A Method for Filling AERMET Upper Air Data

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How does AERMET use Upper Air Data?

- AERMET uses:
  - Height
  - Pressure
  - Temperature
- It does not use the wind speed or direction.
- It only uses the morning sounding (1200 GMT).
- It uses data from 0 – 5000 m.

How does AERMET use Upper Air Data?

- Used to calculate the daytime convective variables:
  - w* (convective velocity scale)
  - VPTG (vertical potential temperature gradient above PBL)
  - PBL (height of convectively-generated boundary layer)
- Upper air data is not used during the non-convective nighttime hours.
- AERMET and AERMOD will both still function if the upper air data is missing.

How are Missing Upper Air Data Handled by AERMET/AERMOD?

- AERMET inserts missing data flags for w*, VPTG and PBL.
- AERMOD uses the default missing data routine (same as calms processing).
  - Set concentration equal to zero.
  - Divide the sum of the concentrations for the period by the number of valid or non-missing hours for the same period*.

* For 3, 8 and 24-hour averages, if the number of valid or non-missing hours is less than 3, 6 or 18 respectively, divide the sum by 3, 6 or 18. From Appendix W Section 9.3.4.

The Effect?

- The convective hours are excluded from the average.
- Effectively, up to 13 or 14 hours are automatically omitted when a sounding is missing.
- Model results will be different than they would have been if the sounding was not missing.

Another Issue

- There is little to no guidance indicating how to deal with missing upper air data in AERMOD.
- 1992 Memo by Dennis Atkinson and Russell Lee addresses missing mixing heights, but not the sounding itself.
- EarthTech's website suggests a method using MM5 for CALPUFF, but it does not directly apply to AERMOD.

The Solution

- Fill the missing data using the sounding from an appropriate adjacent station.
  - The data is readily available.
  - Simple and intuitive procedure.
  - Reduces the error caused by the missing data.

How to Fill the Data – Step 1

- Determine where there are missing morning soundings, or soundings that are incomplete.
  - This can be accomplished manually, or by processing the data through Stage 3 in AERMET.
  - The message file from Stage 3 will contain a summary of all instances where the upper air data is missing or is inadequate.

How to Fill the Data – Step 2

- Obtain the appropriate replacement data.
  - Usually this will be the nearest adjacent upper air station.
  - The station elevation for the two locations should be within a few hundred meters. This will minimize potential errors in translating the data in the following steps, and simplify the process.
  - The average meteorological conditions at the two locations should be similar (don’t apply coastal data to an inland location, etc…).

How to Fill the Data – Step 3

- Paste the replacement soundings into the raw upper air input file.
- Use the find/replace feature of a text editor to change the station id and lat-long information to match the values being used in AERMET.

How to Fill the Data – Step 4

- Run AERMET Stage 1 to extract the data.
  - Filling the data before extraction allows the MODIFY keyword to be used, which performs several data corrections automatically.
  - The difference in elevation between the two different locations causes errors in the measurement heights extracted by AERMET.

How to Fill the Data – Step 5

- Correct the errors caused by the change in elevation by modifying the QA input file.
  - This can be done manually, or a program may be written to perform the task.
  - For each sounding that does not start at ground level, add or subtract the difference in elevation between the first level and the ground to or from each level in the sounding.

Step 5 Continued…

- Using the Hypsometric Equation, calculate the change in pressure due to the difference in elevation at ground level (the mean virtual temperature for the layer may be approximated by using the temperature at ground level if the elevation difference is less than a few hundred meters*).

$$Z_1 - Z_2 = 29.3\overline{T}_V \ln\left(\frac{p_1}{p_2}\right)$$

- Calculate the ratio of the original pressure to the corrected pressure.
- Apply the same ratio to the pressure at each level in the sounding.

*Wallace J. M., and Hobbs P.V. (1977): “Atmospheric Science, An introductory Survey”, pp 57-60

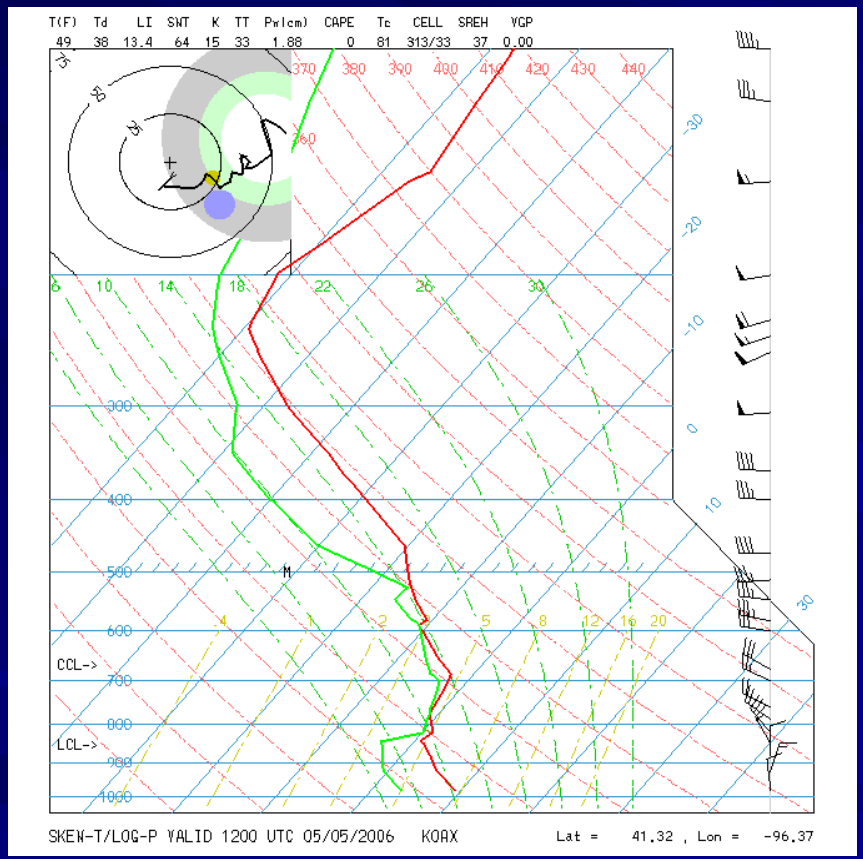
Step 5 Continued…

- The wind direction and speed in the sounding are left unmodified because AERMET does not use these variables.
- The temperature is also left unmodified because any difference due to the change in elevation would be minimal (assuming the difference in elevation is relatively small). It is also more frequently missing, which makes it difficult to perform the necessary calculations.

How to Fill the Data – Step 6

- Run AERMET Stage 1 (QA only) on the edited data.
  - Use the QA results to determine if the data were adversely affected by the modifications.
  - If the data are accurate, then the process is complete and the QA output file may be used as input to Stage 2.

So the Data are Filled…but will they Recreate Reality?



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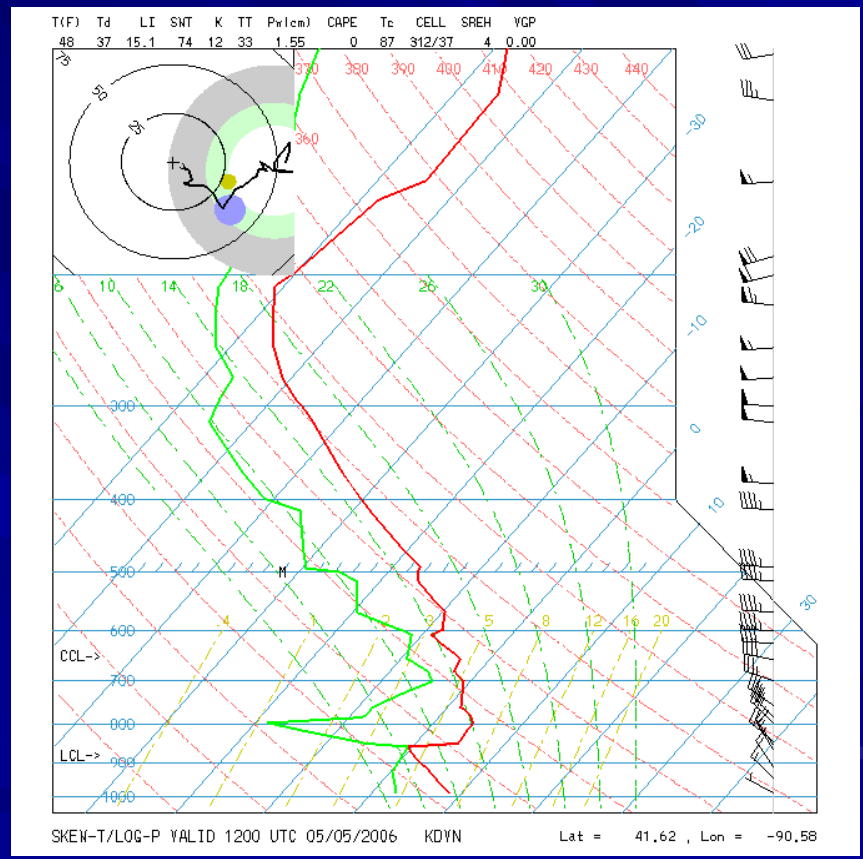


Methodology

- Model three point sources with the following stack heights:
  - 10 meter
  - 25 meter
  - 65 meter
- All other stack parameters are constant.

Methodology Continued…

- Model five* receptors in a row due East of the sources at the following distances:
  - 100 meters
  - 500 meters
  - 1000 meters
  - 2000 meters
  - 5000 meters

*Number of receptors limited by capacity of post-processing software due to the large size of the post files.

Methodology Continued…

- Modify the met data so that all winds are from the West.
  - This allows all three sources to impact the receptors at every hour, which increases the number of results that can be used in the analysis.
  - Eliminates any effect that wind direction may have on the model result.

Methodology Continued…

- Create three separate met data files:
  - "Baseline"
    - 2003 Cedar Rapids, IA/Davenport, IA
  - "Missing Data"
    - Removed all but one* sounding from the "Baseline".
  - "Filled Data"
    - Filled all missing soundings in the "Missing Data" with soundings from Omaha, NE.

* The January 1st sounding was left intact so AERMET would not error out.

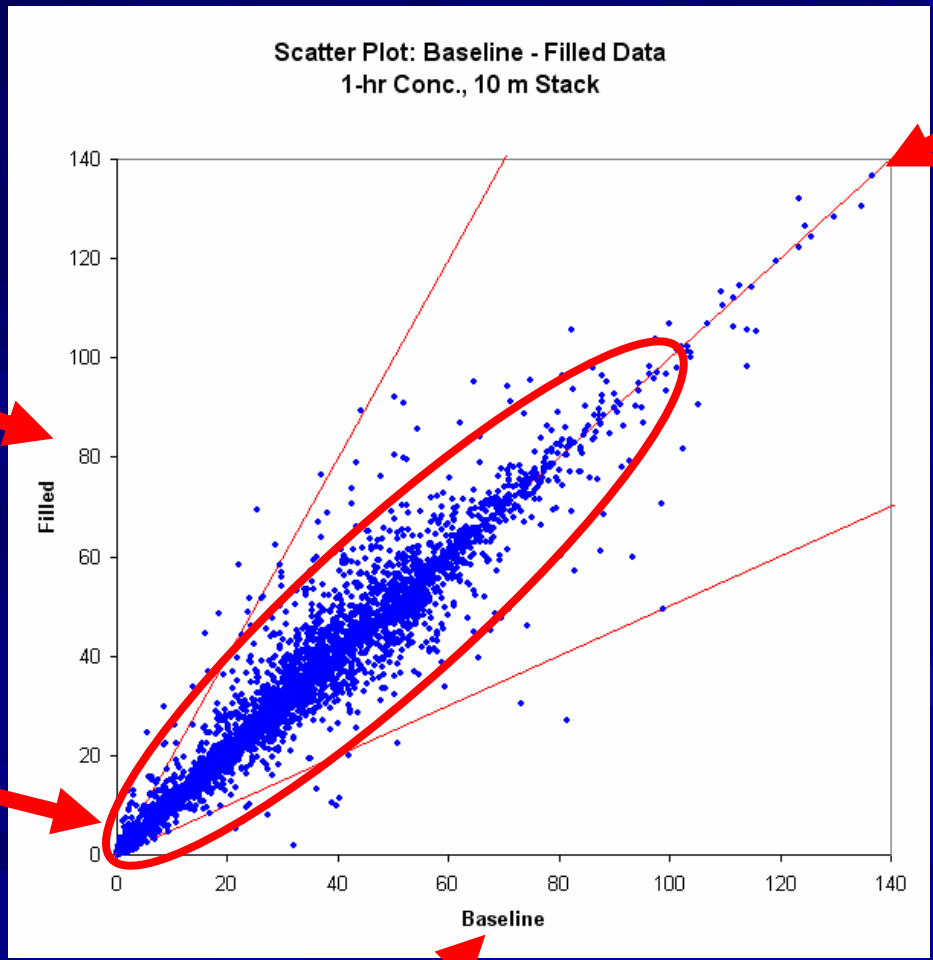
Methodology Continued…

- Run AERMOD with each meteorological data set and produce post files for 1-hr and 24-hr averages.
- Compile and compare the results.
  - Compare “Filled Data” to “Baseline”.
    - Do the filled data recreate the baseline results?
  - Compare “Missing Data” to “Baseline”.
    - Does using missing data adversely affect the model result?
  - Compare “Missing Data” to “Filled Data”.
    - Does filling the data produce better results than leaving it missing?

Results: 1-hr

What the model predicts if all of the morning soundings are stripped away, and filled using data from another location.

There are a large number of instances where the filled data very closely recreate the baseline results.



What the model predicts if there were no missing upper air data.

The maximum concentration is almost exactly the same in both cases.

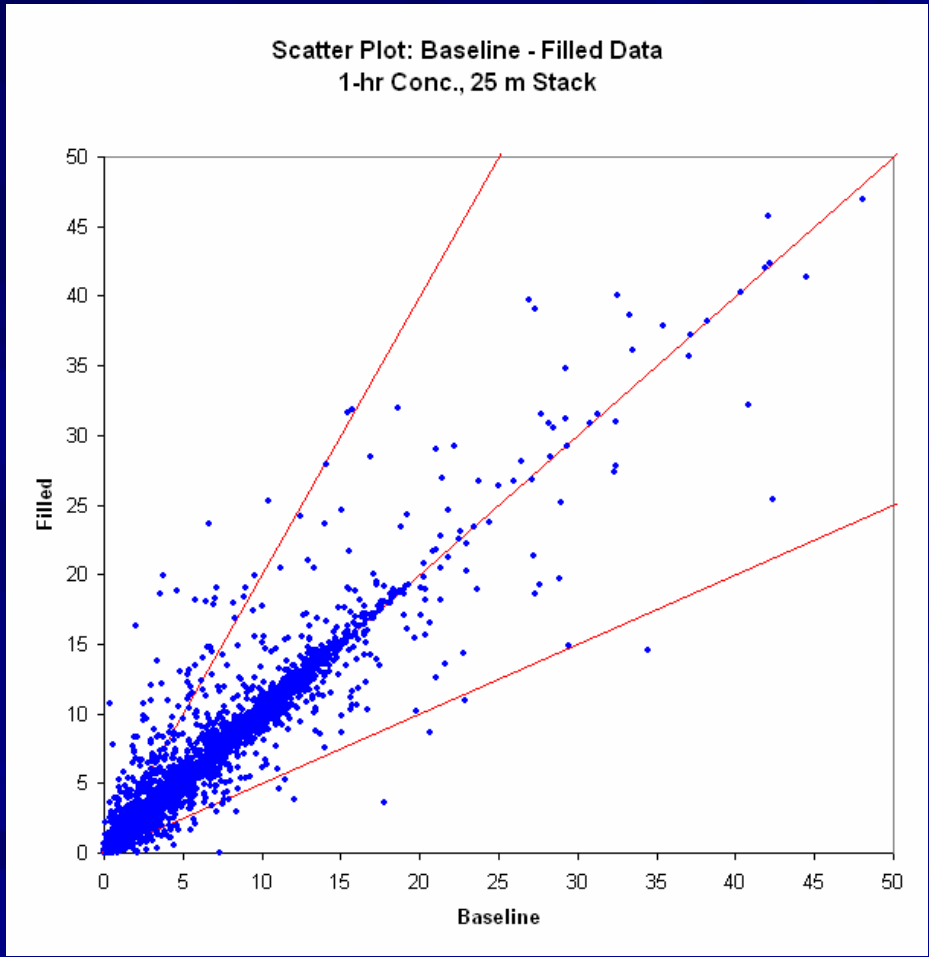
Note:

These are not simply maximum or average values.

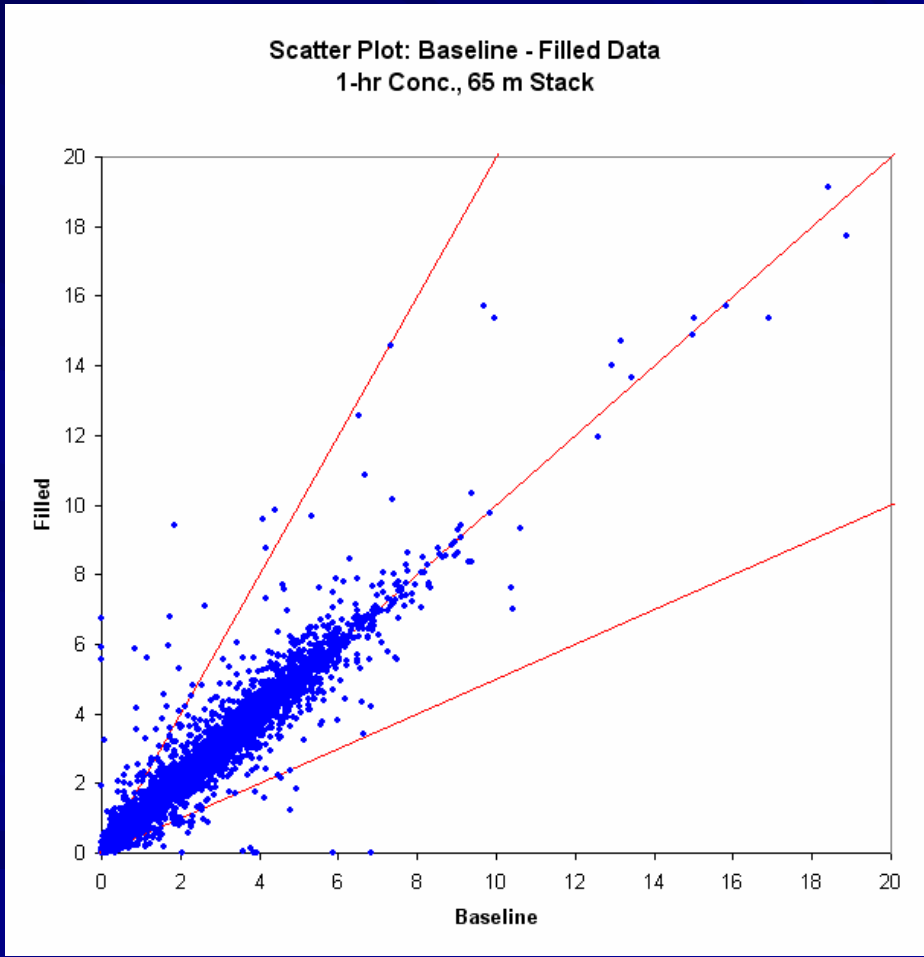
There are 15,100 data points, and all are paired in both space and time.

Also, only the concentrations that are affected by the upper air data were included in this analysis.

Results: 1-hr


Scatter Plot: Baseline - Filled Data
1-hr Conc., 25 m Stack
Filled
Baseline
0
5
10
15
20
25
30
35
40
45
50

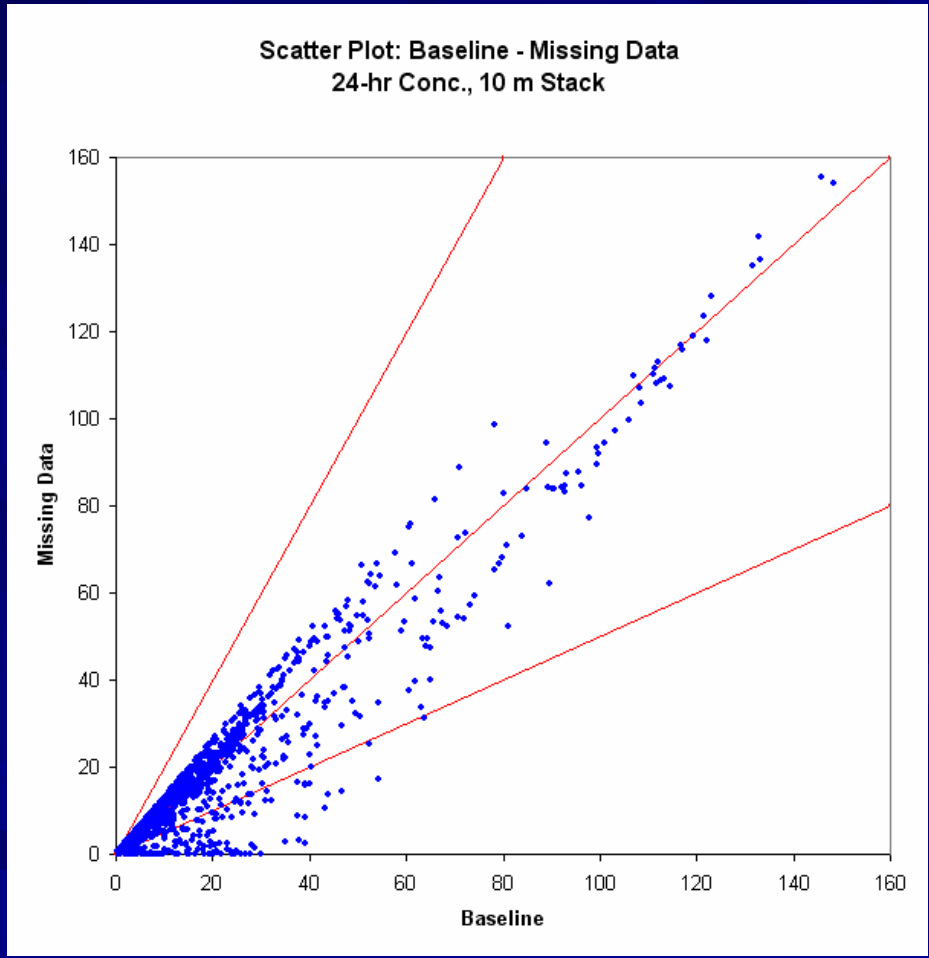
Results: 1-hr


Scatter Plot: Baseline - Filled Data
1-hr Conc., 65 m Stack
Filled
Baseline
0
2
4
6
8
10
12
14
16
18
20

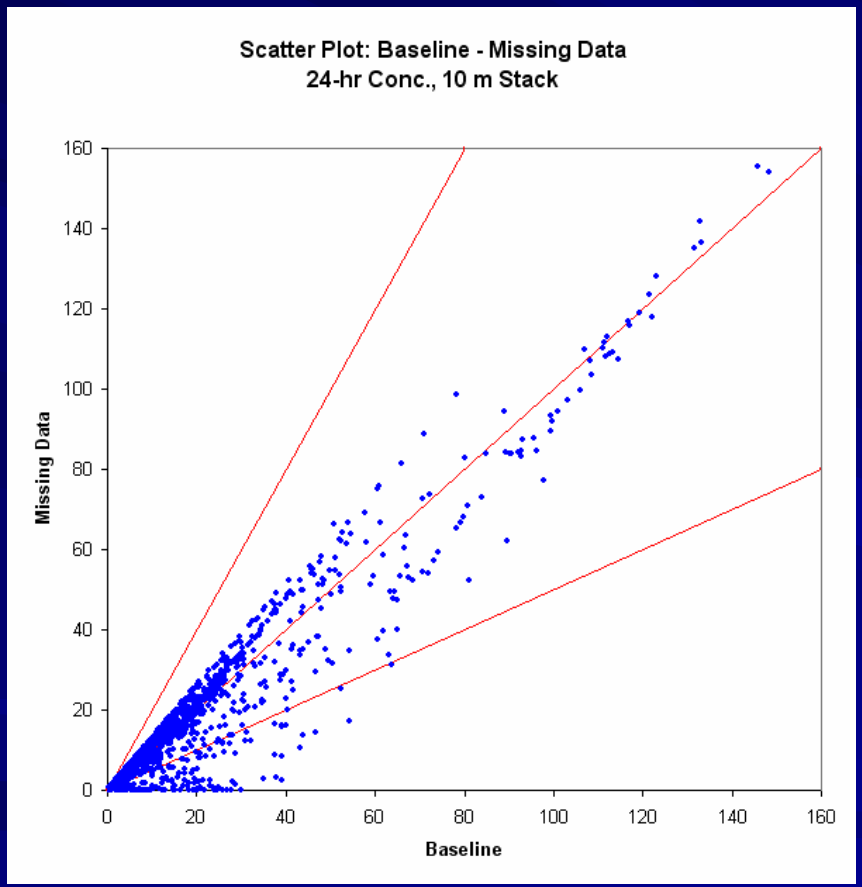
Results: 1-hr

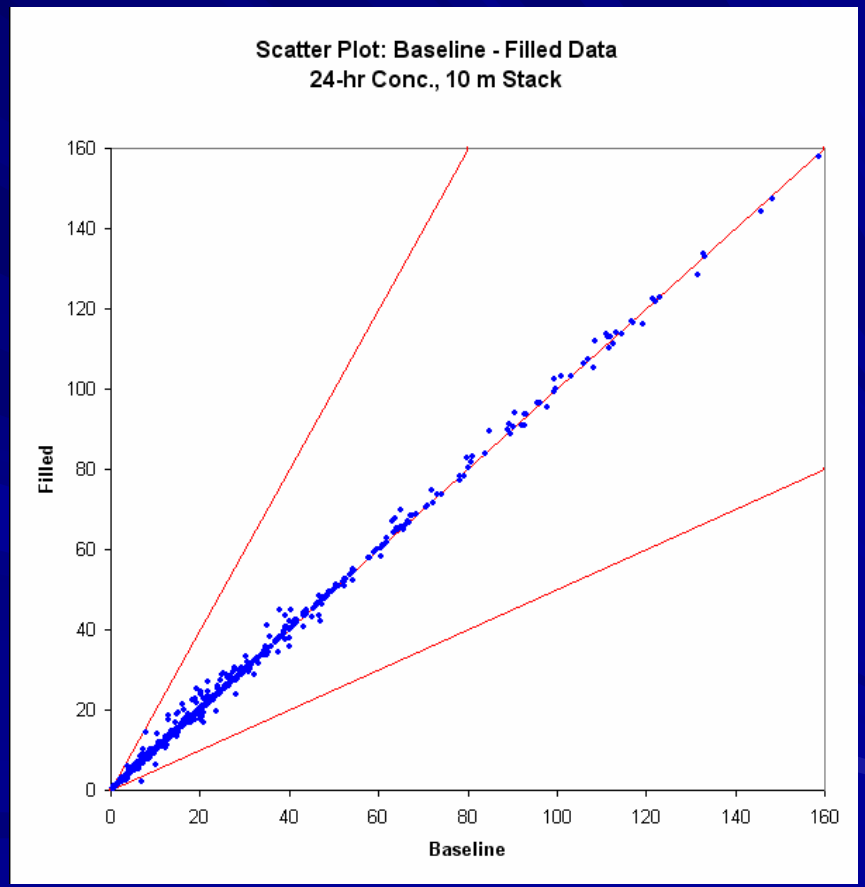
- There is a good correlation between the correct concentrations and those predicted using the filled upper air data.
- There are some outliers…possibly due to fronts or other atmospheric phenomenon that would potentially affect the two upper air stations at different times.
- The maximum concentrations remain near the 1 to 1 line.
- Unfortunately, we cannot compare the results from the missing data when looking at one hour results (they would all be equal to zero).

Results: 24-hr

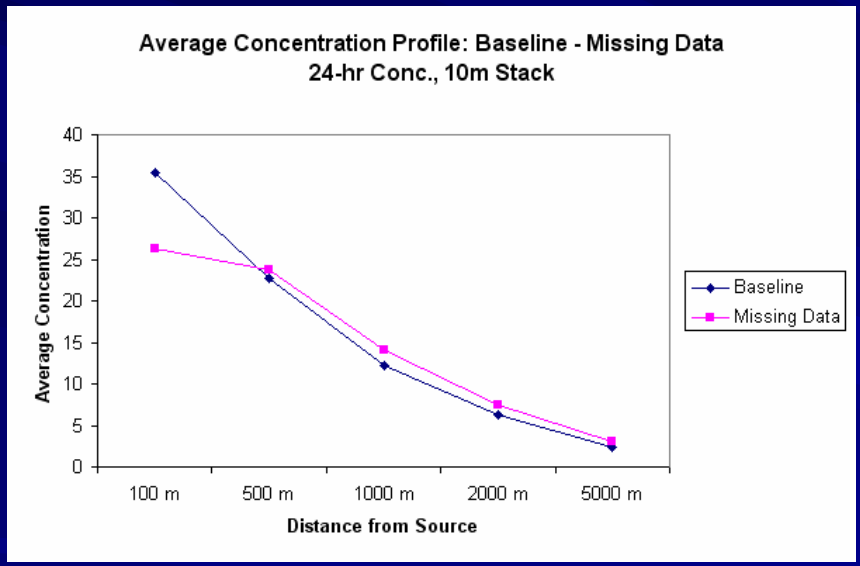


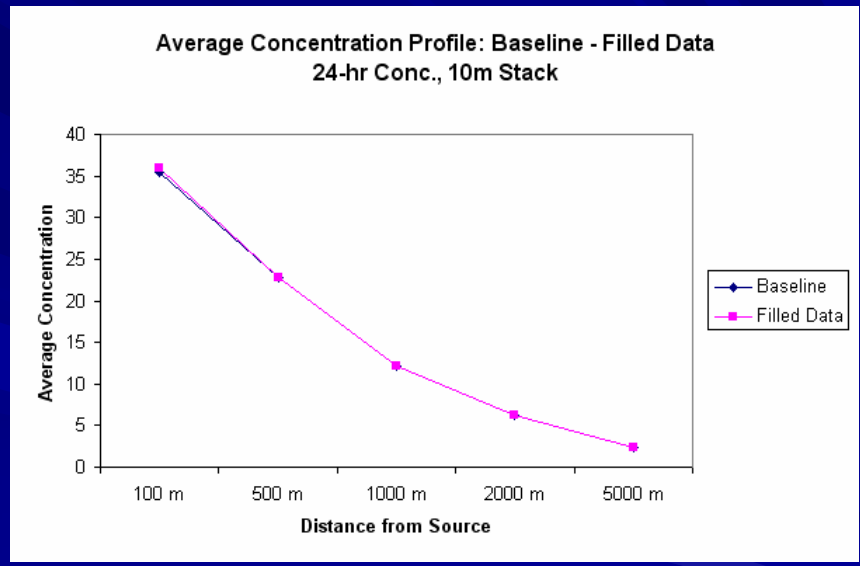
Results: 24-hr



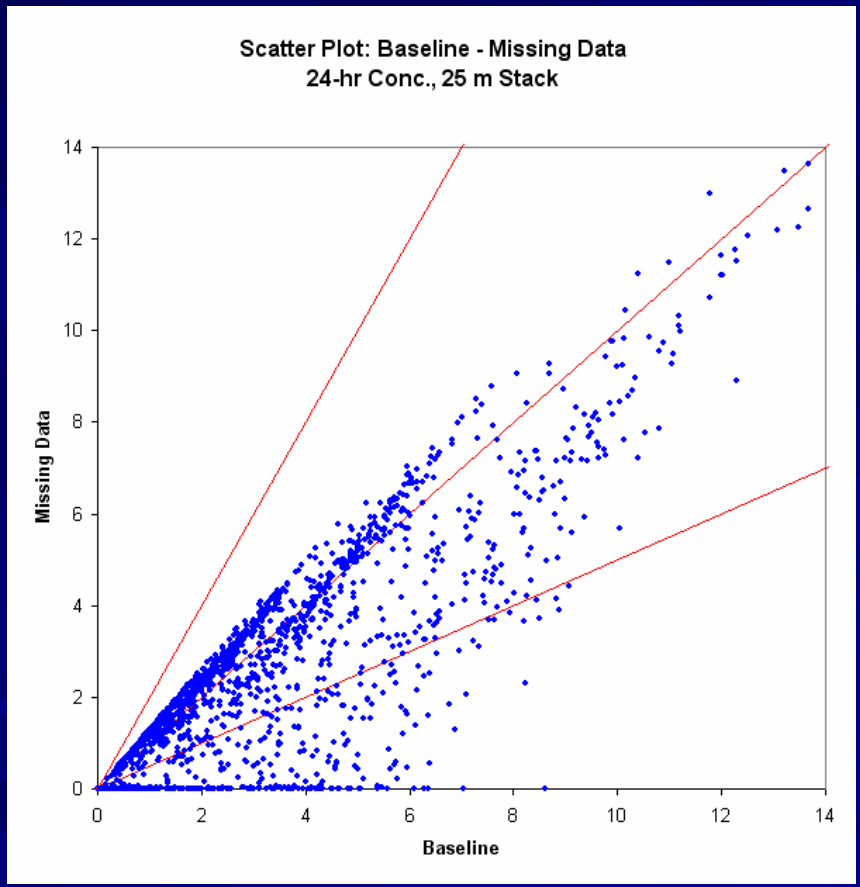


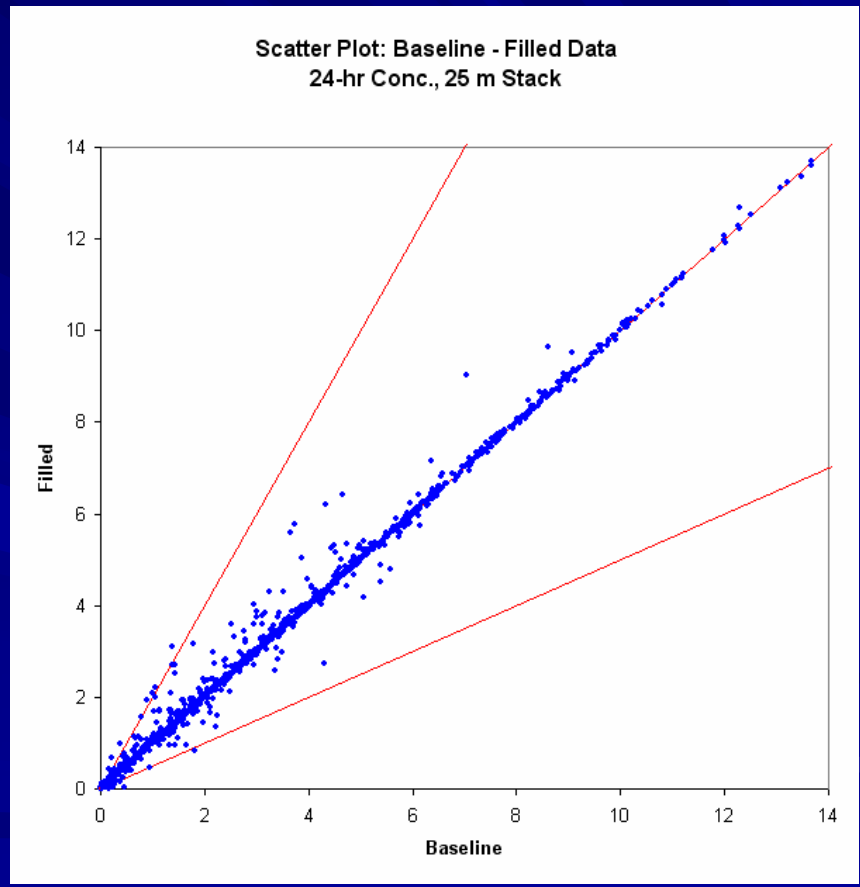
Results: 24-hr



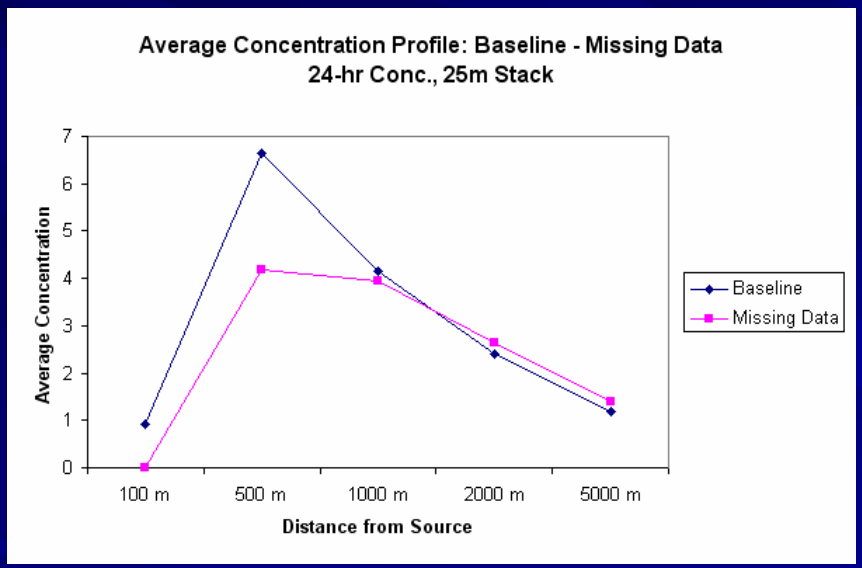


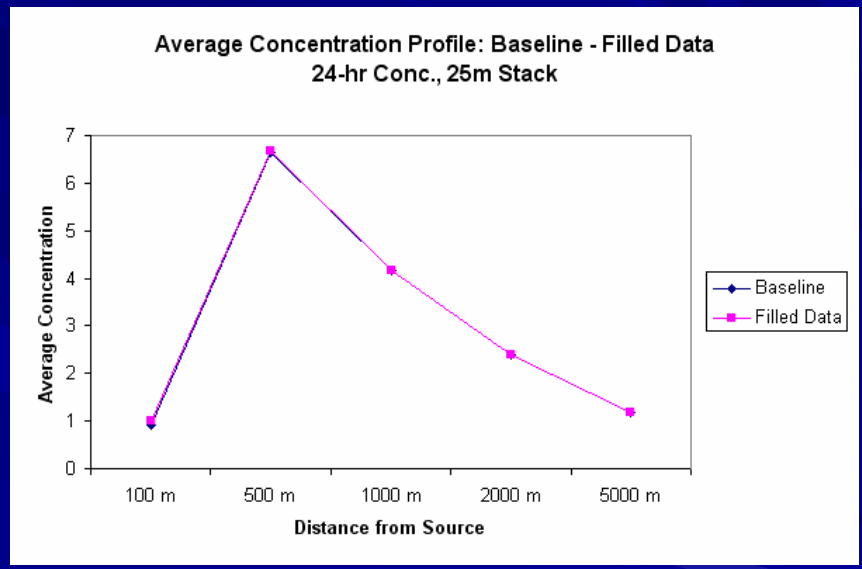
Results: 24-hr



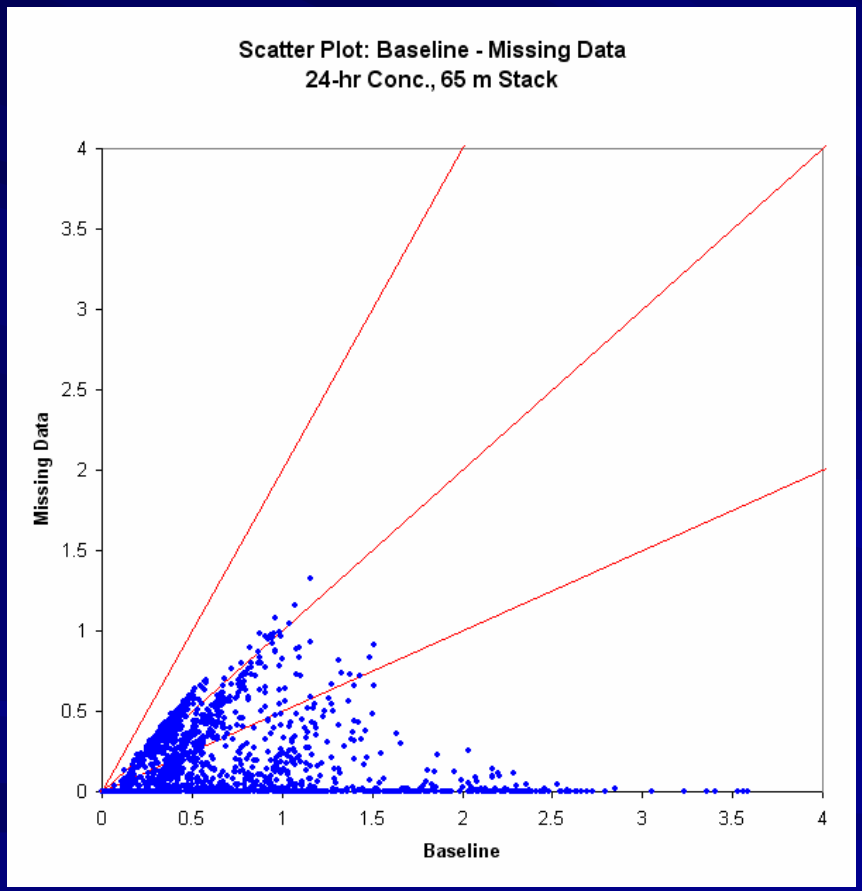


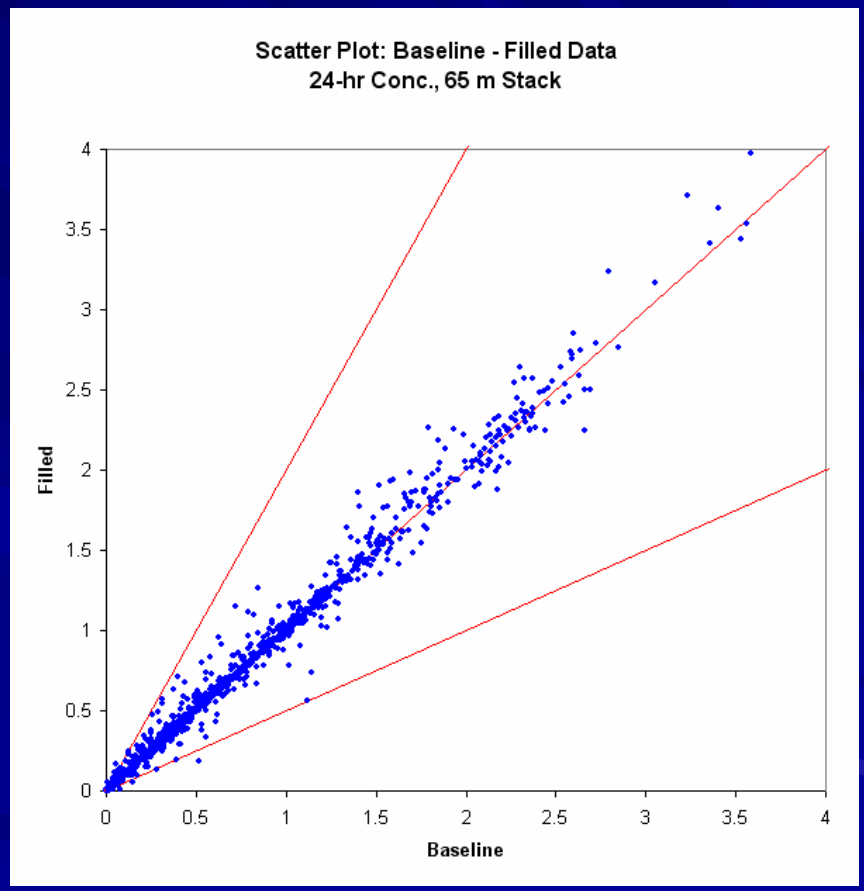
Results: 24-hr



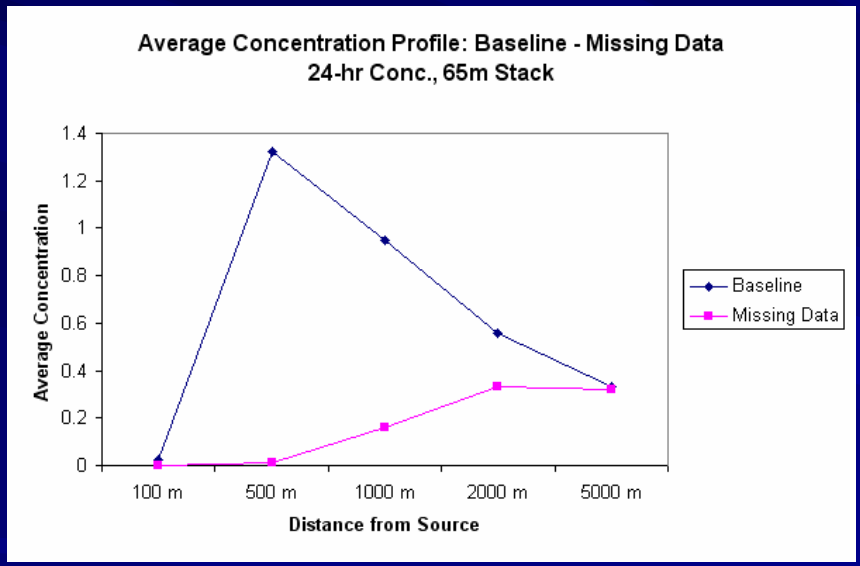


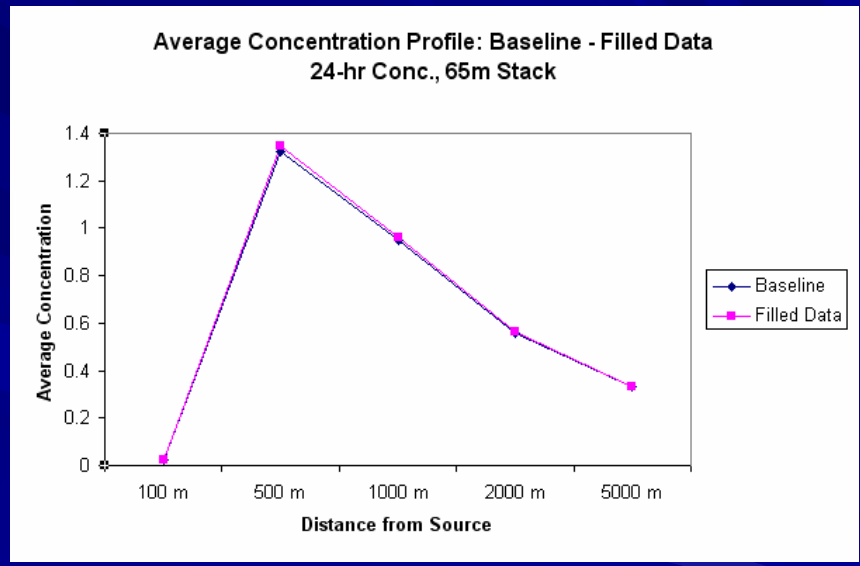
Results: 24-hr





Results: 24-hr





Conclusions

- Filling upper air data by substituting soundings from an adjacent station produces model concentrations that are very similar to the correct concentrations.
- Using upper air data that contains missing soundings tends to result in under-predictions, especially at locations nearer the source.
- The upper air data affects tall stacks more significantly than short stacks.

Questions?

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