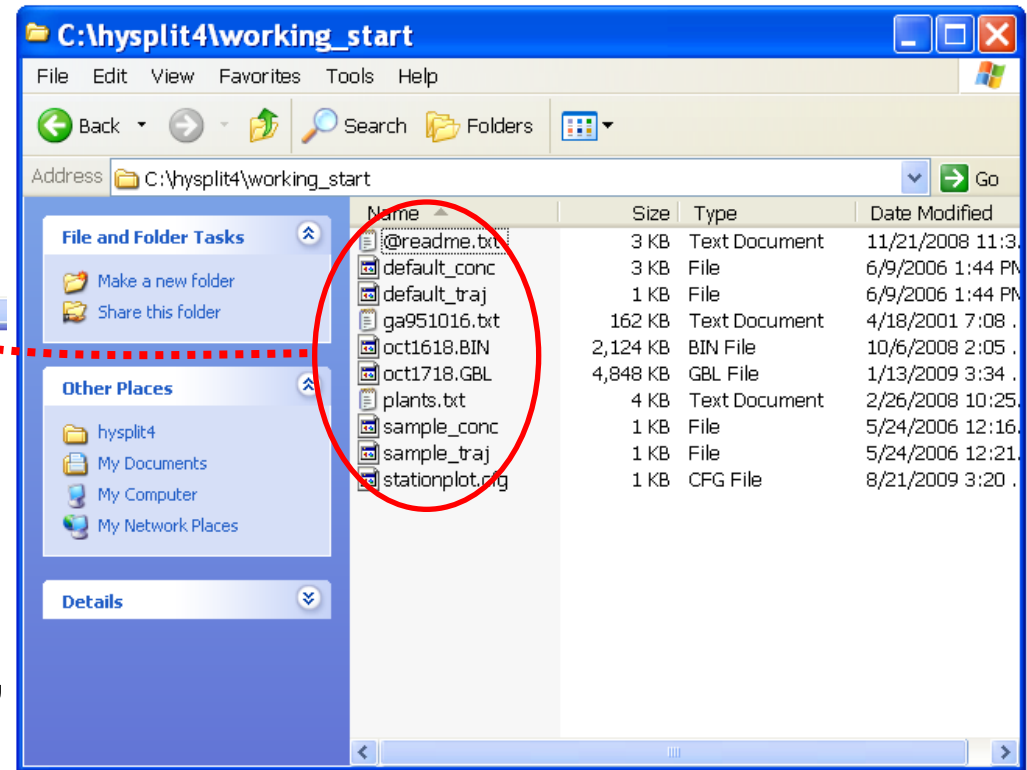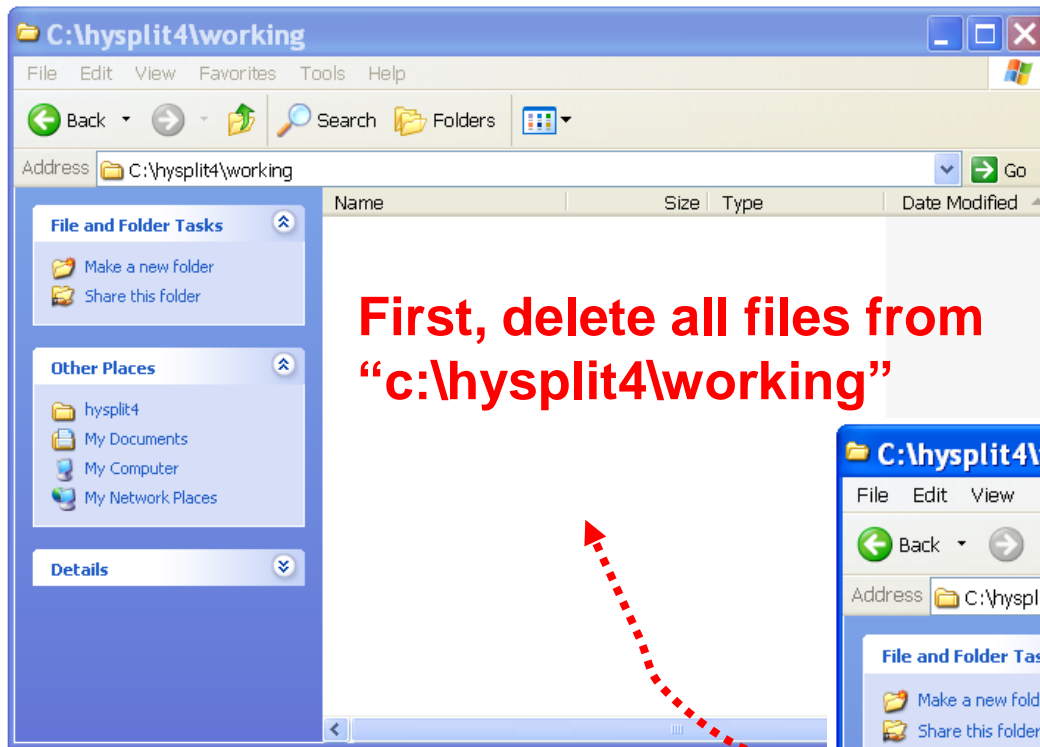
Second, copy all files from "c:\hysplit4\working_start" into "c:\hysplit4\working"

File   Edit   View   Favorites   Tools   Help

Back ▾   ◯ ▾   📁   🔍 Search   📂 Folders   ▦ ▾

Address 📁 C:\hysplit4\working   ✔ → Go
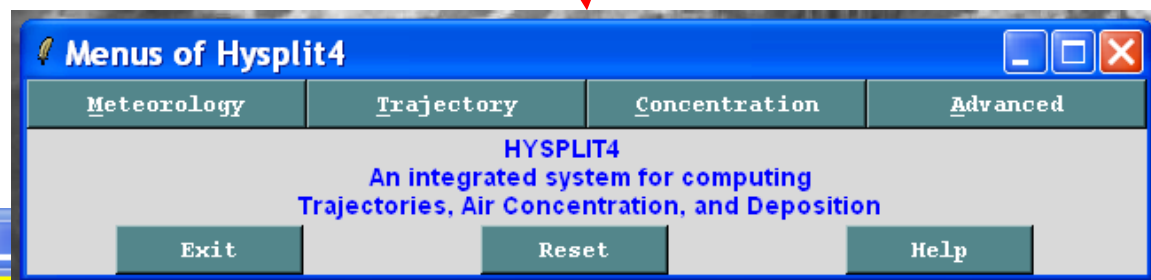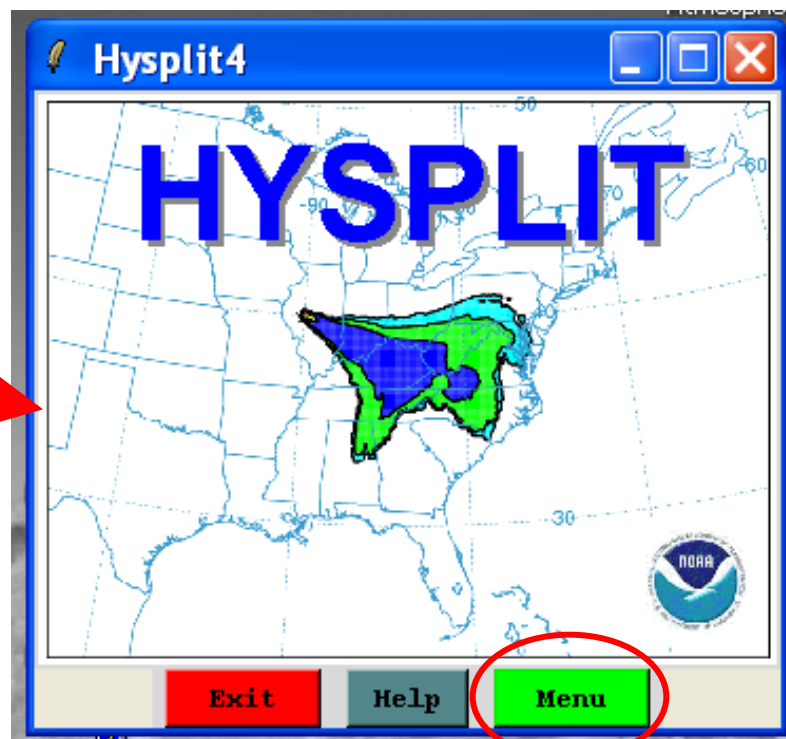
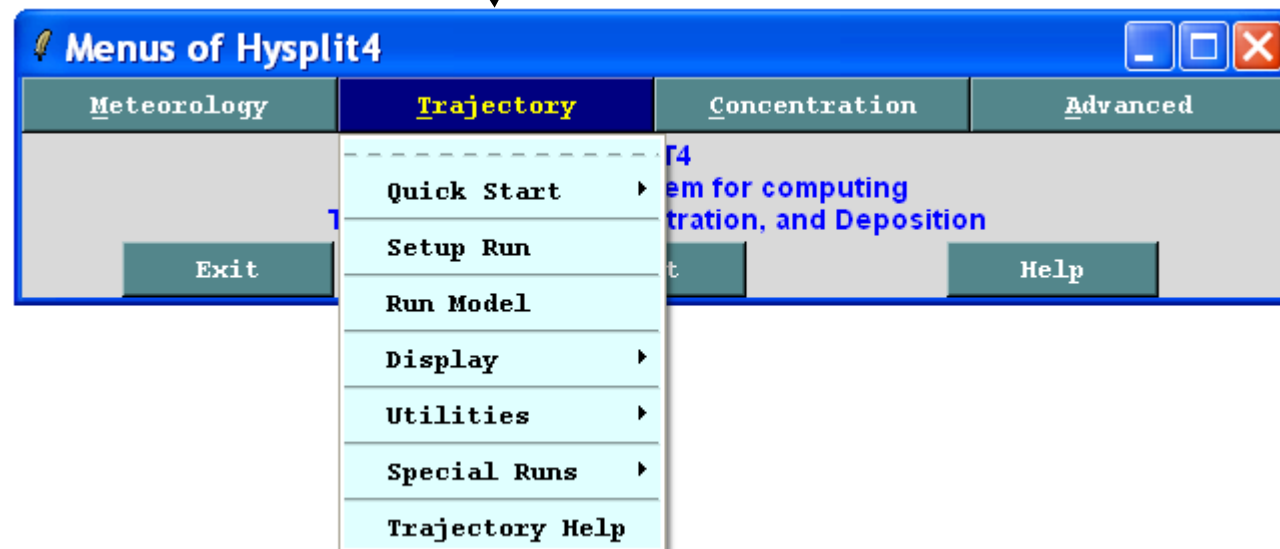**File and Folder Tasks** ⊗

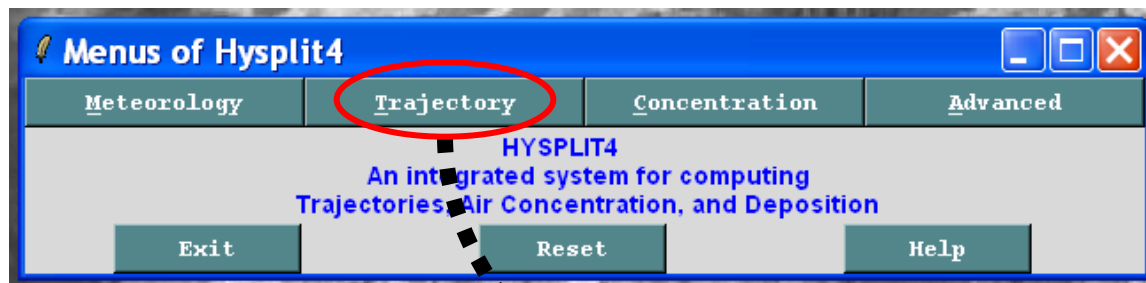📁 Make a new folder
📁 Share this folder

Other Places ⊗

📁 hysplit4
📄 My Documents
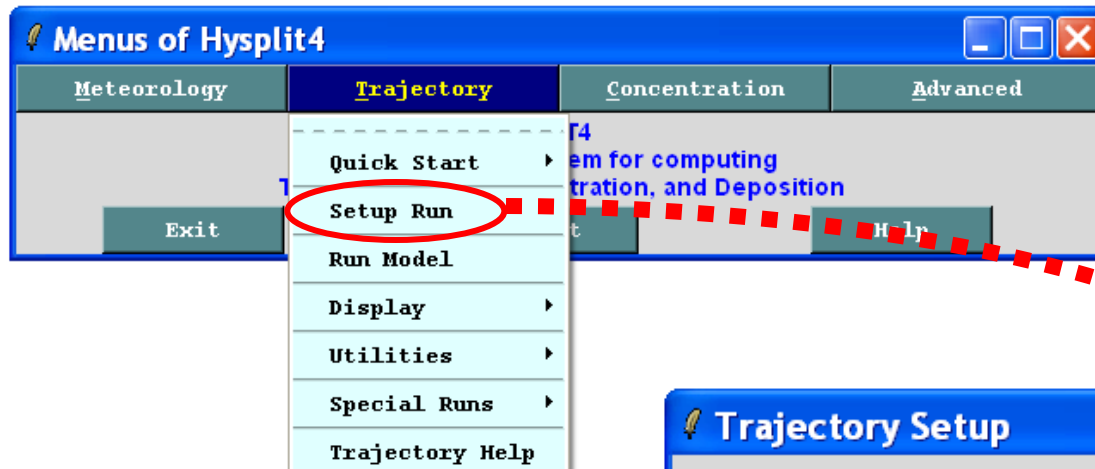🖥 My Computer
🌐 My Network Places

Details ⊗

Name	Size	Type	Date Modified ▲
📄 @readme.txt	3 KB	Text Document	11/21/2008 11:30 AM
📄 default_conc	3 KB	File	6/9/2006 1:44 PM
📄 default_traj	1 KB	File	6/9/2006 1:44 PM
📄 ga951016.txt	162 KB	Text Document	4/18/2001 7:08 AM
📄 oct1618.BIN	2,124 KB	BIN File	10/6/2008 2:05 PM
📄 oct1718.GBL	4,848 KB	GBL File	1/13/2009 3:34 PM
📄 plants.txt	4 KB	Text Document	2/26/2008 10:25 AM
📄 sample_conc	1 KB	File	5/24/2006 12:16 PM
📄 sample_traj	1 KB	File	5/24/2006 12:21 PM
📄 stationplot.cfg	1 KB	CFG File	8/21/2009 3:20 AM

Run Hysplit 4.9

Hysplit4

HYSPLIT

Exit   Help   Menu

Menus of Hysplit4

Meteorology	Trajectory	Concentration	Advanced

HYSPLIT4
An integrated system for computing
Trajectories, Air Concentration, and Deposition

Exit   Reset   Help

Hyspl...

February 2009 Version
(update - 1234567890)

2 "Total run time": change to **-24**

1 "Starting time": change to **08 08 03 15**

6 Change to: **20.25 -103.05   200**

Trajectory Setup

Starting time (YY MM DD HH {mm}): `08 08 03 15`

Number of starting locations: `1` ====> Setup starting locations

Total run time (hrs) `-24`

Direction ○ Fwrd ● Back

Top of model (m agl) `10000.0`

Vertical Motion Method

● 0:data   ○ 1:isob   ○ 2:isen   ○ 3:dens   ○ 4:sigma   ○ 5:divg

Output (/path/file): `./tdump`   Browse

Add Meteorology Files   Clear   Selected Files: `2`

C:/hysplit4/metdata
C:/hysplit4/metdata

edas.aug08.001
edas.jul08.002

Quit   Help   Save as   Retrieve   Save

Starting Location Setup

Set up 1 Starting Locations

Latitude Longitude Height(m-AGL)

Location 1 : `20.25  -103.05   200.0`   List

Quit   OK

7 Click "OK"

5 Click "Setup starting locations"

3 "Direction": change to **"Back"**

4 "Number of starting locations": change to **1**
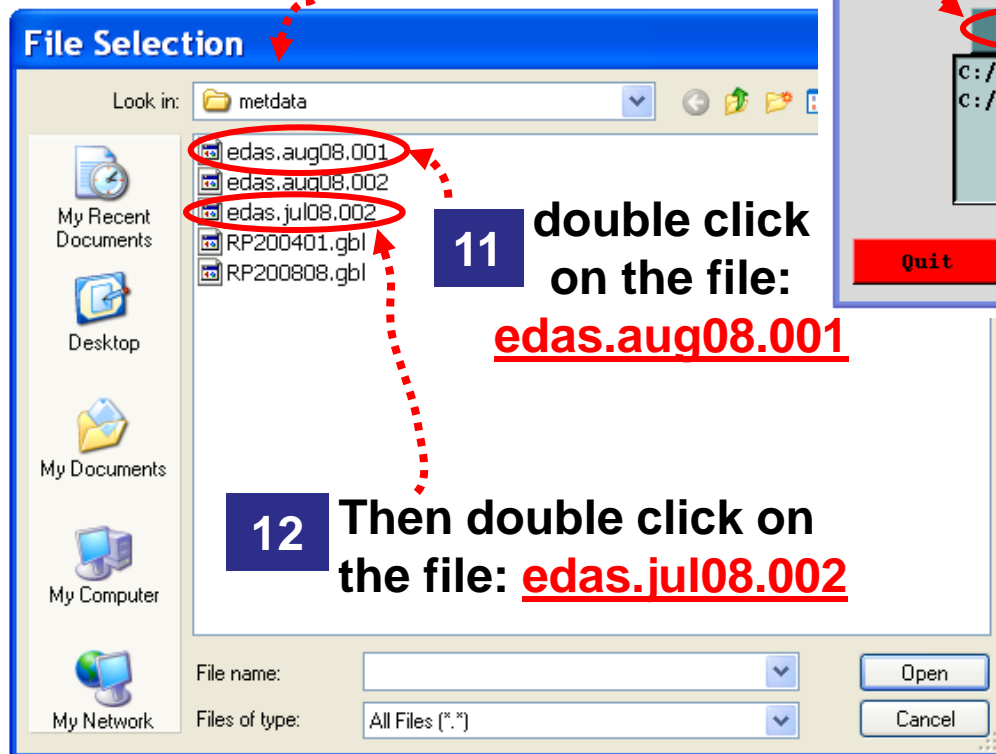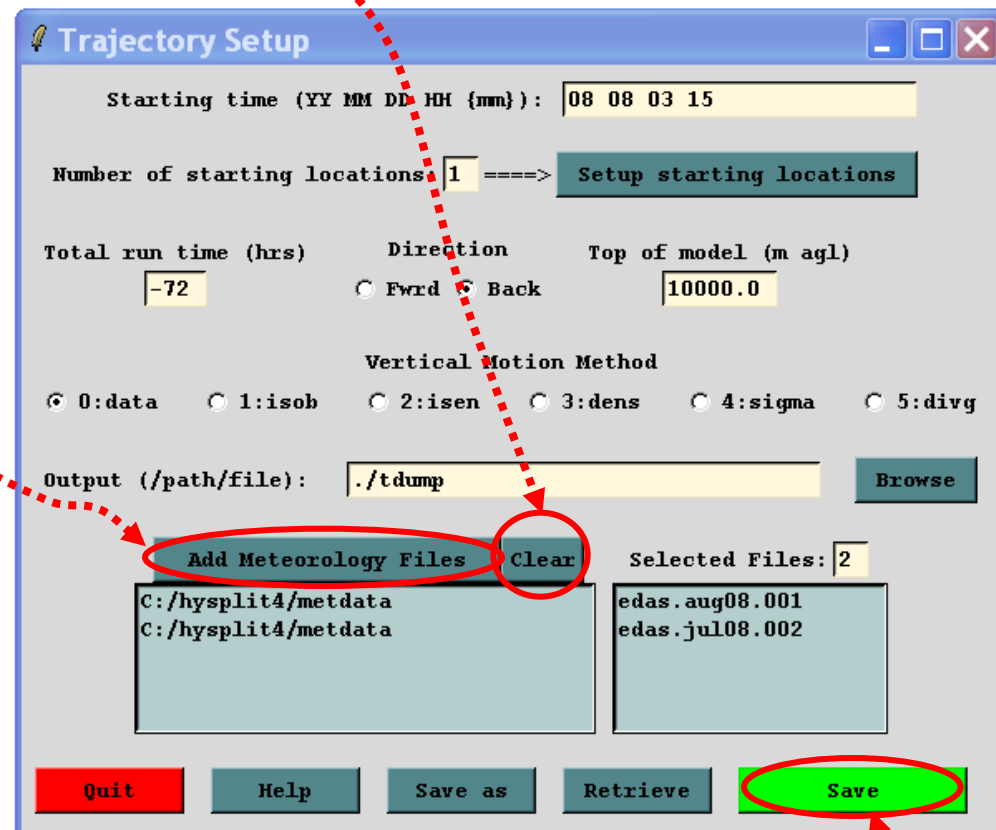
14 click "Trajectory"
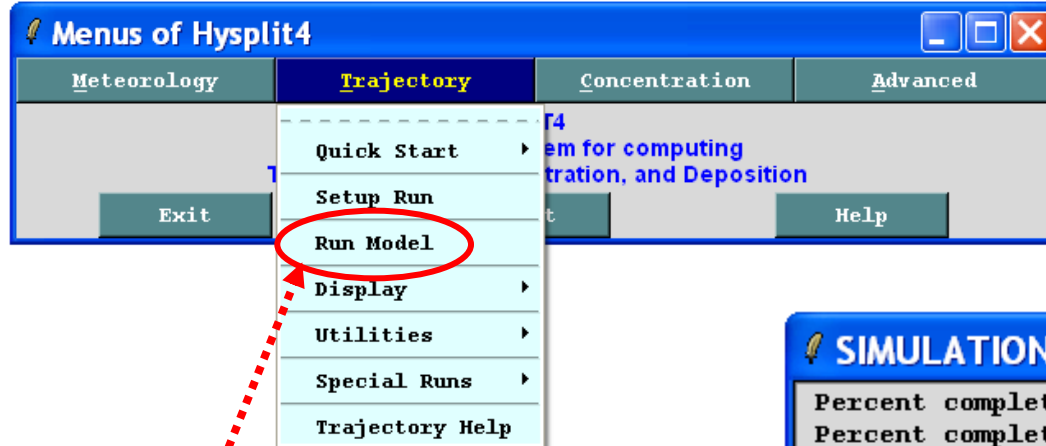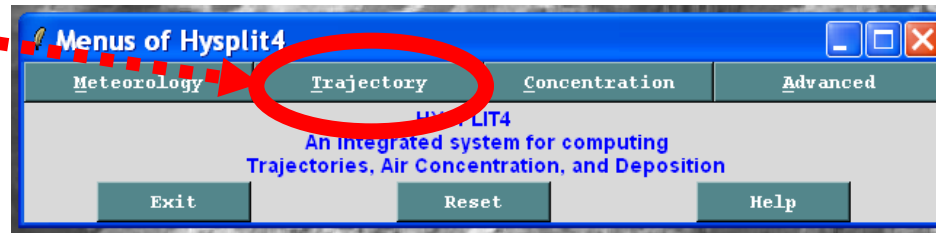
15 click "Run Model"
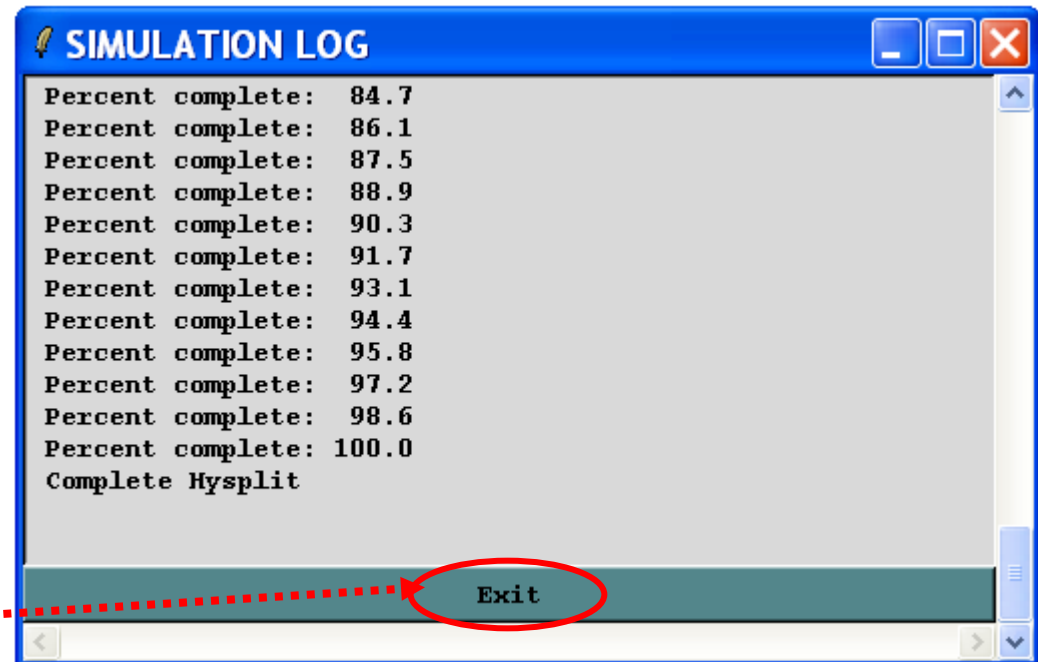
16 When simulation is complete, click "Exit"

SIMULATION LOG

Percent complete: 84.7
Percent complete: 86.1
Percent complete: 87.5
Percent complete: 88.9
Percent complete: 90.3
Percent complete: 91.7
Percent complete: 93.1
Percent complete: 94.4
Percent complete: 95.8
Percent complete: 97.2
Percent complete: 98.6
Percent complete: 100.0
Complete Hysplit

Exit

NOAA HYSPLIT MODEL
Backward trajectory ending at 1500 UTC 03 Aug 08
EDAS Meteorological Data

M	metallurgical facility
A	chlor-alkali
W	waste incinerator
E	coal-fired electric generator
R	petroleum refining
O	oil-fired electric generator
P	pulp and paper
G	natural-gas-fired electric generator

If there is time, we can vary the

trajectory setup

(*and then rerun the trajectory***)**

and/or vary the

trajectory display features

and look at how the trajectory

changes…

What does the Graphical User Interface (GUI) actually do?

❑ **Writes a "control" file**
   and other input files as needed, setup.cfg

❑ **Runs the HYSPLIT Trajectory Model**
   which reads the control file and other input files

❑ **Runs the "Trajplot" Display Program,**
   according to the user's preferences

"Hands On" HYSPLIT Modeling Exercise #2

**Running and Mapping
a Single Back-Trajectory from the
<u>DOS Command Line</u>**

***If a CONTROL file is present in the working directory,
then HYSPLIT will read it and run a trajectory
according to this file's specifications***
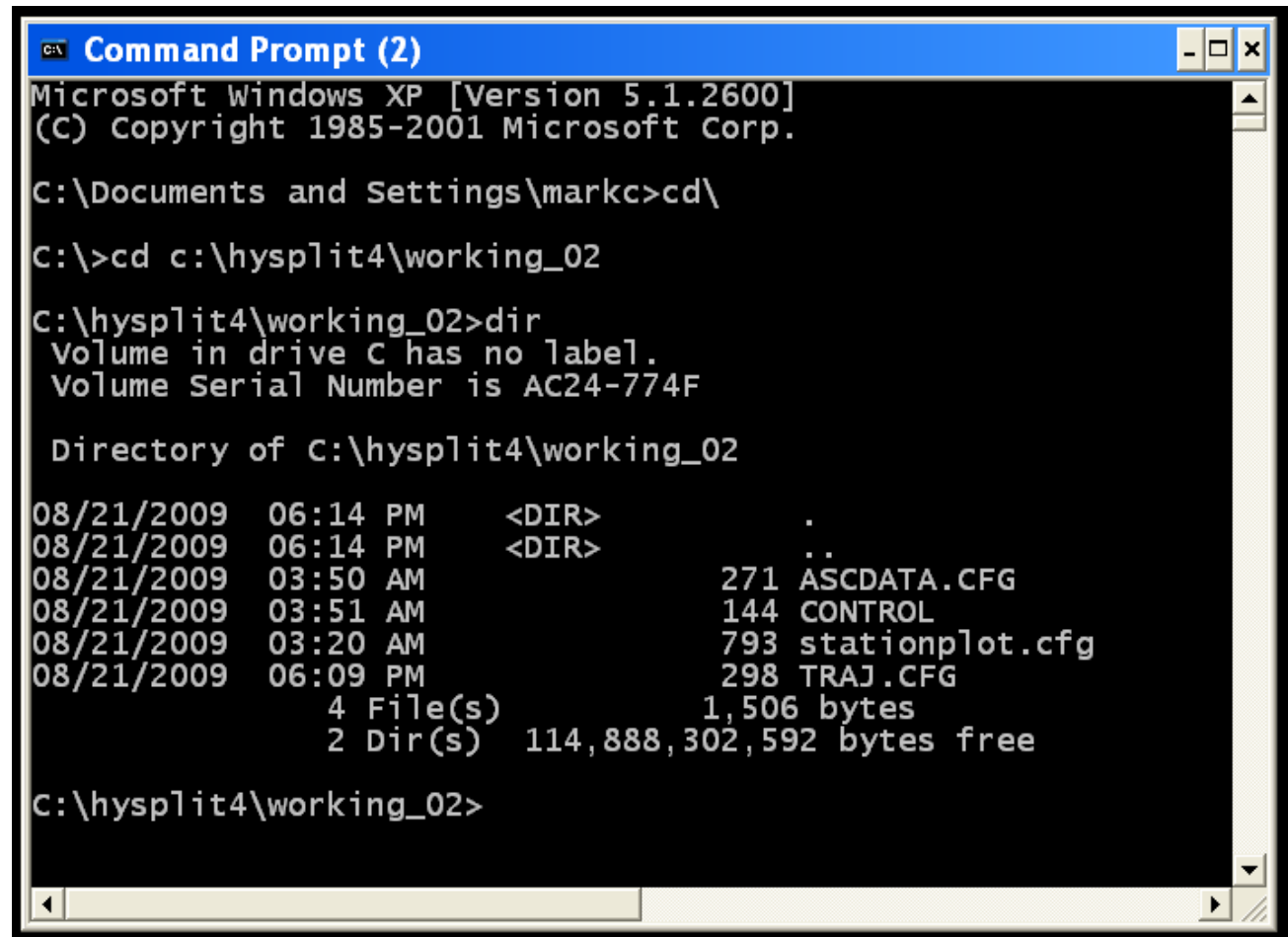
starting year, month, day, hour (UTC) --	`08 08 03 15`
number of starting locations --	`1`
lat, long, height (m-agl) for each location --	`20.25 -103.05 200.0`
hours to run trajectory (if < 0, then backward) --	`-24`
vertical motion option (0:data, …) --	`0`
model top (meters) --	`10000.0`
number of meteorological data files to use --	`2`
location of first file --	`C:/hysplit4/metdata/`
name of first file --	`edas.aug08.001`
location of next file --	`C:/hysplit4/metdata/`
name of next file --	`edas.jul08.002`
location of output (./ = working directory) --	`./`
name of trajectory endpoints file --	`tdump`

❑ Open a DOS Command Prompt Window:
  Start, All Programs, Accessories, Command Prompt

❑ Navigate to c:\hysplit4\working_02:
  cd\ [enter]
  cd c:\hysplit4\working_02 [enter]
  dir [enter]

❑ The files in this directory are equivalent to the files that were just created in the **working** directory by our actions with the GUI

❑ The files were copied for you to this new folder for the next exercise

```
Command Prompt (2)                                        - □ ×
Microsoft Windows XP [Version 5.1.2600]
(C) Copyright 1985-2001 Microsoft Corp.

C:\Documents and Settings\markc>cd\

C:\>cd c:\hysplit4\working_02

C:\hysplit4\working_02>dir
 Volume in drive C has no label.
 Volume Serial Number is AC24-774F

 Directory of C:\hysplit4\working_02

08/21/2009  06:14 PM    <DIR>          .
08/21/2009  06:14 PM    <DIR>          ..
08/21/2009  03:50 AM               271 ASCDATA.CFG
08/21/2009  03:51 AM               144 CONTROL
08/21/2009  03:20 AM               793 stationplot.cfg
08/21/2009  06:09 PM               298 TRAJ.CFG
               4 File(s)          1,506 bytes
               2 Dir(s)  114,888,302,592 bytes free

C:\hysplit4\working_02>
```

- ❑ Run the HYSPLIT Trajectory program by typing:
  ..\exec\hyts_std [enter]

- ❑ HYSPLIT runs!

- ❑ Display files in directory:
  dir [enter]

- ❑ There are two new files:
  MESSAGE
  tdump

```
Command Prompt (2)                                              - □ x

C:\hysplit4\working_02>..\exec\hyts_std
 HYSPLIT49 (Feb 2009) - Initialization
 Calculation Started ... please be patient
 Percent complete:    4.2
 Percent complete:    8.3
 Percent complete:   12.5
 Percent complete:   16.7
 Percent complete:   20.8
 Percent complete:   25.0
 Percent complete:   29.2
 Percent complete:   33.3
 Percent complete:   37.5
 Percent complete:   41.7
 Percent complete:   45.8
 Percent complete:   50.0
 Percent complete:   54.2
 Percent complete:   58.3
 Percent complete:   62.5
 Percent complete:   66.7
 Percent complete:   70.8
 Percent complete:   75.0
 Percent complete:   79.2
 Percent complete:   83.3
 Percent complete:   87.5
 Percent complete:   91.7
 Percent complete:   95.8
 Percent complete: 100.0
 Complete Hysplit

C:\hysplit4\working_02>dir
 Volume in drive C has no label.
 Volume Serial Number is AC24-774F

 Directory of C:\hysplit4\working_02

08/21/2009  06:33 PM    <DIR>          .
08/21/2009  06:33 PM    <DIR>          ..
08/21/2009  03:50 AM               271 ASCDATA.CFG
08/21/2009  03:51 AM               144 CONTROL
08/21/2009  06:33 PM             8,244 MESSAGE
08/21/2009  03:20 AM               793 stationplot.cfg
08/21/2009  06:33 PM             2,539 tdump
08/21/2009  06:33 PM               298 TRAJ.CFG
               6 File(s)         12,289 bytes
               2 Dir(s)  114,888,114,176 bytes free

C:\hysplit4\working_02>_
```

❑ Open up the file **tdump** in Notepad
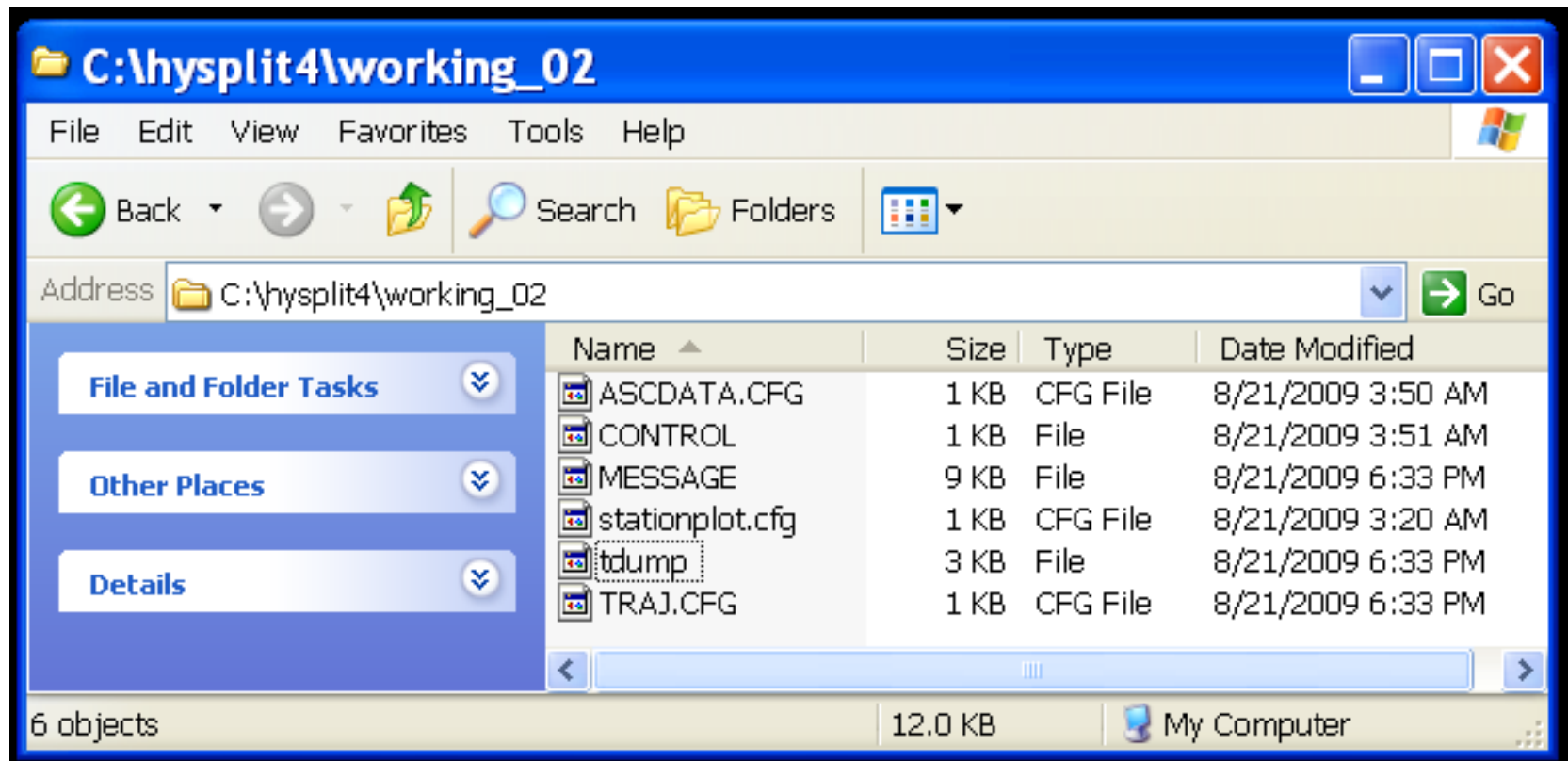
Starting time

Starting location
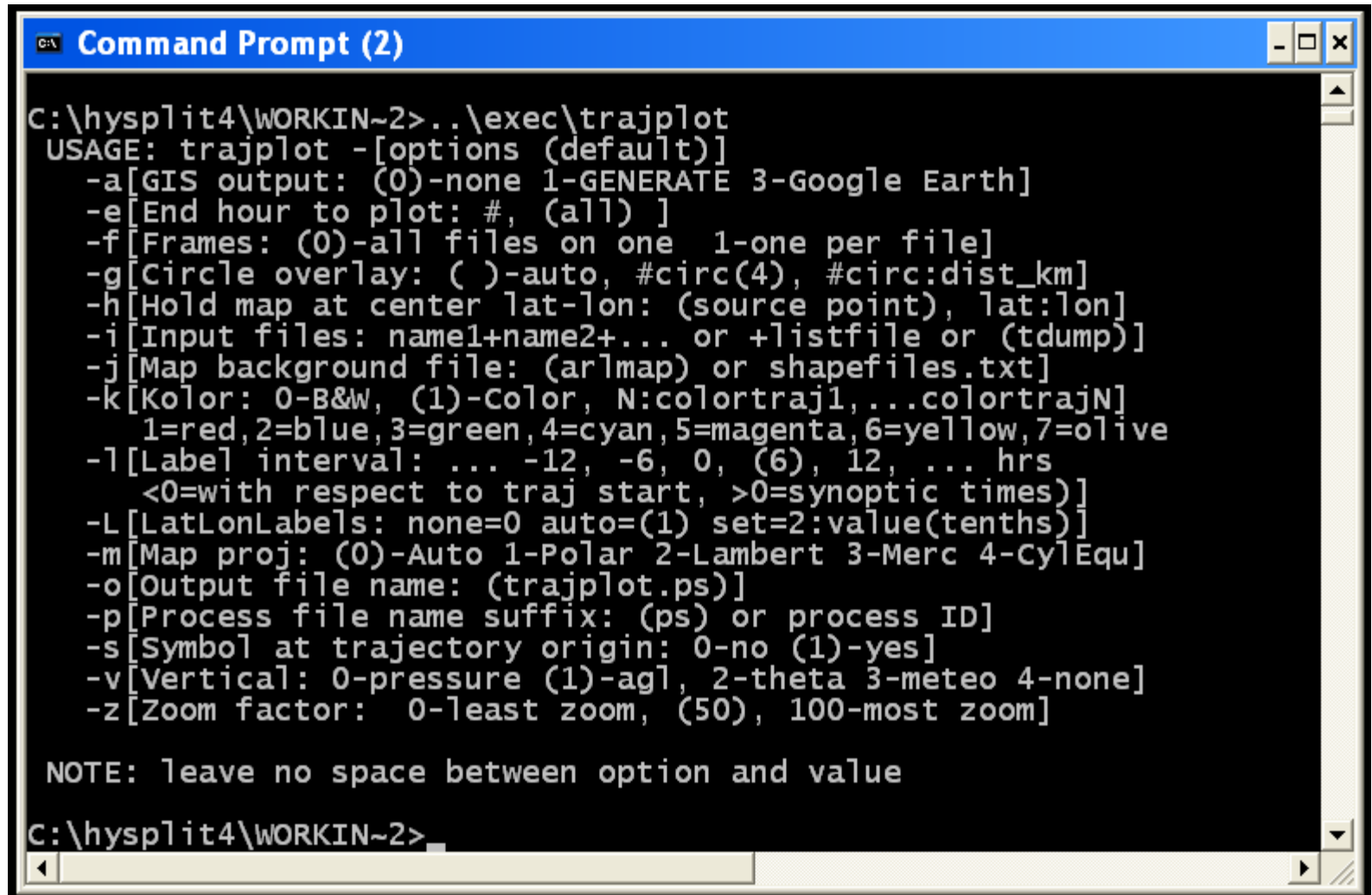
tdump - Notepad

File   Edit   Format   View   Help

```
    2       1
  EDAS      8       7      16       0       0
  EDAS      8       8       1       0       0
    1  BACKWARD  OMEGA
    8       8       3      15      20.250 -103.050      200.0
    1  PRESSURE
```

hour   lat   long   height   pressure

```
    1       1       8       8       3      15       0       0       0.0   20.250 -103.050      200.0     824.8
    1       1       8       8       3      14       0       0      -1.0   20.321 -103.030      181.8     825.6
    1       1       8       8       3      13       0       0      -2.0   20.403 -103.010      168.5     825.9
    1       1       8       8       3      12       0       0      -3.0   20.502 -102.989      170.2     824.0
    1       1       8       8       3      11       0       0      -4.0   20.603 -102.990      187.6     819.6
    1       1       8       8       3      10       0       0      -5.0   20.675 -103.041      198.8     816.7
    1       1       8       8       3       9       0       0      -6.0   20.704 -103.142      192.5     819.5
    1       1       8       8       3       8       0       0      -7.0   20.705 -103.266      170.0     824.3
    1       1       8       8       3       7       0       0      -8.0   20.697 -103.386      141.0     829.4
    1       1       8       8       3       6       0       0      -9.0   20.682 -103.508      112.2     834.3
    1       1       8       8       3       5       0       0     -10.0   20.672 -103.628       90.9     839.5
    1       1       8       8       3       4       0       0     -11.0   20.672 -103.744       81.5     846.0
    1       1       8       8       3       3       0       0     -12.0   20.675 -103.862       86.8     850.7
    1       1       8       8       3       2       0       0     -13.0   20.698 -103.985      105.7     851.6
    1       1       8       8       3       1       0       0     -14.0   20.763 -104.115      119.2     845.7
    1       1       8       8       3       0       0       0     -15.0   20.862 -104.254      109.9     848.6
    1       1       8       8       2      23       0       0     -16.0   20.963 -104.392       79.5     858.3
    1       1       8       8       2      22       0       0     -17.0   21.040 -104.517       53.2     870.9
    1       1       8       8       2      21       0       0     -18.0   21.095 -104.645       37.5     878.1
    1       1       8       8       2      20       0       0     -19.0   21.132 -104.777       26.7     884.3
    1       1       8       8       2      19       0       0     -20.0   21.162 -104.905       17.6     919.7
    1       1       8       8       2      18       0       0     -21.0   21.190 -105.032       11.2     957.1
    1       1       8       8       2      17       0       0     -22.0   21.207 -105.146        7.3     988.9
    1       1       8       8       2      16       0       0     -23.0   21.203 -105.230        4.9     999.8
    1       1       8       8       2      15       0       0     -24.0   21.181 -105.282        3.9    1001.5
```
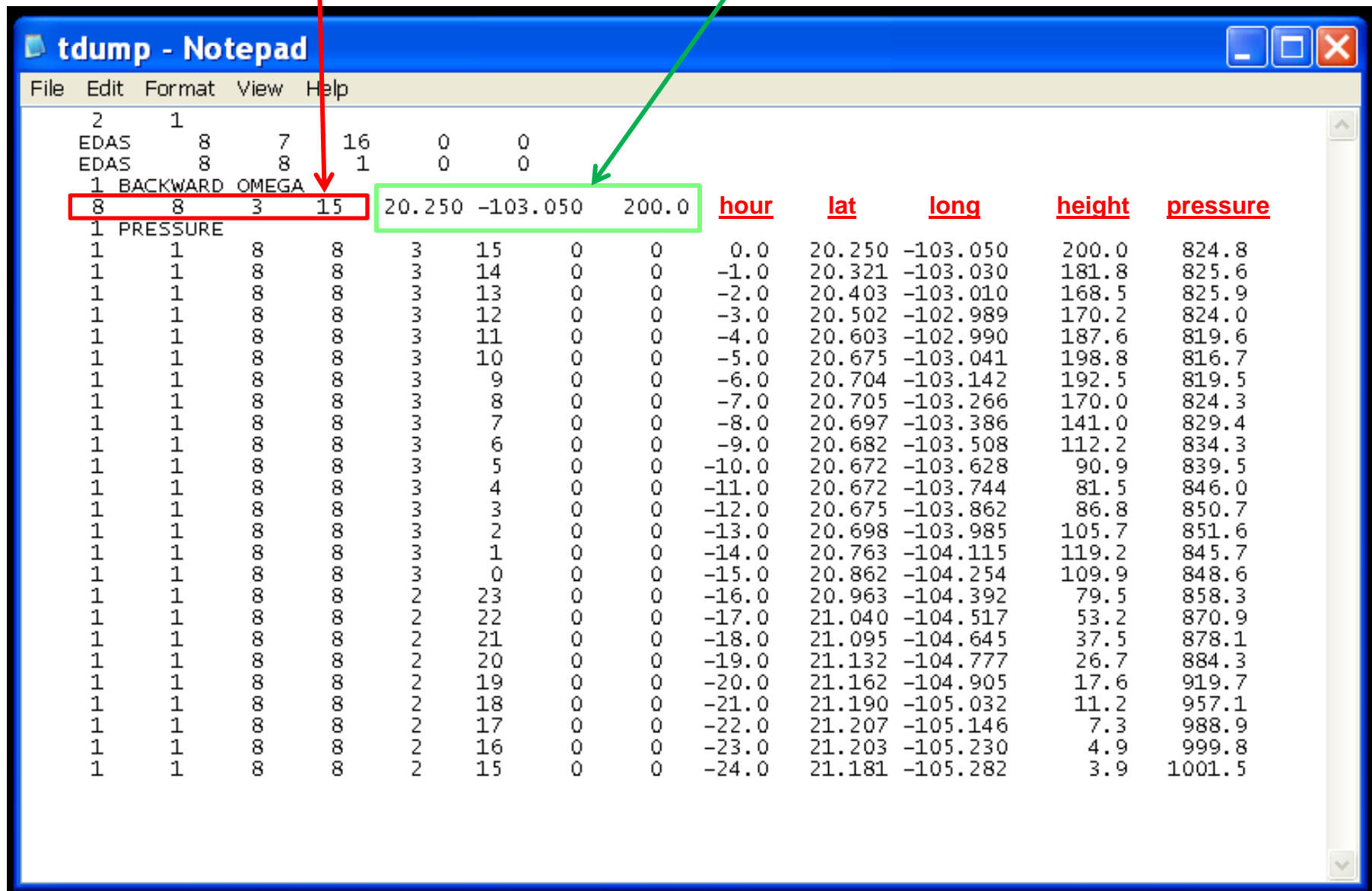
❑ Invoke TRAJPLOT.exe trajectory mapping program with no arguments to see its "USAGE"
   ..\exec\trajplot [enter]

```
C:\hysplit4\WORKIN~2>..\exec\trajplot
 USAGE: trajplot -[options (default)]
   -a[GIS output: (0)-none 1-GENERATE 3-Google Earth]
   -e[End hour to plot: #, (all) ]
   -f[Frames: (0)-all files on one  1-one per file]
   -g[Circle overlay: ( )-auto, #circ(4), #circ:dist_km]
   -h[Hold map at center lat-lon: (source point), lat:lon]
   -i[Input files: name1+name2+... or +listfile or (tdump)]
   -j[Map background file: (arlmap) or shapefiles.txt]
   -k[Kolor: 0-B&W, (1)-Color, N:colortraj1,...colortrajN]
     1=red,2=blue,3=green,4=cyan,5=magenta,6=yellow,7=olive
   -l[Label interval: ... -12, -6, 0, (6), 12, ... hrs
     <0=with respect to traj start, >0=synoptic times)]
   -L[LatLonLabels: none=0 auto=(1) set=2:value(tenths)]
   -m[Map proj: (0)-Auto 1-Polar 2-Lambert 3-Merc 4-CylEqu]
   -o[Output file name: (trajplot.ps)]
   -p[Process file name suffix: (ps) or process ID]
   -s[Symbol at trajectory origin: 0-no (1)-yes]
   -v[Vertical: 0-pressure (1)-agl, 2-theta 3-meteo 4-none]
   -z[Zoom factor:  0-least zoom, (50), 100-most zoom]

 NOTE: leave no space between option and value

C:\hysplit4\WORKIN~2>
```
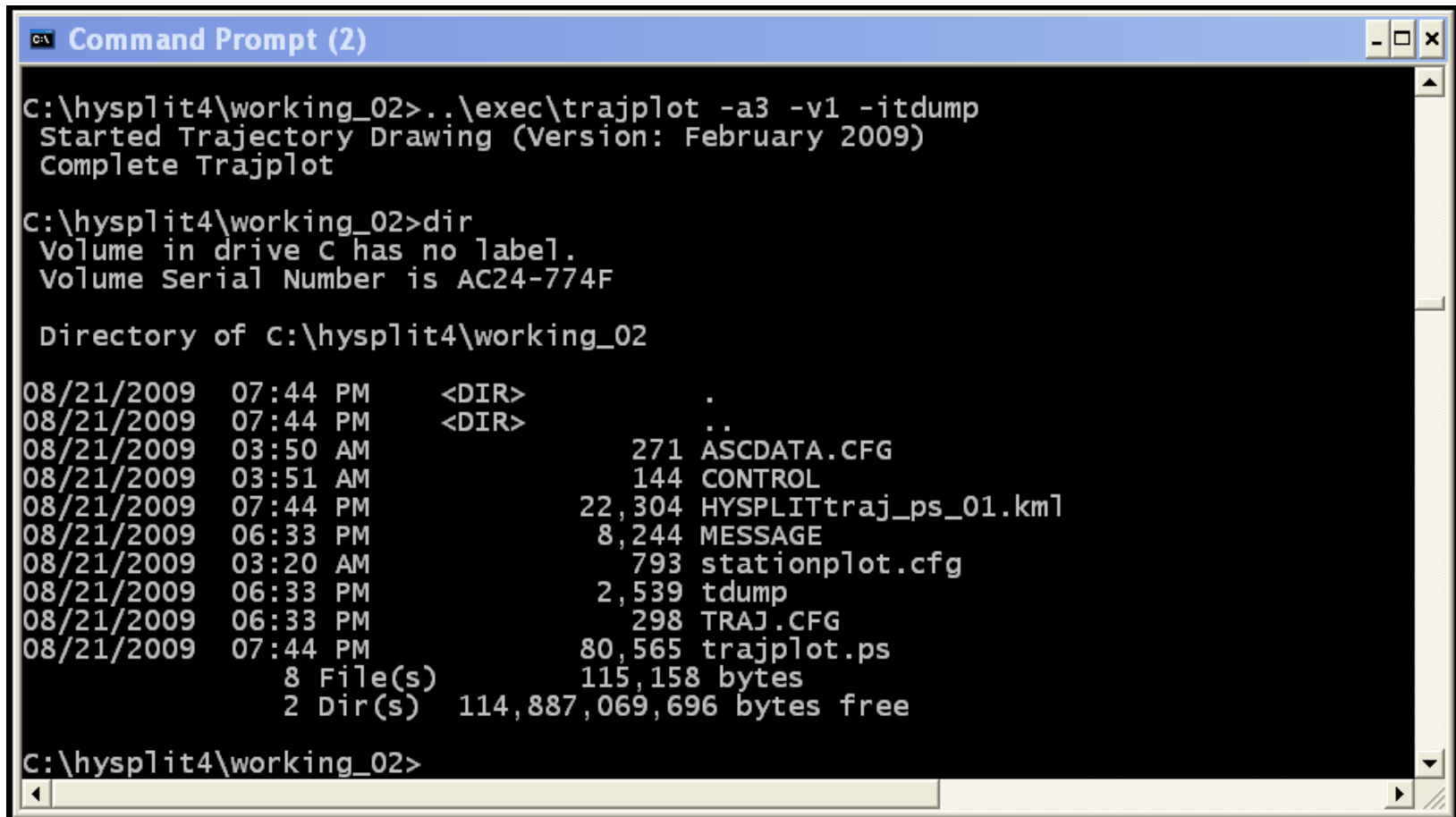
❑ Now run TRAJPLOT.exe program "for real" with a few simple arguments:
..\exec\trajplot –a3 –v1 -itdump [enter]

-a3 gives Google Earth KML file output
-v1 gives vertical output in meters above ground level
-itdump tells program to use tdump as the trajectory endpoints file

```
C:\hysplit4\working_02>..\exec\trajplot -a3 -v1 -itdump
 Started Trajectory Drawing (Version: February 2009)
 Complete Trajplot

C:\hysplit4\working_02>dir
 Volume in drive C has no label.
 Volume Serial Number is AC24-774F

 Directory of C:\hysplit4\working_02

08/21/2009  07:44 PM    <DIR>          .
08/21/2009  07:44 PM    <DIR>          ..
08/21/2009  03:50 AM               271 ASCDATA.CFG
08/21/2009  03:51 AM               144 CONTROL
08/21/2009  07:44 PM            22,304 HYSPLITtraj_ps_01.kml
08/21/2009  06:33 PM             8,244 MESSAGE
08/21/2009  03:20 AM               793 stationplot.cfg
08/21/2009  06:33 PM             2,539 tdump
08/21/2009  06:33 PM               298 TRAJ.CFG
08/21/2009  07:44 PM            80,565 trajplot.ps
               8 File(s)        115,158 bytes
               2 Dir(s)  114,887,069,696 bytes free

C:\hysplit4\working_02>
```

There are two new files present:

- **Trajplot.ps**

- **HYSPLITtraj_ps_01.kml**
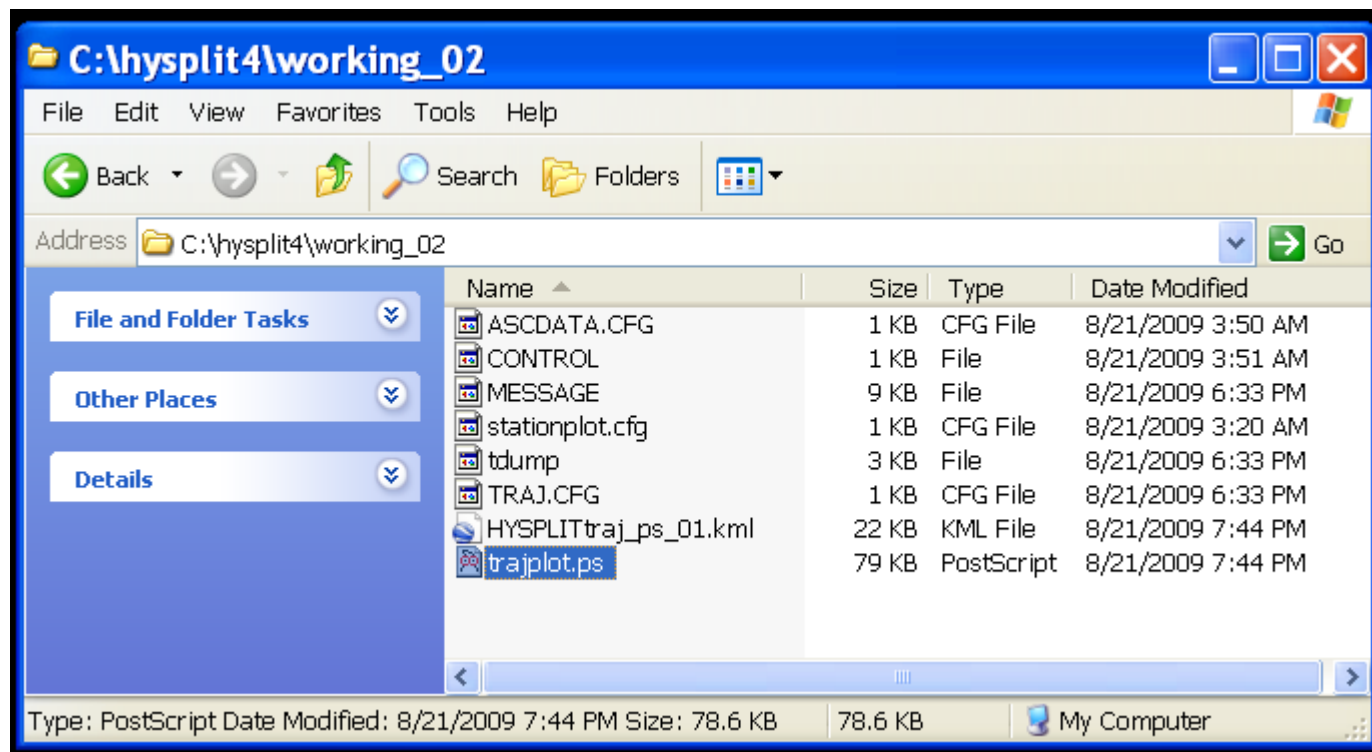
NOAA HYSPLIT MODEL
Backward trajectory ending at 1500 UTC 03 Aug 08
EDAS Meteorological Data
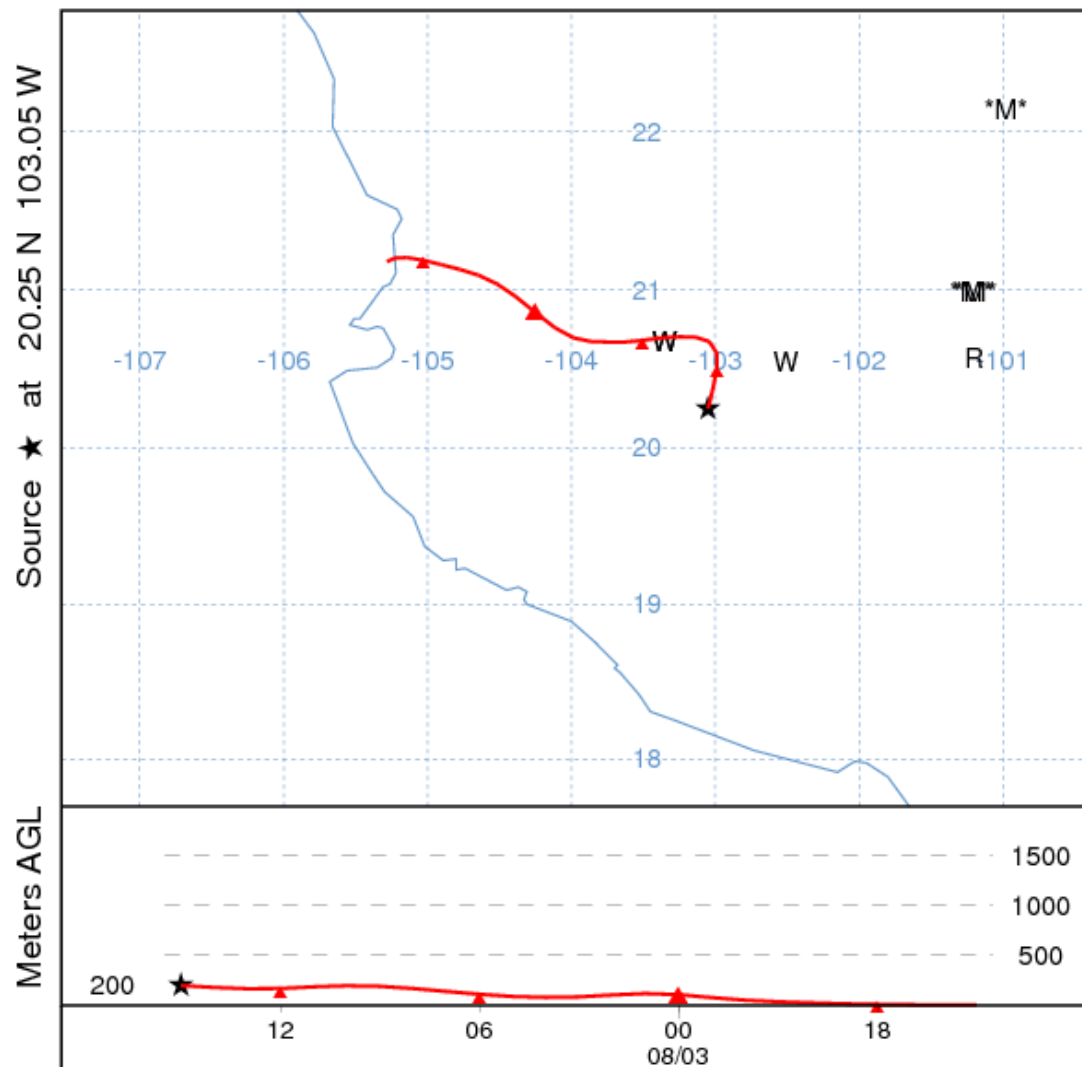
Now Double Click on KML file, if Google Earth has been installed

❑ **You can see this can all be done from the** **Command Line**

❑ **It can also be done using a** **DOS Batch File**

Has anyone had experience using DOS Batch Files?
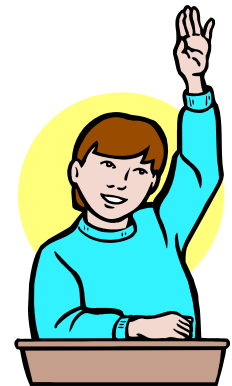
"Hands On"
HYSPLIT Modeling
Exercise #3

Running and Mapping
a Single Back-Trajectory with a
DOS Batch File

```
@ECHO OFF
rem starting time
ECHO 08 08 03 15              > CONTROL.txt
rem number of starting locations
ECHO 1                       >> CONTROL.txt
rem lat, long, height of start location
ECHO 20.25 -103.05 200.0  >> CONTROL.txt
rem number of hours to run trajectory
ECHO -24                    >> CONTROL.txt
rem vertical motion option
rem      (0:data 1:isob 2:isen 3:dens 4:sigma 5:diverg 6:eta)
ECHO 0                      >> CONTROL.txt
rem model top
ECHO 10000.0                >> CONTROL.txt
rem number of meteorological data files
ECHO 2                      >> CONTROL.txt
rem location and name of first met file
ECHO C:/hysplit4/metdata/ >> CONTROL.txt
ECHO edas.aug08.001        >> CONTROL.txt
rem location and name of second met file
ECHO C:/hysplit4/metdata/ >> CONTROL.txt
ECHO edas.jul08.002        >> CONTROL.txt
rem location and name of trajectory endpoints output file
ECHO ./                    >> CONTROL.txt
ECHO tdump                 >> CONTROL.txt
```

```
rem delete earlier CONTROL if present
del CONTROL.

rem copy new file to "control"
copy CONTROL.txt control.

rem run hysplit trajectory model (it will use "control."
..\exec\hyts_std.exe

rem run trajplot to map the trajectory
..\exec\trajplot -itdump -a3 -v1
```

```
Command Prompt (2)                                                    _ □ ×

C:\hysplit4\working_03>TRAJ_RUN_03
        1 file(s) copied.
HYSPLIT49 (Feb 2009) - Initialization
Calculation Started ... please be patient
Percent complete:   4.2
Percent complete:   8.3
Percent complete:  12.5
Percent complete:  16.7
Percent complete:  20.8
Percent complete:  25.0
Percent complete:  29.2
Percent complete:  33.3
Percent complete:  37.5
Percent complete:  41.7
Percent complete:  45.8
Percent complete:  50.0
Percent complete:  54.2
Percent complete:  58.3
Percent complete:  62.5
Percent complete:  66.7
Percent complete:  70.8
Percent complete:  75.0
Percent complete:  79.2
Percent complete:  83.3
Percent complete:  87.5
Percent complete:  91.7
Percent complete:  95.8
Percent complete: 100.0
Complete Hysplit
Started Trajectory Drawing (Version: February 2009)
Complete Trajplot
C:\hysplit4\working_03>dir
 Volume in drive C has no label.
 Volume Serial Number is AC24-774F

 Directory of C:\hysplit4\working_03

08/21/2009  09:07 PM    <DIR>          .
08/21/2009  09:07 PM    <DIR>          ..
08/21/2009  09:07 PM               157 control
08/21/2009  09:07 PM               157 CONTROL.txt
08/21/2009  09:07 PM            22,304 HYSPLITtraj_ps_01.kml
08/21/2009  09:07 PM             8,244 MESSAGE
08/21/2009  09:07 PM             2,539 tdump
08/21/2009  09:07 PM               298 TRAJ.CFG
08/21/2009  09:07 PM            76,992 trajplot.ps
08/21/2009  09:06 PM             1,391 TRAJ_RUN_03.bat
08/21/2009  08:51 PM             1,391 TRAJ_RUN_03.bat.bak
               9 File(s)        113,473 bytes
               2 Dir(s)  114,866,348,032 bytes free
```

"Hands On"
HYSPLIT Modeling
Exercise #4

Running and Mapping a Single Back-Trajectory with a DOS Batch File with Replaceable Parameters

```
@ECHO OFF

rem parameter #1: start year (UTC)
rem parameter #2: start month (UTC)
rem parameter #3: start day (UTC)
rem parameter #4: start hour (UTC)
rem parameter #5: run name
rem parameter #6: metfile_1
rem parameter #7: metfile_2
rem parameter #8: metfile_3

rem starting time
ECHO %1 %2 %3 %4              > CONTROL.txt
rem number of starting locations
ECHO 1                       >> CONTROL.txt
rem lat, long, height of start location
ECHO 20.25 -103.05 200.0  >> CONTROL.txt
rem number of hours to run trajectory
ECHO -24                    >> CONTROL.txt
rem vertical motion option
rem      (0:data 1:isob 2:isen 3:dens 4:sigma 5:diverg 6:eta)
ECHO 0                      >> CONTROL.txt
rem model top
ECHO 10000.0                >> CONTROL.txt
```

```
rem number of meteorological data files
ECHO 3                          >> CONTROL.txt
rem location and name of first met file
ECHO C:/hysplit4/metdata/ >> CONTROL.txt
ECHO %6                         >> CONTROL.txt
rem location and name of second met file
ECHO C:/hysplit4/metdata/ >> CONTROL.txt
ECHO %7                         >> CONTROL.txt
rem location and name of third met file
ECHO C:/hysplit4/metdata/ >> CONTROL.txt
ECHO %8                         >> CONTROL.txt
rem location and name of trajectory endpoints output file
ECHO ./                         >> CONTROL.txt
ECHO tdump.txt                  >> CONTROL.txt
rem delete earlier CONTROL if present
del CONTROL.
rem copy new file to "control"
rename CONTROL.txt control.
rem run hysplit trajectory model, using "control."
..\exec\hyts_std.exe
rem run trajplot to map the trajectory
..\exec\trajplot -itdump -a3 -v1
```

```
rem now rename all files with run name identifier
rename tdump.txt %5.tdp
rename message. %5.msg
rename trajplot.ps %5.ps
rename control. %5.ctl
rename HYSPLITtraj_ps_01.kml %5.kml
rename TRAJ.CFG %5.cfg

rem now create folder for key files
mkdir temp

rem now move all key files into this folder
move %5.* temp

rem now rename folder to run name
rename temp %5
```

TRAJ_RUN_04.bat

```
call TRAJ_SET_04
8   08   03   15
LC_UTC_2008_08_03_15
edas.jul08.002
edas.aug08.001
edas.aug08.002
```

```
rem parameter #1: start year (UTC)
rem parameter #2: start month (UTC)
rem parameter #3: start day (UTC)
rem parameter #4: start hour (UTC)
rem parameter #5: run name
rem parameter #6: metfile_1
rem parameter #7: metfile_2
rem parameter #8: metfile_3
```

Start year   **Start month**   **Start day**   **Start hour**

"run name"

Meteorological data file #2

```
call TRAJ_SET_04  08  08  03  15  LC_n0001_UTC_2008_08_03_15  edas.jul08.002  edas.aug08.001  edas.aug08.002
```

Meteorological data file #1

Meteorological data file #3
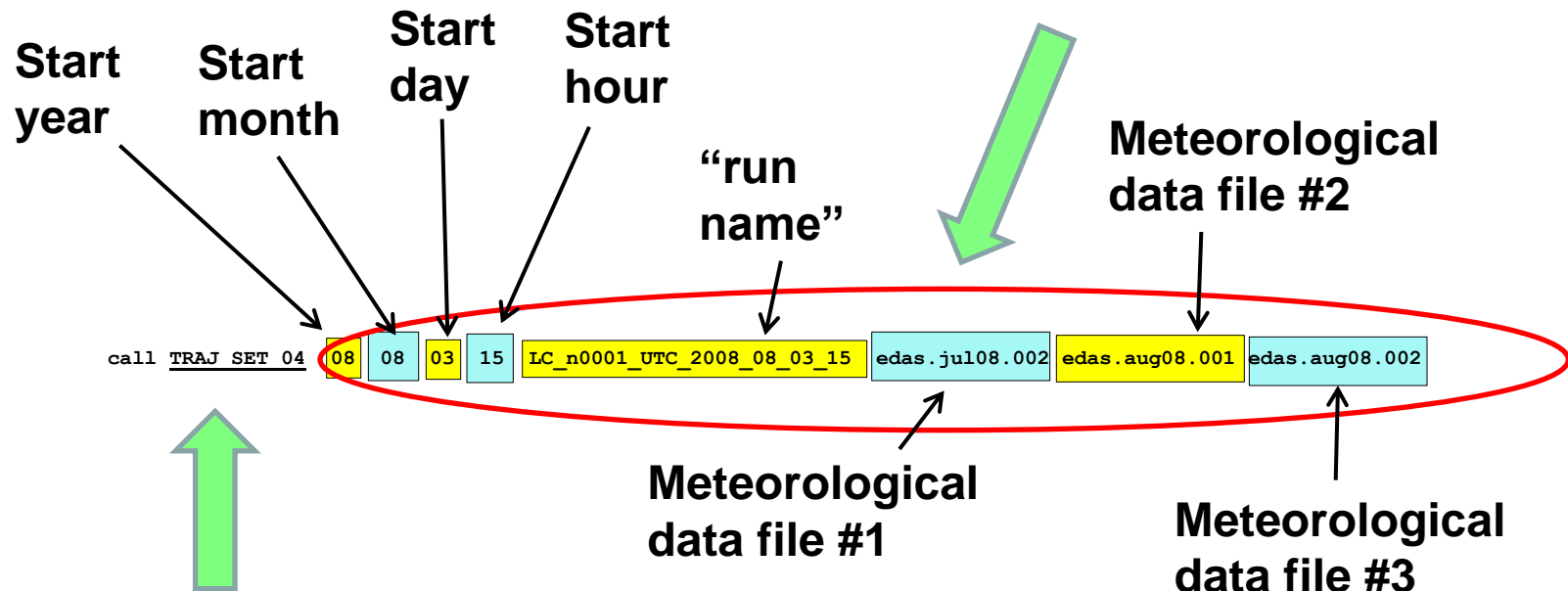
TRAJ_SET_04 is the batch file we were just discussing

It is "called" from the batch file: TRAJ_RUN_04.bat

Type "TRAJ_RUN_04" at the command prompt in working_04, and the batch file does everything!


```
C:\hysplit4\working_04>TRAJ_RUN_04

C:\hysplit4\working_04>call TRAJ_SET_04  08  08  03  15  LC_UTC_2008_08_03_15 ed
02
Could Not Find C:\hysplit4\working_04\CONTROL.
 HYSPLIT49 (Feb 2009) - Initialization
 Calculation Started ... please be patient
 Percent complete:    4.2
 Percent complete:    8.3
 Percent complete:   12.5
 Percent complete:   16.7
 Percent complete:   20.8
 Percent complete:   25.0
 Percent complete:   29.2
 Percent complete:   33.3
 Percent complete:   37.5
 Percent complete:   41.7
 Percent complete:   45.8
 Percent complete:   50.0
 Percent complete:   54.2
 Percent complete:   58.3
 Percent complete:   62.5
 Percent complete:   66.7
 Percent complete:   70.8
 Percent complete:   75.0
 Percent complete:   79.2
 Percent complete:   83.3
 Percent complete:   87.5
 Percent complete:   91.7
 Percent complete:   95.8
 Percent complete:  100.0
 Complete Hysplit
 Started Trajectory Drawing (Version: February 2009)
 Complete Trajplot
C:\hysplit4\working_04\LC_UTC_2008_08_03_15.cfg
C:\hysplit4\working_04\LC_UTC_2008_08_03_15.ctl
C:\hysplit4\working_04\LC_UTC_2008_08_03_15.kml
C:\hysplit4\working_04\LC_UTC_2008_08_03_15.msg
C:\hysplit4\working_04\LC_UTC_2008_08_03_15.ps
C:\hysplit4\working_04\LC_UTC_2008_08_03_15.tdp
C:\hysplit4\working_04>dir
 Volume in drive C has no label.
 Volume Serial Number is AC24-774F

 Directory of C:\hysplit4\working_04

08/21/2009  10:29 PM    <DIR>          .
08/21/2009  10:29 PM    <DIR>          ..
08/21/2009  03:50 AM               271 ASCDATA.CFG
08/21/2009  10:29 PM    <DIR>          LC_UTC_2008_08_03_15
08/21/2009  03:20 AM               793 stationplot.cfg
08/21/2009  10:29 PM                99 TRAJ_RUN_04.bat
08/21/2009  10:09 PM             1,838 TRAJ_SET_04.bat
               4 File(s)          3,001 bytes
               3 Dir(s)  114,865,123,328 bytes free

C:\hysplit4\working_04>
```
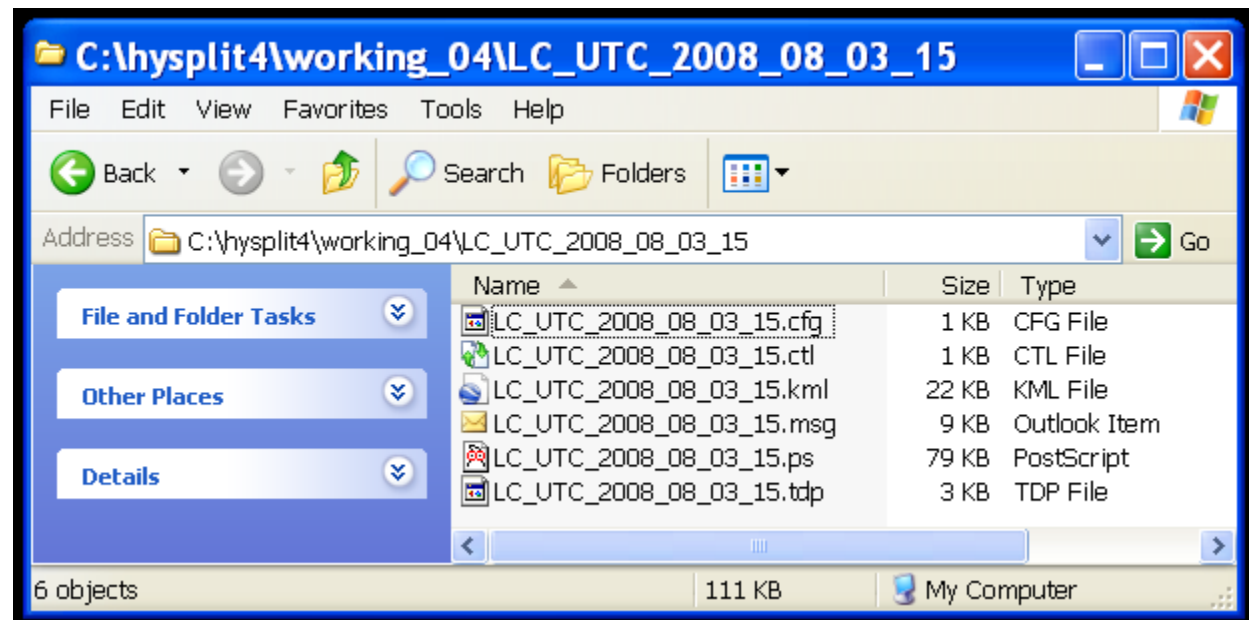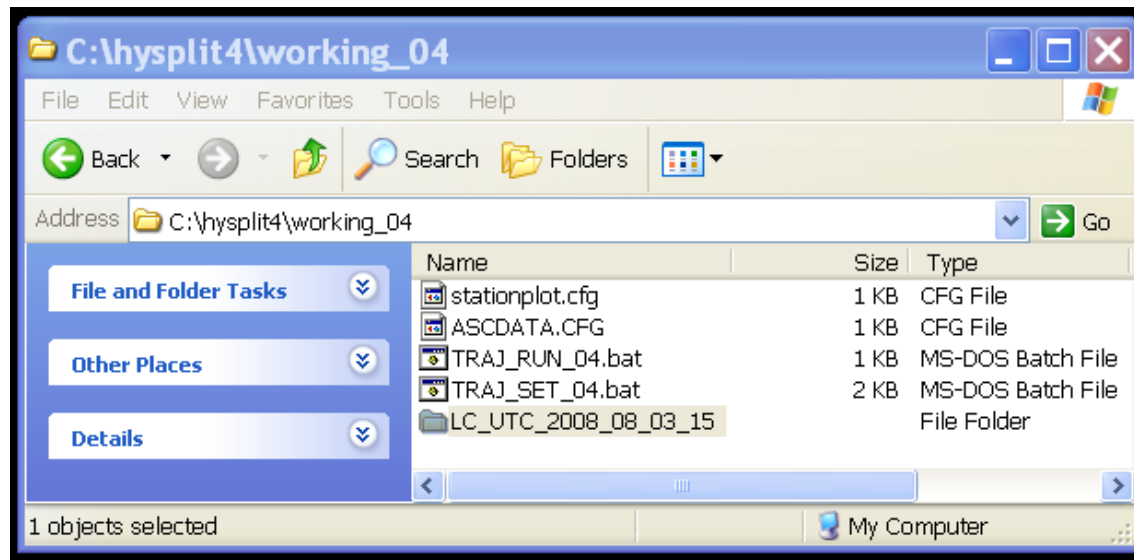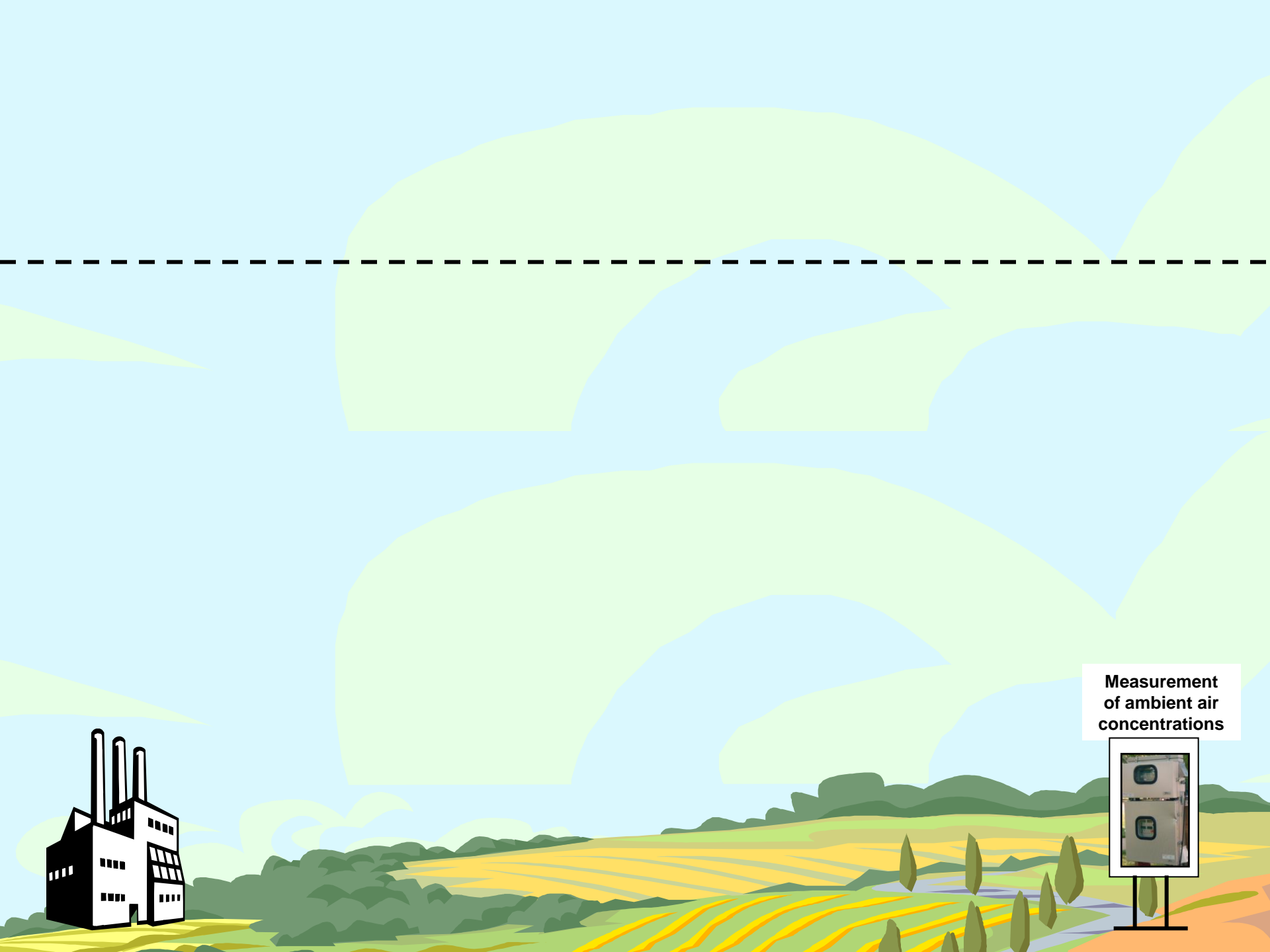
Measurement
of ambient air
concentrations

Greater than ~20km from the source,
if the forward trajectory from the source is within the PBL,
then the source can impact the measurement site,
even if the trajectory endpoint near the site is <u>not at the height of the sampler</u>…
This is because the PBL is relatively well-mixed during the day.

- - - - - - - - - Height of Planetary Boundary Layer (PBL) During the Day - - - - - - - - - - -

❑ **a forward trajectory is the "center line" of a plume**

❑ **horizontal & vertical dispersion around this center line**

Measurement of ambient air concentrations
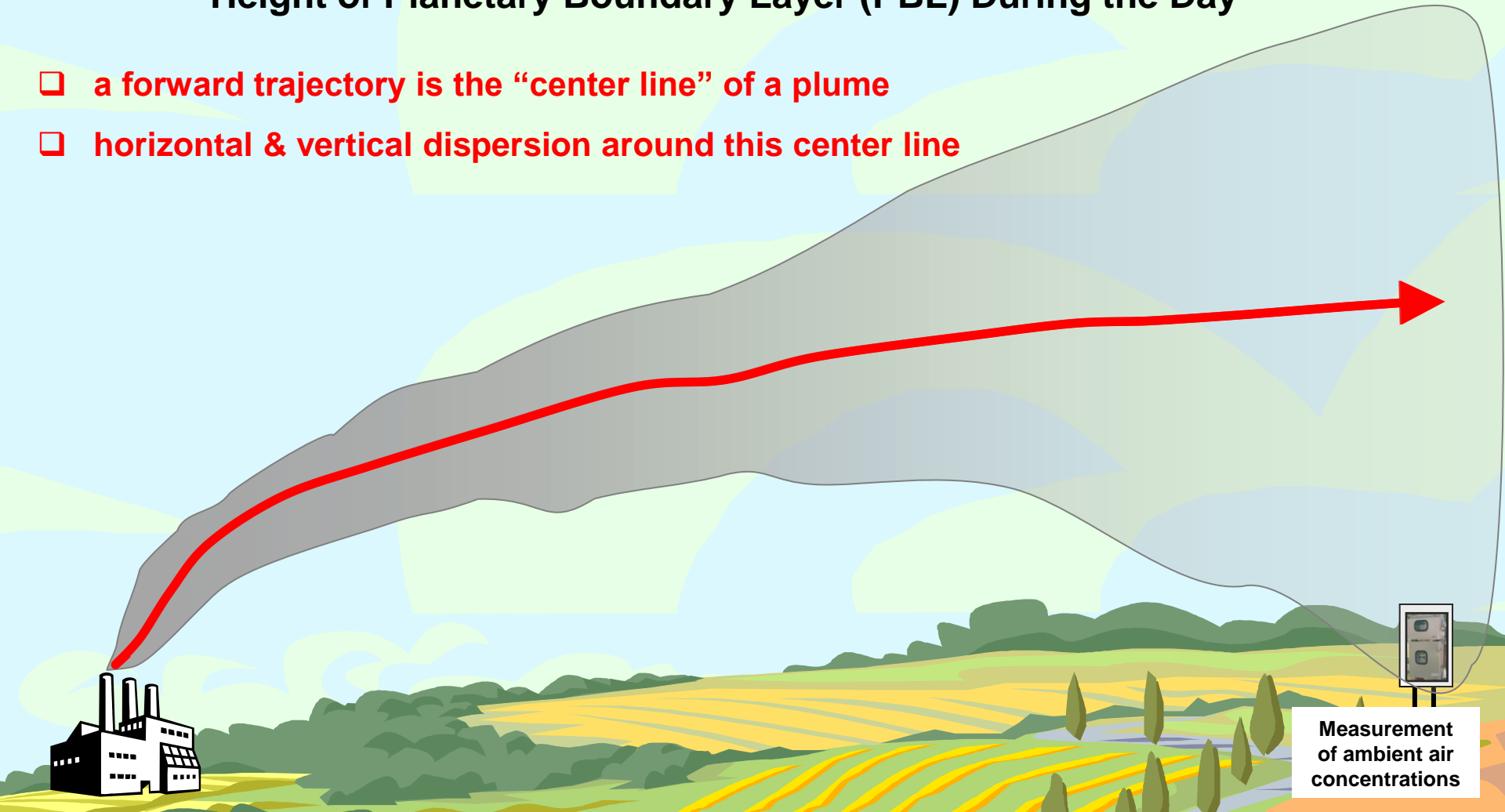
- **At night, the Planetary Boundary Layer (PBL) is generally much shallower**

- **Emissions from an elevated stack may be emitted above the PBL**

- **In this case, little or no impact on a ground-based measurement site until the next daytime period, when the boundary layer grows.**

Height of Planetary Boundary Layer (PBL) At Night

Measurement of ambient air concentrations
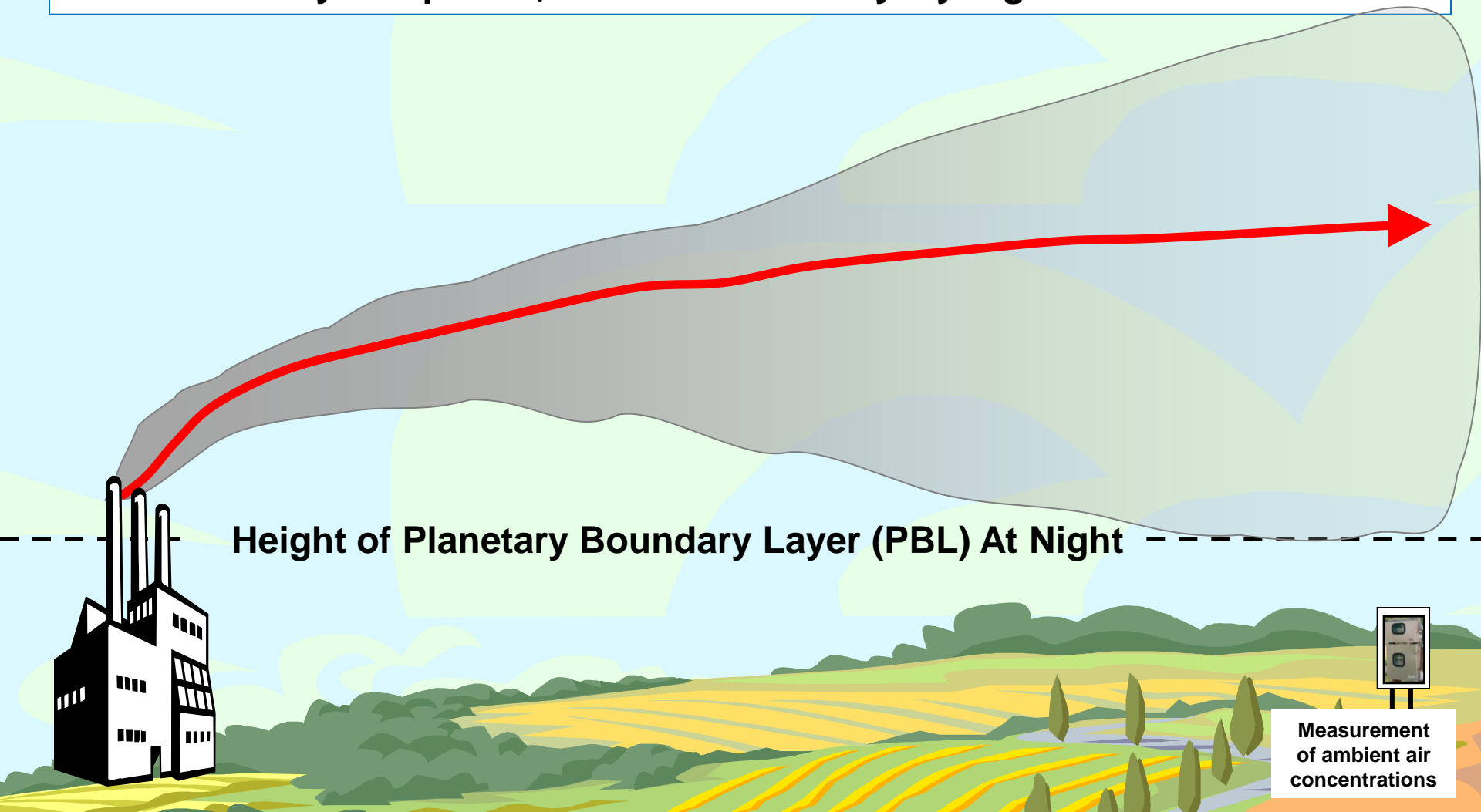
- At night, the Planetary Boundary Layer (PBL) is generally much shallower

- Emissions from an relatively low stack may be emitted within the PBL

- But, if the pollutant dry deposits relatively rapidly (e.g., reactive gaseous mercury ("RGM"), by the time the plume reaches the receptor, there may be little pollutant left…

Height of Planetary Boundary Layer (PBL) At Night

dry deposition can deplete near-ground plume

Measurement of ambient air concentrations
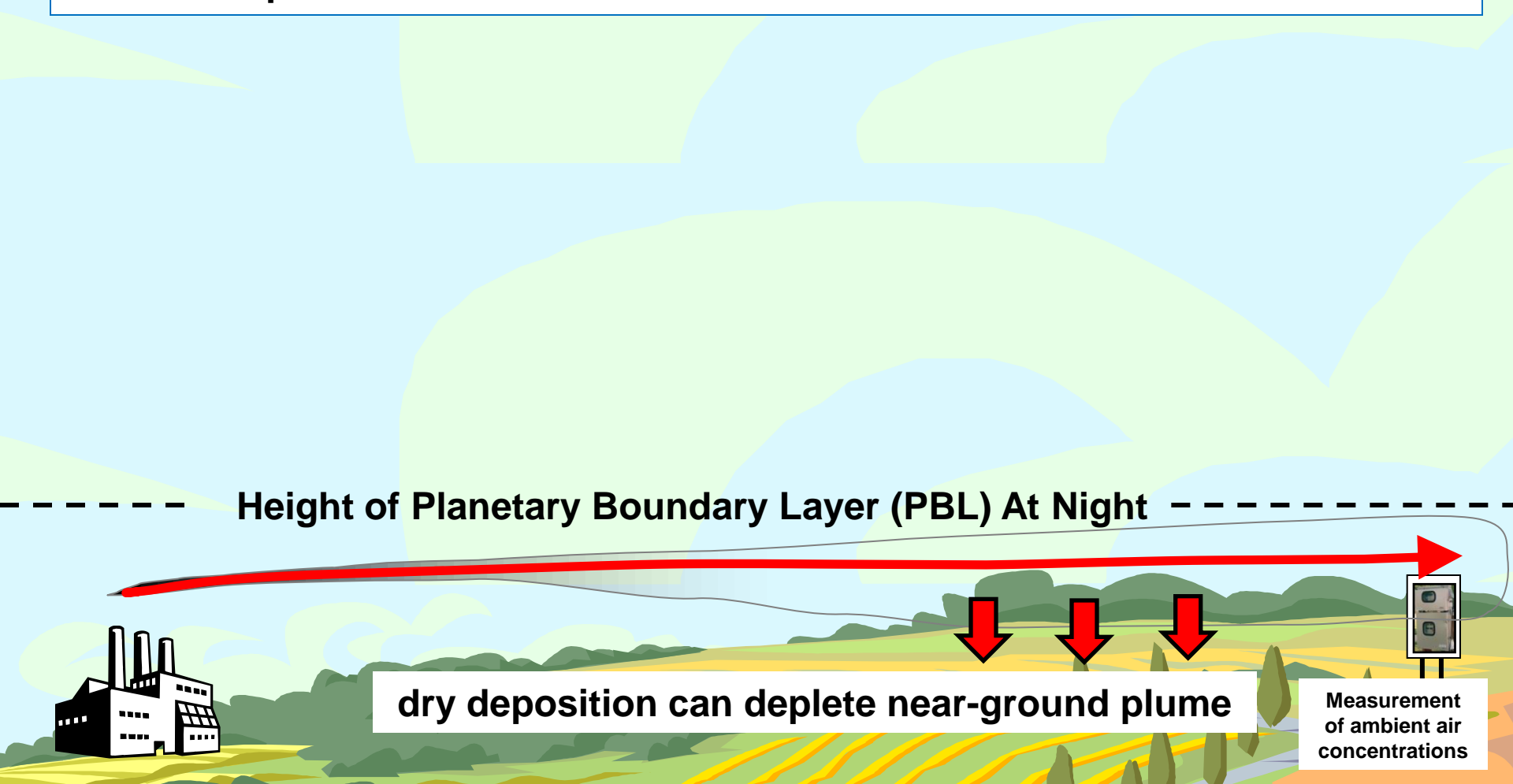
- ❑ **What are the implications of these ideas for back-trajectories?**

- ❑ **What HEIGHT should one start a back-trajectory?**

- ❑ **If you start very low to the ground, at the sampler height, the trajectory program does not work well… the trajectories hit the ground and stop**

- ❑ **"best" starting height for back-trajectories may be from the middle of the Planetary Boundary Layer**

PBL Height

H = 0.5 * PBL

Measurement of ambient air concentrations
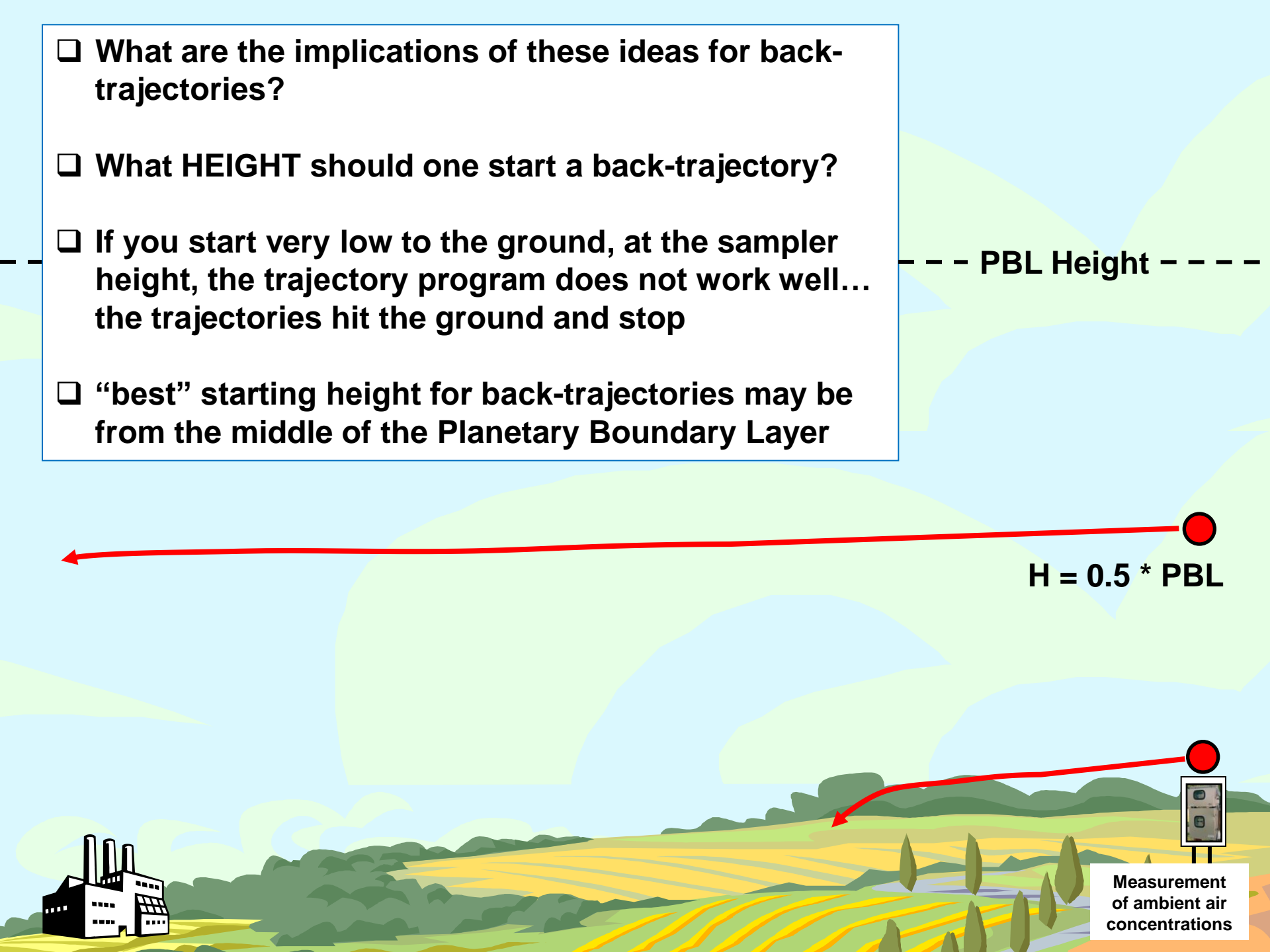
"Hands On" HYSPLIT Modeling Exercise #5

Running and Mapping a Multiple Back-Trajectories with a DOS Batch File with Replaceable Parameters with <u>variations in the SETUP.CFG file, e.g., specifying starting height as fraction of the Planetary Boundary Layer</u>

```
setup_cfg_frac_pbl.txt

 &SETUP
KMSL=2
/
```

- ❑ IF SETUP.CFG Namelist file is present, then HYSPLIT will use it.

- ❑ If not, then HYSPLIT will just use DEFAULT values for these parameters

- ❑ The SETUP.CFG file contains parameters that are less frequently changed, as opposed to the CONTROL file which contains more basic run information

We will add the following statement into the "set" batch file:

```
copy setup_cfg_frac_pbl.txt  setup.cfg
```

And then specify heights as fraction of boundary layer, e.g., 0.5

These are new elements of the TRAJ_SET file,
now in TRAJ_SET_05.bat
The rest of the batch file is essentially the same

```
del setup.cfg
copy setup_cfg_frac_pbl.txt setup.cfg

rem starting time
ECHO %1 %2 %3 %4                    > CONTROL.txt

rem number of starting locations
ECHO 5                            >> CONTROL.txt

rem lat, long, fraction pbl of each start location
ECHO 20.25 -103.05 0.1  >> CONTROL.txt
ECHO 20.25 -103.05 0.3  >> CONTROL.txt
ECHO 20.25 -103.05 0.5  >> CONTROL.txt
ECHO 20.25 -103.05 0.7  >> CONTROL.txt
ECHO 20.25 -103.05 0.9  >> CONTROL.txt
```

The "run" batch file that calls this "set" file is the same

```
 Command Prompt (2)                                                    _ □ ✕

C:\hysplit4\working_05>
C:\hysplit4\working_05>TRAJ_RUN_05

C:\hysplit4\working_05>call TRAJ_SET_05  08  08  03  15  w5_UTC_2008_08_03_15 edas.jul
02
Could Not Find C:\hysplit4\working_05\setup.cfg
        1 file(s) copied.
Could Not Find C:\hysplit4\working_05\CONTROL.
 HYSPLIT49 (Feb 2009) - Initialization
  NOTICE: using namelist file
 SETUP.CFG

 Calculation Started ... please be patient
 Percent complete:    4.2
 Percent complete:    8.3
 Percent complete:   12.5
 Percent complete:   16.7
 Percent complete:   20.8
 Percent complete:   25.0
 Percent complete:   29.2
 Percent complete:   33.3
 Percent complete:   37.5
 Percent complete:   41.7
 Percent complete:   45.8
 Percent complete:   50.0
 Percent complete:   54.2
 Percent complete:   58.3
 Percent complete:   62.5
 Percent complete:   66.7
 Percent complete:   70.8
 Percent complete:   75.0
 Percent complete:   79.2
 Percent complete:   83.3
 Percent complete:   87.5
 Percent complete:   91.7
 Percent complete:   95.8
 Percent complete:  100.0
 Complete Hysplit
 Started Trajectory Drawing (Version: February 2009)
 Complete Trajplot
C:\hysplit4\working_05\w5_UTC_2008_08_03_15.cfg
C:\hysplit4\working_05\w5_UTC_2008_08_03_15.ctl
C:\hysplit4\working_05\w5_UTC_2008_08_03_15.kml
C:\hysplit4\working_05\w5_UTC_2008_08_03_15.msg
C:\hysplit4\working_05\w5_UTC_2008_08_03_15.ps
C:\hysplit4\working_05\w5_UTC_2008_08_03_15.sfg
C:\hysplit4\working_05\w5_UTC_2008_08_03_15.tdp
C:\hysplit4\working_05>
```

NOAA HYSPLIT MODEL
Backward trajectories ending at 1500 UTC 03 Aug 08
EDAS Meteorological Data
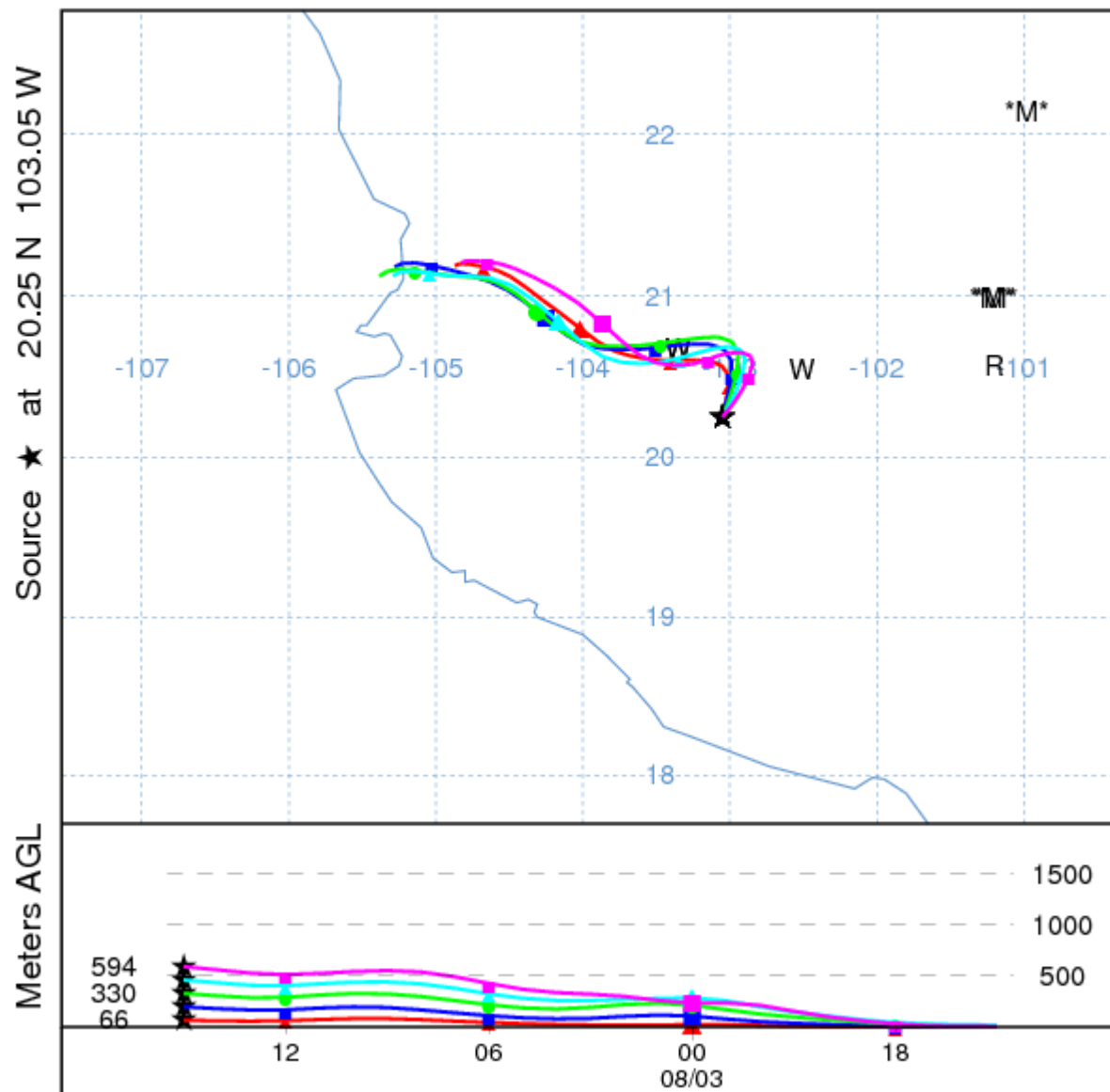
"Hands On"
HYSPLIT Modeling
Exercise #6

Running and Mapping a Multiple Back-Trajectories with a DOS Batch File with Replaceable Parameters with variations in the SETUP.CFG file, e.g., specifying starting height as fraction of the Planetary Boundary Layer, <u>with a range of starting times</u> <u>(in this example, each hour of one day)</u>

```
mkdir results

call TRAJ_SET_06  08  08  03  01  w6_n001_UTC_2008_08_03_01  edas.jul08.002 edas.aug08.001 edas.aug08.002
call TRAJ_SET_06  08  08  03  02  w6_n002_UTC_2008_08_03_02  edas.jul08.002 edas.aug08.001 edas.aug08.002
call TRAJ_SET_06  08  08  03  03  w6_n003_UTC_2008_08_03_03  edas.jul08.002 edas.aug08.001 edas.aug08.002
call TRAJ_SET_06  08  08  03  04  w6_n004_UTC_2008_08_03_04  edas.jul08.002 edas.aug08.001 edas.aug08.002
call TRAJ_SET_06  08  08  03  05  w6_n005_UTC_2008_08_03_05  edas.jul08.002 edas.aug08.001 edas.aug08.002
call TRAJ_SET_06  08  08  03  06  w6_n006_UTC_2008_08_03_06  edas.jul08.002 edas.aug08.001 edas.aug08.002
call TRAJ_SET_06  08  08  03  07  w6_n007_UTC_2008_08_03_07  edas.jul08.002 edas.aug08.001 edas.aug08.002
call TRAJ_SET_06  08  08  03  08  w6_n008_UTC_2008_08_03_08  edas.jul08.002 edas.aug08.001 edas.aug08.002
call TRAJ_SET_06  08  08  03  09  w6_n009_UTC_2008_08_03_09  edas.jul08.002 edas.aug08.001 edas.aug08.002
call TRAJ_SET_06  08  08  03  10  w6_n010_UTC_2008_08_03_10  edas.jul08.002 edas.aug08.001 edas.aug08.002
call TRAJ_SET_06  08  08  03  11  w6_n011_UTC_2008_08_03_11  edas.jul08.002 edas.aug08.001 edas.aug08.002
call TRAJ_SET_06  08  08  03  12  w6_n012_UTC_2008_08_03_12  edas.jul08.002 edas.aug08.001 edas.aug08.002
call TRAJ_SET_06  08  08  03  13  w6_n013_UTC_2008_08_03_13  edas.jul08.002 edas.aug08.001 edas.aug08.002
call TRAJ_SET_06  08  08  03  14  w6_n014_UTC_2008_08_03_14  edas.jul08.002 edas.aug08.001 edas.aug08.002
call TRAJ_SET_06  08  08  03  15  w6_n015_UTC_2008_08_03_15  edas.jul08.002 edas.aug08.001 edas.aug08.002
call TRAJ_SET_06  08  08  03  16  w6_n016_UTC_2008_08_03_16  edas.jul08.002 edas.aug08.001 edas.aug08.002
call TRAJ_SET_06  08  08  03  17  w6_n017_UTC_2008_08_03_17  edas.jul08.002 edas.aug08.001 edas.aug08.002
call TRAJ_SET_06  08  08  03  18  w6_n018_UTC_2008_08_03_18  edas.jul08.002 edas.aug08.001 edas.aug08.002
call TRAJ_SET_06  08  08  03  19  w6_n019_UTC_2008_08_03_19  edas.jul08.002 edas.aug08.001 edas.aug08.002
call TRAJ_SET_06  08  08  03  20  w6_n020_UTC_2008_08_03_20  edas.jul08.002 edas.aug08.001 edas.aug08.002
call TRAJ_SET_06  08  08  03  21  w6_n021_UTC_2008_08_03_21  edas.jul08.002 edas.aug08.001 edas.aug08.002
call TRAJ_SET_06  08  08  03  22  w6_n022_UTC_2008_08_03_22  edas.jul08.002 edas.aug08.001 edas.aug08.002
call TRAJ_SET_06  08  08  03  23  w6_n023_UTC_2008_08_03_23  edas.jul08.002 edas.aug08.001 edas.aug08.002
call TRAJ_SET_06  08  08  03  24  w6_n024_UTC_2008_08_03_24  edas.jul08.002 edas.aug08.001 edas.aug08.002

copy organize.bat results
cd results
organize
```

Changes to "set" batch file

```
rem changing duration to -48 hours
ECHO -48                          >> CONTROL.txt
```

```
rem will add arguments to try to keep projection fixed
rem so each map can be compared more easily
rem and also adding shapefiles for better map background
rem -g0:200
rem  -h20.0:-103.0
rem -jshapefiles.txt
..\exec\trajplot -itdump.txt -a3 -g0:200 -h20.0:-103.0 -v1
-jshapefiles.txt
```

```
rem mkdir temp
rem move %5.* temp
rem rename temp %5
```

Statements now commented out, because:

```
move %5.* results
```

**Will be organizing things differently…
don't want one folder for each run,
But want one folder for each type of output file**

- ❑ Another mapping option is to specify a special pointer file, always called shapefiles.txt to replace the map background file arlmap in the -j command line option (see above).

- ❑ This file would contain the name of one or more shapefiles that can be used to create the map background.

- ❑ The line characteristics (spacing, thickness, color) can be specified for each shapefile following the format specified below:

- ❑ Record format: 'file.shp' dash thick red green blue
  file.shp = /dir/name of input shapefile in quotes
  dash = {0} for solid; {dashes}/in; <0 color fill
  thick = line thickness in inches (default = 0.0)
  Red Green Blue = RGB values (0.0 0.0 0.0 is black)

- ❑ Record example for default: 'arlmap.shp' 0 0.005 0.4 0.6 0.8

shapefiles.txt

```
'c:\hysplit4\shapefile_graphics\mexico_states.shp' 10 0.0001 1.0 0.0 0.0
'c:\hysplit4\shapefile_graphics\arlmap.shp' 0 0.1 0.0 0.0 0.0
'c:\hysplit4\shapefile_graphics\mexico_lakes.shp' -1 0.005 0.0 0.0 1.0
'c:\hysplit4\shapefile_graphics\mexico_rivers.shp' 0 0.005 0.0 0.0 1.0
```

Organize.bat

```
mkdir control
mkdir maps
mkdir tdump
mkdir google_earth
mkdir message
mkdir traj_cfg
mkdir setup_cfg

move *.ctl control
move *.ps maps
move *.tdp tdump
move *.kml google_earth
move *.msg message
move *.cfg traj_cfg
move *.sfg setup_cfg

cd..
```

- ❑ run traj_run_06 from working_06 folder

- ❑ for convenience of viewing, all the postscript maps have been combined into one pdf file in the working_06 folder

- ❑ Here are a few of the maps, for UTC = 1300, 1500, and 1700
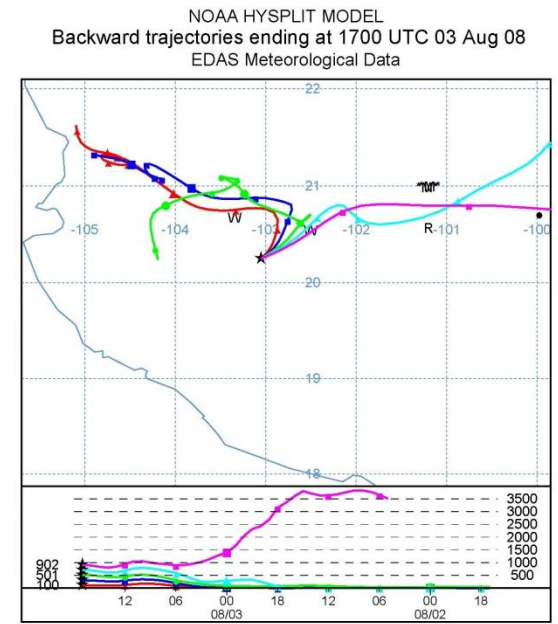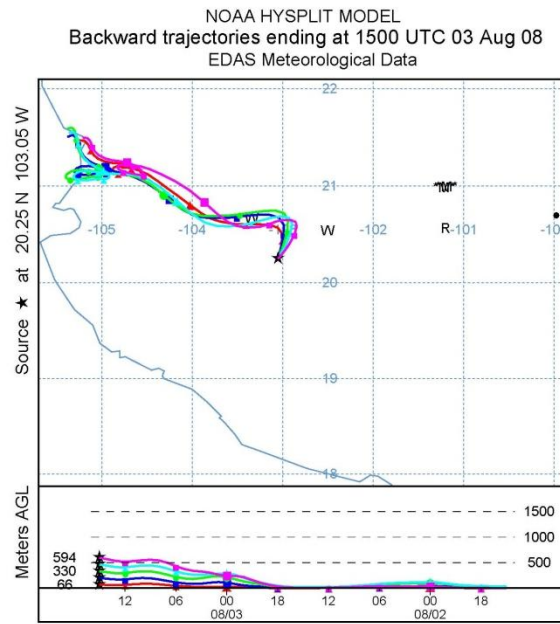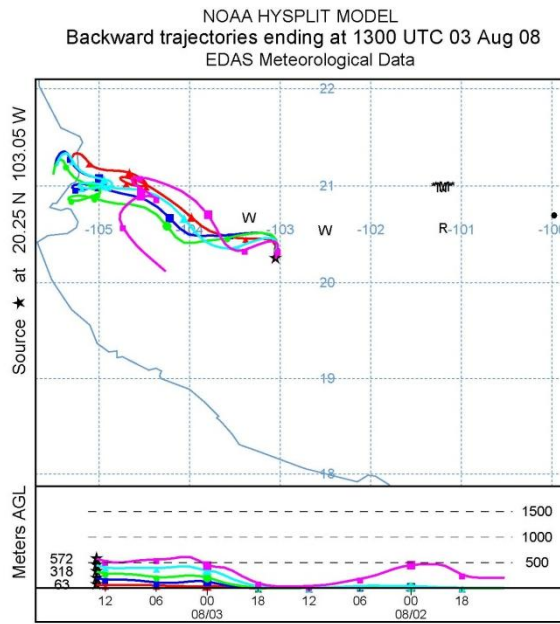
Some Additional Trajectory Examples

Episode Analysis

Beltsville Episode January 7, 2007

Sometimes, we see evidence of local and regional "plume" impacts

Back Trajectories Arriving at 1/07/2007 07:00 EST

Beltsville Mercury Monitoring Site

RGM (pg/m3)

100
80
60
40
20
0

07:30 08:30 09:30 10:30 11:30 12:30 13:30 14:30 15:30 16:30

January 7, 2007
(Eastern Standard Time)

Large sources of 1999 RGM (Reactive Gaseous Mercury) emissions (kg/yr) based on USEPA data from 1999 Nat'l Emissions Inventory

Size and shape of symbol denotes amount of RGM emitted (kg/yr)

△   5 - 10
○   10 - 50
△   50 - 100
□   100 - 300

Color of symbol denotes type of mercury source

coal-fired electricity generation
other fuel combustion
waste incineration
metallurgical processes
manufacturing/other

Back-trajectories starting at the indicated fraction of the mixed layer. height. Circles on the trajectories mark the hourly position of the trajectory.

0.1
0.3
0.5
0.7
0.9

10 0 10 20 30 40 50 Kilometers

N

urbanized areas

Sometimes, we see evidence of local and regional "plume" impacts

Back Trajectories Arriving at 1/07/2007 08:00 EST

Large sources of 1999 RGM (Reactive Gaseous Mercury) emissions (kg/yr) based on USEPA data from 1999 Nat'l Emissions Inventory

Size and shape of symbol denotes amount of RGM emitted (kg/yr)

△ 5 - 10
○ 10 - 50
△ 50 - 100
□ 100 - 300

Color of symbol denotes type of mercury source

coal-fired electricity generation
other fuel combustion
waste incineration
metallurgical processes
manufacturing/other

Back-trajectories starting at the indicated fraction of the mixed layer. height. Circles on the trajectories mark the hourly position of the trajectory.

0.1
0.3
0.5
0.7
0.9

urbanized areas

Beltsville Mercury Monitoring Site

RGM (pg/m3)

January 7, 2007
(Eastern Standard Time)

10 0 10 20 30 40 50 Kilometers

N

Sometimes, we see evidence of local and regional "plume" impacts

Back Trajectories Arriving at 1/07/2007 09:00 EST

Large sources of 1999 RGM (Reactive Gaseous Mercury) emissions (kg/yr) based on USEPA data from 1999 Nat'l Emissions Inventory

Size and shape of symbol denotes amount of RGM emitted (kg/yr)
△ 5 - 10
○ 10 - 50
△ 50 - 100
□ 100 - 300

Color of symbol denotes type of mercury source
coal-fired electricity generation
other fuel combustion
waste incineration
metallurgical processes
manufacturing/other

Back-trajectories starting at the indicated fraction of the mixed layer. height. Circles on the trajectories mark the hourly position of the trajectory.
0.1
0.3
0.5
0.7
0.9

urbanized areas

Beltsville Mercury Monitoring Site

RGM (pg/m3)
100
80
60
40
20
0

07:30 08:30 09:30 10:30 11:30 12:30 13:30 14:30 15:30 16:30

January 7, 2007
(Eastern Standard Time)

10 0 10 20 30 40 50 Kilometers

N

Sometimes, we see evidence of local and regional "plume" impacts

Back Trajectories Arriving at 1/07/2007 10:00 EST

RGM (pg/m3) chart with values on x-axis times (07:30, 08:30, 09:30, 10:30, 11:30, 12:30, 13:30, 14:30, 15:30, 16:30)

January 7, 2007
(Eastern Standard Time)

Beltsville Mercury Monitoring Site

Large sources of 1999 RGM (Reactive Gaseous Mercury) emissions (kg/yr) based on USEPA data from 1999 Nat'l Emissions Inventory

Size and shape of symbol denotes amount of RGM emitted (kg/yr)

△ 5 - 10
○ 10 - 50
△ 50 - 100
□ 100 - 300

Color of symbol denotes type of mercury source

- ■ coal-fired electricity generation
- ■ other fuel combustion
- ■ waste incineration
- ■ metallurgical processes
- ■ manufacturing/other

Back-trajectories starting at the indicated fraction of the mixed layer. height. Circles on the trajectories mark the hourly position of the trajectory.

- 0.1
- 0.3
- 0.5
- 0.7
- 0.9

10 0 10 20 30 40 50 Kilometers

N

urbanized areas

Sometimes, we see evidence of local and regional "plume" impacts

Back Trajectories Arriving at 1/07/2007 11:00 EST

Sometimes, we see evidence of local and regional "plume" impacts

Back Trajectories Arriving at 1/07/2007 12:00 EST

Large sources of 1999 RGM (Reactive Gaseous Mercury) emissions (kg/yr) based on USEPA data from 1999 Nat'l Emissions Inventory

Size and shape of symbol denotes amount of RGM emitted (kg/yr)

△ 5 - 10
○ 10 - 50
△ 50 - 100
□ 100 - 300

Color of symbol denotes type of mercury source

■ coal-fired electricity generation
■ other fuel combustion
■ waste incineration
■ metallurgical processes
■ manufacturing/other

Back-trajectories starting at the indicated fraction of the mixed layer. height. Circles on the trajectories mark the hourly position of the trajectory.

0.1
0.3
0.5
0.7
0.9

urbanized areas

Beltsville Mercury Monitoring Site

RGM (pg/m3)

100
80
60
40
20
0

07:30 08:30 09:30 10:30 11:30 12:30 13:30 14:30 15:30 16:30

January 7, 2007
(Eastern Standard Time)

10 0 10 20 30 40 50 Kilometers

N

Sometimes, we see evidence of local and regional "plume" impacts

Back Trajectories Arriving at 1/07/2007 13:00 EST

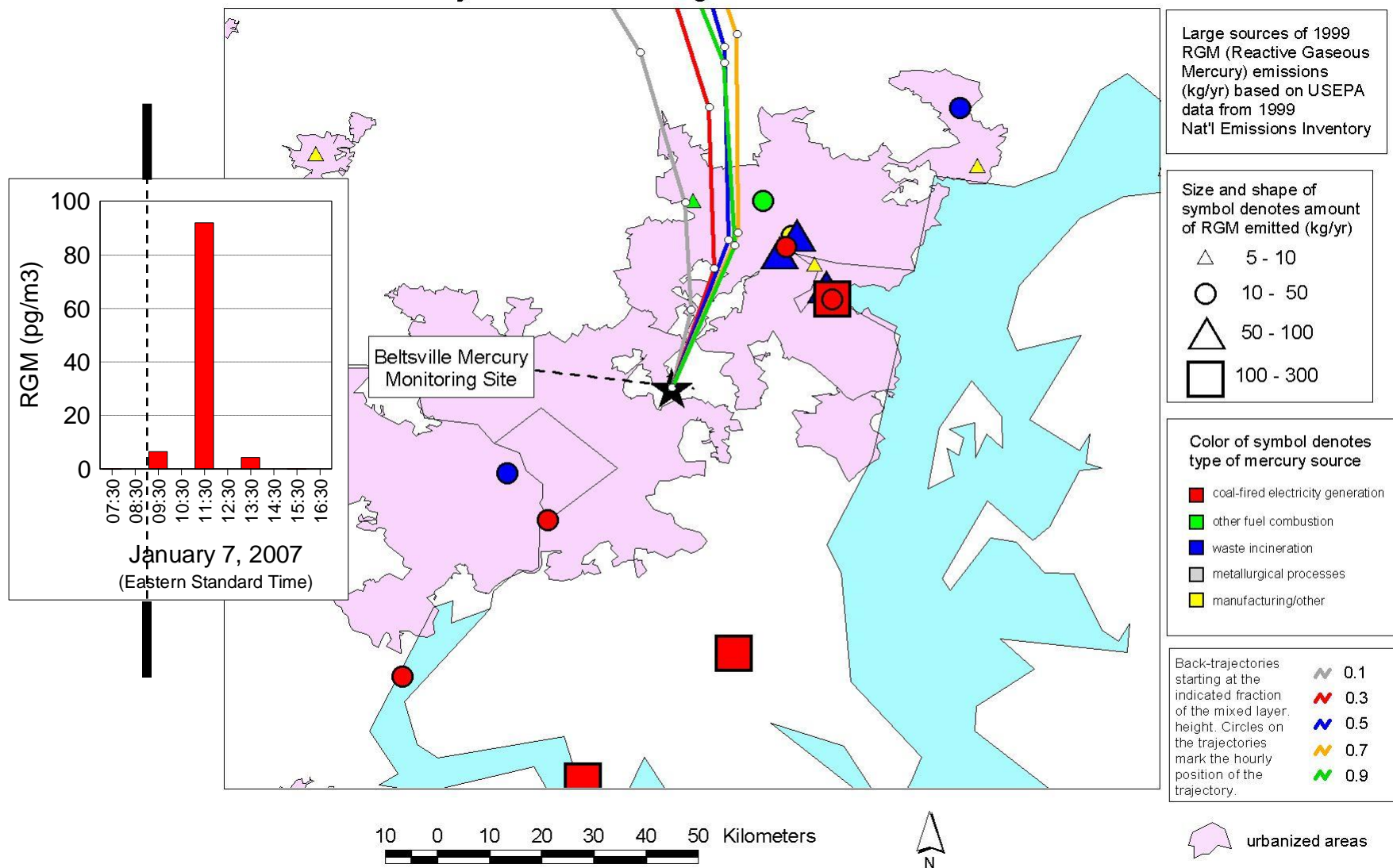Large sources of 1999 RGM (Reactive Gaseous Mercury) emissions (kg/yr) based on USEPA data from 1999 Nat'l Emissions Inventory

Size and shape of symbol denotes amount of RGM emitted (kg/yr)

△   5 - 10
○   10 - 50
△   50 - 100
□   100 - 300

Color of symbol denotes type of mercury source

■ coal-fired electricity generation
■ other fuel combustion
■ waste incineration
■ metallurgical processes
■ manufacturing/other

Back-trajectories starting at the indicated fraction of the mixed layer. height. Circles on the trajectories mark the hourly position of the trajectory.

0.1
0.3
0.5
0.7
0.9

Beltsville Mercury Monitoring Site

RGM (pg/m3)

100
80
60
40
20
0

07:30 08:30 09:30 10:30 11:30 12:30 13:30 14:30 15:30 16:30

January 7, 2007
(Eastern Standard Time)

10   0   10   20   30   40   50   Kilometers

N

urbanized areas

Sometimes, we see evidence of local and regional "plume" impacts

Sometimes, we see evidence of local and regional "plume" impacts

Back Trajectories Arriving at 1/07/2007 15:00 EST

RGM (pg/m3)

January 7, 2007
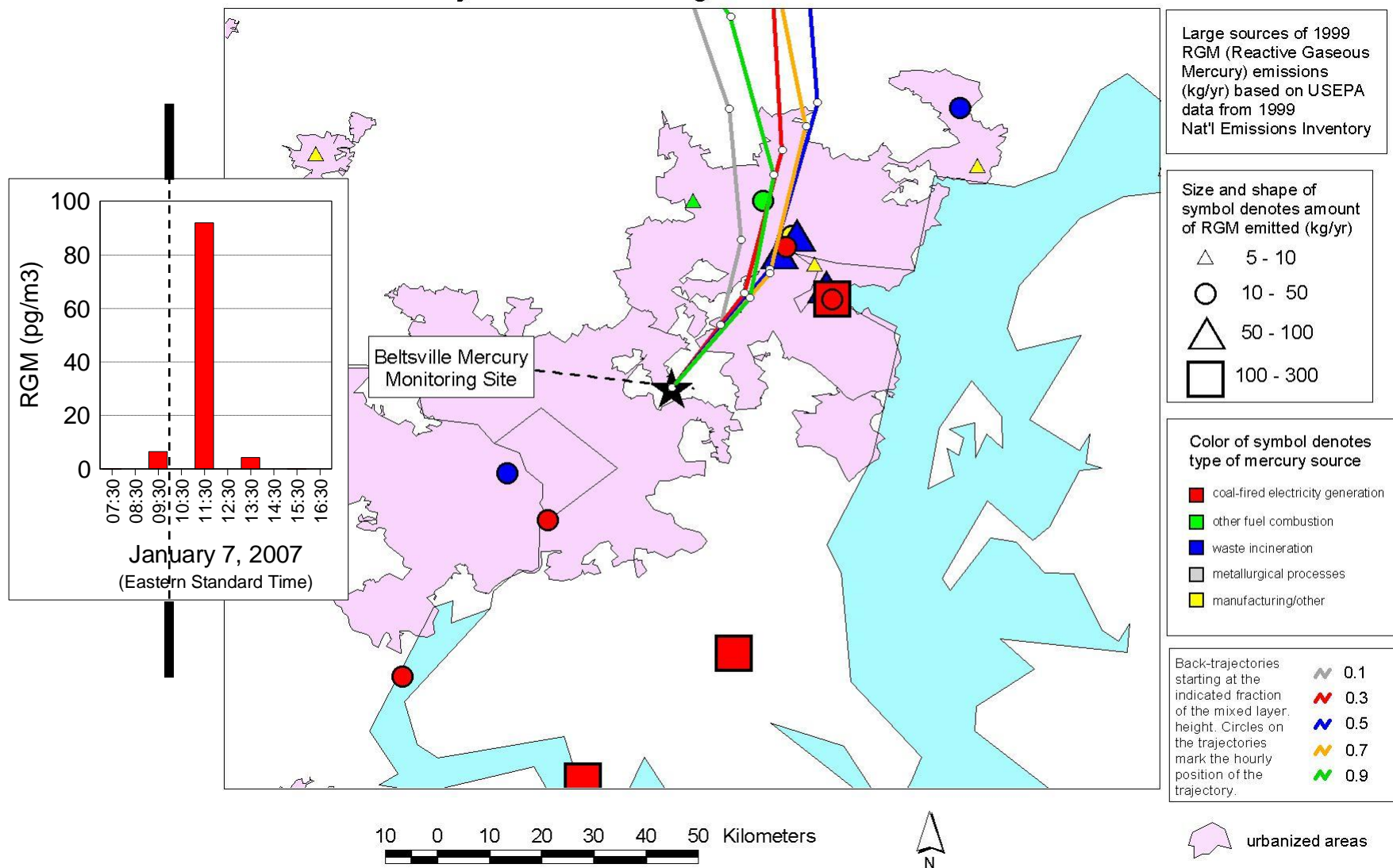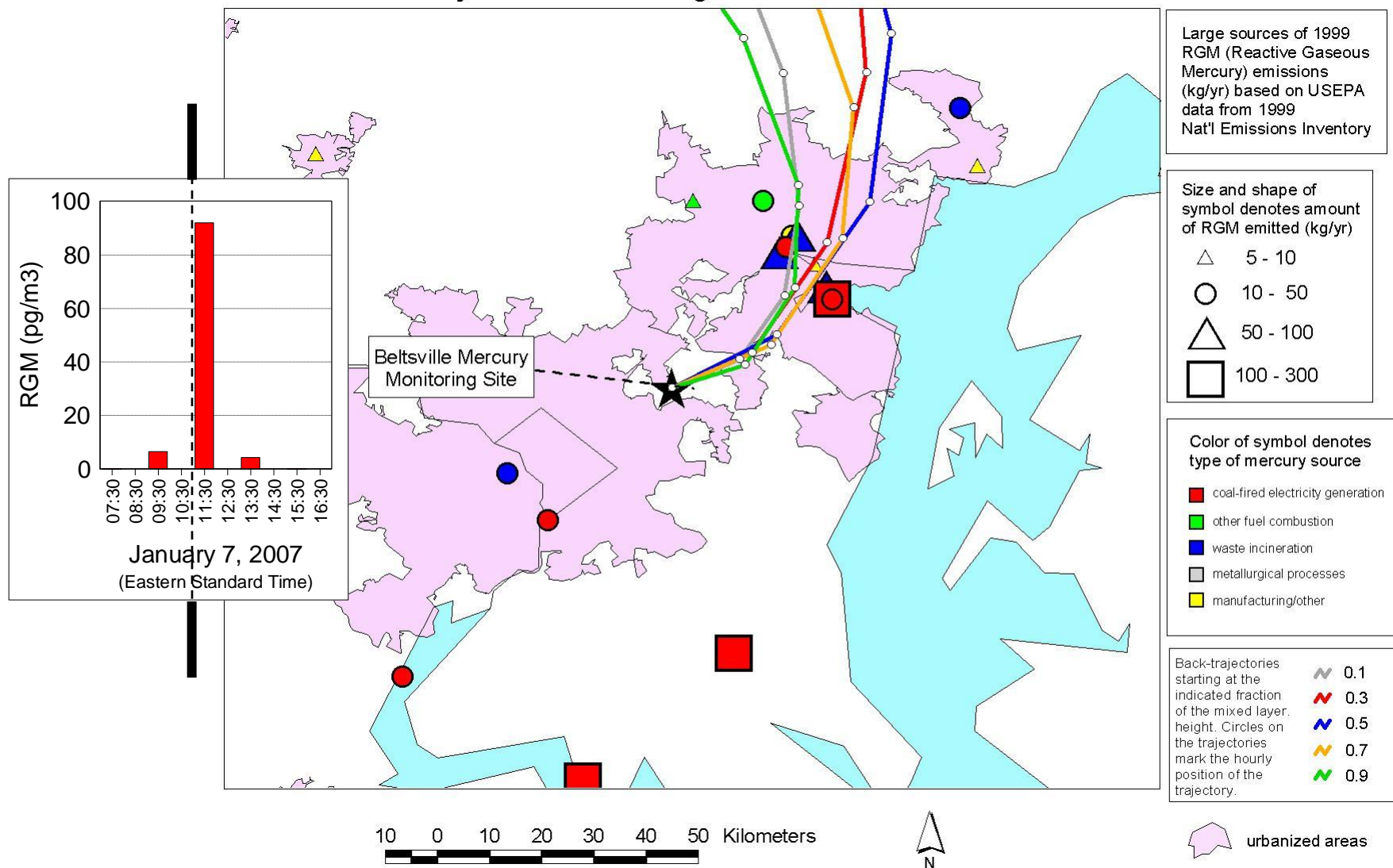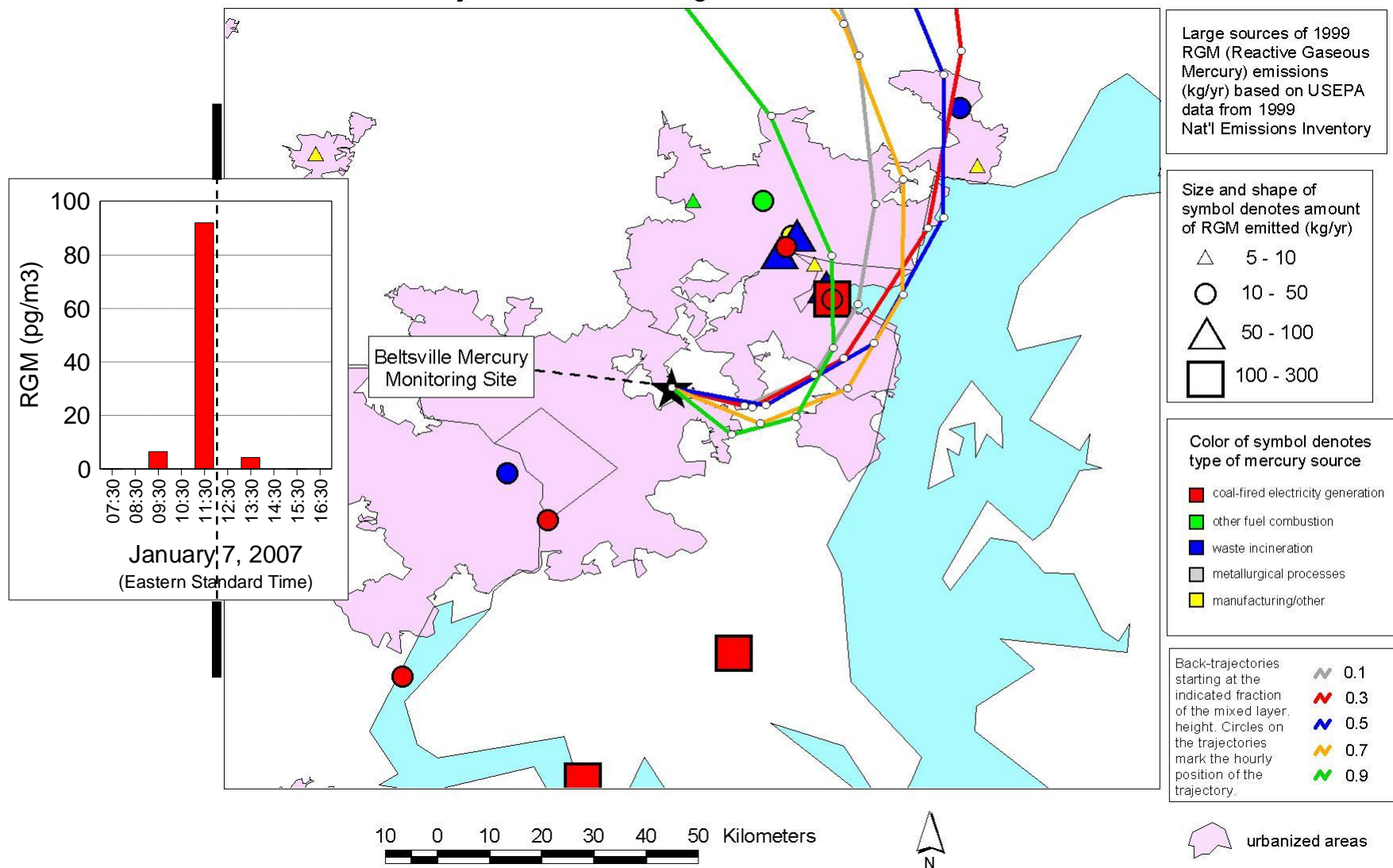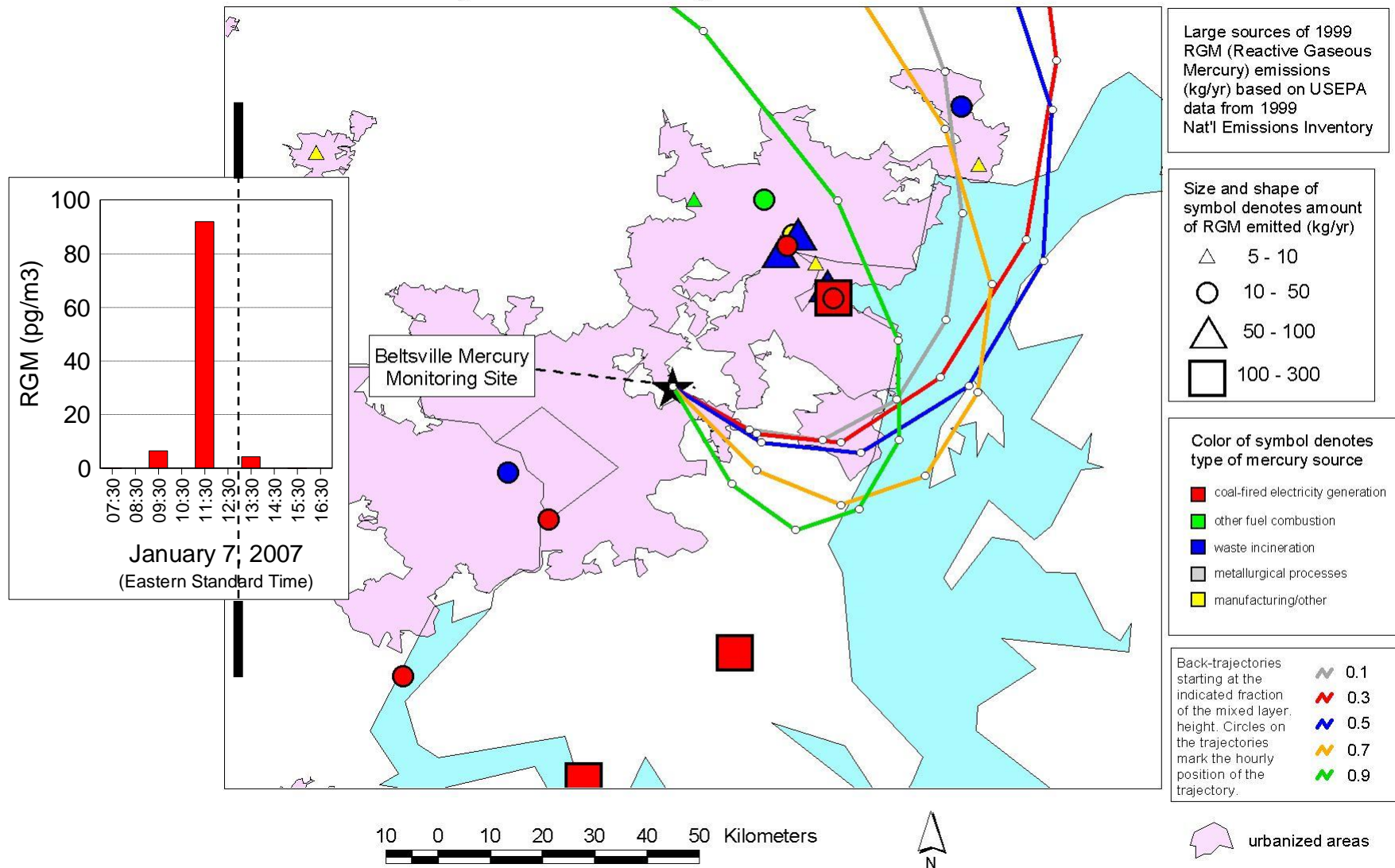(Eastern Standard Time)

Beltsville Mercury
Monitoring Site

Large sources of 1999
RGM (Reactive Gaseous
Mercury) emissions
(kg/yr) based on USEPA
data from 1999
Nat'l Emissions Inventory

Size and shape of
symbol denotes amount
of RGM emitted (kg/yr)

△   5 - 10

○   10 - 50

△   50 - 100

▢   100 - 300

Color of symbol denotes
type of mercury source

■ coal-fired electricity generation

■ other fuel combustion

■ waste incineration

■ metallurgical processes

■ manufacturing/other

Back-trajectories
starting at the
indicated fraction
of the mixed layer.
height. Circles on
the trajectories
mark the hourly
position of the
trajectory.

〰 0.1
〰 0.3
〰 0.5
〰 0.7
〰 0.9

10   0   10   20   30   40   50   Kilometers

N

urbanized areas

Sometimes, we see evidence of local and regional "plume" impacts
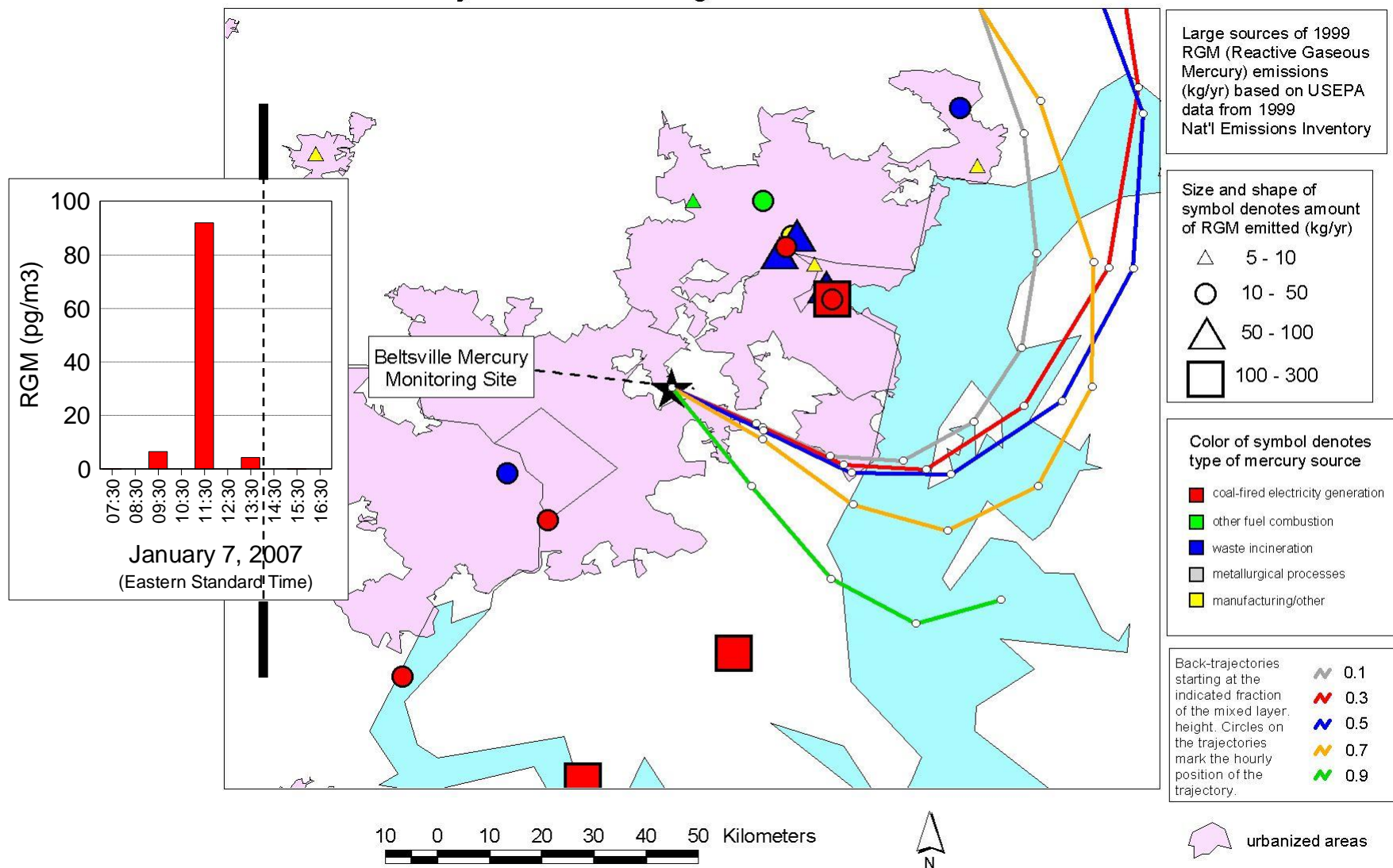
Back Trajectories Arriving at 1/07/2007 16:00 EST

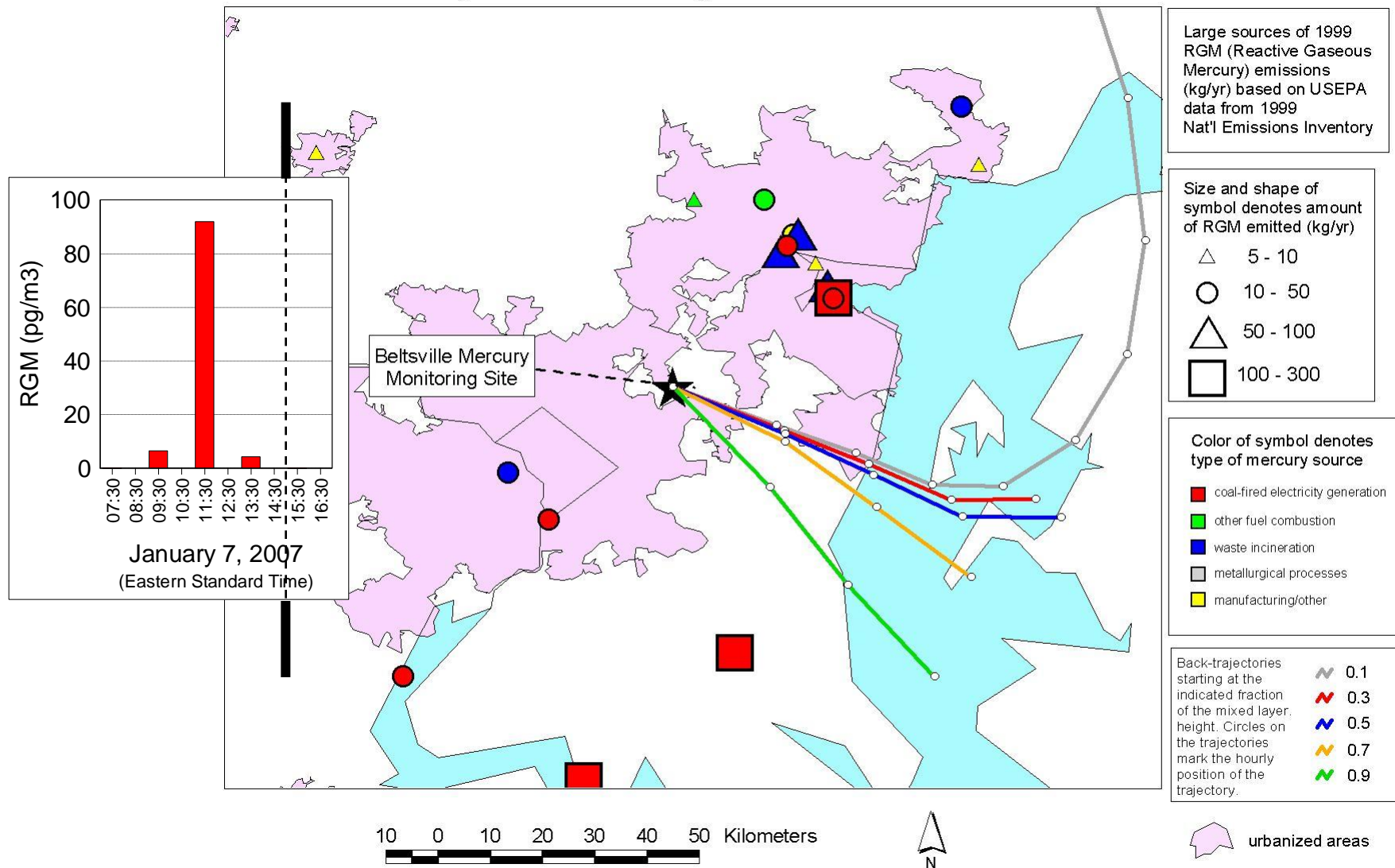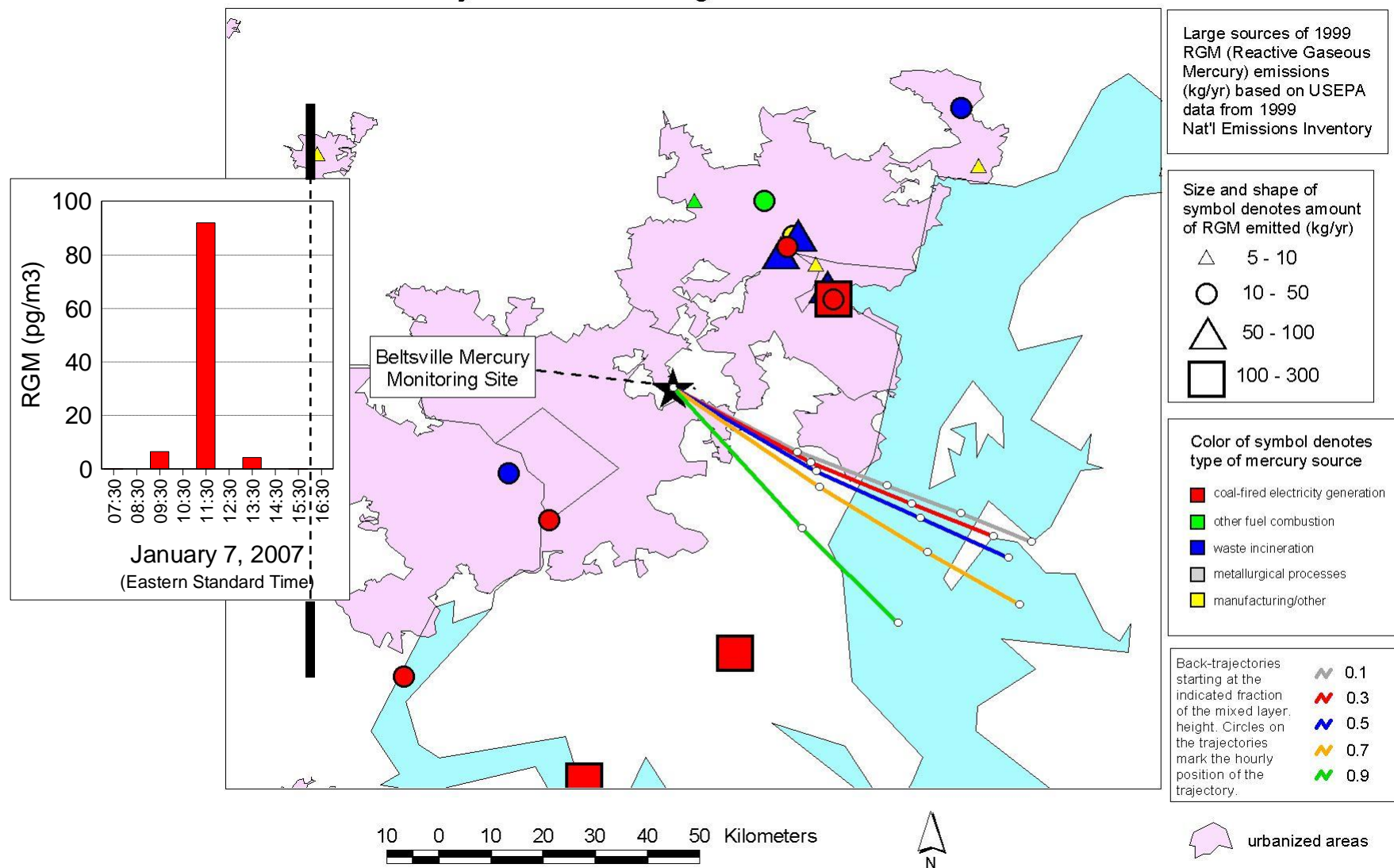Large sources of 1999 RGM (Reactive Gaseous Mercury) emissions (kg/yr) based on USEPA data from 1999 Nat'l Emissions Inventory

Size and shape of symbol denotes amount of RGM emitted (kg/yr)

△ 5 - 10

○ 10 - 50

△ 50 - 100

□ 100 - 300

Color of symbol denotes type of mercury source

■ coal-fired electricity generation

■ other fuel combustion

■ waste incineration

■ metallurgical processes

■ manufacturing/other

Back-trajectories starting at the indicated fraction of the mixed layer. height. Circles on the trajectories mark the hourly position of the trajectory.

0.1
0.3
0.5
0.7
0.9

urbanized areas

Beltsville Mercury Monitoring Site

RGM (pg/m3)

100
80
60
40
20
0

07:30 08:30 09:30 10:30 11:30 12:30 13:30 14:30 15:30 16:30

January 7, 2007
(Eastern Standard Time)

10 0 10 20 30 40 50 Kilometers

N

**Although sometimes we see elevated
RGM due to other factors**

❑ **oxidation of elemental mercury to form RGM**
(elemental mercury may be from "global background")

❑ **atmospheric mixing processes**
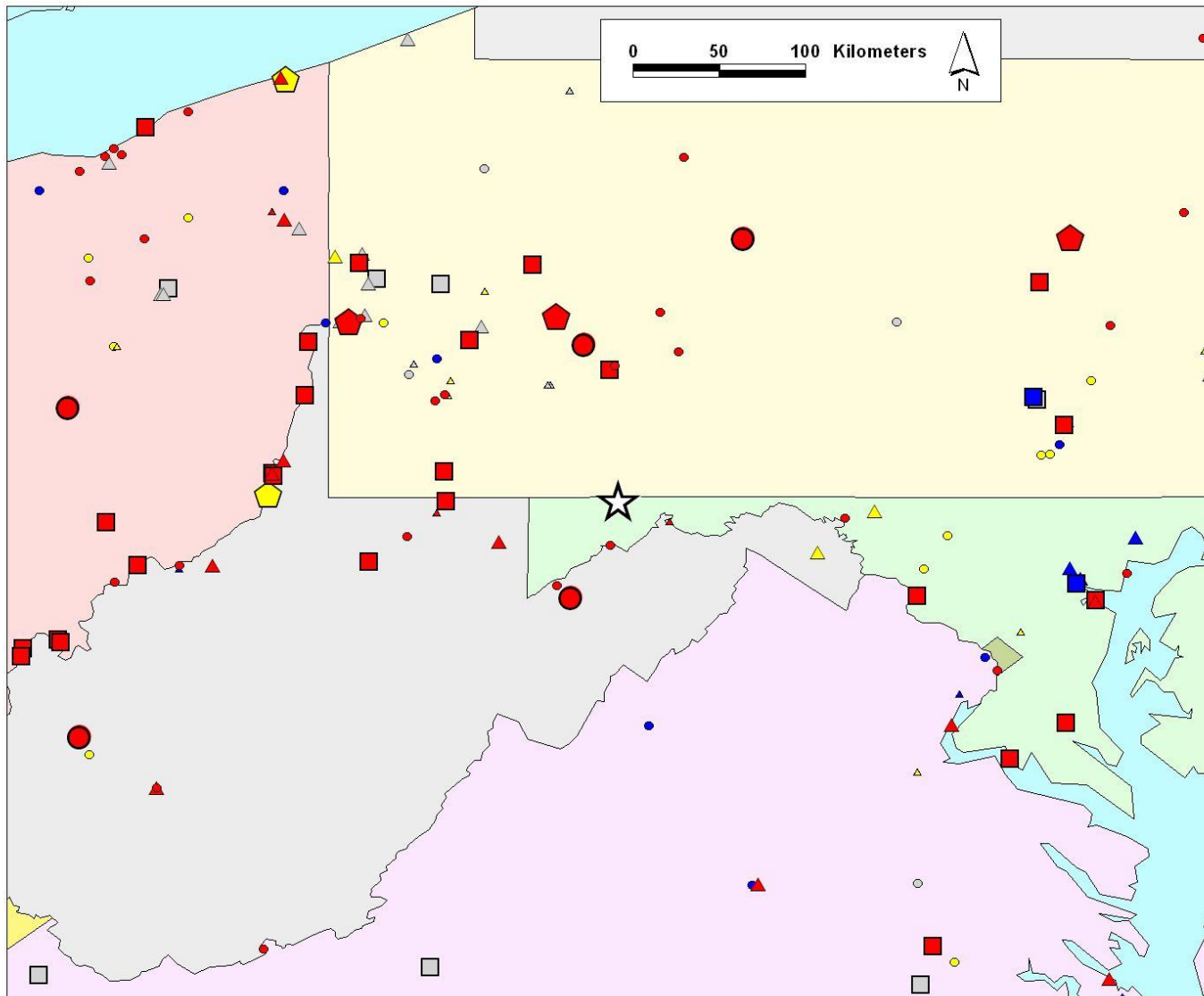(e.g., parcels of air from higher altitudes mix down to the ground)

**Without atmospheric models,
it is difficult to unravel the
"reasons" for the mercury
concentrations & deposition
that we observe**

Gridded Frequency Trajectory Statistics

Piney Measurement Site and Surrounding Region
with estimated 2002 emissions of total mercury

☆ **Piney Measurement Site**

Air Emissions

size/shape of symbol denotes amount of mercury emitted (kg/yr)

△	5 –	10
○	10 –	50
△	50 –	100
□	100 –	300
○	300 –	500
⬠	500 –	1000
⬡	1000 –	3500

color of symbol denotes type of mercury source

🟥 coal-fired power plants

🟩 other fuel combustion

🟦 waste incineration

⬜ metallurgical

🟨 manufacturing & other

0   50   100 Kilometers
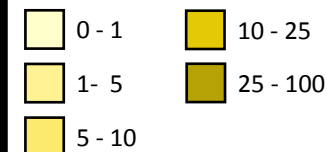
N

Spatial distribution of hourly trajectory endpoint frequencies
Entire year, Starting Height = ½ Planetary Boundary Layer
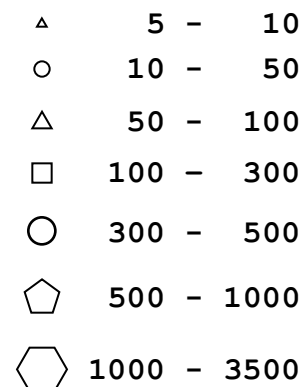with estimated 2002 emissions of reactive gaseous mercury

0.5 degree lat/long grid

☆ Piney Measurement Site

Percent of back-trajectories passing through grid square

0 - 1   10 - 25
1- 5   25 - 100
5 - 10

Air Emissions

size/shape of symbol denotes amount of mercury emitted (kg/yr)

△   5   –   10
○   10   –   50
△   50   –   100
□   100   –   300
○   300   –   500
⬠   500   –   1000
⬡   1000   –   3500

color of symbol denotes type of mercury source

■ coal-fired power plants
■ other fuel combustion
■ waste incineration
■ metallurgical
■ manufacturing & other

0   250   500   Kilometers

N

Trajectory Endpoint Frequency Graphics
showing the difference in grid frequencies
between the trajectories corresponding
to a given set of measurements and
those for the entire year

0.5 degree lat/long regional grid

Starting height for all trajectories in this group
= ½ planetary boundary layer height

Spatial distribution of hourly trajectory endpoint frequencies
top 10% of daytime RGM vs. total year
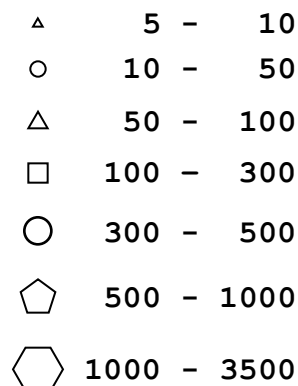**with estimated 2002 emissions of reactive gaseous mercury**

The yellow and orange grid squares are areas where the trajectories pass more often than the "average" for the entire year

The purple grid squares represent areas where the trajectories pass less often than the "average" for the entire year

0.5 degree lat/long regional grid

⭐ **Piney Measurement Site**

Difference between two cases in percent of back-trajectories passing through grid square

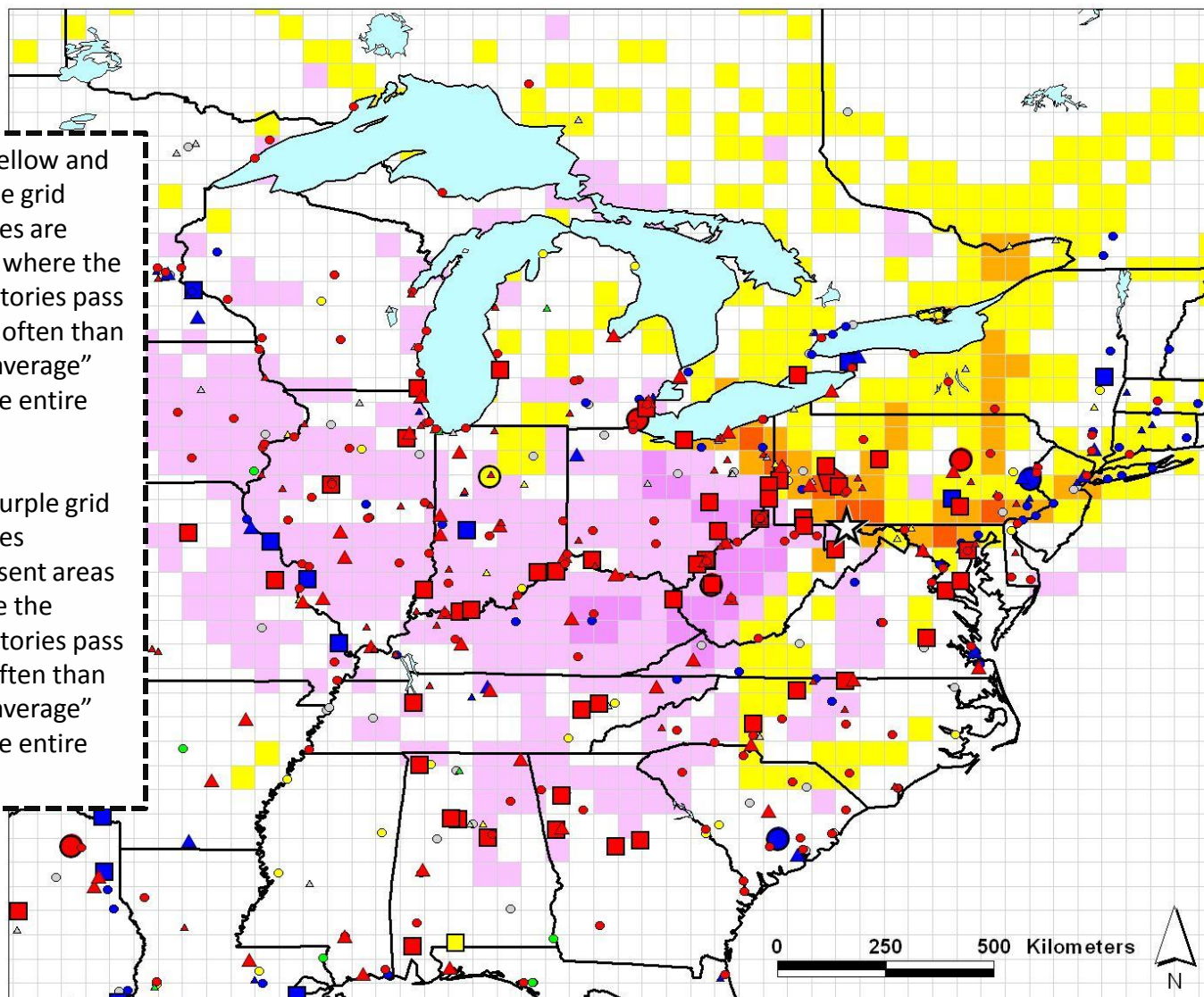|	
-13 to -4	1 to 4
-4 to -1	4 to 7
-1 to 1	7 to 22

Air Emissions

size/shape of symbol denotes amount of mercury emitted (kg/yr)

△	5 – 10
○	10 – 50
△	50 – 100
□	100 – 300
○	300 – 500
⬠	500 – 1000
⬡	1000 – 3500

color of symbol denotes type of mercury source

🟥	coal-fired power plants
🟩	other fuel combustion
🟦	waste incineration
⬜	metallurgical
🟨	manufacturing & other

0   250   500 Kilometers

Spatial distribution of hourly trajectory endpoint frequencies
bottom 10% of daytime RGM vs. total year
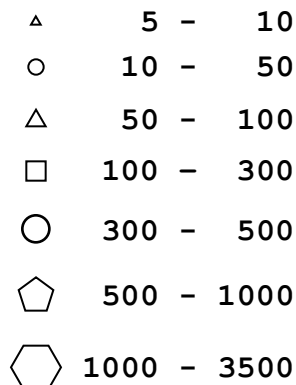**with estimated 2002 emissions of reactive gaseous mercury**

☆ **Piney Measurement Site**

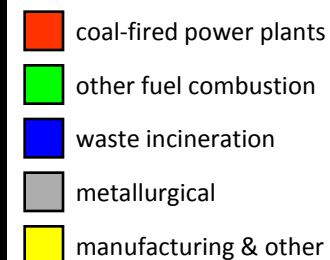**Difference between two cases in percent of back-trajectories passing through grid square**

■ -13 to -4		■ 1 to 4	
■ -4 to -1		■ 4 to 7	
□ -1 to 1		■ 7 to 22	

Air Emissions

size/shape of symbol denotes amount of mercury emitted (kg/yr)

△	5	–	10
○	10	–	50
△	50	–	100
□	100	–	300
◯	300	–	500
⬠	500	–	1000
⬡	1000	–	3500

color of symbol denotes type of mercury source

■	coal-fired power plants
■	other fuel combustion
■	waste incineration
■	metallurgical
■	manufacturing & other

The yellow and orange grid squares are areas where the trajectories pass more often than the "average" for the entire year

The purple grid squares represent areas where the trajectories pass less often than the "average" for the entire year

0   250   500   Kilometers
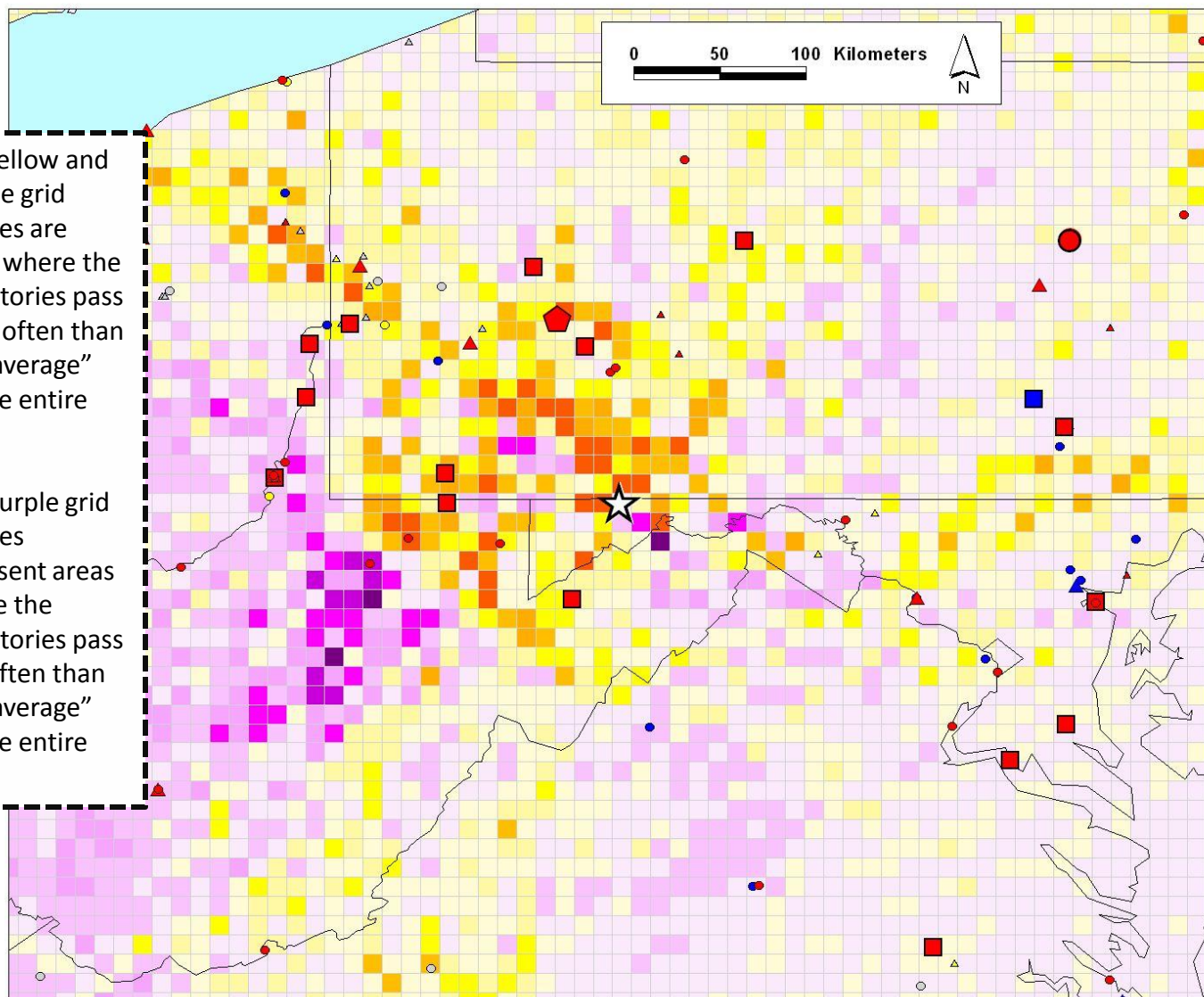
N

0.5 degree lat/long regional grid

Trajectory Endpoint Frequency Graphics
showing the difference in grid frequencies
between the trajectories corresponding
to a given set of measurements and
those for the entire year

0.1 degree lat/long regional grid

Starting height for all trajectories in this group
= ½ planetary boundary layer height

Spatial distribution of hourly trajectory endpoint frequencies
top 10% of daytime RGM vs. total year
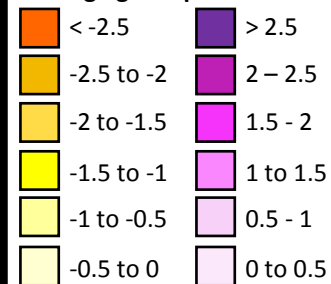with estimated 2002 emissions of reactive gaseous mercury

The yellow and orange grid squares are areas where the trajectories pass more often than the "average" for the entire year

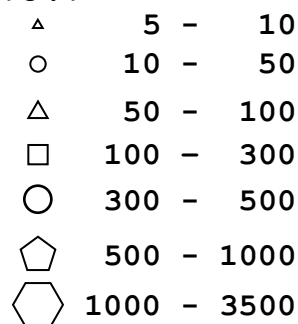The purple grid squares represent areas where the trajectories pass less often than the "average" for the entire year

0.1 degree lat/long regional grid

Piney Measurement Site

Difference between selected case and total year in percent of back-trajectories passing through grid square

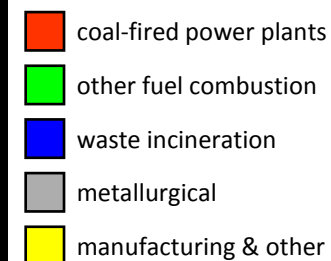|	
< -2.5	> 2.5
-2.5 to -2	2 – 2.5
-2 to -1.5	1.5 - 2
-1.5 to -1	1 to 1.5
-1 to -0.5	0.5 - 1
-0.5 to 0	0 to 0.5

Air Emissions

size/shape of symbol denotes amount of mercury emitted (kg/yr)

△	5	–	10
○	10	–	50
△	50	–	100
□	100	–	300
○	300	–	500
⬠	500	–	1000
⬡	1000	–	3500

color of symbol denotes type of mercury source

coal-fired power plants

other fuel combustion

waste incineration
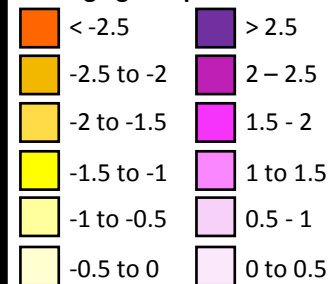
metallurgical

manufacturing & other

Spatial distribution of hourly trajectory endpoint frequencies
bottom 10% of daytime RGM vs. total year
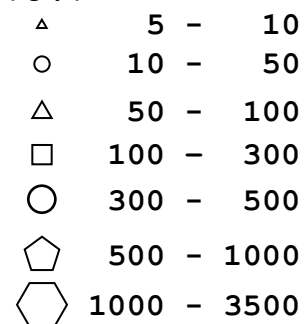**with estimated 2002 emissions of reactive gaseous mercury**
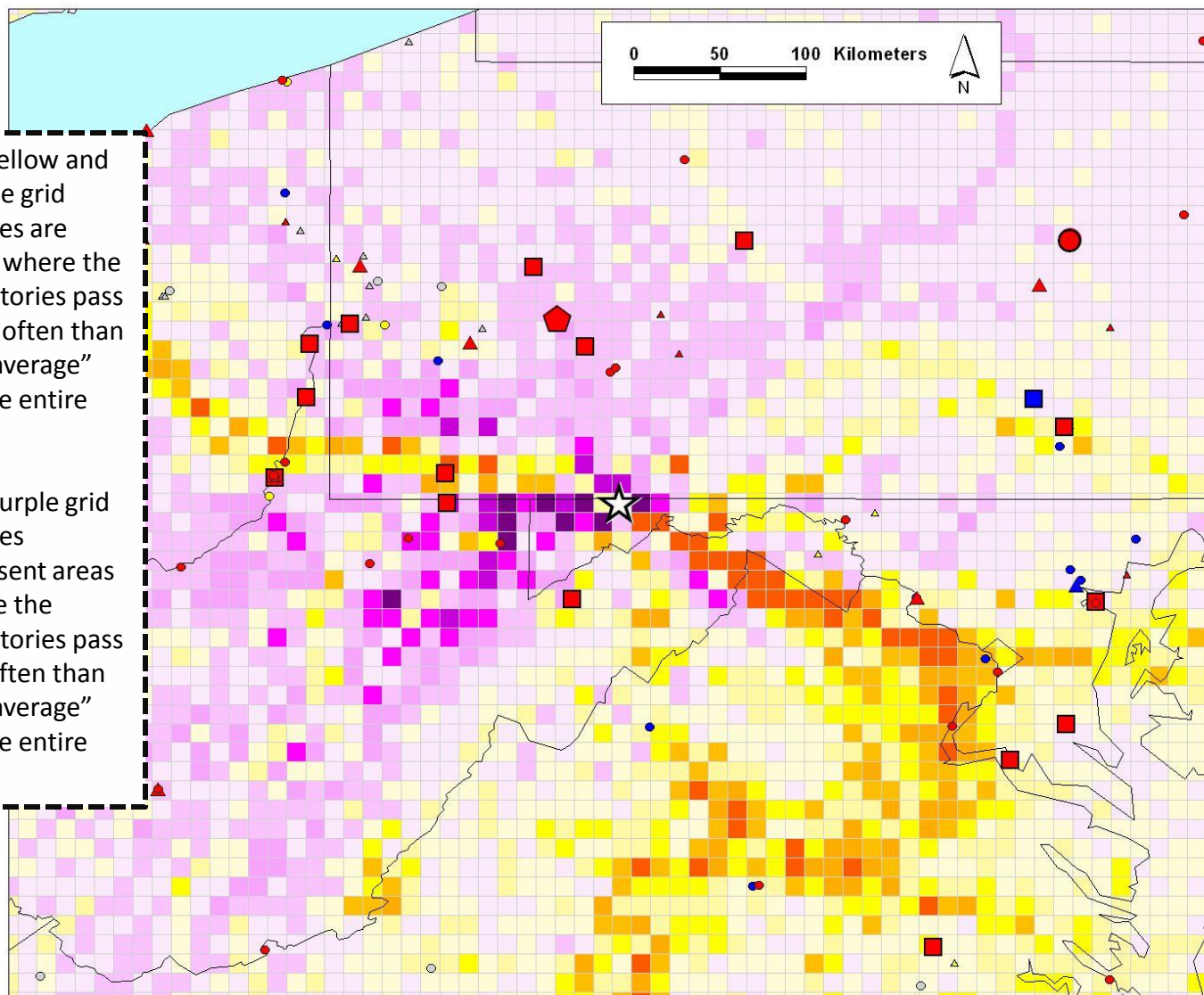
The yellow and orange grid squares are areas where the trajectories pass more often than the "average" for the entire year

The purple grid squares represent areas where the trajectories pass less often than the "average" for the entire year

0.1 degree lat/long regional grid

☆ **Piney Measurement Site**

Difference between selected case and total year in percent of back-trajectories passing through grid square

< -2.5	> 2.5
-2.5 to -2	2 – 2.5
-2 to -1.5	1.5 - 2
-1.5 to -1	1 to 1.5
-1 to -0.5	0.5 - 1
-0.5 to 0	0 to 0.5

Air Emissions

size/shape of symbol denotes amount of mercury emitted (kg/yr)

symbol	range	
△	5 –	10
○	10 –	50
△	50 –	100
□	100 –	300
○	300 –	500
⬠	500 –	1000
⬡	1000 –	3500

color of symbol denotes type of mercury source

color	type
🟥	coal-fired power plants
🟩	other fuel combustion
🟦	waste incineration
⬜	metallurgical
🟨	manufacturing & other