World Trade Center Project

Abstract

This objective is to find out the impact of World Trade Center crash to the concentration of particulate matter in the New York area by Bayesian Maximum Entropy method.

Data

The data on hand are mainly from three sources. One is AIRS data; one is from NYSDEC; the other one is post-911 data. The data related to particulate matter are PM2.5 and PM10. In the past, most monitoring stations collected PM10 data daily in New York City area. After 2000, the PM10 monitoring stations were reduced very fast. Oppositely, after that point, the number of PM2.5 monitoring stations increases, and most PM2.5 monitoring stations collected data hourly. After 911, some post-911 monitoring stations were gradually set up. The first few post-911 monitoring stations were set up around 13 September to 18 September, but these stations are located in Staten island which is about 15 miles away from the World Trade Center (WTC) site. Most post-911 monitoring stations which were set up in the vicinity of WTC area are after the end of September, 2001. These post-911 monitoring stations collected data in the base of hourly. Since these data are obtained from different institutions, some of data monitoring stations may be duplicated. The reason of duplication is some monitoring stations with two different govern institutions. However, since our data are from different institutions and these institutions provide their own coordinates to us from their database, the same monitoring station may have two different coordinates in our database. In order to avoid accounting duplicated monitoring stations in our analysis, one of the monitoring stations will be taken out of our analysis if their distance of degree is smaller than 0.00001. Figure 1 shows the locations of monitoring stations around the New York City on October 1, 2001.

The data available are listed in the Table 1.

Table 1: data category

Source		Data Type			Collection period
Category	Institution	Pollution Type	hourly	daily	
AIRS		PM10		○	1982-2002
AIRS		PM2.5	○		2000-2002
Post-911	NYSDEC	PM10	○	○	09/2001-05/2002
Post-911	NYSDEC	PM2.5	○		09/2001-05/2003
Post-911	EPA Website	PM10		○	09/2001-05/2004
Post-911	EPA Website	PM2.5		○	09/2001-05/2005
Post-911	JHU	PM10			only few periods

Method and Process

The main purpose for us is to obtain the space time mappings of the New York City after the 911. Bayesian Maximum Entropy (BME) method has a powerful theory background to deal with spatio-temporal geostatistic problem. Besides, BMElib was created in the base of BME method under the Matlab platform. In our analysis, the BMElib is used to estimate the spatio-temporal mappings. The summary of our work can be shown as follows:

1) PM2.5 is a criteria air pollutant providing a useful indicator to assess the impact of the WTC collapse on air quality. The distribution of log-transformed PM2.5 across space $\boldsymbol{s}$ and time t may be conceptualized for the WTC event as a Space/Time Random Field (S/TRF) $Y(\boldsymbol{s},t)$ that is the sum of a mean trend function $m_Y(\boldsymbol{s},t)=E[Y(\boldsymbol{s},t)]$, where E[.] is the expectation operator, and a homogeneous/stationary random field $X(\boldsymbol{s},t)$, so that $Y(\boldsymbol{s},t)=m_Y(\boldsymbol{s},t)+X(\boldsymbol{s},t)$. The mean trend function $m_Y(\boldsymbol{s},t)$ of $Y(\boldsymbol{s},t)$ represent systematic trends in air pollution, while the covariance function $c_Y(\boldsymbol{s},t;\boldsymbol{s'},t')=E[(Y(\boldsymbol{s},t)-m_Y(\boldsymbol{s},t))(Y(\boldsymbol{s'},t')-m_Y(\boldsymbol{s'},t'))]$ describes it's variability over space and time.
2) The mean trend function was obtained applying a space/time moving average algorithm on several years of data in the greater WTC. A clear yearly pattern was found in the years prior to the 9/11/2001 event. The pattern shows an expected decrease of pollution every year in the 3-month period of September till November. The impact of the WTC collapse on air quality is modeled by using a discontinuous mean trend function with a source starting on 9/11/2001 at the WTC site.
3) The space/time covariance function is modeled using three space/time separable exponential covariance functions. The component of this model explaining most of the variability has a spatial range of about 0.09 degrees (1 degree is approximately equal to 111 Km) and a temporal range of about 7 hours.

From figure 2 to figure 4, they show the spatio-temporal mean trend and their collected values of three specified monitoring stations around the WTC site, and the covariance function is

$$c(r,t) = 0.119\exp(\frac{-3r}{0.09})\exp(\frac{-3t}{7}) + 0.0175\exp(\frac{-3r}{150})\exp(\frac{-3t}{7}) + 0.0175\exp(\frac{-3r}{150})\exp(\frac{-3t}{365})$$

and it is shown in Figure 5. The analytic covariance function can be put into BMElib to estimate the PM2.5 concentration in the New York City area.

Result and Discussion

By using BMElib, one can find that the spatio-temporal mappings of PM2.5 around 911 are shown in figure 6 to figure 9

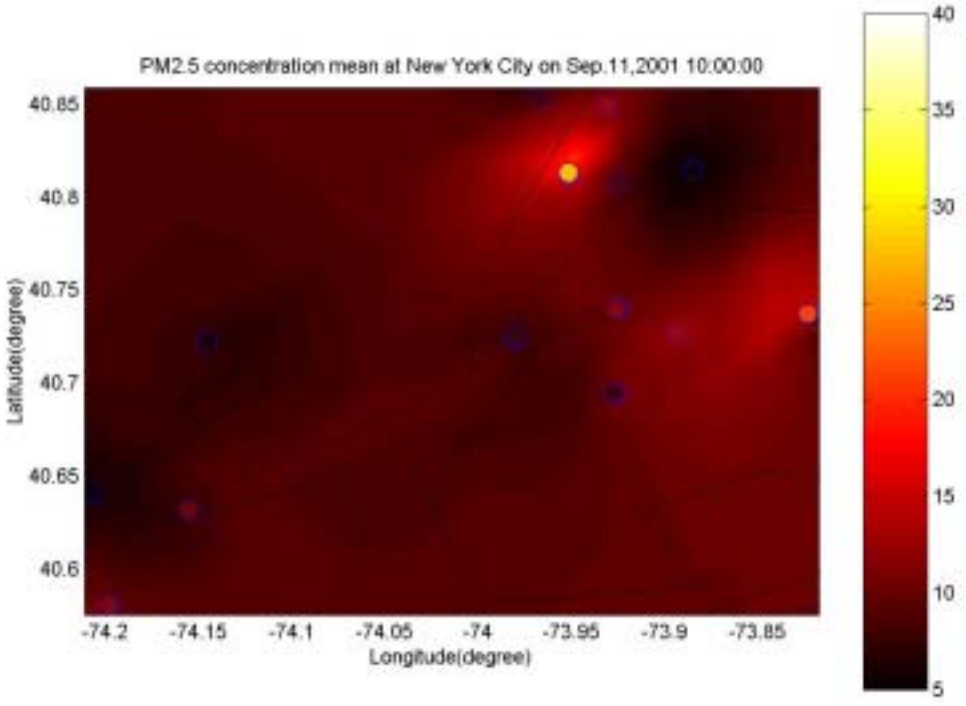


Figure 6

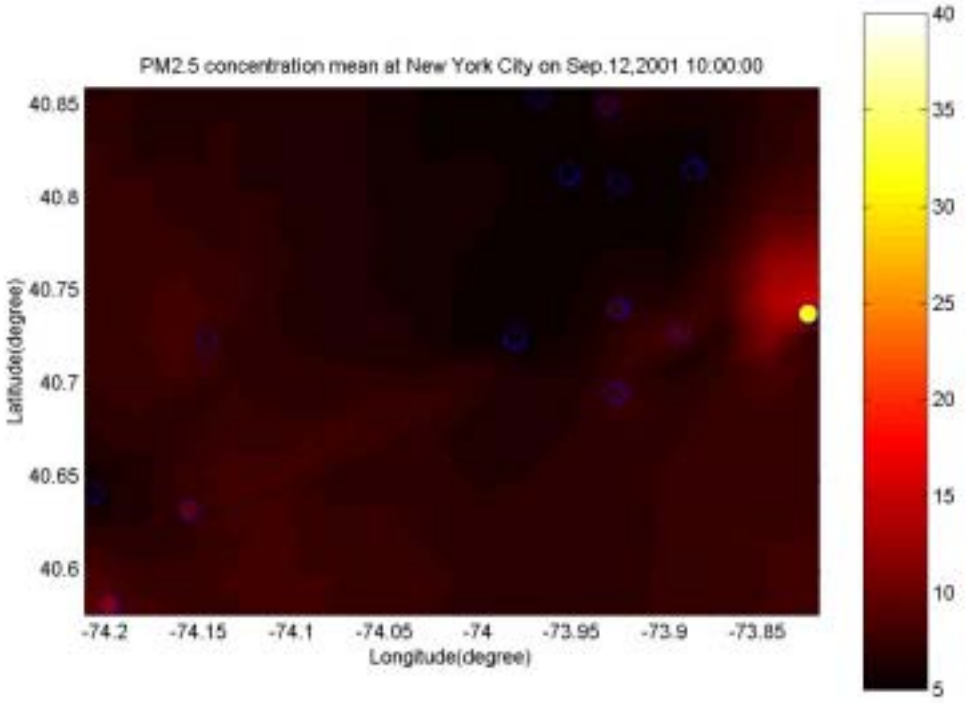


Figure 7

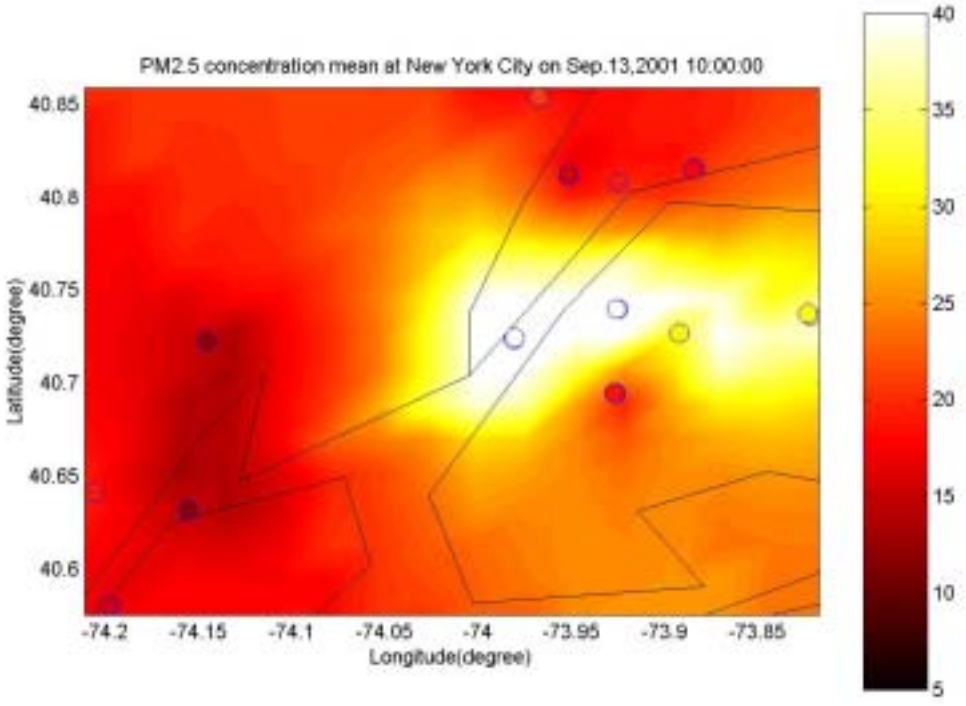


Figure 8

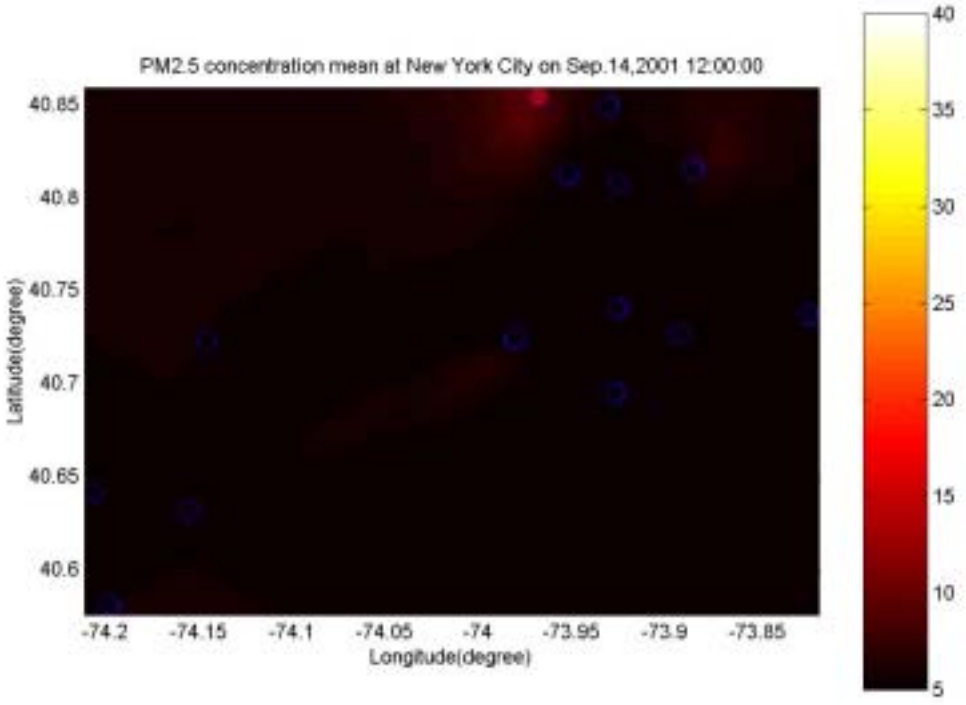


Figure 9

From figure 6 to figure 9, after the WTC crashed, the monitoring stations did not collect really high concentrations of PM2.5 except Sep. 13. (For the more detail information, please go to www.unc.edu/~hlyu/WTC/WTCFrame.html) The pollution plume can not be seen clearly and consistently from the data of monitoring stations. Besides, one can notice that even the plume shown in Sep 13, the values of monitoring stations are not extremely high values. The space/time maps obtained for the 3-month period after 9/11/2001 show that in general the AIRS monitoring data provide information about the background air pollution away from the WTC source, however this data is too sparse and too far from the WTC source to provide a coverage that would allow the reconstruction of the space/time plume in the vicinity of the WTC. The informal version of the post 9/11 WTC database seems to have some data point with questionable data quality, and may be incomplete. Including the monitoring data in this version of the database adds a few monitoring stations that are closer to the WTC, but does not seem in general to provide a sufficient coverage to re-construct the space time plume in the vicinity of the WTC. It will therefore be necessary to combine the present monitoring data with output from dispersion plume modeling in order to obtain a more accurate representation of the air pollution plume. A few high air pollution episodes have been identified in the monitoring data for the 3-month period following 9/11/2001. These episodes will be extremely useful in order to calibrate the dispersion model. Due to the fact that additional monitoring stations were added only several weeks after 9/11, the episodes identified in the monitoring data are mainly in October 2001, with one of the main episode centered on Oct 3. (From figure 10 to figure 16)

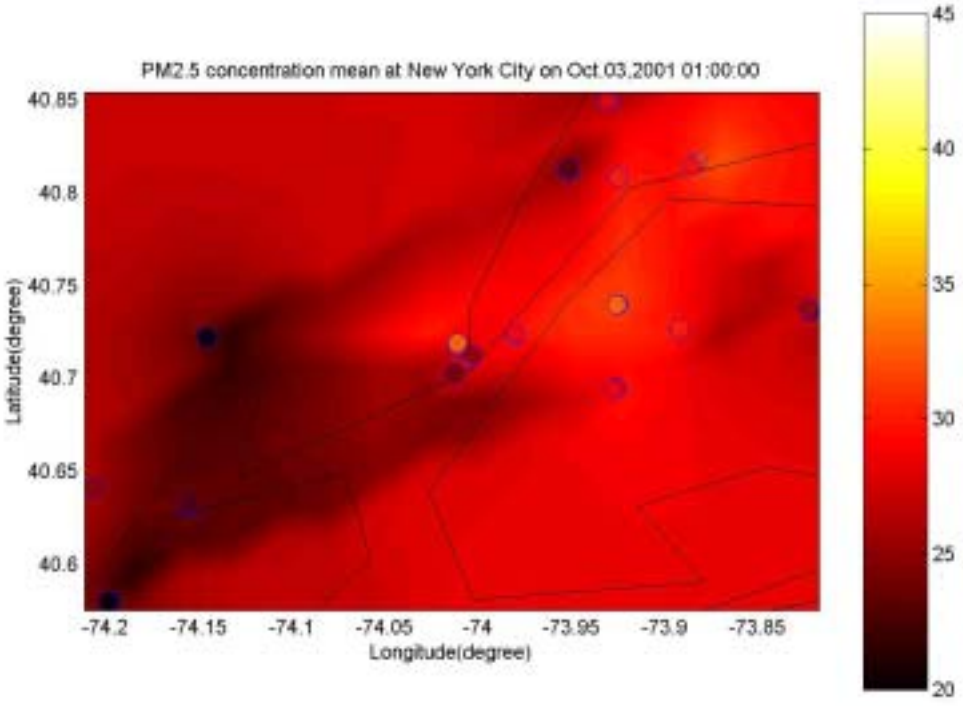


Figure 10

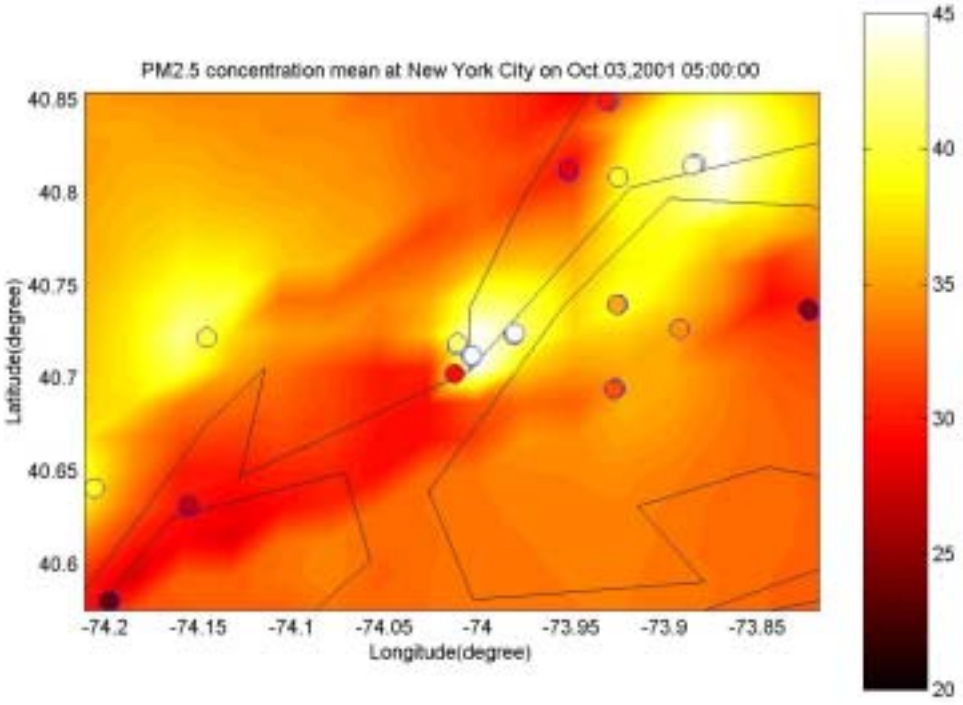


Figure 11

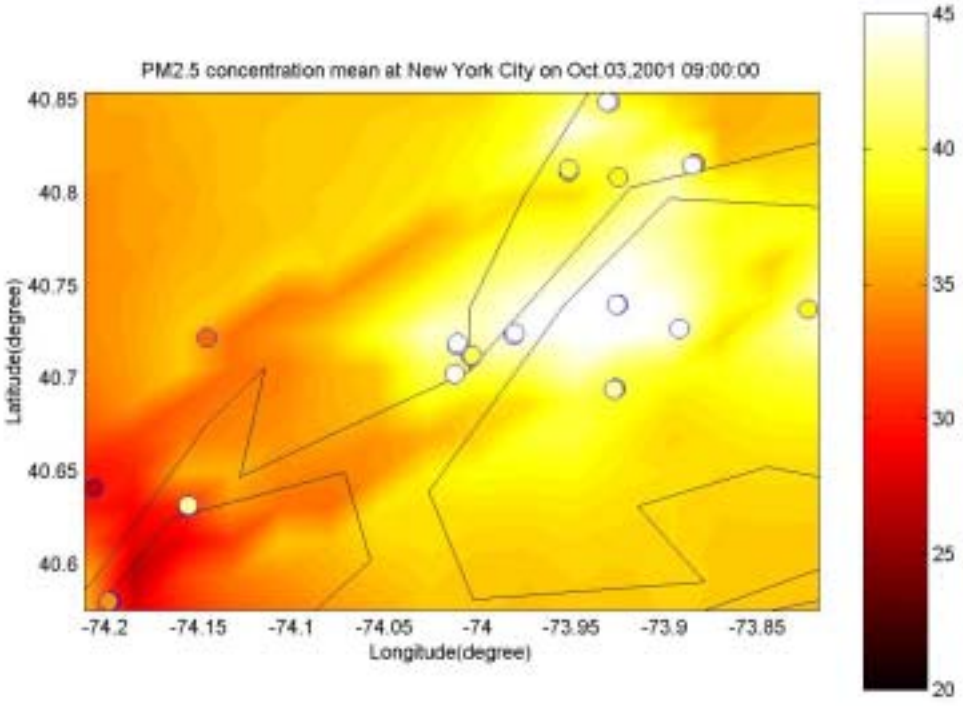


Figure 12

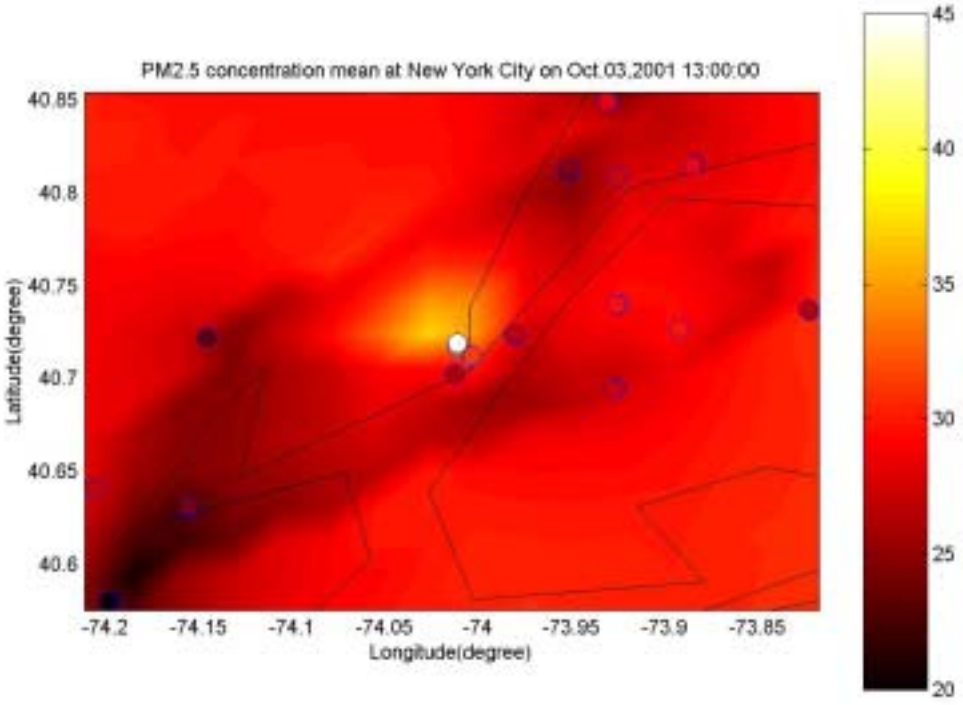


Figure 13

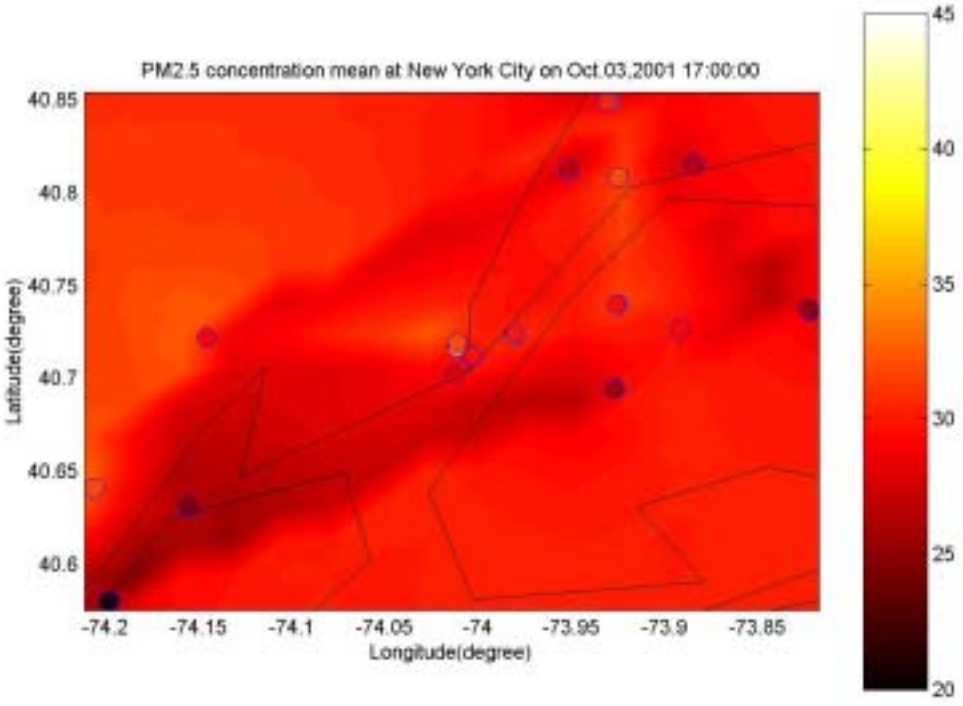


Figure 14

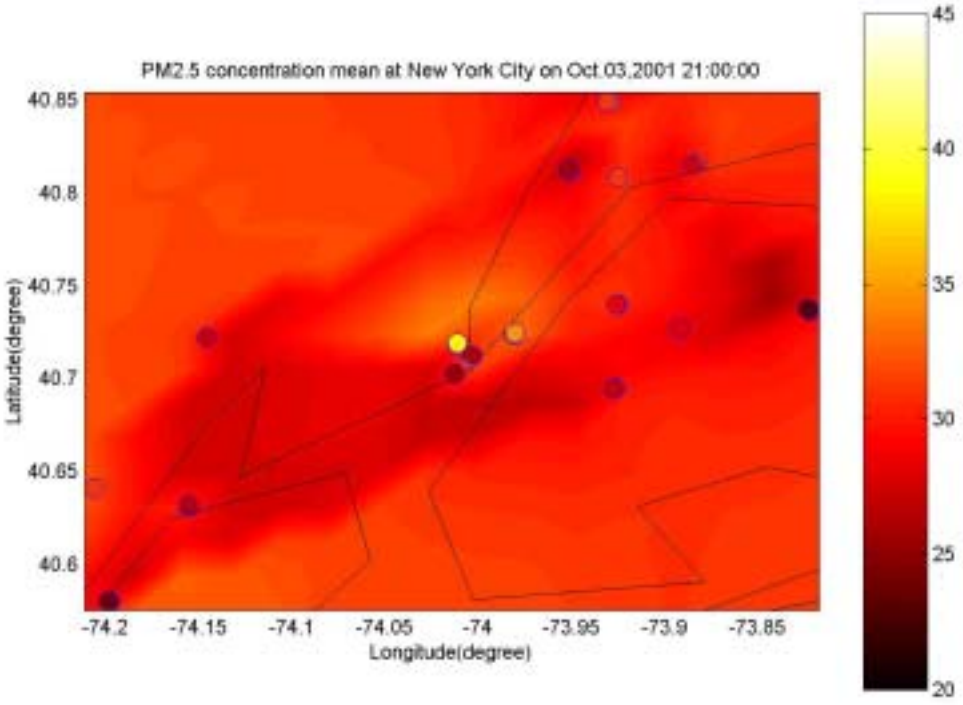


Figure 15

From the figures above, even the post-911 monitoring stations are accounted into our analysis; the clear plume which is generated by WTC crash can not be detected.

From the long time series plot of PM10 data in figure 17, the averaged PM10 concentration is clearly raised after Sep, 2001 by comparing with the series from 1996 to 1999. Since it exists a linear relationship between PM10 and PM2.5, one can understand the WTC crash increase the background concentration in New York City Area, though no clear plume evidence is found.

From the movies (www.unc.edu/~hlyu/WTC/WTCFrame.html), we can tell there are always at least one monitoring stations around the WTC with higher concentration; besides, as we know, the closest post-911 monitoring station to WTC is located few blocks from the site. Though one can not clear tell the plume from WTC by sptio-temporal mappings, they seem to show some evidence that the pollution from WTC was constricted in a local space after October. The reason is after the WTC crash, the WTC is not as high as before; oppositely, the residual WTC then may be just few floors high. It means that the polluted source is very low, but lots of high buildings located around the WTC site; therefore, the movement of the pollution fro WTC was blocked by the buildings around, so it is not easy to get very high concentration value from all monitoring stations even they are very close to the site.

Under this situation, it is not easy to figure out the evidence of behavior of plume by simple geostatistics. A better way to estimate the real impact from the WTC is to include the physical model to account for the ejection and transport the pollutant from the WTC.

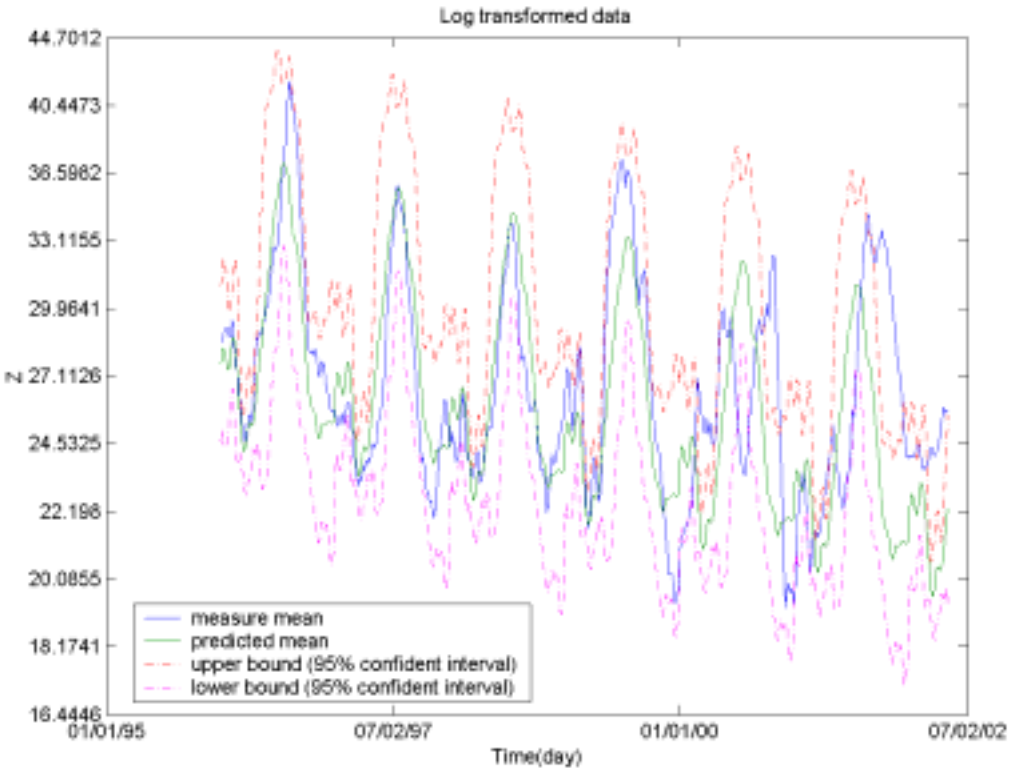


Figure 16

In order to simulate the real behavior around the WTC without the physical model, the simplest way to do this is using outer interpolation from measured value of post-911 monitoring stations. As mentioned, the first post-911 monitoring stations were set up after the end of September, and then some were set up in October, some in November, December, and January. There is a downward tendency of the measured values of these monitoring stations; for example, figure 4 and figure 5. The spatio-temporal mappings by accounting into the outer interpolation value are figure 17-figure 20.

As described, Johns Hopkins University (JHU) has been to the WTC site to make some measurement in few periods. The locations where they measured are just beside the WTC site, not few blocks away. However, what they measured is PM10, not PM2.5. In order to include their measurement into our analysis; the linear relationship between PM10 and PM2.5 is applied which is estimated by calculating the ratio between PM10 and PM2.5 from 2001 data. After getting the estimated PM2.5 values of JHU data, these data are used to estimated the mean trend at WTC site by localizing the mean trend calculation. From this approach, one can obtained the estimated PM2.5 values after 911 which are shown in figure 21-figure23

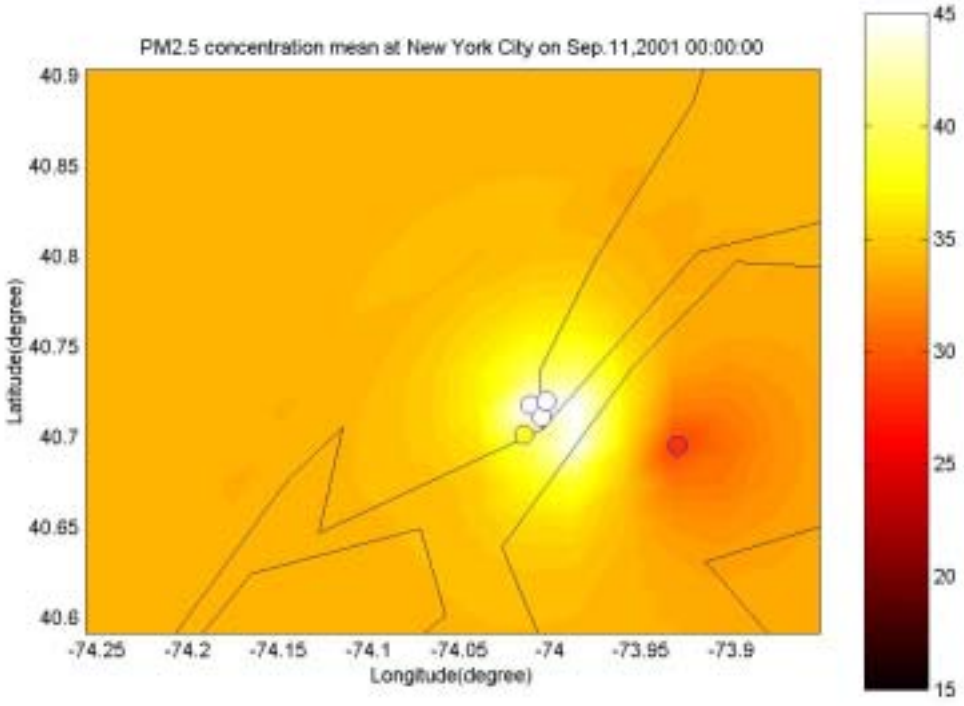


Figure 17

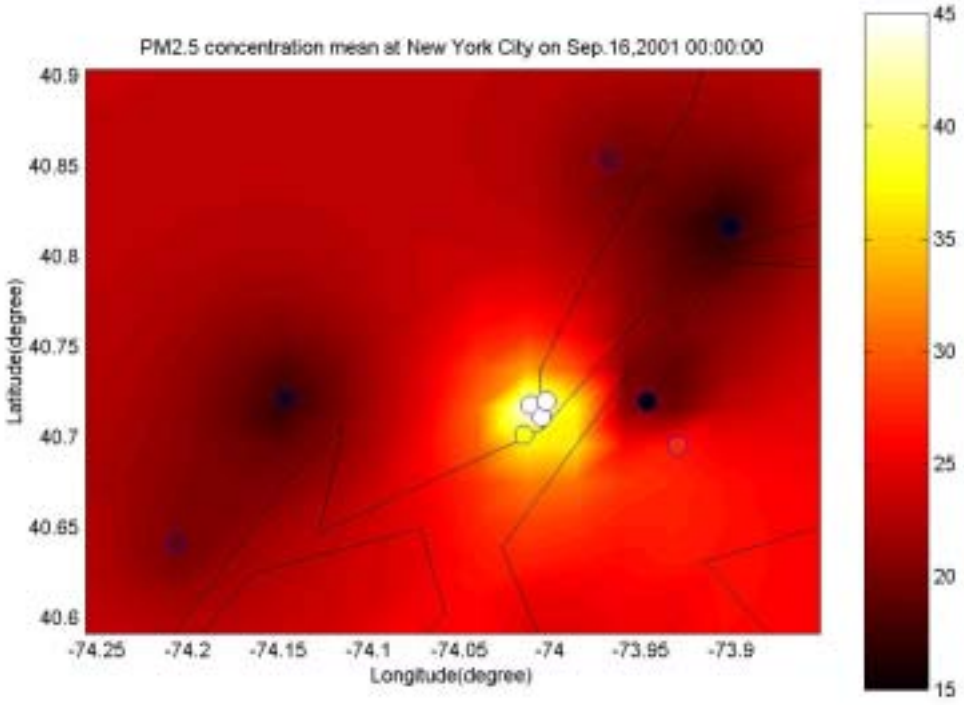


Figure 18

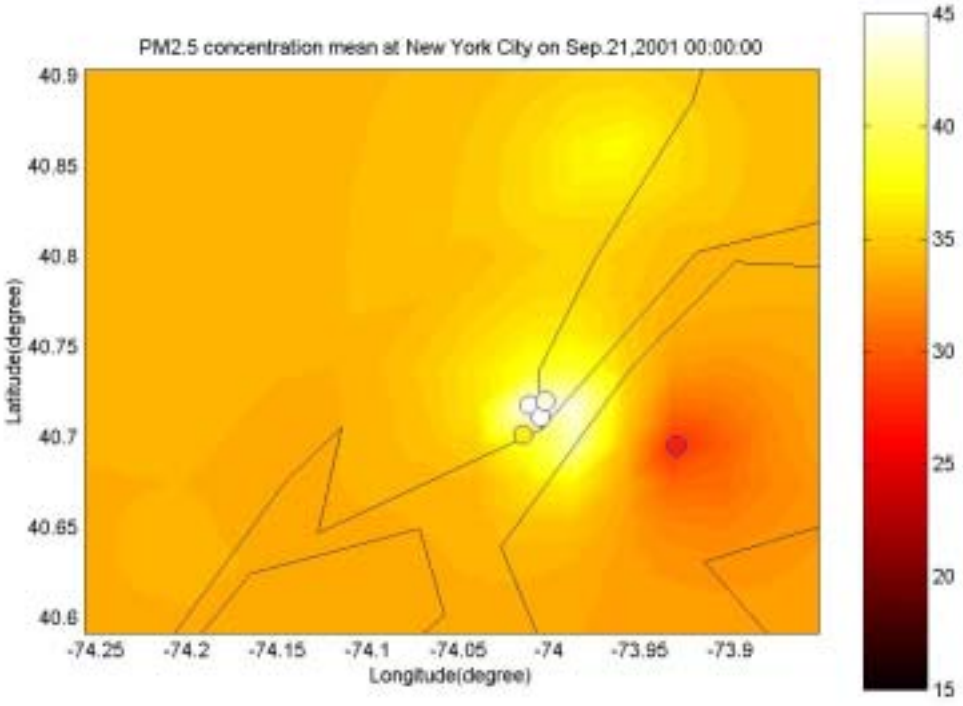


Figure 19

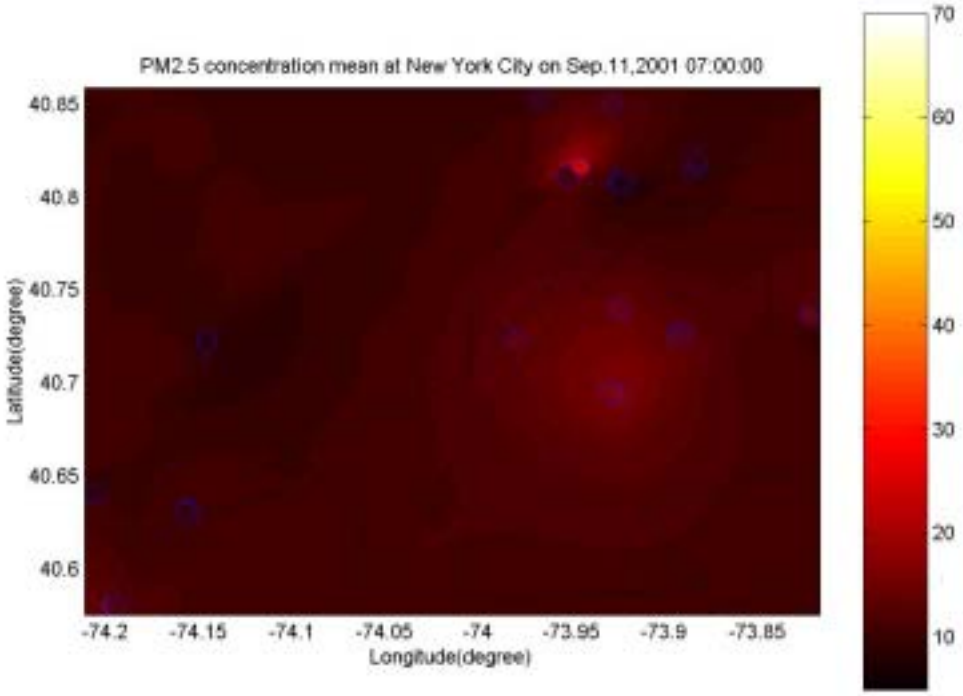


Figure 20

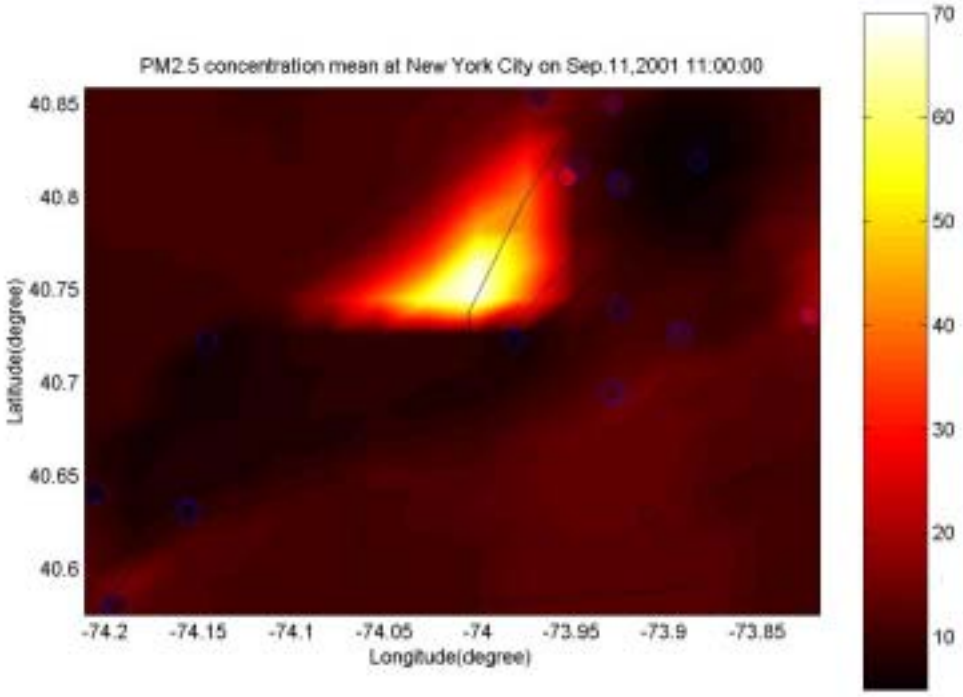


Figure 21

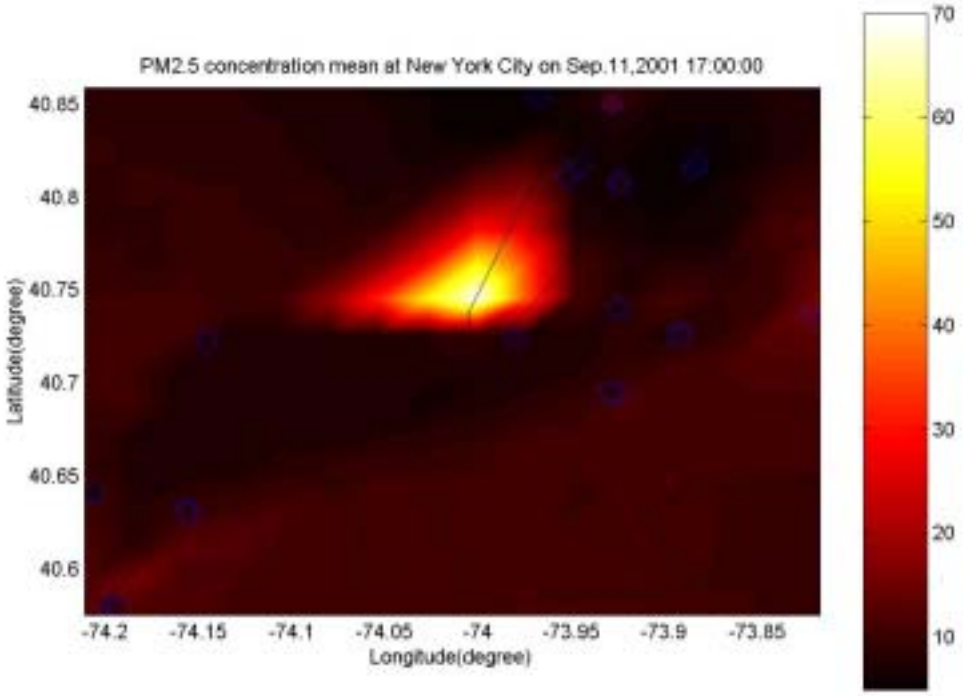
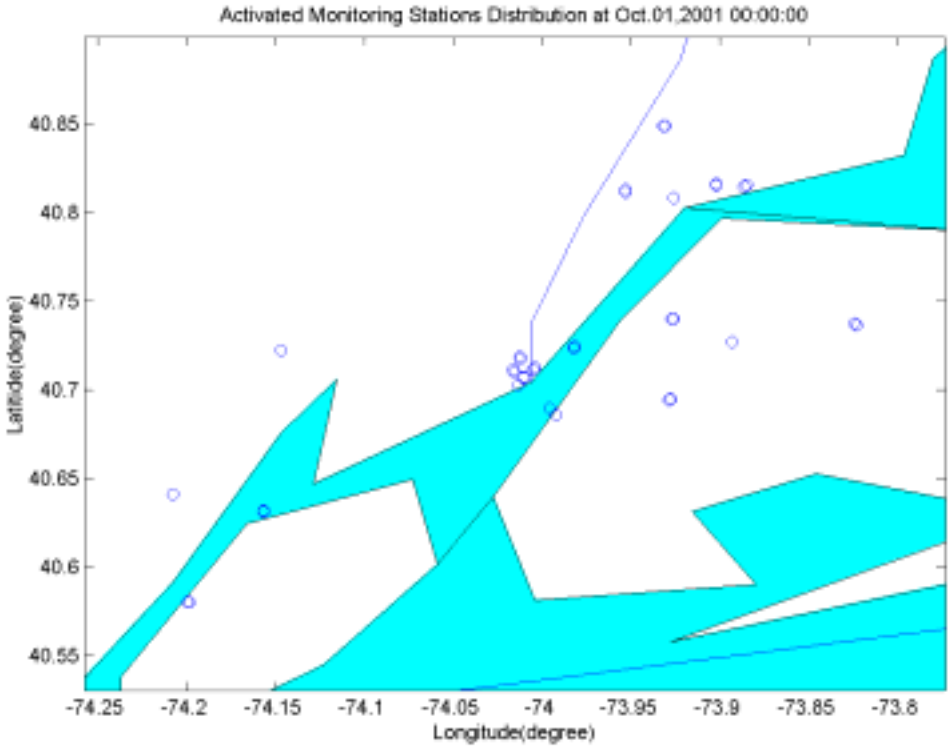


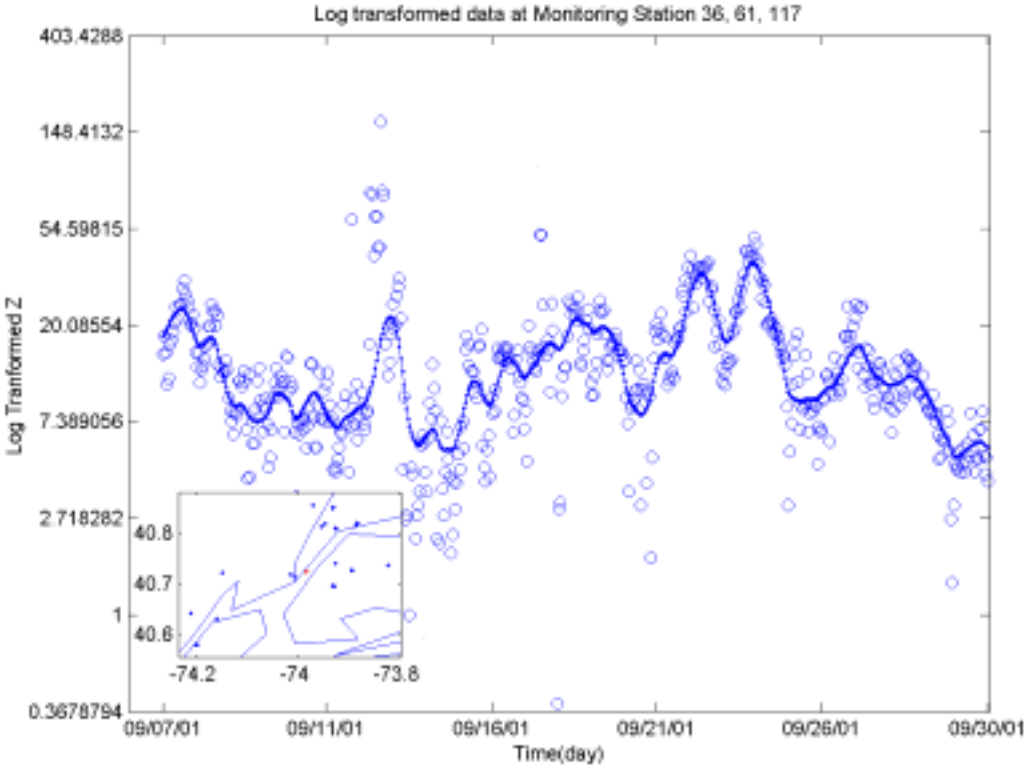
Figure 22

Figures

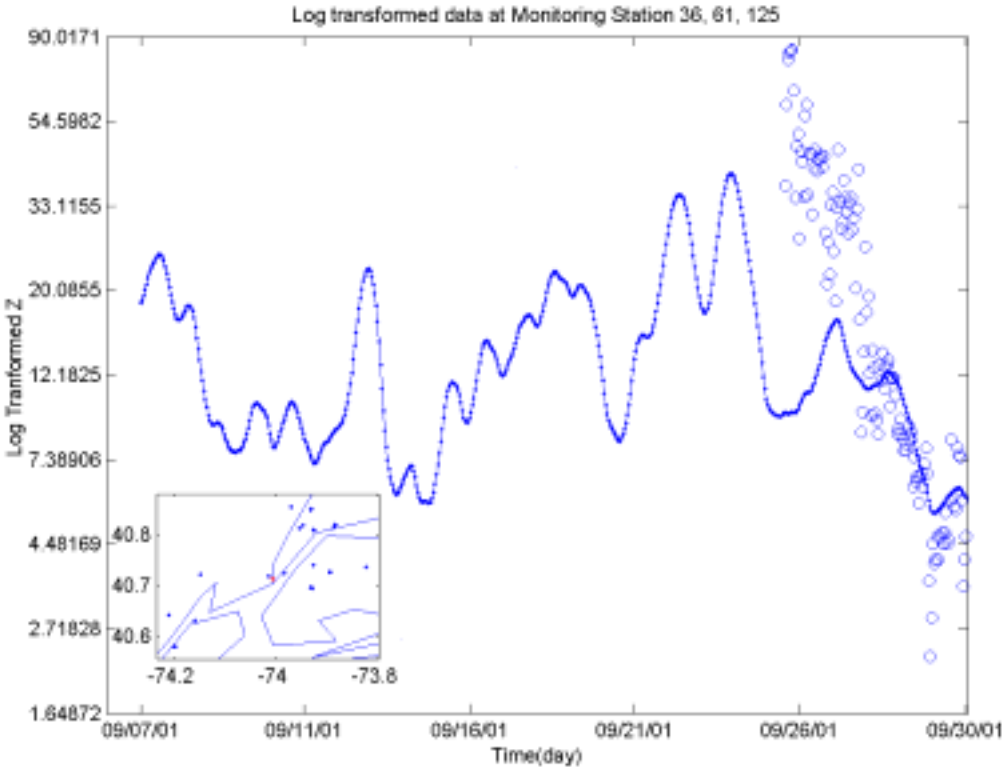
1. The spatial distribution of monitoring stations in New York City on 00:00 Oct 1.



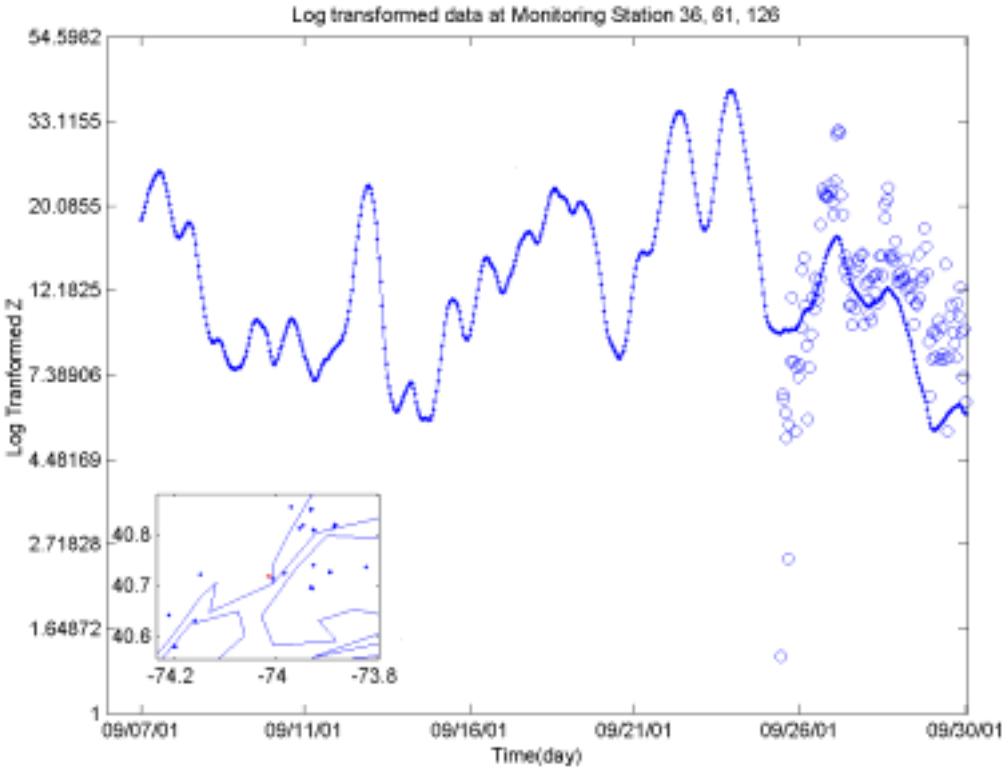
2. The mean trend plot of a monitoring station near WTC site



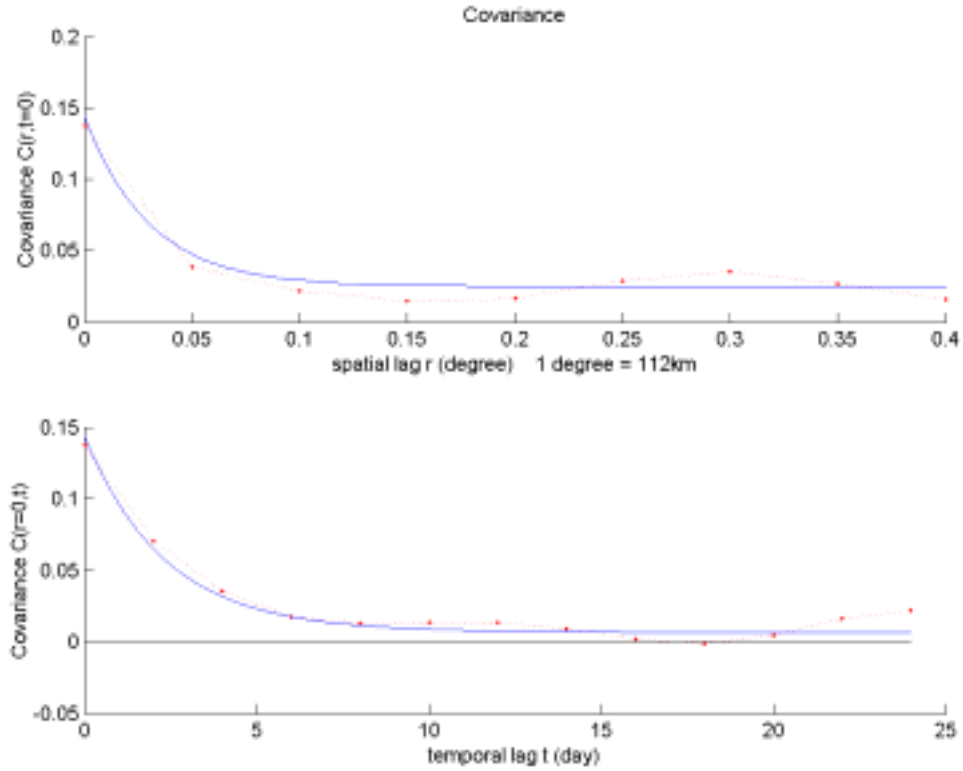
3. Another mean trend plot of a monitoring station near WTC site



4. The other mean trend plot of a monitoring station near WTC site



5.


Covariance
Covariance C(r,t=0)
0.2
0.15
0.1
0.05
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
spatial lag r (degree) 1 degree = 112km
Covariance C(r=0,t)
0.15
0.1
0.05
0
-0.05
0
5
10
15
20
25
temporal lag t (day)