Source Attribution Methods

HYSPLIT Workshop 2022, Jun. 16, 2022

Version 5.2.1 (revision 1694)

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13.1 Emissions from a Known Location

Concentration (M) is the product of the atmospheric dilution (D) from the source to the receptor and the emission rate (Q):

Counterpart of the measurement (M): C [g/m3] = D [hr/m3] Q [g/hr]

Because the model computes the dilution factor, we can simply re-arrange the equation and adjusting for units :

Q [g/hr] = M [pg/m3] / (D [hr/m3] * 1E+12 [pg/g])

3-hr release from 17Z Sep. 25, 1983

Q= 67 Kg/hr * (2303/759) = 220 Kg/hr

```
Contents of statA.txt ...

          C:/Users/Ti results file: statA.txt
Model variation:    Tracer number: 0   Station select: All
          ------------------------------------

       48 Unaveraged data points for processing
     0.00 Percentile input for zero measured
     0.00 Zero measured concentration value

     0.91 Correlation coefficient (P=99%)
     0.25 Regression Slope
    14.81 T-value (|Slope|/Standard Error)
  2303.92 Average measured concentration
   759.84 Average calculated concentration
     0.33 Ratio of calculated/measured
    12.14 Normalized mean square error
  4609.71 Root mean square error
       48 Number of pairs analyzed
```

21-hr release from 15Z Sep. 25, 1983

Q= 1 g/hr * (2303/0.03)/1000 = 77 Kg/hr

```
Contents of statA.txt ...

          C:/Users/Ti results file: statA.txt
Model variation:    Tracer number: 0   Station select: All
          ------------------------------------

       48 Unaveraged data points for processing
     0.00 Percentile input for zero measured
     0.00 Zero measured concentration value

     0.82 Correlation coefficient (P=99%)
     0.00 Regression Slope
     9.63 T-value (|Slope|/Standard Error)
  2303.92 Average measured concentration
     0.03 Average calculated concentration
     0.00 Ratio of calculated/measured
507828.03 Normalized mean square error
  6168.21 Root mean square error
       48 Number of pairs analyzed
```

13.2 Backward versus Forward Dispersion

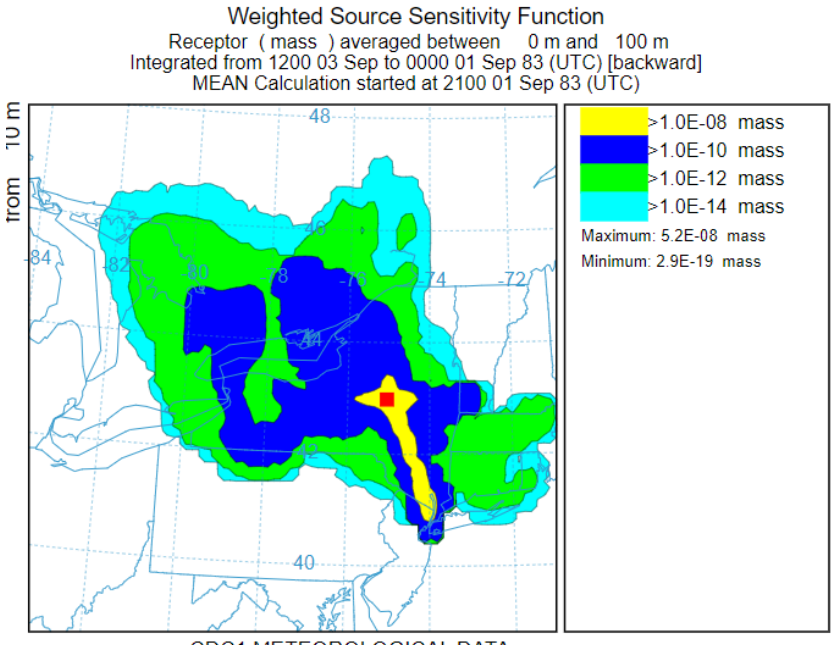
Forward run from S001 (39.90,-82.22)
1-hr release from **83 09 25 17**
Dilution factor (×1E15) at S316

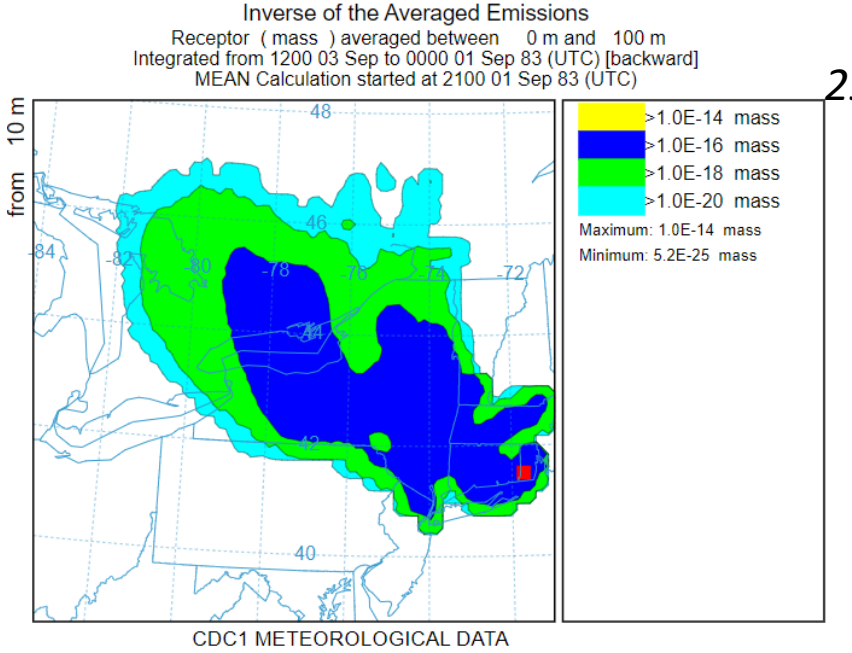
JDAY	YR	MO	DA1	HR1	MN1	DA2	HR2	MN2	S316
268.708	83	9	25	17	0	25	18	0	0.
…									
268.958	83	9	25	23	0	26	0	0	0.
269.000	83	9	26	0	0	26	1	0	0.259
269.042	83	9	26	1	0	26	2	0	0.431
269.083	83	9	26	2	0	26	3	0	1.378
269.125	83	9	26	3	0	26	4	0	4.564
269.167	83	9	26	4	0	26	5	0	12.057
269.208	83	9	26	5	0	26	6	0	19.288
269.250	83	9	26	6	0	26	7	0	30.080
269.292	**83**	**9**	**26**	**7**	**0**	**26**	**8**	**0**	**30.772**
269.333	83	9	26	8	0	26	9	0	22.274
269.375	83	9	26	9	0	26	10	0	17.334
269.417	83	9	26	10	0	26	11	0	9.872
269.458	83	9	26	11	0	26	12	0	4.247
269.500	83	9	26	12	0	26	13	0	1.378
269.542	83	9	26	13	0	26	14	0	0.115

Backward run from S316 (41.30, -84.22)
1-hr release from **83 09 26 08**
Dilution factor (×1E15) at S001

JDAY	YR	MO	DA1	HR1	MN1	DA2	HR2	MN2	S001
269.333	83	9	26	8	0	26	7	0	0.
269.292	83	9	26	7	0	26	6	0	0.
269.250	83	9	26	6	0	26	5	0	0.
269.208	83	9	26	5	0	26	4	0	0.
269.167	83	9	26	4	0	26	3	0	0.
269.125	83	9	26	3	0	26	2	0	0.
269.083	83	9	26	2	0	26	1	0	0.
269.042	83	9	26	1	0	26	0	0	0.
269.000	83	9	26	0	0	25	23	0	0.
268.958	83	9	25	23	0	25	22	0	0.
268.917	83	9	25	22	0	25	21	0	5.913
268.875	83	9	25	21	0	25	20	0	24.104
268.833	83	9	25	20	0	25	19	0	21.284
268.792	83	9	25	19	0	25	18	0	18.238
268.750	**83**	**9**	**25**	**18**	**0**	**25**	**17**	**0**	**9.679**

13.3 Emissions from an Unknown Location





Hypothetical measurements (29) were generated using a HYSPLIT run with release from (43N, 75W) (starting at 83090100, Q=3000g/h)

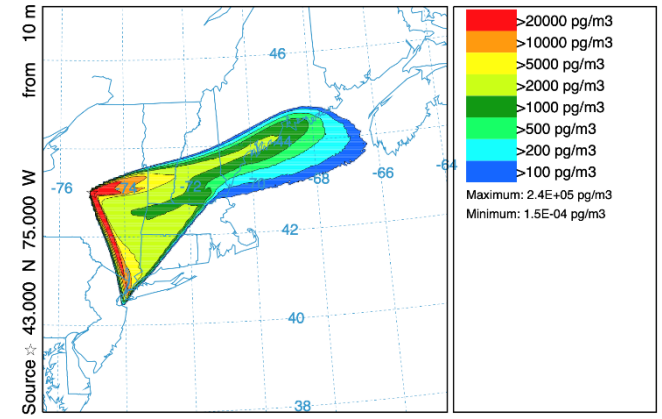
Mean dilution factors are weighted by Measurements (the measured value in the **numerator** of the source rate)

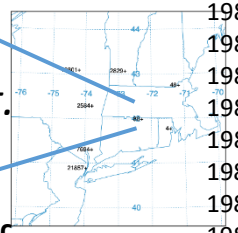
29 inverse runs from each measurement.

Inverse: the source term as 1/M for the calculation

Q = M / D ⟹ **1/Q = D / M**

At (43N,75W), D/M= 1/Q= 0.584×10^{-15}
Q= 1.7×10^{15} pg/h or about **1700 g/h**

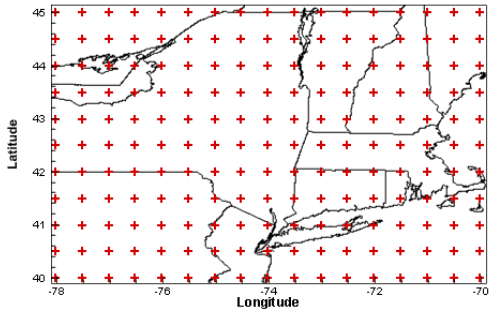




CAPTEX Hypothetical

year	mn	dy	shr	dur	lat	lon	pmch	stn
1983	9	1	1800	0300	40.8500	-73.9700	445.4	903
1983	9	1	2100	0300	40.8500	-73.9700	322097.5	903
1983	9	2	0000	0300	40.8500	-73.9700	114424.1	903
1983	9	2	0000	0300	41.2700	-73.8000	149894.9	904
1983	9	2	0000	0300	42.2500	-73.8000	47820.9	906
1983	9	2	0300	0300	40.8500	-73.9700	181.7	903
1983	9	2	0300	0300	41.2700	-73.8000	3990.4	904
1983	9	2	0300	0300	42.2500	-73.8000	3878.4	906
1983	9	2	0600	0300	43.0500	-74.2000	216939.7	908
1983	9	2	0900	0300	43.0500	-74.2000	38505.6	908
1983	9	2	0900	0300	41.9500	-72.3000	208.4	4
1983	9	2	0900	0300	43.0300	-72.8000	54686.5	6
1983	9	2	1200	0300	43.0500	-74.2000	88.3	908
1983	9	2	1200	0300	41.9500	-72.3000	1399.1	4
1983	9	2	1200	0300	41.7300	-71.4300	7.2	102
1983	9	2	1500	0300	43.0500	-74.2000	6781.0	908
1983	9	2	1500	0300	43.0300	-72.8000	11.0	6
1983	9	2	1500	0300	41.7300	-71.4300	72.2	102
1983	9	2	1500	0300	42.7000	-71.1700	326.4	104
1983	9	2	1800	0300	43.0500	-74.2000	6310.8	908
19839	2	1800	0300	43.0300	-72.8000	762.5	6	
19841983	9	2	2100	0300	43.0500	-74.2000	985.0	908
19851983	9	2	2100	0300	43.0300	-72.8000	845.8	6
19861983	9	3	0000	0300	43.0300	-72.8000	22.1	6
19871983	9	3	0300	0300	43.0300	-72.8000	221.3	6
19881983	9	3	0600	0300	43.0300	-72.8000	44.2	6
19891983	9	3	0600	0300	42.7000	-71.1700	126.5	104
19901983	9	3	0900	0300	43.0500	-74.2000	126425.6	908
19911983	9	3	0900	0300	42.7000	-71.1700	500.7	104

13.4 Source-receptor matrix approach



…

17x11=187

HYSPLIT runs

	A	B	C	D	E	F	G
1		Receptor 1	Receptor 2	Receptor 3	…	Receptor M	
2	Source 1						Rm from S1
3	Source 2						Rm from S2
4	Source 3						Rm from S3
5	…						
6	Source N						
7		Sn to R1	Sn to R2	Sn to R3			
8							

Source Sensitivity Maps

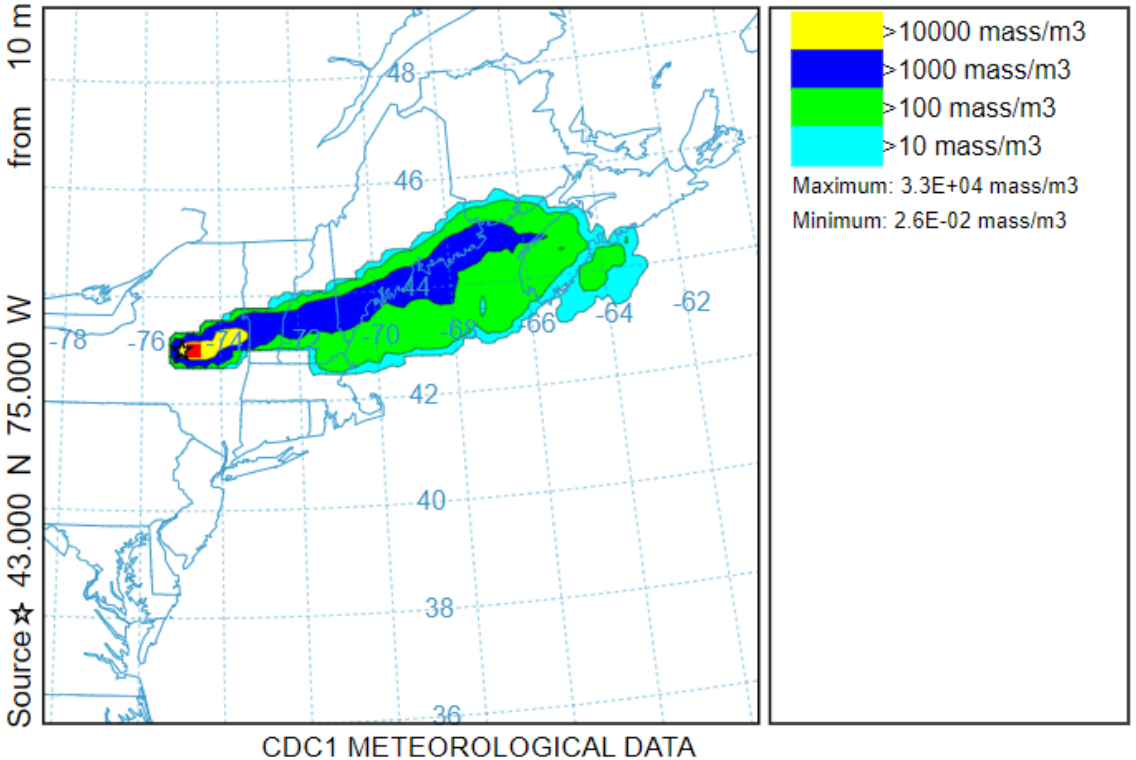
Air Concentration Maps

Contributions from the selected Source

Air Concentration (mass/m3) averaged between 0 m and 100 m

Integrated from 0900 03 Sep to 1200 03 Sep 83 (UTC)

C(R) Release started at 0000 01 Sep 83 (UTC)



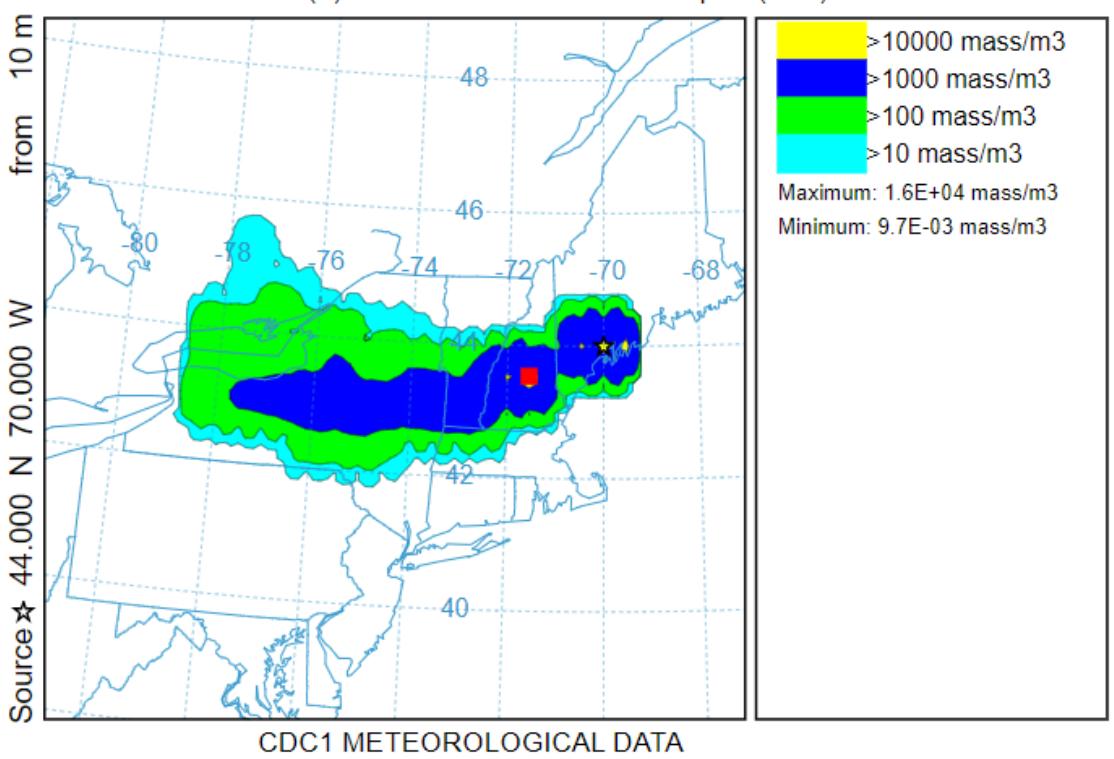
Dilution factor from (43N, 75W) to (44N 70W) approximately $(1000 \times 10^{-15}) = 10^{-12}$

Sources Contributing to the selected Receptor

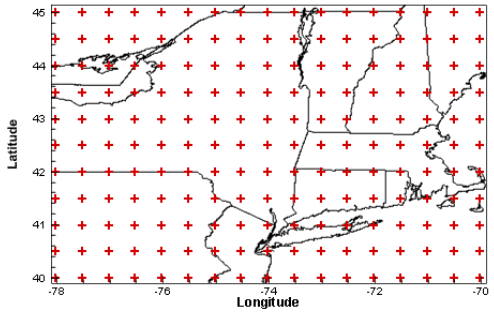
Values (mass/m3) averaged between 0 m and 100 m

Integrated from 0900 03 Sep to 1200 03 Sep 83 (UTC)

C(S) Release started at 0000 01 Sep 83 (UTC)



13.5 Source Location Statistics



…

17x11=187

HYSPLIT runs

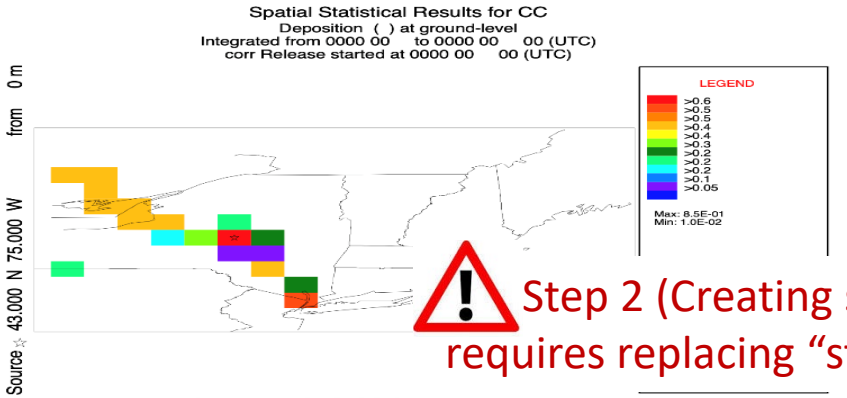
	A	B	C	D	E	F	G
1		Receptor 1	Receptor 2	Receptor 3	…	Receptor M	
2	Source 1						Rm from S1
3	Source 2						Rm from S2
4	Source 3						Rm from S3
5	…						
6	Source N						
7		Sn to R1	Sn to R2	Sn to R3			
8							

Source Sensitivity Maps

Air Concentration Maps

(43N, 75W)

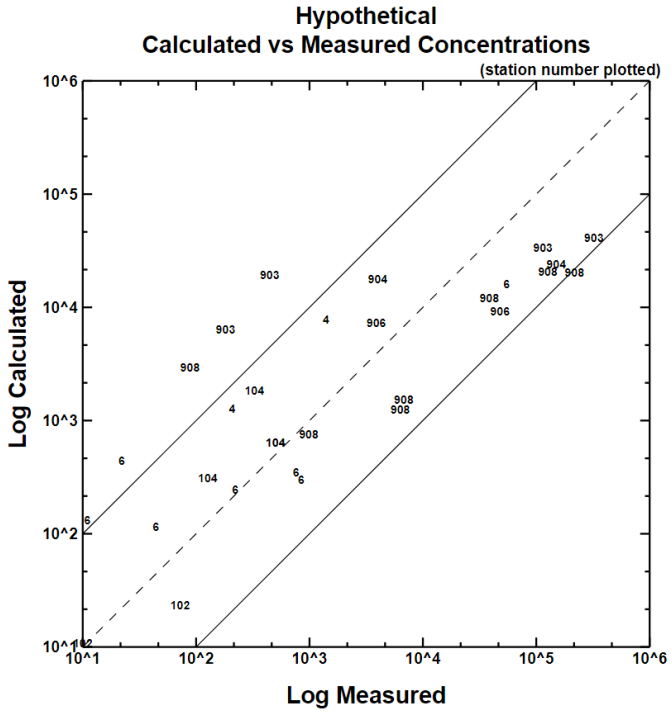
```
 37862.18 Average measured concentration
  7836.88 Average calculated concentration
     0.21 Ratio of calculated/measured
```



Step 2 (Creating source map) requires replacing "statmain.exe" !

STAT METEOROLOGICAL DATA

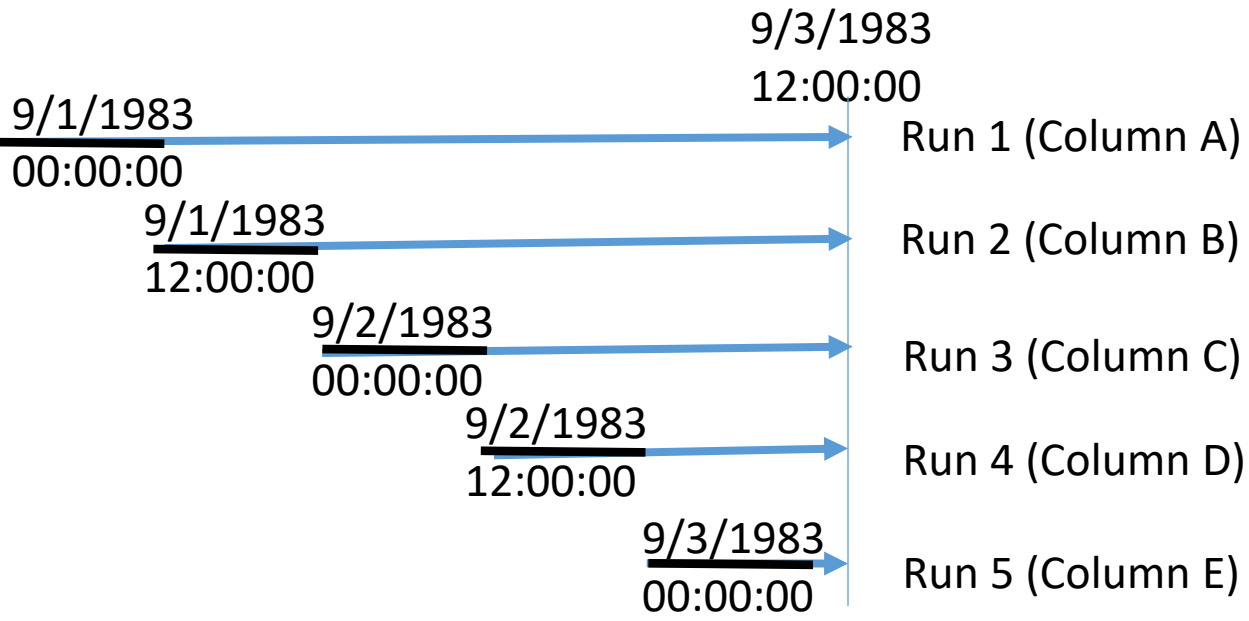
Lat	Lon	Corr	NMSE	FB	FMS	KSP	Rank
…							
41.50	-75.00	0.00	999.99	-2.00	0.00	100.00	0.00
42.00	-75.00	-0.15	596.18	-1.97	10.34	87.00	0.27
42.50	-75.00	0.05	40.20	-1.57	51.72	45.00	1.28
43.00	-75.00	0.85	17.01	-1.29	82.76	14.00	2.76
43.50	-75.00	0.20	96.09	-1.81	31.03	66.00	0.78
44.00	-75.00	-0.01	611.09	-1.97	27.59	69.00	0.60
44.50	-75.00	0.02	9678.20	-2.00	3.45	100.00	0.04



$Q = 10^{15}$ pg/hr / 0.21
~ 5000 g/hr

A significant number of sampling locations will move toward over-prediction if all the points are shifted upward by a factor-of-five.

13.6 Solving the coefficient matrix (CM)



Transfer Coeffient Matrix: $(D_{ij})^T$

Measurements (pg/m^3), $\mathbf{R_j}$

	A	B	C	D	E	F
1	9/1/83 0:00	9/1/83 12:00	9/2/83 0:00	9/2/83 12:00	9/3/83 0:00	9/3/83 12:00
2	1.18E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.45E+02
3	9.75E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.22E+05
4	1.50E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.14E+05
5	4.32E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.50E+05
6	0.00E+00	1.36E+01	0.00E+00	0.00E+00	0.00E+00	4.78E+04
7	1.42E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.82E+02
8	2.21E+00	1.71E-02	0.00E+00	0.00E+00	0.00E+00	3.99E+03
9	0.00E+00	2.76E+00	0.00E+00	0.00E+00	0.00E+00	3.88E+03
10	0.00E+00	0.00E+00	4.69E+01	0.00E+00	0.00E+00	2.17E+05
11	0.00E+00	0.00E+00	4.41E-02	0.00E+00	0.00E+00	3.85E+04
12	0.00E+00	6.51E-02	0.00E+00	0.00E+00	0.00E+00	2.08E+02
13	0.00E+00	1.78E+01	0.00E+00	0.00E+00	0.00E+00	5.47E+04
14	0.00E+00	0.00E+00	4.39E-03	0.00E+00	0.00E+00	8.83E+01
15	5.37E+00	1.11E+01	0.00E+00	0.00E+00	0.00E+00	1.40E+03
16	0.00E+00	4.75E-02	0.00E+00	0.00E+00	0.00E+00	7.20E+00
17	0.00E+00	0.00E+00	3.07E-02	1.01E+00	0.00E+00	6.78E+03
18	0.00E+00	1.34E-01	0.00E+00	0.00E+00	0.00E+00	7.22E+01
19	0.00E+00	5.62E-01	0.00E+00	0.00E+00	0.00E+00	3.26E+02
20	0.00E+00	0.00E+00	0.00E+00	4.39E-01	0.00E+00	6.31E+03
21	0.00E+00	0.00E+00	4.38E-03	1.19E-01	0.00E+00	7.62E+02
22	0.00E+00	0.00E+00	0.00E+00	4.39E-03	0.00E+00	9.85E+02
23	0.00E+00	0.00E+00	0.00E+00	1.58E-01	0.00E+00	8.46E+02
24	0.00E+00	0.00E+00	0.00E+00	2.19E-02	0.00E+00	2.21E+02
25	0.00E+00	0.00E+00	0.00E+00	2.63E-02	0.00E+00	4.42E+01
26	0.00E+00	0.00E+00	0.00E+00	1.18E-01	0.00E+00	1.26E+02
27	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.33E+01	1.26E+05
28	0.00E+00	0.00E+00	0.00E+00	2.40E-01	0.00E+00	5.01E+02
29						

$$\sum_{i=1}^{5} (D_{ij}\, S_i) = R_j$$

Get S_i by using Singular value decomposition **(SVD)**

source.txt file contents:

Date,	Result,
30560.000,	3.353E+03,
30560.500,	2.291E+03,
30561.000,	4.628E+03,
30561.500,	7.430E+03,
30562.000,	9.474E+03,

13.7 Cost Function Minimization of the CM

Transfer Coeffient Matrix: $(D_{ij})^T$

Measurements (pg/m^3), C_j

	A	B	C	D	E	F
1	9/1/83 0:00	9/1/83 12:00	9/2/83 0:00	9/2/83 12:00	9/3/83 0:00	9/3/83 12:00
2	1.18E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.45E+02
3	9.75E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.22E+05
4	1.50E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.14E+05
5	4.32E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.50E+05
6	0.00E+00	1.36E+01	0.00E+00	0.00E+00	0.00E+00	4.78E+04
7	1.42E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.82E+02
8	2.21E+00	1.71E-02	0.00E+00	0.00E+00	0.00E+00	3.99E+03
9	0.00E+00	2.76E+00	0.00E+00	0.00E+00	0.00E+00	3.88E+03
10	0.00E+00	0.00E+00	4.69E+01	0.00E+00	0.00E+00	2.17E+05
11	0.00E+00	0.00E+00	4.41E-02	0.00E+00	0.00E+00	3.85E+04
12	0.00E+00	6.51E-02	0.00E+00	0.00E+00	0.00E+00	2.08E+02
13	0.00E+00	1.78E+01	0.00E+00	0.00E+00	0.00E+00	5.47E+04
14	0.00E+00	0.00E+00	4.39E-03	0.00E+00	0.00E+00	8.83E+01
15	5.37E+00	1.11E+01	0.00E+00	0.00E+00	0.00E+00	1.40E+03
16	0.00E+00	4.75E-02	0.00E+00	0.00E+00	0.00E+00	7.20E+00
17	0.00E+00	0.00E+00	3.07E-02	1.01E+00	0.00E+00	6.78E+03
18	0.00E+00	1.34E-01	0.00E+00	0.00E+00	0.00E+00	7.22E+01
19	0.00E+00	5.62E-01	0.00E+00	0.00E+00	0.00E+00	3.26E+02
20	0.00E+00	0.00E+00	0.00E+00	4.39E-01	0.00E+00	6.31E+03
21	0.00E+00	0.00E+00	4.38E-03	1.19E-01	0.00E+00	7.62E+02
22	0.00E+00	0.00E+00	0.00E+00	4.39E-03	0.00E+00	9.85E+02
23	0.00E+00	0.00E+00	0.00E+00	1.58E-01	0.00E+00	8.46E+02
24	0.00E+00	0.00E+00	0.00E+00	2.19E-02	0.00E+00	2.21E+02
25	0.00E+00	0.00E+00	0.00E+00	2.63E-02	0.00E+00	4.42E+01
26	0.00E+00	0.00E+00	0.00E+00	1.18E-01	0.00E+00	1.26E+02
27	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.33E+01	1.26E+05
28	0.00E+00	0.00E+00	0.00E+00	2.40E-01	0.00E+00	5.01E+02
29						

$$F(S) = \sum_{i=1}^{5} \frac{(S_i - Sib)^2}{\sigma^2_{ij}} + \sum_{j=1}^{27} \frac{(R^h_j - R^o_j)^2}{\varepsilon^2_{ij}}$$

$$R^h_j = \sum_{i=1}^{5} (D_{ij}\, S_i)$$

Get S_j by minimizing F

source.txt file contents:

```
30560.0000   1.3808E+03
30560.5000   1.3165E+03
30561.0000   3.0695E+03
30561.5000   3.5270E+03
30562.0000   2.9136E+03
```

Source attribution methods – Summary

$$C(x, y, z, t) = \mathbf{D(x, y, z, t)} \times S(x, y, z, t)$$

- A single model run to estimate emission rate (a crude estimation)
  - 13.1 forward dispersion
  - 13.2 forward/backward dispersion
- A series of backward dispersion from measurement location/time (13.3)
  - Measurements as numerators to estimate release location
  - Measurements as denominator for (1/Q or 1/S)
- Matrix runs – 187 forward runs from different locations (13.4, 13.5)
  - Using statistics to infer likely release location
  - Estimate emission rate from the inferred release location
- Find emission temporal variations using a Coefficient Matrix (CM or TCM)
  - Using SVD to solve source terms
  - Minimizing a cost function to estimate the emissions (considering model and observation uncertainties)