ATMS490: Individual Study

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[github]gciaglia: https://github.com/gciaglia/ATMS490-Individual-Study-SP21.git

1 Introduction

Understanding how aerosol particles move around a city and changes presence are of great interest. Aerosol particles can range from the size of a few micrometers to the size of a nanometer. These particles are present in the air that humans and all living creatures readily breathe in. Within urbanizing cities and areas that produce large amounts of these particles, these particles can pose a hazard to human health. One of the major sources of these particles and the increased presence of them are from motor traffic. This is predicted to increase as road traffic expands and populations will be further exposed. However, these concentrations of particles vary between regions with regards to their increase potential and frequency. Additionally, not all people live in urban regions and people within these regions participate in different activities. Developing insight into spatial distributions and contribution emissions can better evaluate what individuals are exposed to, **Kumar et al., 2014**.

This can lead to better knowledge on air quality standards, at risk environments, and help identify health risks, **Kumar et al., 2014**.The impacts on human health are not fully understood but further analysis can give commentary on air quality, regional variability, and can even give information on climate.

From the Institute for Petrology and Climate Research and Karlsruhe Institute of Technology, a study was focused on the spatial variability of particle concentration on NO_x. This study was done in Karlsruhe, Germany with the use of a mobile laboratory on an electric tramway of the municipal transport services of Karlsruhe. The measurement device measures gaseous components H_2O, O_3, NO, NO_x, CO, and CO_2 with very specific sensors. The tram covers two different main routes that links regions northward and southward of the city. These cover regions of the Rhine Valley and the Northern Black Forest. Route 1 specifically links the Norther Black Forest to a village north of the city. Route 2 links rural areas west of the city to the city and on northeast of the city. Data was collected on particle size distributions, concentrations, tram velocity, and various other atmospheric variables over time and space, **Hagemann et al., 2014**.

The data collected in this study was used to focus on the trends around the city. Specifically, the routes where the variable PNC1 was measured were investigated. The variable PNC1 represents the particle number concentration for diameters between 10 nm and 3 mu. The distance from the city, velocity, concentrations, and the particle distributions were used to see particle trends in the region as the tram travels.

2 Method

Analysis of the provided data was done through MATLAB where various averaging techniques and computation was completed.

The data itself consists of many measured concentrations at specific locations in time and often needed to be indexed to isolate specific regions of interest within it. The data consists of valid, measured values and ones that are missing denoted by an entry of ”-999.”

For plotting, the geobubble function in MATLAB was heavily used to visually represent the data to identify trends within particle concentrations over time and in space at a specific locations. The locations were determined distances from the city based on longitude and latitude values.

2.1 Data Set and Variables

The data set comprises of several variables that were measured over time and space from 2009 to 2011.

Table 1: Variables Measured in the Provided Data Set

Parameter	Variable Name	Unit
Time	time	Seconds
Longitude	lon	° E
Latitude	lat	° N
Tram Velocity	tram.vel	m/s
Particle Number Concentration (3 mu - 10 nm)	PNC1	cm^3
Particle Number Concentration (3 mu - 4 nm)	PNC2	cm^3
Route Number	Route	#
Loop Start	Start	#
Loop End	End	#
Number of Runs	Start	#

Table 1 represents all the data utilized in this investigation. The variable PNC1 is representative of particle number concentrations for diameters between 10 nm and 3 mu. The variable PNC2 is representative of particle number concentrations for diameters between 4 nm and 3 mu. The unit represented as # is a unit-less value in the set. Instead, it has a range of values that signify an organization in the data collected. For instance, the Route number is a value that ranges from 1 to 99 that identifies a specific route within the data of the two overarching main routes. This route only accounts for a portion of the total distance traveled. The Loop Start and Loop End identify the start and end of a loop and range from a value of 110 to 250. The number of runs identifies a specific run, runs are tied to a specific route and ranges from a value of 1 to 2770. Other values include the longitude and latitude which gives a specific location for each measurement, the time that the measurement device was running since the start of January 1st, 2010, the velocity of the tram at all measurement locations, and the particle concentration that are measured every second since this start time.

2.2 Determining Distance from the City

To find the distance from the city, the values within the variables longitude and latitude were used to create a coordinate pair. The location of the city was noted to be at coordinates 49°E, 8.4°N. Then, the MATLAB distance function was used inside of a loop to find the distance between each coordinate pair and the city location. This distance was then converted to kilometers. This populated a new array with the distance of each measurement from the city.

However, this distance did not account for a direction specifically from the city. Another loop was embedded into the distance loop that set the condition that if a value was larger than the city's longitude and latitude, it was converted to a negative value. Essentially, on a map, if any measurement location is North of the city it was considered to be negative. This allowed the distance to be measured relative to the city so the position of a measurement could be clearly noted.

2.3 Find Logical AND

To look at a specific route within the data and to isolate only valid data, Find Logical AND was employed in MATLAB. Essentially, it performs a conditional on a whole array where the longitude, latitude, and PNC1 were set to values greater than "-999" and route was set to a specific value of interest. This determined where the condition was true and could be applied into the parameters of the total data set to isolate the specific values of interest.

This was fundamental to isolate specific data for routes, runs, and the locations in which the time aligned for all the parameters so that it could be used for further investigation of the data trends.

2.4 Averaging Techniques

In the data analysis, both interpolation and averaging techniques were used.

Since data was recorded every second within the initial data set, this illustrated limitations on MATLAB's geobubble function to spatially present information adversely impacted interpretation of the data. To alleviate some of the cluttering and to allow better trend recognition, for intervals of 20 seconds and 40 seconds, data points within the interval was averaged to a single point. This is later noted in the paper.

When characterizing the variability of the data within specific routes, interpolation was used. This smoothed the data and allowed multiple routes to be compared at different locations within the city by giving congruent data array sizes.

3 Results and Discussion

The data analysis focused on looking at the data as a whole and narrowing it down to both the routes and the runs within a route. The techniques described in Section 2 resulted in the following results.

3.1 All Route Concentrations

In the analysis of the data collected from the tramcar, the concentrations of variable PNC1 was investigated for several different routes and runs. The data collected consists of a tramcar that covers the region around the city where portions of this main route (Route 1 and Route 2) is organized into 99 different sub-routes each covering various portions of the main route. These routes travel both inside and out of the city Karlsruhe, henceforth sub-routes will be referred to as 'routes.'

First and foremost, all the measurements were plotted with respect to the concentration recorded at each latitude and longitudinal location. This is a trace for all the locations and all the routes with a concentration recorded, as shown in Figure 1.

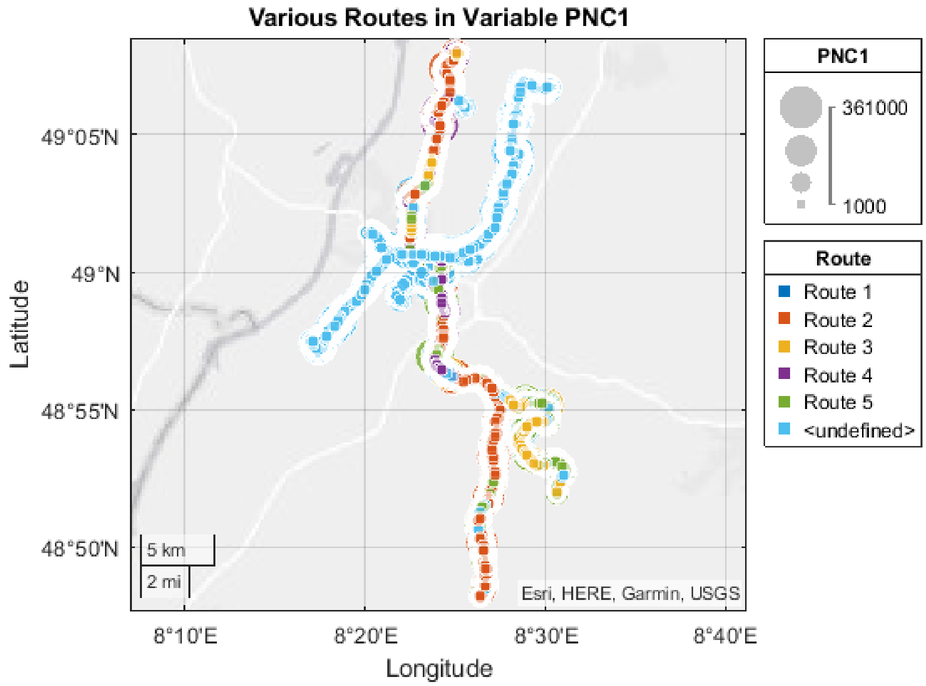


Figure 1: Route Concentration Trace

In Figure 1, there is a trace of all the measurements taken for all of the routes. This represents all of the data taken within this study and its geographic placement. The varying size of the bubble shows the concentration measured at the respective latitudinal and longitudinal location. The larger the bubble, the larger the concentration measured. The data was then focused to look at specifically Route 2 and run 472 within it.

3.2 Route 2 Concentration Focus

The total collection of data points was narrowed down to the only the data points in Route 2 and Run 472.

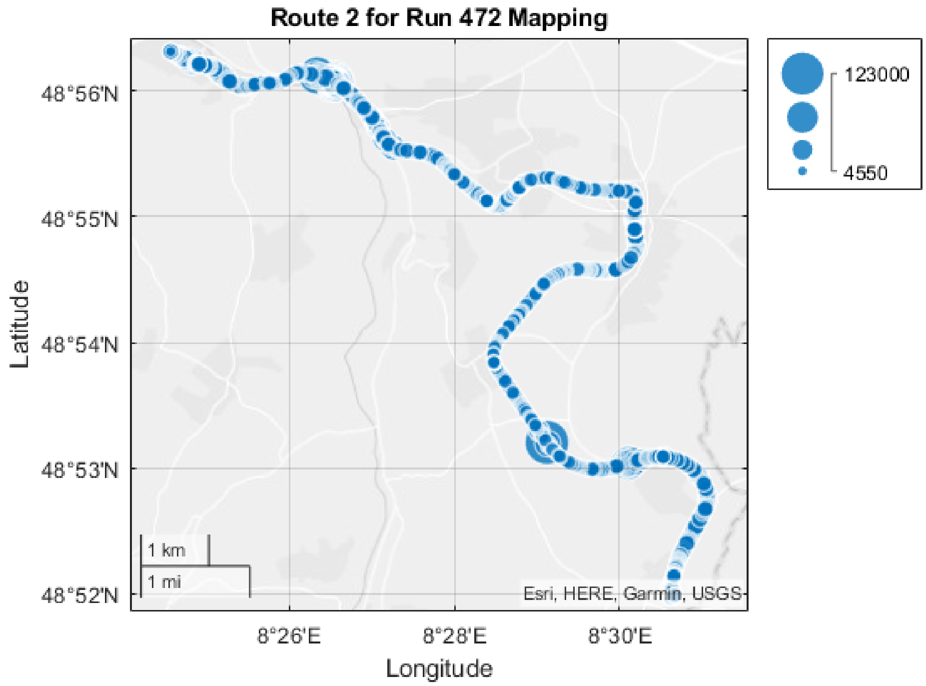
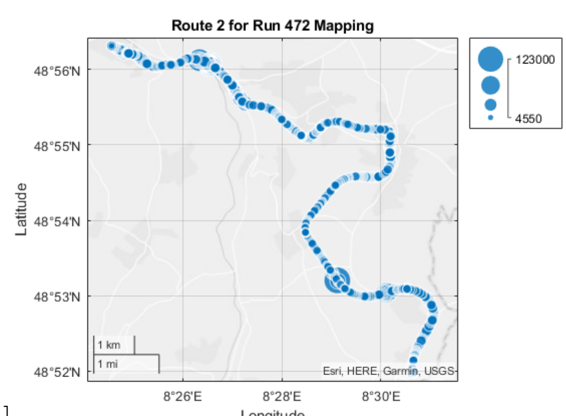


Figure 2: Route 2, Run 472 Concentration Trace

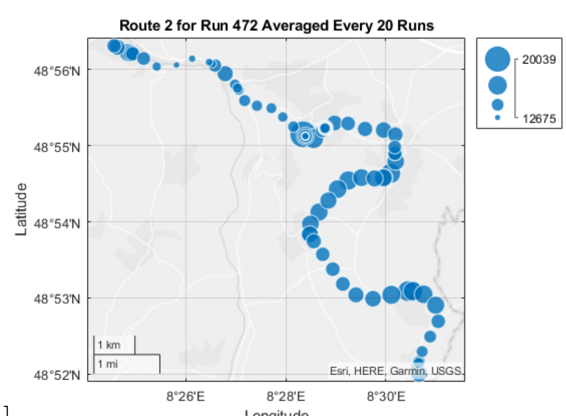
In Figure 2, the concentrations for Route 2 and for Run 472 are shown. As seen, this is a specific route within all of the routes shown in Figure 1 and covers only a portion of the location shown previously. This is representative of data that accounts for measurements of the tram going in and out of the city. However, this figure contains a lot of data points and does not narrow down any trends in changing concentration. To further narrow this down, the data in this route was averaged over an interval of 20 seconds and over an interval of 40 seconds.

3.3 Averaging Concentration Data Points

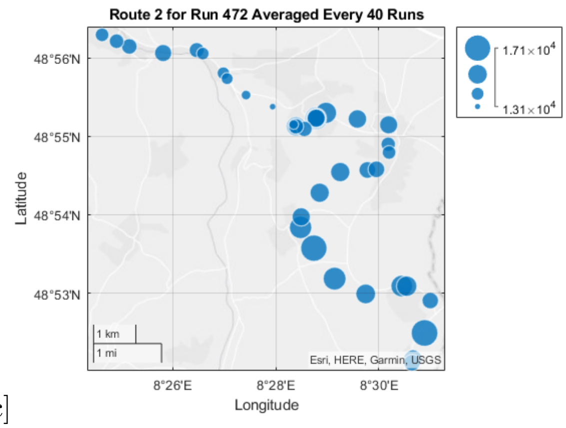
Every 20 seconds of data points and every 40 seconds of data points from Route 2, Run 472 were averaged. Each 20 second interval consists of 20 data points and every 40 second interval consists of 40 data points.



[a]



[b]



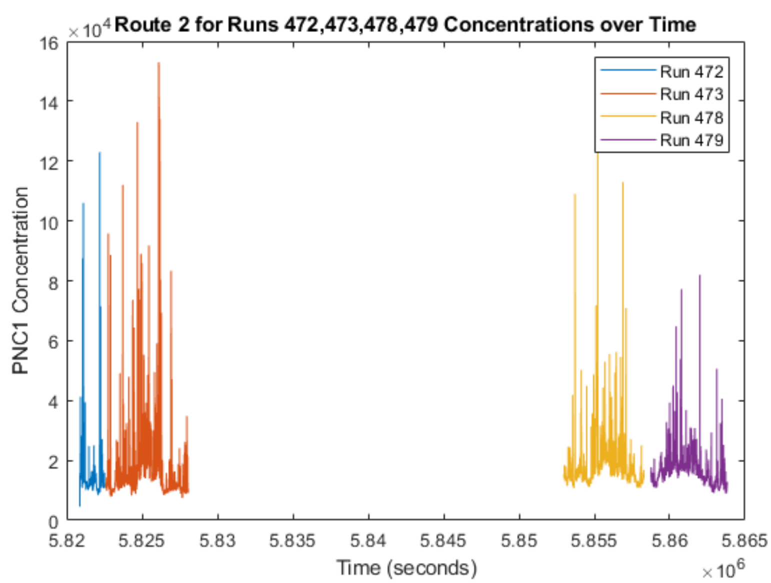
[c]

Figure 3: Route 2, Run 472 Concentration Averaging
(a) All data points (b) Mean of every 20 values (c) Mean of every 40 values

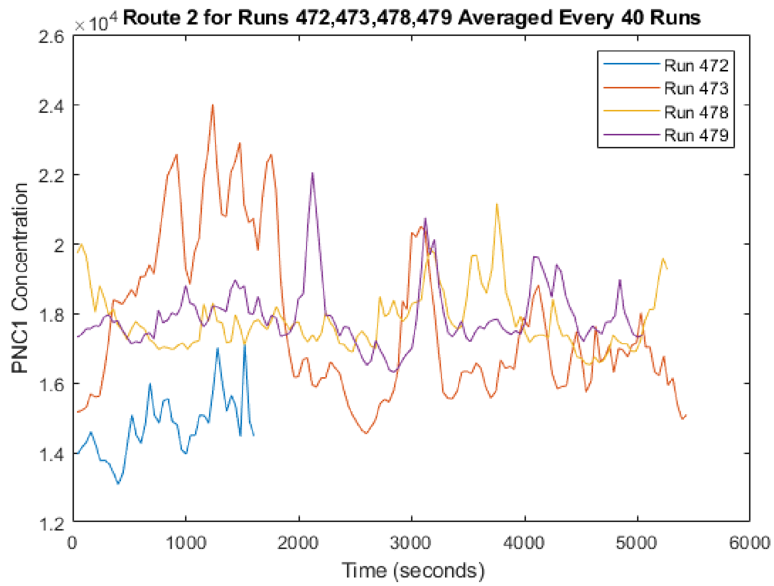
In Figure 3 (a), represents the all the concentrations for Route 2, Run 472. As seen in Figure 3 (b) and (c), there are less points than in (a). This averaging brought down the largest concentration in (a) by a factor of 10 with each 20 point average. Additionally, averaging allows for a trend in the concentration to be more easily seen and reduces the total amount of points. The larger the bubble, the larger the concentration that is measured. In Figure 3(c), the percent difference in the maximum and minimum is 26% whereas in Figure 3(b) the percent difference is 45%. So as averaging is applied, the concentration range decreases where maximums of the averaged data set are lower than the maximums of the original data set and variation in the points are reduced as larger intervals are averaged.

3.4 Examining Specific Runs within Specific Routes

To further examine Route 2, multiple runs within it were considered. Specifically, these were runs 472, 473, 478, and 489.



[a]



[b]

Figure 4: Route 2, Runs 472,473,478,479 Concentration Averaging over Time
(a) Runs in Time (b)Runs Overlapped in Time

Figure 4 (a) shows the concentration of runs in the time they were measured and (b) shows the concentration for each of these runs but aligned in time. Besides run 472, the runs in Route 2 run for about 5500 seconds, approximately 90 minutes.

However, the tram moves towards and away from the city. Therefore, determining the direction in which the measurements were taken in Figure 4 is important.

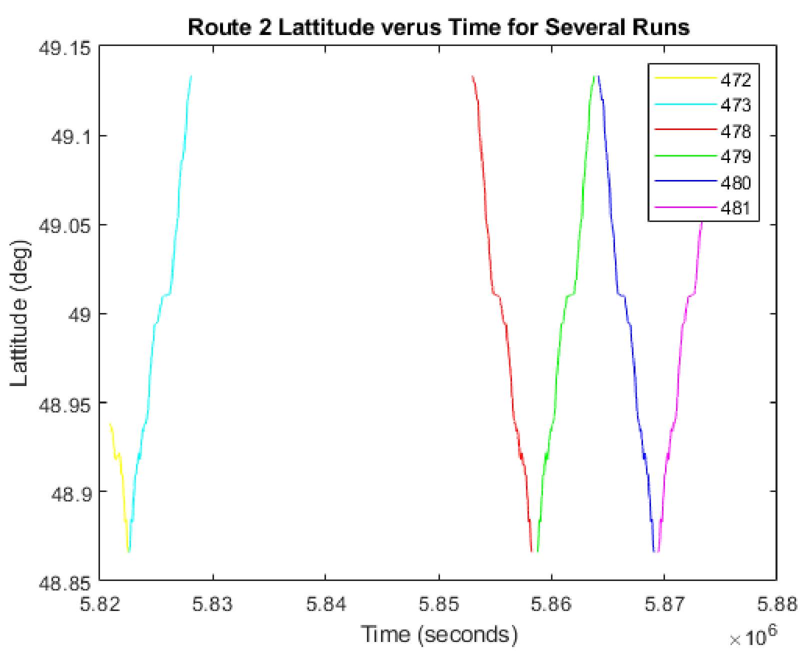


Figure 5: Route 2, Latitude of Runs over Time

In Figure 5, the runs change over time with respect to latitude and additional runs 480 and 481 were considered. The city of Karlsruhe is at a latitude of 49°N where the runs examined contain measurements from latitudes both greater and less than the location of the city. Within Route 2, runs 472, 478, and 480 decrease in latitude over time. This suggests that these runs head south towards the city and continue to head south outside of the city. In contrast, runs 473, 479, and 481 head north toward the city and continue north away from the city.

3.5 Mapping Concentrations for Different Runs in Route 2

To further characterize the measured concentrations for PNC1, runs 472 and 473 were compared. Run 472 is began measurements on Tuesday, March 9th, 2010 at approximately 8:52 am whereas Run 473 began measurements on Tuesday, March 9th, 2010 at approximately 9:23 am. Approximately 99 seconds lapsed between the start of run 473 measurements and the end of run 472 measurements.

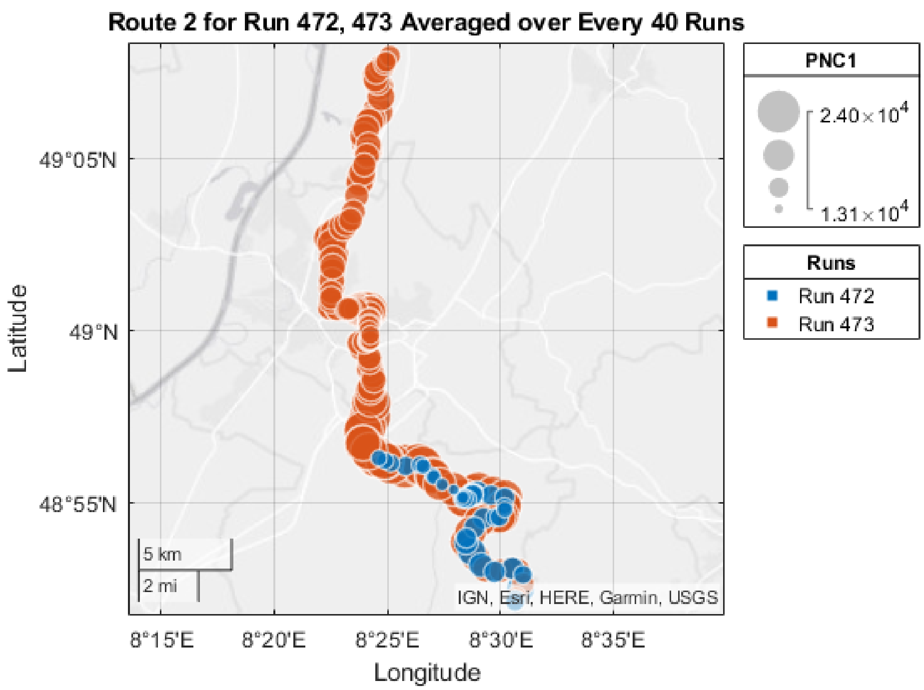


Figure 6: Route 2, Concentrations for Different Runs

Please note, runs 472 and 473 are measurements that were made when the tram was traveling in opposite directions. In Figure 6, the runs can be seen with their measured concentrations of PNC1 shown by the size of the bubble. Interesting enough, run 472 only has a fraction of the measurements that 473 has and the measurements significantly differ in concentration. This difference is due to the fact there are no valid measurements prior to the time of run 472 starting. In relatively the same location, 472 reports a concentration that is smaller than that of 473. These differences in concentration can be attributed to the fact these measurements were on different times of the day and the tram moving in opposite directions. Run 473 runs until 10:20 am for a full duration of approximately an hour.

3.6 Comparing Runs in Route 2 and Route 3

Route 2 is now compared with Route 3 to see the variation in measured concentrations across runs in variable PNC1.

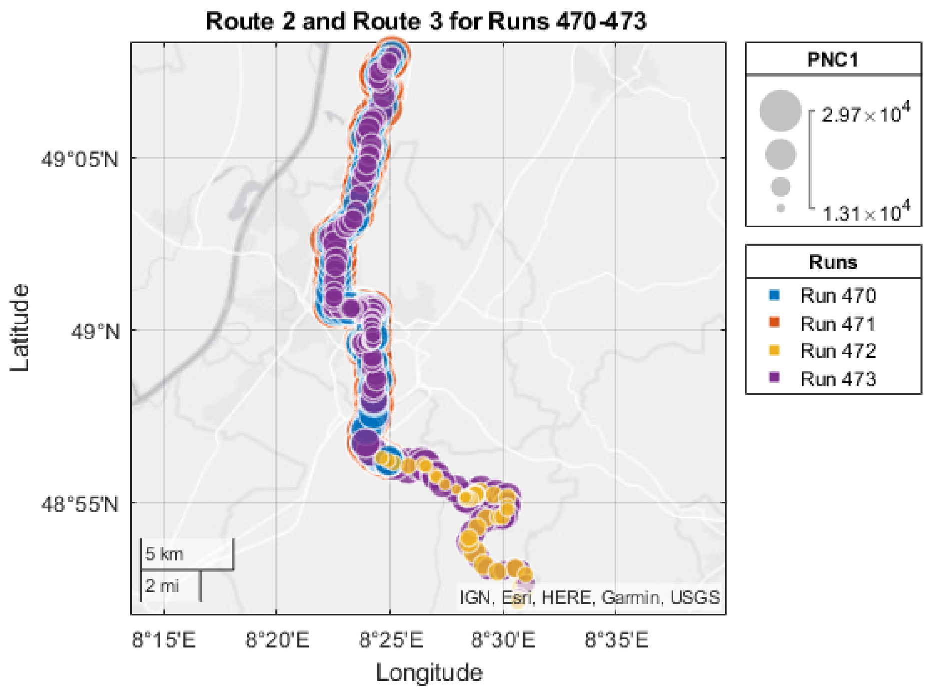


Figure 7: Route 2 and Route 3 Concentrations

In Figure 7, the concentrations of two runs in both Route 2 and Route 3 are compared. Runs 472 and 473 are of Route 2 where runs 470 and 471 are of Route 3. Run 470 starts measurements on Monday, March 8th, 2010 at 6:02 am and Run 471 starts measurements on Monday, March 8th, 2010 at 7:18 am.

Route 3 in contrast to Route 2 covers a slightly different region that does not go as far south as Route 2. Interestingly, Route 3 also has concentration measurements that are much larger than those of Route 2. These variations again can be contributed to measurements being made at different times of day as each measurement is recorded at its own unique time. Run 471 at 7am has a larger concentration over its full run time than all the other runs as the orange bubbles on Figure 7 are the largest. The values of Route 3 are within a business day and a prime time for commute.

3.7 Tram Velocity

Upon looking at the concentrations, another parameter investigated was the tram velocity. The tram velocity was compared to concentration at specific locations over time.

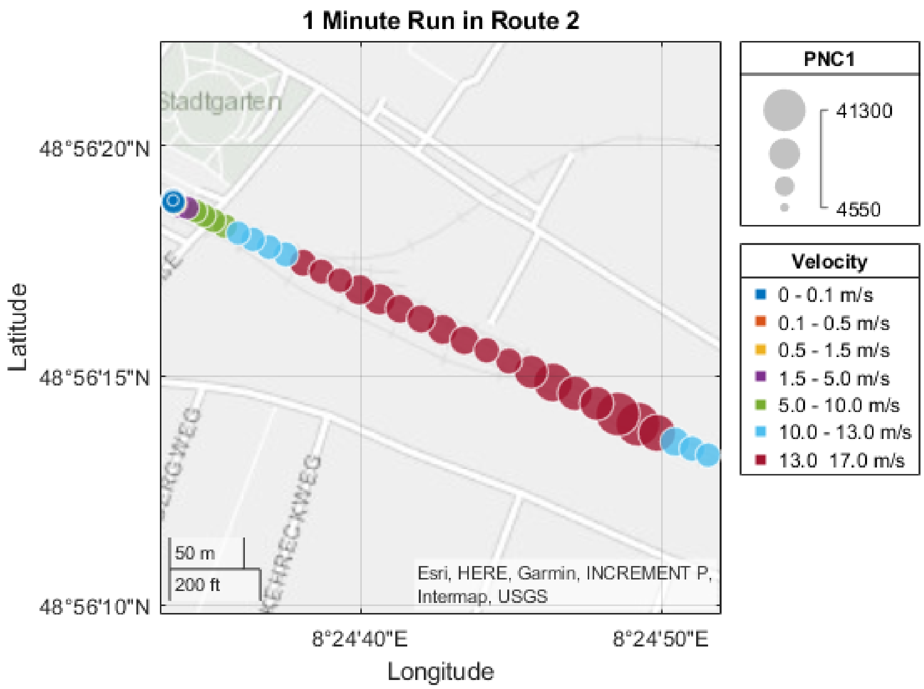


Figure 8: Route 2 Comparison of Velocity and Time

To take a very specific, localized look at the data, route 2 was focused on for a short 1 minute interval. In Figure 8, the velocity is denoted by color and the size of the bubble represents the concentration measured at the specific geographic point. Generally, as the tram velocity increases the concentration measured increases. This makes sense for as velocity increases more particles are making contact with the measuring device, more particles are apparent in one second of a moving point than that of a non-moving point. The measuring device is calibrated for such variance and there are locations at the max velocity speed that have concentrations similar to those of lower velocities. This variation ties into the locations of these measurements and what is spatially oriented around it. However, in Figure 9, there is another perspective on the trend.

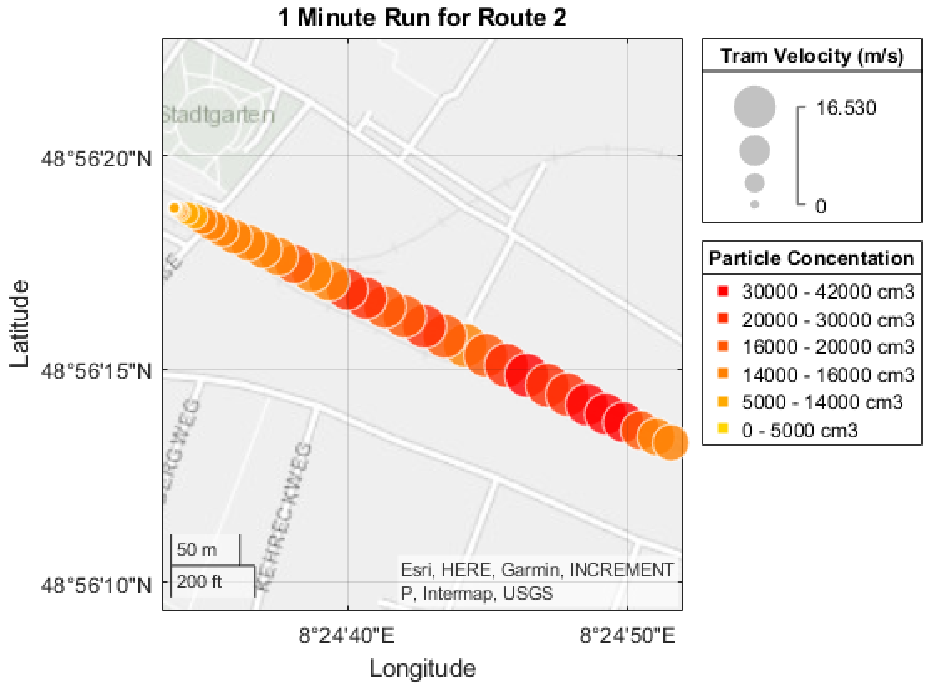


Figure 9: Route 2 Comparison of Velocity and Time

Figure 9 shows the velocity of the tram as the bubble size and the color as the concentration measured. It agrees with the previous figure that as the velocity increases, the concentration increases but it also shows that as the velocity decreases there is an increase in the concentration measured, as seen by the dominant red regions.

These plots are very focused and only show a specific route at a very narrowed range of time. It would not be sufficient to suggest a trend across all of the data. Further investigation of the relation between velocity and the concentration needs examined, the concentration variations could be attributed to time and location but also that of the changing tram velocity.

3.8 Variability

The data up to this point has shown that as time goes on and measurements are made, there is variability in the concentration measurement for similar locations for different runs within the same route. To further investigate this, runs 473, 478, and 479 were averaged to represent a single trend for Route 2 with respect to the distance from the city.

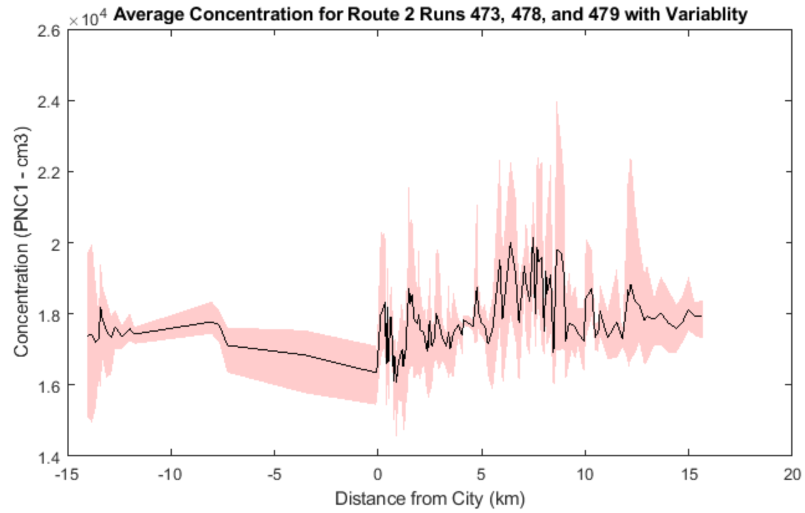


Figure 10: Route 2 Distance from City Variability in Concentration

In Figure 10, the variability is shown by the red region around the averaged values of the black line. This is representative of concentration diameters from 10nm to 3 mu. In this, the variability at a distance of -8 km to 0 km from the city is large. Additionally, there is an increase of concentration in the data at a distance of 0 km to about 10 km.

Route 2, 3, and 4 were investigated to see the variability across different routes.

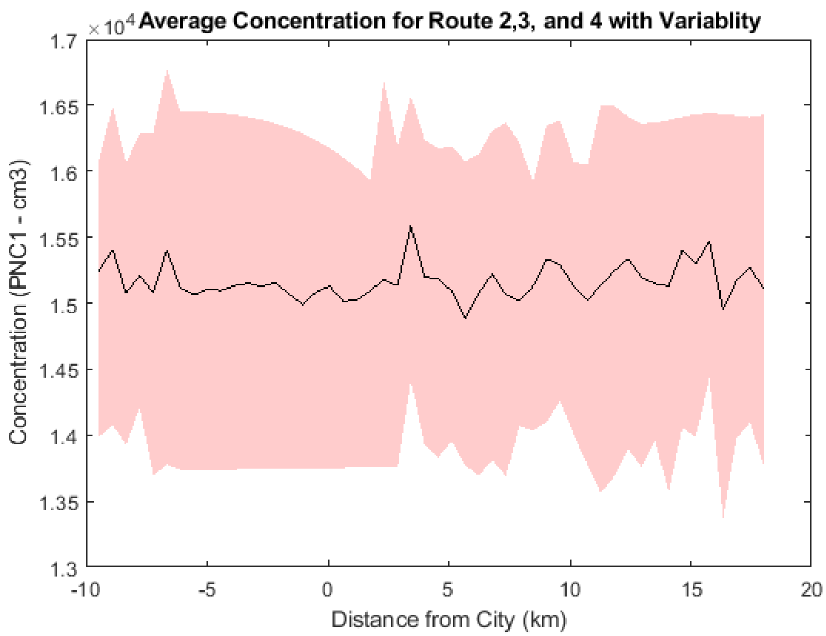


Figure 11: Route 2, 3, and 4 Distance from City Variability in Concentration

The distance from the city in Figure 11 is less than that of Figure 10 for this data is restricted to encompass locations where all the routes overlap. The curve resulting from the average of all the concentrations for the routes is much smoother than that of Route 2 on its own. Additionally, the variability is larger than that of Route 2. This is because the routes cumulatively have a wider range of maximums and minimum values measured for concentrations.

4 Conclusion

In conclusion, this data shows how particle concentration changes over time with respect to location. As seen, one geographic point can have multiple, differing measurements that change over time. There is significant variation in the measurements taken between different routes. Route 2 specifically appears to have an increase in particle concentration as the tram is south of the main city Karlsruhe. In general, it appears that in routes south of the city there is a slightly higher concentration of particles.

This work could be improved upon by looking more in depth at the impact of the tram's velocity on concentration measurements. Additionally, more data could be considered and looked at beyond just Route 2 and Route 3 as considering more data will give a better image of what the trends are for the region. The region experiences various particle concentrations and tying this to specific days of the week and regional characteristics could help identify more concrete trends in the data and explain why concentrations may or may not be elevated.

5 References

[1] **Kumar et al., 2014** Prashant Kumar, Lidia Morawska, Wolfram Birmili, Pauli Paasonen, Min Hu, Markku Kulmala, Roy M. Harrison, Leslie Norford, Rex Britter
Ultrafine particles in cities
Environment Internationalt, Volume 66 (2014), pp. 1-10
`https://doi.org/10.1016/j.envint.2014.01.013`

[2] **Hagemann et al., 2014** Rowell Hagemann, Ulrich Corsmeier, Christoph Kottmeier, Rayk Rinke, Andreas Wieser, Bernhard Vogel
Spatial variability of particle number concentrations and NOx in the Karlsruhe (Germany) area obtained with the mobile laboratory 'AERO-TRAM'
Atmospheric Environment, Volume 94 (2014), pp. 341-352
`https://doi.org/10.1016/j.atmosenv.2014.05.051`

6 Appendix: Code for Figures

6.1 Figure 1

```
%Gianna Ciaglia
%ATMS 490: Individual Study Spring 2021

%Document Figure 1
%This is a figure that represents all the measurements taken, their
%measured size (as shown by the bubble), and their location geographically
%given by their respective Longitude and Lattitude

clear all
%Import all required data from NC file Aerosolmodul_2010.nc
long = ncread('Aerosolmodul_2010.nc','lon');
latt = ncread('Aerosolmodul_2010.nc','lat');
route = ncread('Aerosolmodul_2010.nc','Route'); %focus on route 2
pnc1 = ncread('Aerosolmodul_2010.nc','PNC_1'); %concentration
%time  = ncread('Aerosolmodul_2010.nc','time'); %time [s]
tramvel  = ncread('Aerosolmodul_2010.nc','tram.vel'); %tram velocity [s]
%nrun  = ncread('Aerosolmodul_2010.nc','nrun'); %tram velocity [s]

%Create arrays that only have data that is useable, get rid of all the
%missing data and locate locations in all the data where all three
%requirements are true
validAllIdx = latt >= -90 & long >= 8 & pnc1 > -999 & tramvel > -999 & route > 0 ;

%applying the conditional statement to the variables
pnc1Filtered = pnc1(validAllIdx) ;
lattFiltered = latt(validAllIdx);
longFiltered = long(validAllIdx);
routeFiltered = route(validAllIdx);

figure (1)

table_1Min= table(lattFiltered,longFiltered, pnc1Filtered,routeFiltered,...
    'VariableNames',{'Lattitude','Longitude','PNC1','Route'}) ;
% table_1Min.PNC1 = categorical(table_1Min.PNC1);

gb = geobubble(table_1Min, 'Lattitude','Longitude','SizeVariable','PNC1');
gb.SourceTable.Route = discretize(table_1Min.Route,[0 1 2 3 4 5 ],...
    'categorical', {'Route 1', 'Route 2', 'Route 3',...
    'Route 4','Route 5'});
```

```
gb.ColorVariable = 'Route';
title('Various Routes in Variable PNC1')
```

6.2 Figure 2

```
%Gianna Ciaglia
%ATMS 490: Individual Study Spring 2021

%Document Figure 2
%This is a figure that represents measurements taken for Route 2 and run 472 specifically,
%their measured size (as shown by the bubble), and their location
%geographically given by their respective Longitude and Lattitude

%Import all required data from NC file Aerosolmodul_2010.nc
long = ncread('Aerosolmodul_2010.nc','lon');
latt = ncread('Aerosolmodul_2010.nc','lat');
route = ncread('Aerosolmodul_2010.nc','Route'); %focus on route 2
pnc1 = ncread('Aerosolmodul_2010.nc','PNC_1'); %concentration
%time  = ncread('Aerosolmodul_2010.nc','time'); %time [s]
%tramvel  = ncread('Aerosolmodul_2010.nc','tram.vel'); %tram velocity [s]
nrun  = ncread('Aerosolmodul_2010.nc','nrun'); %tram velocity [s]

%Create arrays that only have data that is useable, get rid of all the
%missing data and locate locations in all the data where all five
%requirements are true
validAllIdx = latt >= -90 & long >= 8 & pnc1 > -999 & route ==2 & nrun ==472;

%applying the conditional statement to the variables
pnc1Filtered = pnc1(validAllIdx) ;
lattFiltered = latt(validAllIdx);
longFiltered = long(validAllIdx);

%create the figure, look at Mathworks MATLAB 'geobubble' function for more
%information
figure(1)
geobubble(lattFiltered, longFiltered,pnc1Filtered );
title('Route 2 for Run 472 Mapping')
```

6.3 Figure 3

```
%Gianna Ciaglia
%ATMS 490: Individual Study Spring 2021

%Document Figure 3
```

```
%This is a figure that represents measurements taken for Route 2 and run 472 specifically ,
%their measured size (as shown by the bubble), and their location
%geographically given by their respective Longitude and Lattitude, the same
%data either creates points averaged every 20 or 40 data points

%Import all required data from NC file Aerosolmodul_2010.nc
long = ncread('Aerosolmodul_2010.nc','lon');
latt = ncread('Aerosolmodul_2010.nc','lat');
route = ncread('Aerosolmodul_2010.nc','Route'); %focus on route 2
pnc1 = ncread('Aerosolmodul_2010.nc','PNC_1'); %concentration
%time  = ncread('Aerosolmodul_2010.nc','time'); %time [s]
%tramvel  = ncread('Aerosolmodul_2010.nc','tram.vel'); %tram velocity [s]
nrun  = ncread('Aerosolmodul_2010.nc','nrun'); %tram velocity [s]

%Create arrays that only have data that is useable, get rid of all the
%missing data and locate locations in all the data where all five
%requirements are true
validAllIdx = latt >= -90 & long >= 8 & pnc1 > -999 & route ==2 & nrun ==472;

pnc1Filtered = pnc1(validAllIdx) ;
lattFiltered = latt(validAllIdx);
longFiltered = long(validAllIdx);

latt_1run = lattFiltered;
long_1run = longFiltered;
pnc1_1run = pnc1Filtered;


figure(1)
geobubble(latt_1run, long_1run, pnc1_1run );
title('Route 2 for Run 472 Mapping')

% %Now trying to get averages for every 40 seconds with 1600 values

column2 = pnc1_1run ;
out = reshape(column2(1:1600), [], 40);
means40sec = mean(out, 2);
lattMeans = latt_1run(40:40:end) ;
longMeans = long_1run(40:40:end) ;

%decreasing spacing to 20 sec intervals %%%%%%%%%%%%%%%%%%%%%%%%%%%%
column2 = pnc1_1run ;
out = reshape(column2(1:1620), [], 20);
means20sec = mean(out, 2);
```

```
lattMeans2 = latt_1run(20:20:end) ;
longMeans2 = long_1run(20:20:end) ;

figure(2)
geobubble(lattMeans2, longMeans2, means20sec );
title('Route 2 for Run 472 Averaged Every 20 Runs')

figure(3)
geobubble(lattMeans, longMeans, means40sec );
title('Route 2 for Run 472 Averaged Every 40 Runs')
```

6.4 Figure 4

```
%Gianna Ciaglia
%ATMS 490: Individual Study Spring 2021

%Document Figure 4
%This is a figure that represents concentrations measurements taken for Route 2 and runs
%472, 473, 478, and 479 over time


%Import all required data from NC file
long = ncread('Aerosolmodul_2010.nc','lon');
latt = ncread('Aerosolmodul_2010.nc','lat');
route = ncread('Aerosolmodul_2010.nc','Route'); %focus on route 2
pnc1 = ncread('Aerosolmodul_2010.nc','PNC_1'); %concentration
time = ncread('Aerosolmodul_2010.nc','time'); %time [s]
tramvel = ncread('Aerosolmodul_2010.nc','tram.vel'); %tram velocity [s]
nrun = ncread('Aerosolmodul_2010.nc','nrun'); %tram velocity [s]

validAllIdxRt2 = latt >= -90 & long >= 8 & pnc1 > -999 &route == 2 & nrun > -999;

pnc1FilteredR2 = pnc1(validAllIdxRt2) ;
lattFilteredR2 = latt(validAllIdxRt2);
longFilteredR2 = long(validAllIdxRt2);
runFilteredR2 = nrun(validAllIdxRt2) ;
timeFilteredR2 = time(validAllIdxRt2) ;

%run 472
validAllIdxR472 = latt >= -90 & long >= 8 & pnc1 > -999 &route == 2 & nrun == 472;
pnc1FilteredR472 = pnc1(validAllIdxR472) ;
lattFilteredR472 = latt(validAllIdxR472);
longFilteredR472 = long(validAllIdxR472);
runFilteredR472 = nrun(validAllIdxR472) ;
```

```
timeFilteredR472 = time(validAllIdxR472) ;

%run 473
validAllIdxR473 = latt >= -90 & long >= 8 & pnc1 > -999 &route == 2 &
    nrun == 473;
pnc1FilteredR473 = pnc1(validAllIdxR473) ;
lattFilteredR473 = latt(validAllIdxR473);
longFilteredR473 = long(validAllIdxR473);
runFilteredR473 = nrun(validAllIdxR473) ;
timeFilteredR473 = time(validAllIdxR473) ;

%run 478
validAllIdxR478 = latt >= -90 & long >= 8 & pnc1 > -999 &route == 2 &
    nrun == 478;
pnc1FilteredR478 = pnc1(validAllIdxR478) ;
lattFilteredR478 = latt(validAllIdxR478);
longFilteredR478 = long(validAllIdxR478);
runFilteredR478 = nrun(validAllIdxR478) ;
timeFilteredR478 = time(validAllIdxR478) ;

%run 479
validAllIdxR479 = latt >= -90 & long >= 8 & pnc1 > -999 &route == 2 &
    nrun == 479;
pnc1FilteredR479 = pnc1(validAllIdxR479) ;
lattFilteredR479 = latt(validAllIdxR479);
longFilteredR479 = long(validAllIdxR479);
runFilteredR479 = nrun(validAllIdxR479) ;
timeFilteredR479 = time(validAllIdxR479) ;

figure(1) %proves they are all diff run times
plot(timeFilteredR472, pnc1FilteredR472)
hold on
plot(timeFilteredR473, pnc1FilteredR473)
plot(timeFilteredR478, pnc1FilteredR478)
plot(timeFilteredR479, pnc1FilteredR479)
hold off
xlabel('Time (seconds)')
ylabel('PNC1 Concentration')
title('Route 2 for Runs 472,473,478,479 Concentrations over Time')
legend('Run 472', 'Run 473' , 'Run 478', 'Run 479')

%Now trying to get averages for every 40 seconds %%%%%%%%%%%%%%%%%%%%

%472
column472 = pnc1FilteredR472 ;
out = reshape(column472(1:1600), [], 40);
means472 = mean(out, 2);
timeforMeans472 = timeFilteredR472(40:40:end) ;
```

```
lattMeans472 = lattFilteredR472(40:40:end) ;
longMeans472 = longFilteredR472(40:40:end) ;

%473
column473 = pnc1FilteredR473 ;
out = reshape(column473(1:5360), [], 40);
means473 = mean(out, 2);
timeforMeans473 = timeFilteredR473(40:40:end) ;
lattMeans473 = lattFilteredR473(40:40:end) ;
longMeans473 = longFilteredR473(40:40:end) ;

%478
column478 = pnc1FilteredR478 ;
out = reshape(column478(1:5160), [], 40);
means478 = mean(out, 2);
timeforMeans478 = timeFilteredR478(40:40:end) ;
lattMeans478 = lattFilteredR478(40:40:end) ;
longMeans478 = longFilteredR478(40:40:end) ;

%479
column479 = pnc1FilteredR479 ;
out = reshape(column478(1:5040), [], 40);
means479 = mean(out, 2);
timeforMeans479 = timeFilteredR479(40:40:end) ;
lattMeans479 = lattFilteredR479(40:40:end) ;
longMeans479 = longFilteredR479(40:40:end) ;

figure(2) %Concentrations Aligned in Time
plot((timeforMeans472 - 5820874) , means472);
hold on
plot(timeforMeans473 -5822613, means473)
plot(timeforMeans478 - 5852984, means478)
plot(timeforMeans479 - 5858758, means479)
hold off
legend('Run 472', 'Run 473' , 'Run 478', 'Run 479')
xlabel('Time (seconds)')
ylabel('PNC1 Concentration')
title('Route 2 for Runs 472,473,478,479 Averaged Every 40 Runs')
```

6.5 Figure 5

```
%Gianna Ciaglia
%ATMS 490: Individual Study Spring 2021

%Document Figure 5
%This figure represetns the direction of the measurements for runs 472,
%473, 478, 479, 480, and 481 in route 2 by comparing the lattitude over
%time
```

```
%Import all required data from NC file
long = ncread('Aerosolmodul_2010.nc','lon');
latt = ncread('Aerosolmodul_2010.nc','lat');
route = ncread('Aerosolmodul_2010.nc','Route'); %focus on route 2
pnc1 = ncread('Aerosolmodul_2010.nc','PNC_1'); %concentration
time  = ncread('Aerosolmodul_2010.nc','time'); %time [s]
tramvel  = ncread('Aerosolmodul_2010.nc','tram.vel'); %tram velocity [s
    ]
nrun  = ncread('Aerosolmodul_2010.nc','nrun'); %tram velocity [s]

%Create arrays that only have data that is useable, get rid of all the
%missing data and locate locations in all the data where all
%requirements are true
validAll472 = latt >= -90 & long >= -90 & pnc1 > -999 &route == 2 &
    nrun == 472 ;
validAll473 = latt >= -90 & long >= -90 & pnc1 > -999 &route == 2 &
    nrun == 473 ;
validAll478 = latt >= -90 & long >= -90 & pnc1 > -999 &route == 2 &
    nrun == 478 ;
validAll479 = latt >= -90 & long >= -90 & pnc1 > -999 &route == 2 &
    nrun == 479 ;
validAll480 = latt >= -90 & long >= -90 & pnc1 > -999 &route == 2 &
    nrun == 480 ;
validAll481 = latt >= -90 & long >= -90 & pnc1 > -999 &route == 2 &
    nrun == 481 ;

run472 = latt(validAll472) ;
time472 = time(validAll472) ;
run473 = latt(validAll473) ;
time473 = time(validAll473) ;
run478 = latt(validAll478) ;
time478 = time(validAll478) ;
run479 = latt(validAll479) ;
time479 = time(validAll479) ;
run480 = latt(validAll480) ;
time480 = time(validAll480) ;
run481 = latt(validAll481) ;
time481 = time(validAll481) ;


figure(1)
plot(time472, run472 ,'y')
hold on
plot(time473, run473, 'c')
plot(time478, run478 , 'r')
plot(time479, run479 ,'g')
plot(time480, run480 , 'b')
```

```
plot(time481, run481, 'm')
hold off
legend('472', '473','478','479','480','481')
xlabel('Time (seconds)')
ylabel('Lattitude (deg)')
title('Route 2 Lattitude verus Time for Several Runs')
```

6.6 Figure 6

```
%Gianna Ciaglia
%ATMS 490: Individual Study Spring 2021

%Document Figure 6
%This figure is a geobubble of the runs 472 and 473 in route 2 where
    every
%40 data points are averaged and plotted using matlabs 'geobubble'
%fucntion.

%Import all required data from NC file
long = ncread('Aerosolmodul_2010.nc','lon');
latt = ncread('Aerosolmodul_2010.nc','lat');
route = ncread('Aerosolmodul_2010.nc','Route'); %focus on route 2
pnc1 = ncread('Aerosolmodul_2010.nc','PNC_1'); %concentration
time  = ncread('Aerosolmodul_2010.nc','time'); %time [s]
tramvel  = ncread('Aerosolmodul_2010.nc','tram.vel'); %tram velocity [s
    ]
nrun  = ncread('Aerosolmodul_2010.nc','nrun'); %tram velocity [s]


%run 472
validAllIdxR472 = latt >= -90 & long >= 8 & pnc1 > -999 &route == 2 &
    nrun == 472;
pnc1FilteredR472 = pnc1(validAllIdxR472) ;
lattFilteredR472 = latt(validAllIdxR472);
longFilteredR472 = long(validAllIdxR472);
runFilteredR472 = nrun(validAllIdxR472) ;
timeFilteredR472 = time(validAllIdxR472) ;

%run 473
validAllIdxR473 = latt >= -90 & long >= 8 & pnc1 > -999 &route == 2 &
    nrun == 473;
pnc1FilteredR473 = pnc1(validAllIdxR473) ;
lattFilteredR473 = latt(validAllIdxR473);
longFilteredR473 = long(validAllIdxR473);
runFilteredR473 = nrun(validAllIdxR473) ;
timeFilteredR473 = time(validAllIdxR473) ;

%472 averaged over 40 runs
```

```
column472 = pnc1FilteredR472 ;
out = reshape(column472(1:1600), [], 40);
means472 = mean(out, 2);
timeforMeans472 = timeFilteredR472(40:40:end) ;
lattMeans472 = lattFilteredR472(40:40:end) ;
longMeans472 = longFilteredR472(40:40:end) ;
run472 = runFilteredR472(40:40:end) ;

%473 averaged over 40 runs
column473 = pnc1FilteredR473 ;
out = reshape(column473(1:5360), [], 40);
means473 = mean(out, 2);
timeforMeans473 = timeFilteredR473(40:40:end) ;
lattMeans473 = lattFilteredR473(40:40:end) ;
longMeans473 = longFilteredR473(40:40:end) ;
run473 = runFilteredR473(40:40:end) ;

lattCombo = [lattMeans472 ; lattMeans473] ;
longCombo = [longMeans472 ; longMeans473] ;
meansCombo = [means472 ; means473] ;
runCombo = [run472 ; run473] ;

table_1Min= table(lattCombo,longCombo, meansCombo,runCombo,...
    'VariableNames',{'Lattitude','Longitude','PNC1','Run'}) ;
% table_1Min.PNC1 = categorical(table_1Min.PNC1);

gb = geobubble(table_1Min, 'Lattitude','Longitude','SizeVariable','PNC1
    ');
gb.SourceTable.Runs = discretize(table_1Min.Run,[0 473 474],...
    'categorical', {'Run 472', 'Run 473'});
gb.ColorVariable = 'Runs';
title('Route 2 for Run 472, 473 Averaged over Every 40 Runs')
```

6.7 Figure 7

```
%Gianna Ciaglia
%ATMS 490: Individual Study Spring 2021

%Document Figure 7
%This figure is a geobubble of the runs 470-473 in route 2 where every
%40 data points are averaged and plotted using matlabs 'geobubble'
%fucntion.

%Import all required data from NC file
long = ncread('Aerosolmodul_2010.nc','lon');
latt = ncread('Aerosolmodul_2010.nc','lat');
route = ncread('Aerosolmodul_2010.nc','Route'); %focus on route 2
pnc1 = ncread('Aerosolmodul_2010.nc','PNC_1'); %concentration
```

```
time   = ncread('Aerosolmodul_2010.nc','time'); %time [s]
tramvel  = ncread('Aerosolmodul_2010.nc','tram.vel'); %tram velocity [s]
nrun  = ncread('Aerosolmodul_2010.nc','nrun'); %tram velocity [s]

%run 470
validAllIdxR470 = latt >= -90 & long >= 8 & pnc1 > -999 &route == 3 & nrun == 470;
pnc1FilteredR470 = pnc1(validAllIdxR470) ;
lattFilteredR470 = latt(validAllIdxR470);
longFilteredR470 = long(validAllIdxR470);
runFilteredR470 = nrun(validAllIdxR470) ;
timeFilteredR470 = time(validAllIdxR470) ;

%run 471
validAllIdxR471 = latt >= -90 & long >= 8 & pnc1 > -999 &route == 3 & nrun == 471;
pnc1FilteredR471 = pnc1(validAllIdxR471) ;
lattFilteredR471 = latt(validAllIdxR471);
longFilteredR471 = long(validAllIdxR471);
runFilteredR471 = nrun(validAllIdxR471) ;
timeFilteredR471 = time(validAllIdxR471) ;

%run 472
validAllIdxR472 = latt >= -90 & long >= 8 & pnc1 > -999 &route == 2 & nrun == 472;
pnc1FilteredR472 = pnc1(validAllIdxR472) ;
lattFilteredR472 = latt(validAllIdxR472);
longFilteredR472 = long(validAllIdxR472);
runFilteredR472 = nrun(validAllIdxR472) ;
timeFilteredR472 = time(validAllIdxR472) ;

%run 473
validAllIdxR473 = latt >= -90 & long >= 8 & pnc1 > -999 &route == 2 & nrun == 473;
pnc1FilteredR473 = pnc1(validAllIdxR473) ;
lattFilteredR473 = latt(validAllIdxR473);
longFilteredR473 = long(validAllIdxR473);
runFilteredR473 = nrun(validAllIdxR473) ;
timeFilteredR473 = time(validAllIdxR473) ;


%470 Averaged every 40 data points
column470 = pnc1FilteredR470 ;
out = reshape(column470(1:3960), [], 40);
means470 = mean(out, 2);
timeforMeans470 = timeFilteredR470(40:40:end) ;
lattMeans470 = lattFilteredR470(40:40:end) ;
```

```
longMeans470 = longFilteredR470(40:40:end) ;
run470 = runFilteredR470(40:40:end) ;

%471 Averaged every 40 data points
column471 = pnc1FilteredR471 ;
out = reshape(column471(1:4040), [], 40);
means471 = mean(out, 2);
timeforMeans471 = timeFilteredR471(40:40:end) ;
lattMeans471 = lattFilteredR471(40:40:end) ;
longMeans471 = longFilteredR471(40:40:end) ;
run471 = runFilteredR471(40:40:end) ;

%472 Averaged every 40 data points
column472 = pnc1FilteredR472 ;
out = reshape(column472(1:1600), [], 40);
means472 = mean(out, 2);
timeforMeans472 = timeFilteredR472(40:40:end) ;
lattMeans472 = lattFilteredR472(40:40:end) ;
longMeans472 = longFilteredR472(40:40:end) ;
run472 = runFilteredR472(40:40:end) ;

%473 Averaged every 40 data points
column473 = pnc1FilteredR473 ;
out = reshape(column473(1:5360), [], 40);
means473 = mean(out, 2);
timeforMeans473 = timeFilteredR473(40:40:end) ;
lattMeans473 = lattFilteredR473(40:40:end) ;
longMeans473 = longFilteredR473(40:40:end) ;
run473 = runFilteredR473(40:40:end) ;

figure(1) %combining route 2 and 3 470-473

lattComboR2a3 = [lattMeans470 ; lattMeans471 ; lattMeans472 ;
    lattMeans473] ;
longComboR2a3 = [longMeans470 ; longMeans471 ; longMeans472 ;
    longMeans473] ;
meansComboR2a3 = [means470 ; means471; means472 ; means473] ;
runComboR2a3 = [run470 ; run471 ; run472 ; run473] ;
table_R2a3= table(lattComboR2a3,longComboR2a3, meansComboR2a3,
    runComboR2a3,...
    'VariableNames',{'Lattitude','Longitude','PNC1','Run'}) ;
% table_R3.PNC1 = categorical(table_R3.PNC1);

gb = geobubble(table_R2a3, 'Lattitude','Longitude','SizeVariable','PNC1
    ');
gb.SourceTable.Runs = discretize(table_R2a3.Run,[0 471 472 473 474],...
    'categorical', {'Run 470', 'Run 471','Run 472', 'Run 473'});
gb.ColorVariable = 'Runs';
```

```
title('Route 2 and 3 for Runs 470-473 ')
```

6.8 Figure 8

```
%Gianna Ciaglia
%ATMS 490: Individual Study Spring 2021

%Document Figure 8
%This figure represetnats a short interval of 60 seconds of route 2
    where
%the bubbles size represents the concentration size and the color
%represents the velocity

%Inmport all required data from NC file
long = ncread('Aerosolmodul_2010.nc','lon');
latt = ncread('Aerosolmodul_2010.nc','lat');
route = ncread('Aerosolmodul_2010.nc','Route'); %focus on route 2
pnc1 = ncread('Aerosolmodul_2010.nc','PNC_1'); %concentration
time  = ncread('Aerosolmodul_2010.nc','time'); %time [s]
tramvel  = ncread('Aerosolmodul_2010.nc','tram.vel'); %tram velocity [s
    ]
nrun  = ncread('Aerosolmodul_2010.nc','nrun'); %tram velocity [s]

figure(1)
validAllIdx2 = latt >= -90 & long >= 8 & pnc1 > -999 & tramvel > -999 &
     route == 2;

pnc1Filtered = pnc1(validAllIdx2) ;
lattFiltered = latt(validAllIdx2);
longFiltered = long(validAllIdx2);
tramvel = tramvel(validAllIdx2) ;

latt_1run = lattFiltered(1:61) ;
long_1run = longFiltered(1:61) ;
pnc1_1run = pnc1Filtered(1:61);
velT_1run = tramvel(1:61);

table_1Min= table(latt_1run,long_1run, pnc1_1run,velT_1run,...
     'VariableNames',{'Lattitude','Longitude','PNC1','TramVel'}) ;
% table_1Min.PNC1 = categorical(table_1Min.PNC1);

gb = geobubble(table_1Min, 'Lattitude','Longitude','SizeVariable','PNC1
    ');
gb.SourceTable.Velocity = discretize(table_1Min.TramVel,[0 0.10 0.50
    1.5 5 10 13 17],...
     'categorical', {'0 - 0.1 m/s', '0.1 - 0.5 m/s', '0.5 - 1.5 m/s', '
        1.5 - 5.0 m/s',...
     '5.0 - 10.0 m/s','10.0 - 13.0 m/s','13.0  17.0 m/s'});
```

```
gb.ColorVariable = 'Velocity';
title('1 Minute Run in Route 2')
```

6.9 Figure 9

```
%Gianna Ciaglia
%ATMS 490: Individual Study Spring 2021

%Document Figure 9
%This figure represetnats a short interval of 60 seconds of route 2 where
%the bubbles size represents the trams velocity and the color
%represents the particle concentration

%Import all required data from NC file
long = ncread('Aerosolmodul_2010.nc','lon');
latt = ncread('Aerosolmodul_2010.nc','lat');
route = ncread('Aerosolmodul_2010.nc','Route'); %focus on route 2
pnc1 = ncread('Aerosolmodul_2010.nc','PNC_1'); %concentration
time  = ncread('Aerosolmodul_2010.nc','time'); %time [s]
tramvel  = ncread('Aerosolmodul_2010.nc','tram.vel'); %tram velocity [s]
nrun  = ncread('Aerosolmodul_2010.nc','nrun'); %tram velocity [s]

figure(1)
validAllIdx2 = latt >= -90 & long >= 8 & pnc1 > -999 & tramvel > -999 & route == 2;

pnc1Filtered = pnc1(validAllIdx2) ;
lattFiltered = latt(validAllIdx2);
longFiltered = long(validAllIdx2);
tramvel = tramvel(validAllIdx2) ;

latt_1runF= lattFiltered(1:61) ;
long_1run = longFiltered(1:61) ;
pnc1_1run = pnc1Filtered(1:61);
velT_1run = tramvel(1:61);

table_1Min= table(latt_1run,long_1run, pnc1_1run,velT_1run,...
    'VariableNames',{'Lattitude','Longitude','PNC1','TramVel'}) ;
% table_1Min.PNC1 = categorical(table_1Min.PNC1);

gb = geobubble(table_1Min, 'Lattitude','Longitude','SizeVariable','TramVel');
gb.SourceTable.ParticleConc = discretize(table_1Min.PNC1,[0 5000 14000 16000 20000 30000 42000],...
    'categorical', {'0 - 5000 cm3', '5000 - 14000 cm3', '14000 - 16000 cm3', ...
```

```
    '16000 - 20000 cm3','20000 - 30000 cm3','30000 - 42000 cm3'});
gb.ColorVariable = 'ParticleConc';

neworder = {'30000 - 42000 cm3','20000 - 30000 cm3','16000 - 20000 cm3'
    ,...
    '14000 - 16000 cm3','5000 - 14000 cm3','0 - 5000 cm3'};
gb.SourceTable.ParticleConc = reordercats(gb.SourceTable.ParticleConc,
    neworder);
gb.BubbleColorList = autumn(7);
title('1 Minute Run for Route 2')
gb.SizeLegendTitle = 'Tram Velocity (m/s)';
gb.ColorLegendTitle = 'Particle Concentation';
```

6.10 Figure 10

```
%Gianna Ciaglia
%ATMS 490: Individual Study Spring 2021

%Document Figure 10
%This figure represetnats the variation of runs 473, 478, and 479 in
    route 2
%concetrations with respect to the distances from the city

clear all

%Import all required data from NC file
long = ncread('Aerosolmodul_2010.nc','lon');
latt = ncread('Aerosolmodul_2010.nc','lat');
route = ncread('Aerosolmodul_2010.nc','Route'); %focus on route 2
pnc1 = ncread('Aerosolmodul_2010.nc','PNC_1'); %concentration
time  = ncread('Aerosolmodul_2010.nc','time'); %time [s]
tramvel  = ncread('Aerosolmodul_2010.nc','tram.vel'); %tram velocity [s
    ]
nrun  = ncread('Aerosolmodul_2010.nc','nrun'); %tram velocity [s]


validAll473 = latt >= -90 & long >= -90 & pnc1 > -999 &route == 2 &
    nrun == 473 ;
validAll478 = latt >= -90 & long >= -90 & pnc1 > -999 &route == 2 &
    nrun == 478 ;
validAll479 = latt >= -90 & long >= -90 & pnc1 > -999 &route == 2 &
    nrun == 479 ;

run473 = latt(validAll473) ;
pnc1473 = pnc1(validAll473) ;
time473 = time(validAll473) ;
run478 = latt(validAll478) ;
pnc1478 = pnc1(validAll478) ;
```

```
time478 = time(validAll478) ;
run479 = latt(validAll479) ;
pnc1479 = pnc1(validAll479) ;
time479 = time(validAll479) ;

%finding the distance
%run 473
pnc1473 = pnc1(validAll473) ;
long473 = long(validAll473) ;

%473
column473 = pnc1473 ;
out = reshape(column473(1:5360), [], 40);
means473 = mean(out, 2);
timeforMeans473 = time473(40:40:end) ;
lattMeans473 = run473(40:40:end) ;
longMeans473 = long473(40:40:end) ;

a = 1 ;

for k = (1:length(lattMeans473))
    Latt(a) = lattMeans473(k) ;
    Long(a) = longMeans473(k) ;

    %dist(a) = distance(Latt(a), Long(a) ,Latt2(a) , Long2(a)) ;
    dist473(a) = distance(49.0069 , 8.4037 , Latt(a), Long(a) ) ; %
        origin, destination
    dist473(a) = deg2km(dist473(a)) ;
    if Latt(a) > 49.0069
        if Long(a) >  8.4037
        dist473(a) = dist473(a) * (-1) ;
        end
    end

    a = a + 1 ;

end

[sortedDist2, sortIndex] = sort(dist473) ;
sortedPNC12 = means473(sortIndex)  ;


% x = double(unique(sortedDist2 ) );
% v = double(sortedPNC12(x) );
% xq = linspace(min(x), max(x) , 50);
% vq1 = pchip(x,v,xq);
```

```
%for 478
pnc1478 = pnc1(validAll478) ;
long478 = long(validAll478) ;

%478
column478 = pnc1478 ;
out = reshape(column478(1:5160), [], 40);
means478 = mean(out, 2);
timeforMeans478 = time478(40:40:end) ;
lattMeans478 = run478(40:40:end) ;
longMeans478 = long478(40:40:end) ;

a = 1 ;

for k = (1:length(lattMeans478))
    Latt(a) = lattMeans478(k) ;
    Long(a) = longMeans478(k) ;

    %dist(a) = distance(Latt(a), Long(a) ,Latt2(a) , Long2(a)) ;
    dist478(a) = distance(49.0069 , 8.4037 , Latt(a), Long(a) ) ; %
        origin, destination
    dist478(a) = deg2km(dist478(a)) ;
    if Latt(a) > 49.0069
        if Long(a) >  8.4037
        dist478(a) = dist478(a) * (-1) ;
        end
    end

    a = a + 1 ;

end

[sortedDist3, sortIndex] = sort(dist478) ;
sortedPNC13 = means478(sortIndex)  ;

% x3 = sortedDist3  ;
% v3 = sortedPNC13 ;
%
% xq3 = linspace(min(x3), max(x3) , 50);
% vq3 = pchip(x3,v3,xq3);

%for 479
pnc1479 = pnc1(validAll479) ;
long479 = long(validAll479) ;

%479
column479 = pnc1479 ;
out = reshape(column478(1:5040), [], 40);
```

```
means479 = mean(out, 2);
timeforMeans479 = time479(40:40:end) ;
lattMeans479 = run479(40:40:end) ;
longMeans479 = long479(40:40:end) ;

a = 1 ;

for k = (1:length(lattMeans479))
    Latt(a) = lattMeans479(k) ;
    Long(a) = longMeans479(k) ;

    %dist(a) = distance(Latt(a), Long(a) ,Latt2(a) , Long2(a)) ;
    dist479(a) = distance(49.0069 , 8.4037 , Latt(a), Long(a) ) ; %
        origin, destination
    dist479(a) = deg2km(dist479(a)) ;
    if Latt(a) > 49.0069
        if Long(a) >  8.4037
        dist479(a) = dist479(a) * (-1) ;
        end
    end

    a = a + 1 ;

end

[sortedDist4, sortIndex] = sort(dist479) ;
sortedPNC14 = means479(sortIndex)  ;

Ax = [sortedDist2(1:126)' , sortedDist3(1:126)' , sortedDist4' ] ;
Ay = [sortedPNC12(1:126) , sortedPNC13(1:126), sortedPNC14] ;

Max2 = max(Ay, [], 2) ;
Min2 = min(Ay, [], 2) ;
Average_conc2 = mean(Ay, 2) ;
Average_dist2 = mean(Ax, 2) ;

figure(1) %this is with interpolation
x = Average_dist2 ;
p = fill([x;flipud(x)],[Min2;flipud(Max2)],'red')   ;
p.FaceColor = [1 0.8 0.8];
p.EdgeColor = 'none';
hold on
%p.FaceColor = [1 0.8 0.8];
plot(Average_dist2, Average_conc2, 'k')
hold off
title('Average Concentration for Route 2 Runs 473, 478, and 479 with
    Variablity' )
xlabel('Distance from City (km)')
```

```
ylabel('Concentration (PNC1 - cm3)')
```

6.11 Figure 11

```
%Gianna Ciaglia
%ATMS 490: Individual Study Spring 2021

%Document Figure 11
%This figure represetnats the variation of routes 2,3, and 4 in
%concetration with respect to the distances from the city

clear all

%Import all required data from NC file
long = ncread('Aerosolmodul_2010.nc','lon');
latt = ncread('Aerosolmodul_2010.nc','lat');
route = ncread('Aerosolmodul_2010.nc','Route'); %focus on route 2
pnc1 = ncread('Aerosolmodul_2010.nc','PNC_1'); %concentration
time  = ncread('Aerosolmodul_2010.nc','time'); %time [s]
tramvel  = ncread('Aerosolmodul_2010.nc','tram.vel'); %tram velocity [s]
nrun  = ncread('Aerosolmodul_2010.nc','nrun'); %tram velocity [s]

validAllIdxRt2 = latt >= -90 & long >= 4 & pnc1 > -999 &route == 2 & nrun > -999;

pnc1FilteredR2 = pnc1(validAllIdxRt2) ;
lattFilteredR2 = latt(validAllIdxRt2);
longFilteredR2 = long(validAllIdxRt2);
runFilteredR2 = nrun(validAllIdxRt2) ;
timeFilteredR2 = time(validAllIdxRt2) ;

column2 = pnc1FilteredR2 ;
out = reshape(column2(1:412000), [], 500);
means2 = mean(out, 2);
timeforMeans2 = timeFilteredR2(500:500:end) ;
lattMeans2 = lattFilteredR2(500:500:end)  ;
longMeans2 = longFilteredR2(500:500:end)  ;

a = 1 ;
z = length(lattMeans2) ;
for k = (1:z)
    Latt(a) = lattMeans2(k) ;
    Long(a) = longMeans2(k) ;

    %dist(a) = distance(Latt(a), Long(a) ,Latt2(a) , Long2(a)) ;
    dist2(a) = distance(49.0069 , 8.4037 , Latt(a), Long(a) ) ; %origin, destination
```

```
    dist2(a) = deg2km(dist2(a)) ;
    if Latt(a) > 49.0069
        if Long(a) >  8.4037
        dist2(a) = dist2(a) * (-1) ;
        end
    end

    a = a + 1 ;

end

[sortedDist2, sortIndex] = sort(dist2) ;
sortedPNC12 = means2(sortIndex)  ;


x = sortedDist2  ;
v = sortedPNC12 ;
xq = linspace(min(x), max(x) , 50);
vq1 = pchip(x,v,xq);

%adding Route 3

validAllIdxRt3 = latt >= -90 & long >= 4 & pnc1 > -999 &route == 3 &
    nrun > -999;

pnc1FilteredR3 = pnc1(validAllIdxRt3) ;
lattFilteredR3 = latt(validAllIdxRt3);
longFilteredR3 = long(validAllIdxRt3);
runFilteredR3 = nrun(validAllIdxRt3) ;
timeFilteredR3 = time(validAllIdxRt3) ;

column3 = pnc1FilteredR3 ;
out = reshape(column3(1:374920), [], 455);
means3 = mean(out, 2);
timeforMeans3 = timeFilteredR3(455:455:end) ;
lattMeans3 = lattFilteredR3(455:455:end)  ;
longMeans3 = longFilteredR3(455:455:end)  ;

a = 1 ;
z = length(lattMeans3) ;
for k = (1:z)
    Latt(a) = lattMeans3(k) ;
    Long(a) = longMeans3(k) ;

    %dist(a) = distance(Latt(a), Long(a) ,Latt2(a) , Long2(a)) ;
    dist3(a) = distance(49.0069 , 8.4037 , Latt(a), Long(a) ) ; %origin
        , destination
    dist3(a) = deg2km(dist3(a)) ;
```

```
    if Latt(a) > 49.0069
        if Long(a) >  8.4037
        dist3(a) = dist3(a) * (-1) ;
        end
    end

    a = a + 1 ;

end

dist3 = dist3(1:824) ;
means3 = means3(1:824) ;

[sortedDist3, sortIndex] = sort(dist3) ;
sortedPNC13 = means3(sortIndex)  ;

x3 = sortedDist3  ;
v3 = sortedPNC13 ;
xq3 = linspace(min(x3), max(x3) , 50);
vq3 = pchip(x3,v3,xq3);

%adding Route 4

validAllIdxRt4 = latt >= -90 & long >= 4 & pnc1 > -999 &route == 4 &
    nrun > -999;

pnc1FilteredR4 = pnc1(validAllIdxRt4) ;
lattFilteredR4 = latt(validAllIdxRt4);
longFilteredR4 = long(validAllIdxRt4);
runFilteredR4 = nrun(validAllIdxRt4) ;
timeFilteredR4 = time(validAllIdxRt4) ;

column4 = pnc1FilteredR4 ;
out = reshape(column4(1:407880), [], 495);
means4 = mean(out, 2);
timeforMeans4 = timeFilteredR4(495:495:end) ;
lattMeans4 = lattFilteredR4(495:495:end)  ;
longMeans4 = longFilteredR4(495:495:end)  ;

a = 1 ;
z = length(lattMeans4) ;
for k = (1:z)
    Latt(a) = lattMeans4(k) ;
    Long(a) = longMeans4(k) ;

    %dist(a) = distance(Latt(a), Long(a) ,Latt2(a) , Long2(a)) ;
    dist4(a) = distance(49.0069 , 8.4037 , Latt(a), Long(a) ) ; %origin
        , destination
```

```
    dist4(a) = deg2km(dist4(a)) ;
    if Latt(a) > 49.0069
        if Long(a) >  8.4037
        dist4(a) = dist4(a) * (-1) ;
        end
    end

    a = a + 1 ;

end

[sortedDist4, sortIndex] = sort(dist4) ;
sortedPNC14 = means4(sortIndex)  ;

x4 = sortedDist4  ;
v4 = sortedPNC14 ;

xq4 = linspace(min(x4), max(x4) , 50);
vq4 = pchip(x4,v4,xq4);

Ax = [xq' , xq3' , xq4' ] ;
Ay = [vq1' , vq3', vq4' ] ;

Max2 = max(Ay, [], 2) ;
Min2 = min(Ay, [], 2) ;
Average_conc2 = mean(Ay, 2) ;
Average_dist2 = mean(Ax, 2) ;

figure(1) %this is with interpolation
x = Average_dist2 ;
p = fill([x;flipud(x)],[Min2;flipud(Max2)],'red')  ;
p.FaceColor = [1 0.8 0.8];
p.EdgeColor = 'none';
hold on
%p.FaceColor = [1 0.8 0.8];
plot(Average_dist2, Average_conc2, 'k')
hold off
title('Average Concentration for Route 2,3, and 4 with Variablity' )
xlabel('Distance from City (km)')
ylabel('Concentration (PNC1 - cm3)')
```