Milestone 2

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Air Quality Data

Introduction

The adverse affects of air pollution on health are well documented and air pollution can lead to a large range of diseases and increased morbidity and mortality (Younger et al., 2008). Adverse health impacts include, but are not limited to, lung cancer risk, respiritory infections, allergic disease and asthma (Younger et al., 2008; Shea et al., 2008). These health risks can affect a large proportion of the population as many different groups are vulnerable to the effects of air pollution including infants, children, the elderly, people with impaired immune systems, and people who work or are physically active outdoors (Matooane et al., 2004).

Because of the many, and severe, impacts of air quality, it is important to understand patterns in the data. We have a dataset of air quality observations as well as temperature and humidity data which we will use to gain understanding of the patterns and impacts of weather on air quality.

Data Description

The air quality dataset used in this analysis was obtained from the University of California Irvine Machine learning Repository. It was contributed by Saverio De Vito from the National Agency for New Technologies, Energy and Sustainable Economic Development.

The dataset contains 15 variables and 9358 observations of hourly averaged responses from an Air Quality Chemical Multisensor Device. Data were recorded from March 2004 to February 2005, in a significantly polluted area, at road level, within a city in Italy. Variables include the date and time each response was recorded, and the corresponding concentrations of 13 air pollutants analyzed by the sensor device. Missing values are tagged with -200 value. Below is the entire variable set:

Variables	Type	Description
Date	character	Date (DD/MM/YYYY)
Time	time	Time (HH.MM.SS)
CO(GT)	double	True hourly averaged concentration CO in mg/m^3 (reference analyzer)
PT08.S1(CO)	integer	PT08.S1 (tin oxide) hourly averaged sensor response (nominally CO targeted)
NMHC(GT)	integer	True hourly averaged overall Non Metanic HydroCarbons concentration in microg/m^3 (ref
C6H6(GT)	double	True hourly averaged Benzene concentration in microg/m^3 (reference analyzer)
PT08.S2(NMHC)	integer	PT08.S2 (titania) hourly averaged sensor response (nominally NMHC targeted)
NOx(GT)	integer	True hourly averaged NOx concentration in ppb (reference analyzer)
PT08.S3(NOx)	integer	PT08.S3 (tungsten oxide) hourly averaged sensor response (nominally NOx targeted)
NO2(GT)	integer	True hourly averaged NO2 concentration in microg/m^3 (reference analyzer)
PT08.S4(NO2)	integer	PT08.S4 (tungsten oxide) hourly averaged sensor response (nominally NO2 targeted)
PT08.S5(O3)	integer	PT08.S5 (indium oxide) hourly averaged sensor response (nominally O3 targeted)
T	double	Temperature in °C
RH	double	Relative Humidity (%)
AH	double	AH Absolute Humidity

Exploring the dataset

```
# first we read the data in
airq <- readr::read_csv(here::here("data","airquality.csv"))
```

```
## Parsed with column specification:
## cols(
##   Date = col_date(format = ""),
##   Time = col_time(format = ""),
##   `CO(GT)` = col_double(),
##   `PT08.S1(CO)` = col_integer(),
##   `NMHC(GT)` = col_integer(),
##   `C6H6(GT)` = col_double(),
##   `PT08.S2(NMHC)` = col_integer(),
##   `NOx(GT)` = col_integer(),
##   `PT08.S3(NOx)` = col_integer(),
##   `NO2(GT)` = col_integer(),
##   `PT08.S4(NO2)` = col_integer(),
##   `PT08.S5(O3)` = col_integer(),
##   T = col_double(),
##   RH = col_double(),
##   AH = col_double()
## )
```

```
DT::datatable(airq)
```

Show 10 entries Search:

	Date	Time	CO(GT)	PT08.S1(CO)	NMHC(GT)	C6H6(GT)	PT08.S2(NMHC)	NOx(GT)	PT08.S3(NOx)	NO2(GT)	PT08.S4(NO2)	PT08.S5(O3)	T	RH	AH
1	2004-03-10	18:00:00	2.6	1360	150	11.9	1046	166	1056	113	1692	1268	13.6	48.9	0.7578
2	2004-03-10	19:00:00	2	1292	112	9.4	955	103	1174	92	1559	972	13.3	47.7	0.7255
3	2004-03-10	20:00:00	2.2	1402	88	9	939	131	1140	114	1555	1074	11.9	54	0.7502
4	2004-03-10	21:00:00	2.2	1376	80	9.2	948	172	1092	122	1584	1203	11	60	0.7867
5	2004-03-10	22:00:00	1.6	1272	51	6.5	836	131	1205	116	1490	1110	11.2	59.6	0.7888
6	2004-03-10	23:00:00	1.2	1197	38	4.7	750	89	1337	96	1393	949	11.2	59.2	0.7848
7	2004-03-11	00:00:00	1.2	1185	31	3.6	690	62	1462	77	1333	733	11.3	56.8	0.7603
8	2004-03-11	01:00:00	1	1136	31	3.3	672	62	1453	76	1333	730	10.7	60	0.7702
9	2004-03-11	02:00:00	0.9	1094	24	2.3	609	45	1579	60	1276	620	10.7	59.7	0.7648
10	2004-03-11	03:00:00	0.6	1010	19	1.7	561	-200	1705	-200	1235	501	10.3	60.2	0.7517

Showing 1 to 10 of 9,357 entries Previous 1 2 3 4 5 … 936 Next

Summary Statistics

The following shows the five-number stats summary for each variable:

```
# Five-number summary for each variable
summary(airq)
```

```
##       Date                Time               CO(GT)          PT08.S1(CO)
##  Min.   :2004-03-10   Length:9357        Min.   :-200.00   Min.   :-200
##  1st Qu.:2004-06-16   Class1:hms         1st Qu.:   0.60   1st Qu.: 921
##  Median :2004-09-21   Class2:difftime    Median :   1.50   Median :1053
##  Mean   :2004-09-21   Mode  :numeric     Mean   : -34.21   Mean   :1049
##  3rd Qu.:2004-12-28                      3rd Qu.:   2.60   3rd Qu.:1221
```

```
##  Max.   :2005-04-04                      Max.   :  11.90   Max.   :2040
##     NMHC(GT)         C6H6(GT)        PT08.S2(NMHC)       NOx(GT)
##  Min.   :-200.0   Min.   :-200.000   Min.   :-200.0   Min.   :-200.0
##  1st Qu.:-200.0   1st Qu.:   4.000   1st Qu.: 711.0   1st Qu.:  50.0
##  Median :-200.0   Median :   7.900   Median : 895.0   Median : 141.0
##  Mean   :-159.1   Mean   :   1.866   Mean   : 894.6   Mean   : 168.6
##  3rd Qu.:-200.0   3rd Qu.:  13.600   3rd Qu.:1105.0   3rd Qu.: 284.0
##  Max.   :1189.0   Max.   :  63.700   Max.   :2214.0   Max.   :1479.0
##   PT08.S3(NOx)     NO2(GT)         PT08.S4(NO2)   PT08.S5(O3)
##  Min.   :-200   Min.   :-200.00   Min.   :-200   Min.   :-200.0
##  1st Qu.: 637   1st Qu.:  53.00   1st Qu.:1185   1st Qu.: 700.0
##  Median : 794   Median :  96.00   Median :1446   Median : 942.0
##  Mean   : 795   Mean   :  58.15   Mean   :1391   Mean   : 975.1
##  3rd Qu.: 960   3rd Qu.: 133.00   3rd Qu.:1662   3rd Qu.:1255.0
##  Max.   :2683   Max.   : 340.00   Max.   :2775   Max.   :2523.0
##        T                  RH                AH
##  Min.   :-200.000   Min.   :-200.00   Min.   :-200.0000
##  1st Qu.:  10.900   1st Qu.:  34.10   1st Qu.:   0.6923
##  Median :  17.200   Median :  48.60   Median :   0.9768
##  Mean   :   9.778   Mean   :  39.49   Mean   :  -6.8376
##  3rd Qu.:  24.100   3rd Qu.:  61.90   3rd Qu.:   1.2962
##  Max.   :  44.600   Max.   :  88.70   Max.   :   2.2310
```

The following shows some preliminary info on the air quality dataset that we are using. We record the number of total observations, number of missing observations, percentage of missing values and the number of usable observations.

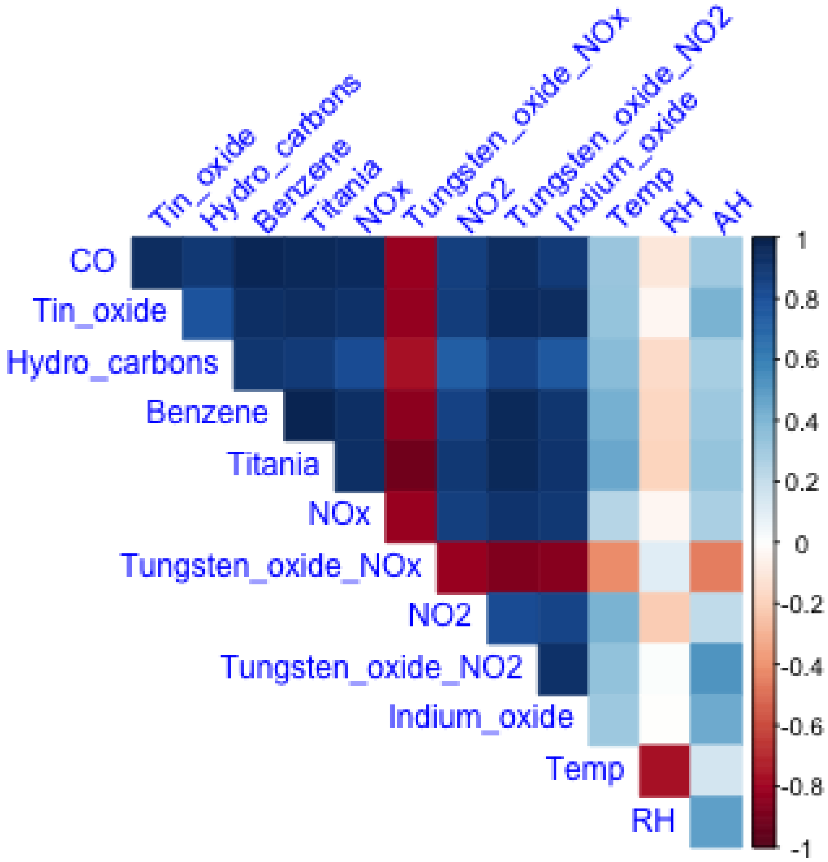
```
# Look at missing values for each variable
missing = list()
for(i in 1:15) {
  l = length(which(airq[i] == -200))
  missing[[i]] = l
}
obs = list()
for(i in 1:15) {
  o = length(airq[[i]])
  obs[[i]] = o
}
dfmissing = data.frame(Variables,
                       matrix(unlist(missing), nrow=length(missing), byrow=T),
                       matrix(unlist(obs), nrow=length(missing), byrow=T))
names(dfmissing)[names(dfmissing) == "matrix.unlist.missing...nrow...length.missing...byrow...T."] = "Co
names(dfmissing)[names(dfmissing) == "matrix.unlist.obs...nrow...length.missing...byrow...T."] = "Total
dfmissing %>%
  mutate(`% Missing Values` = `Count of Missing Values`/`Total Observations`*100) %>%
  mutate(`Usable Observations` = `Total Observations` - `Count of Missing Values`)
```

```
##        Variables Count of Missing Values Total Observations
## 1           Date                       0               9357
## 2           Time                       0               9357
## 3         CO(GT)                    1683               9357
## 4    PT08.S1(CO)                     366               9357
## 5       NMHC(GT)                    8443               9357
## 6       C6H6(GT)                     366               9357
## 7  PT08.S2(NMHC)                     366               9357
```

```
## 8        NOx(GT)                    1639               9357
## 9   PT08.S3(NOx)                     366               9357
## 10       NO2(GT)                   1642               9357
## 11  PT08.S4(NO2)                     366               9357
## 12   PT08.S5(O3)                     366               9357
## 13             T                     366               9357
## 14            RH                     366               9357
## 15            AH                     366               9357
##    % Missing Values Usable Observations
## 1           0.00000                9357
## 2           0.00000                9357
## 3          17.98653                7674
## 4           3.91151                8991
## 5          90.23191                 914
## 6           3.91151                8991
## 7           3.91151                8991
## 8          17.51630                7718
## 9           3.91151                8991
## 10         17.54836                7715
## 11          3.91151                8991
## 12          3.91151                8991
## 13          3.91151                8991
## 14          3.91151                8991
## 15          3.91151                8991
```

From this we see that for many of the observations less than 4% of the data is missing. This is adequate for the research we are conducting.

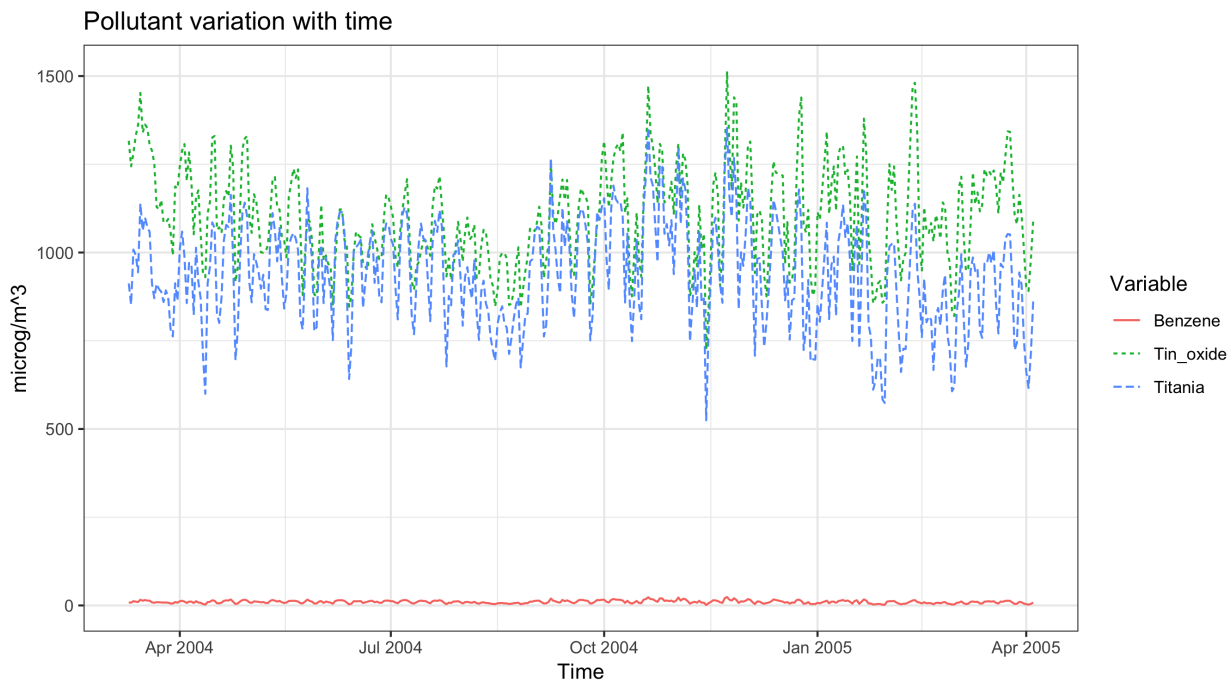
Graph 1: Correlogram of pollutants



Looking at the correlations of the pollutants with weather, we can see that for all pollutants except NOx, temperature (T) is positively correlated, although weakly so. This means that higher temperatures correspond to higher concentrations of the gases. Relative humidity (RH) is negatively and correlated to temperature and has a weak negative correlation to the concentrations of pollutants, except NOx. Absolute humidity (AH) has stronger correlations, mostly positive, although, like temperature, it has a negative correlation with NOx.

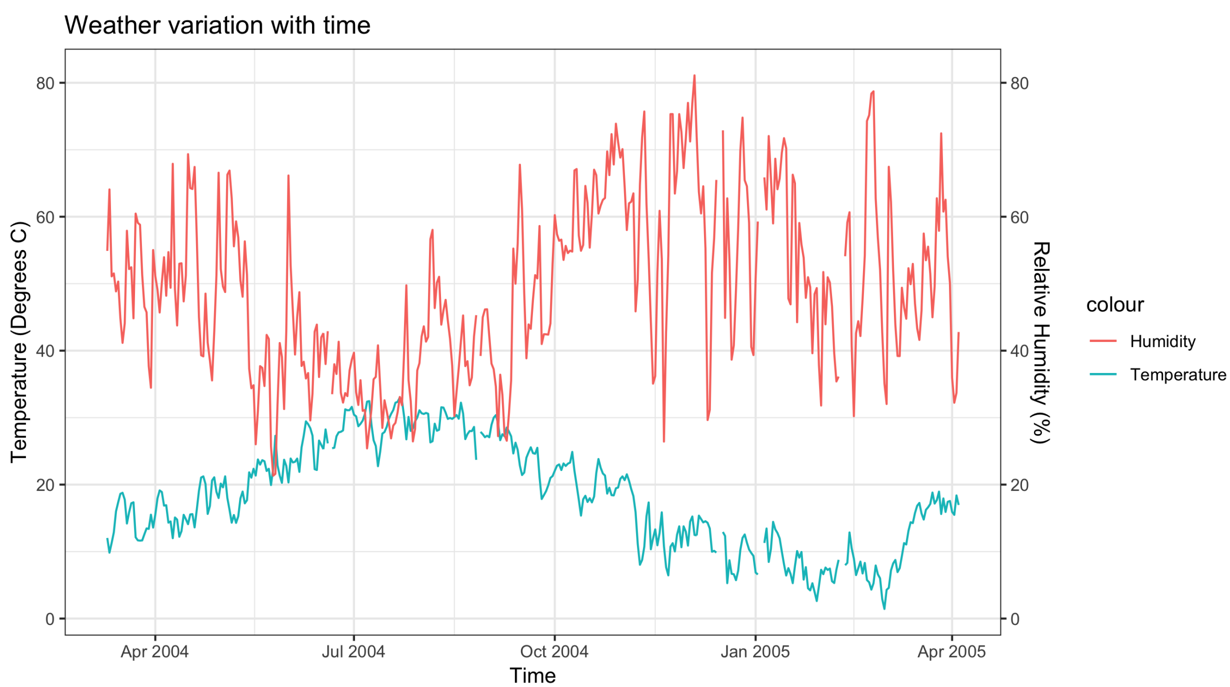
Graph 2: Concentration of some Air Pollutants, Temperature, Humidity over Time, daily average

The plot below shows the **daily** averaged concentrations of some of the pollutants (tin oxide, benzene, and Titania) for a year.



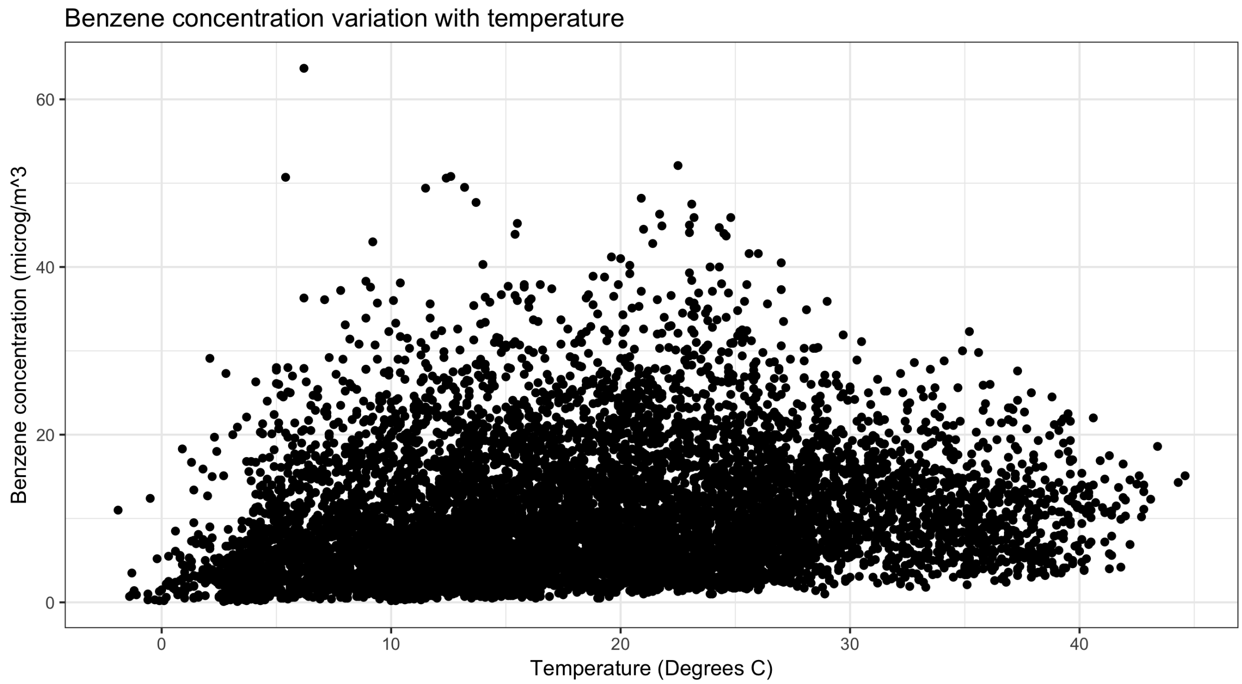
Graph 3: Concentration Temperature and Humidity over Time

The plot below show the **daily** averaged values of temperature and humidity for a year.



Graph 4: Temperature vs. Benzene concentration

The following graph shows the relationship of benzene to temperature over the year in which data was recorded. The plot suggests there is perhaps a slight relationship. Linear regression in future work will help to clarify the relationships between weather and pollutant concentrations.



Research question

In this analysis, we will attempt to determine the effects of temperature and humidity on the concentration of air pollutants so our research question is:

What is the affect of temperature and humidity on the concentration of air pollutants, such as benzene, titania, and tin oxide?

Plan of action

With our research question, we are interested in the hourly averaged concentrations of air pollutants, temperature and humidity. We will ignore variables which have too many missing data to increase the precision of this analysis. The air pollutants that we will focus on are benzene, titania and tin oxide. After dealing with the missing data, we will perform a linear regression analysis using OLS (ordinary least square) method. Coefficients of relevant variables will be plotted with confidence intervals.

References

S. De Vito, E. Massera, M. Piga, L. Martinotto, G. Di Francia, On field calibration of an electronic nose for benzene estimation in an urban pollution monitoring scenario, Sensors and Actuators B: Chemical, Volume 129, Issue 2, 22 February 2008, Pages 750-757, ISSN 0925-4005.

Matooane, M., John, J., Oosthuizen, R., and Binedell, M. 2004. Vulnerability of South African communities to air pollution. In: 8th World Congress on Environmental Health. Durban, South Africa: Document Transformation Technologies.

Shea, K., Truckner, R., Weber, R., and Peden, D. 2008. Climate change and allergic disease. Journal of Allergy and Clinical Immunology, 122(3): 443-453.

Younger, M., Morrow-Almeida, H., Vindigni, S., and Dannenberg, A. 2008. The Built Environment, Climate Change, and Health Opportunities for Co-Benefits. American Journal of Preventative Medicine, 35 (5): 517-526.