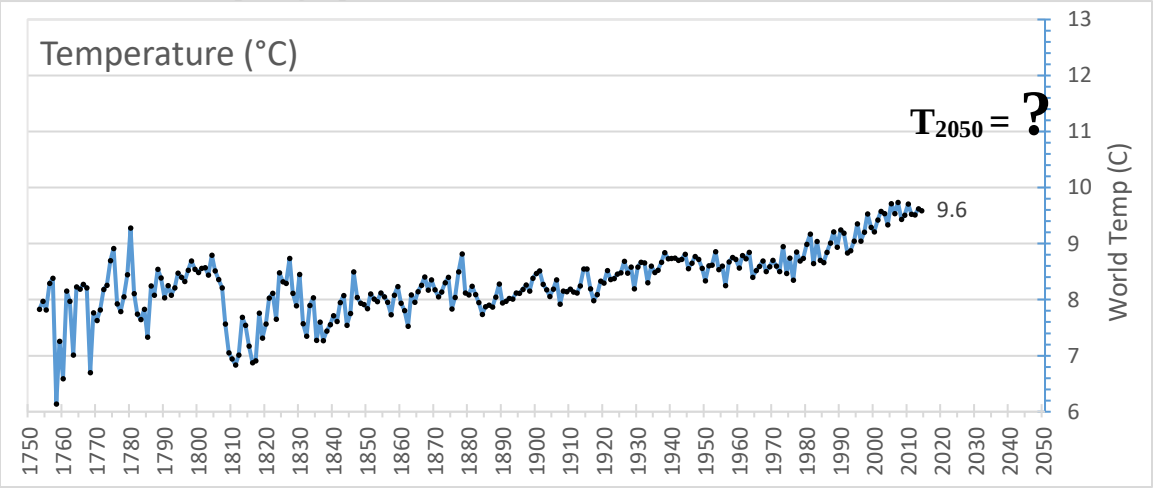
Developing Simple Climate Model

Objective: Your group is part of the Department of Climate Change of the USA. USA government requested for you to make assessment of the changing climate in the country. Your goal is to predict what temperature will be in USA in 2050 under different climate scenarios and advice on a better policy option.



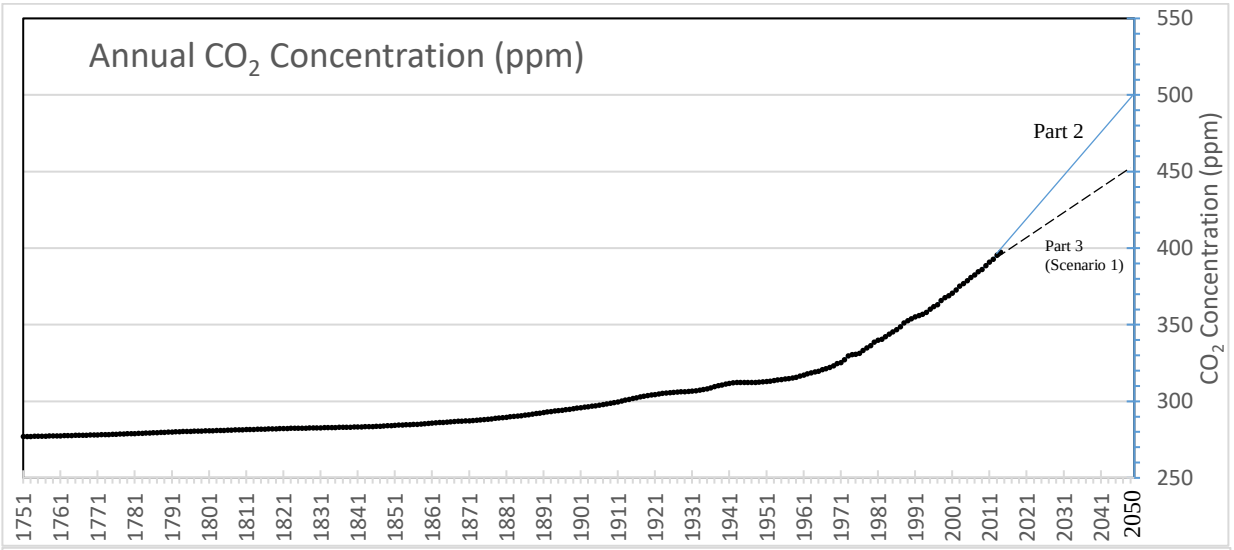
Part 1: Explore the Trend

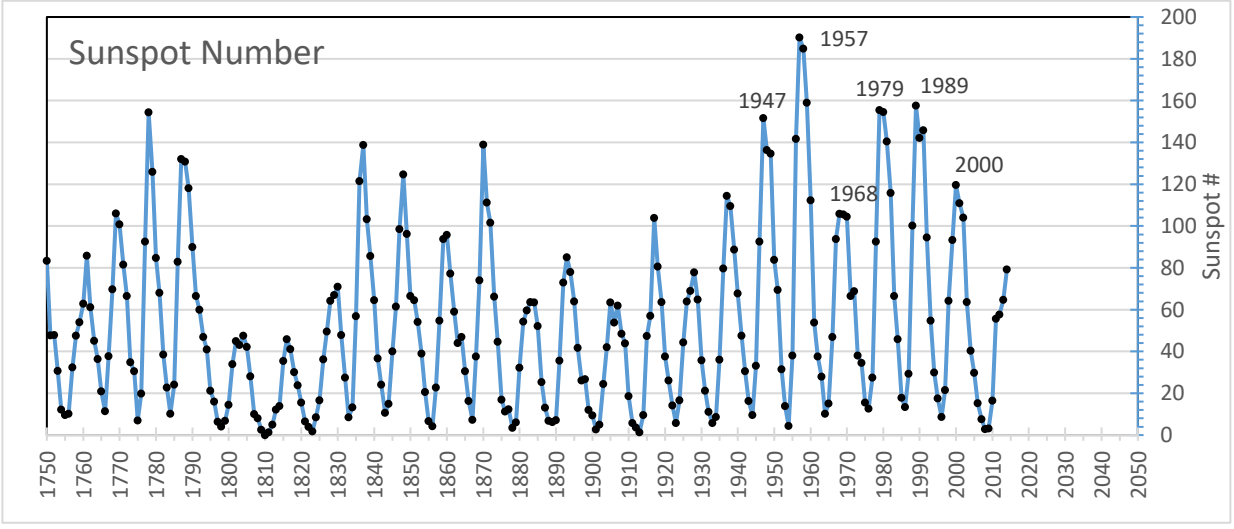
Prior to any modeling, it is important to explore and get familiar with your data. Thus, to predict the event that will happen in the future it is important to understand how certain parameter varied in the past and present.

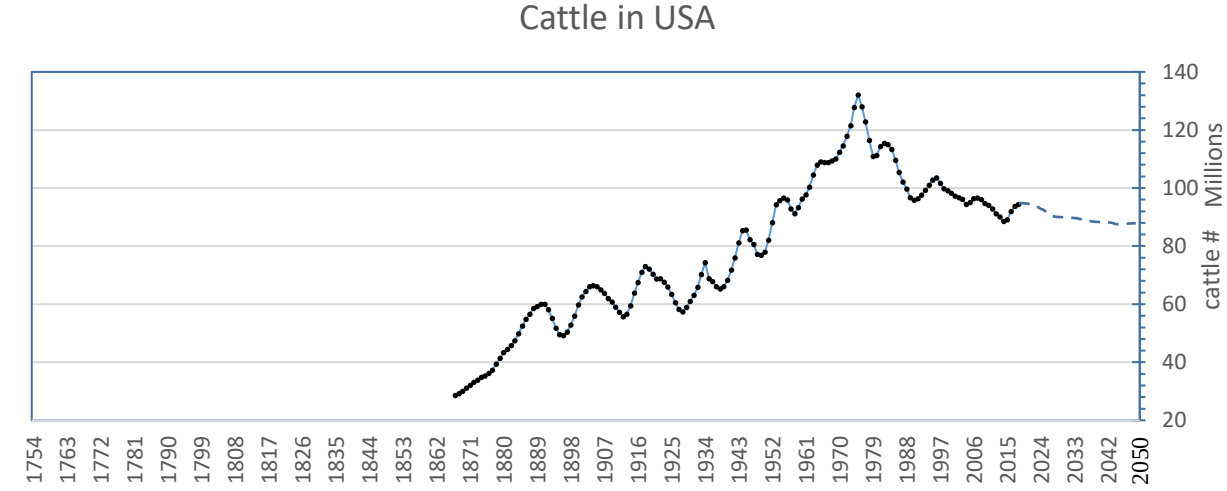
1) Explore the data given below that are available to your team (annual variability between 1750-2014)
2) Fill in the table below, briefly describing the trend in the data (is it increasing, decreasing, cyclic or staying the same over time), variability (is the trend constant over time or does it vary widely from year-to-year), and general notes on the pattern that you see.

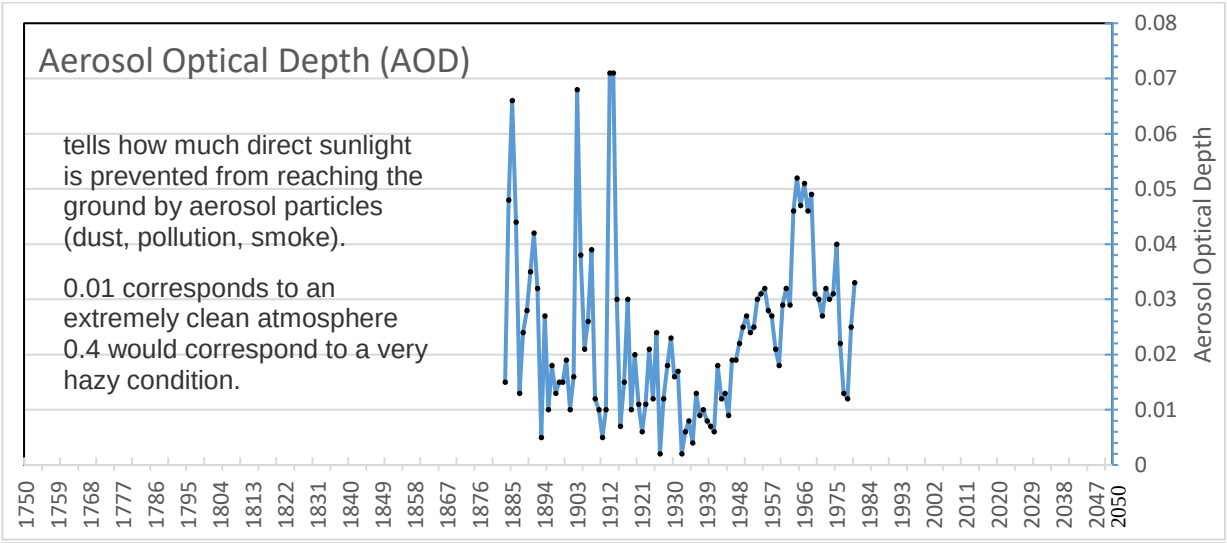
Variable	General Trend	Variability	Notes
CO_2 Concentration	increasing	Fairly constant	Slow increase in CO_2 until mid 90s and then sharp increase until present
Sunspot Number	Cyclic	Varies	~ 11-year cycle, with max number of sunspots (peaks) varies significantly between ~40 to ~200 for certain years
Cattle in USA	Increase/decrease	Varies	Increasing sharply until 1974, after that slowly drops to 89 million.

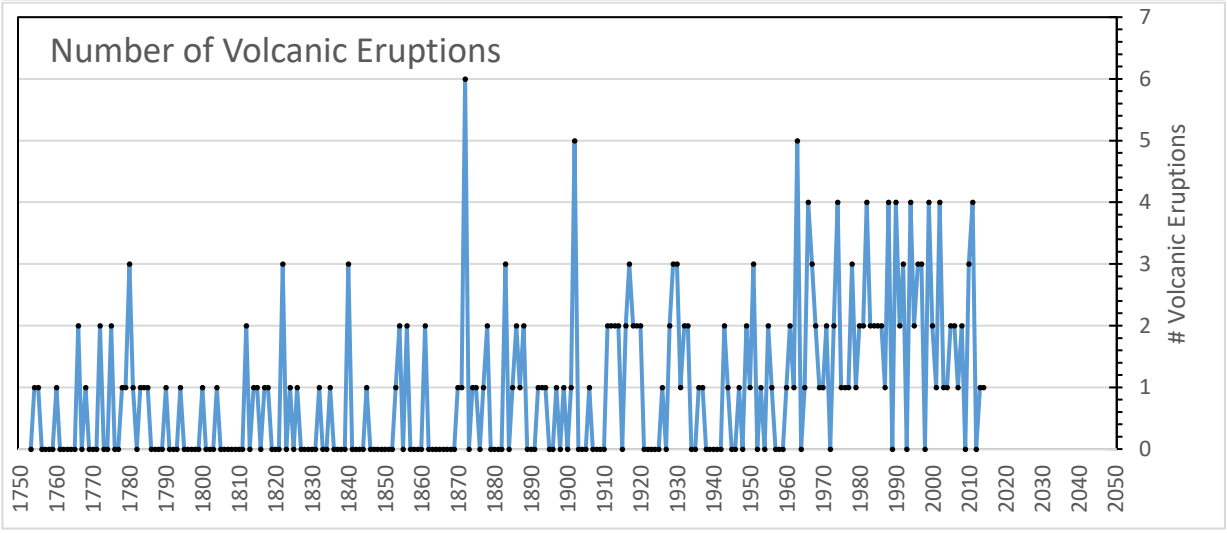
Aerosol Optical Depth	No trend	Varies a lot	AOD varied a lot with no apparent trend
Volcanic Eruptions	No trend	Varies	Slightly increase in volcanic activities after 1960s (less years with no eruptions)






Cattle in USA
140
120
100
80
60
40
20
cattle # Millions
1754
1763
1772
1781
1790
1799
1808
1817
1826
1835
1844
1853
1862
1871
1880
1889
1898
1907
1916
1925
1934
1943
1952
1961
1970
1979
1988
1997
2006
2015
2024
2033
2042
2050


Aerosol Optical Depth (AOD)
tells how much direct sunlight is prevented from reaching the ground by aerosol particles (dust, pollution, smoke).
0.01 corresponds to an extremely clean atmosphere
0.4 would correspond to a very hazy condition.
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Aerosol Optical Depth
1750
1759
1768
1777
1786
1795
1804
1813
1822
1831
1840
1849
1858
1867
1876
1885
1894
1903
1912
1921
1930
1939
1948
1957
1966
1975
1984
1993
2002
2011
2020
2029
2038
2047
2050

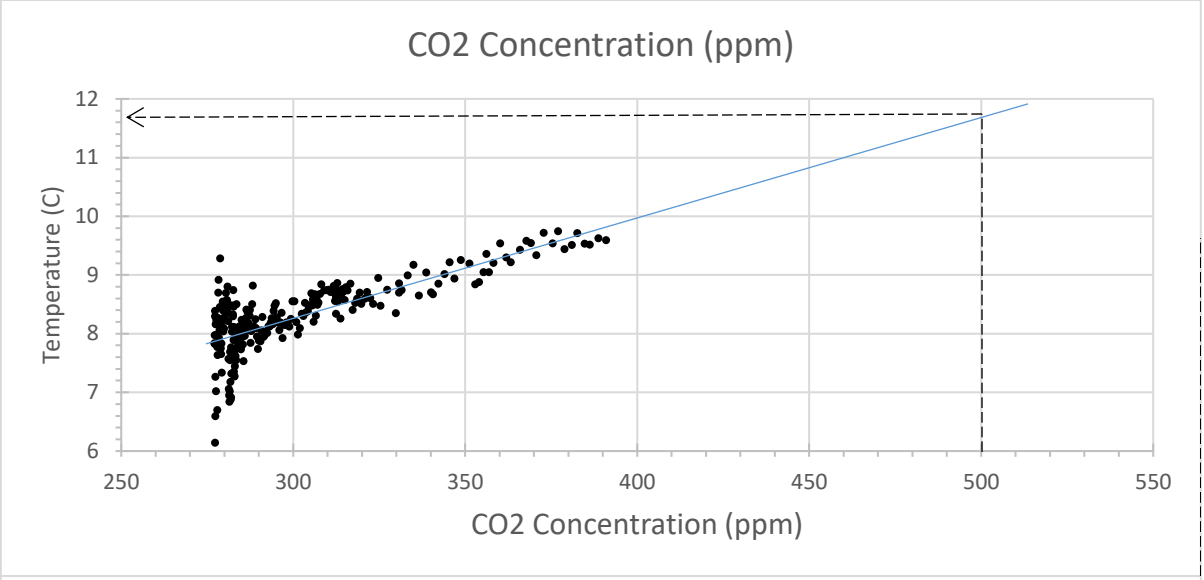

Number of Volcanic Eruptions
7
6
5
4
3
2
1
0
Volcanic Eruptions
1750
1760
1770
1780
1790
1800
1810
1820
1830
1840
1850
1860
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050

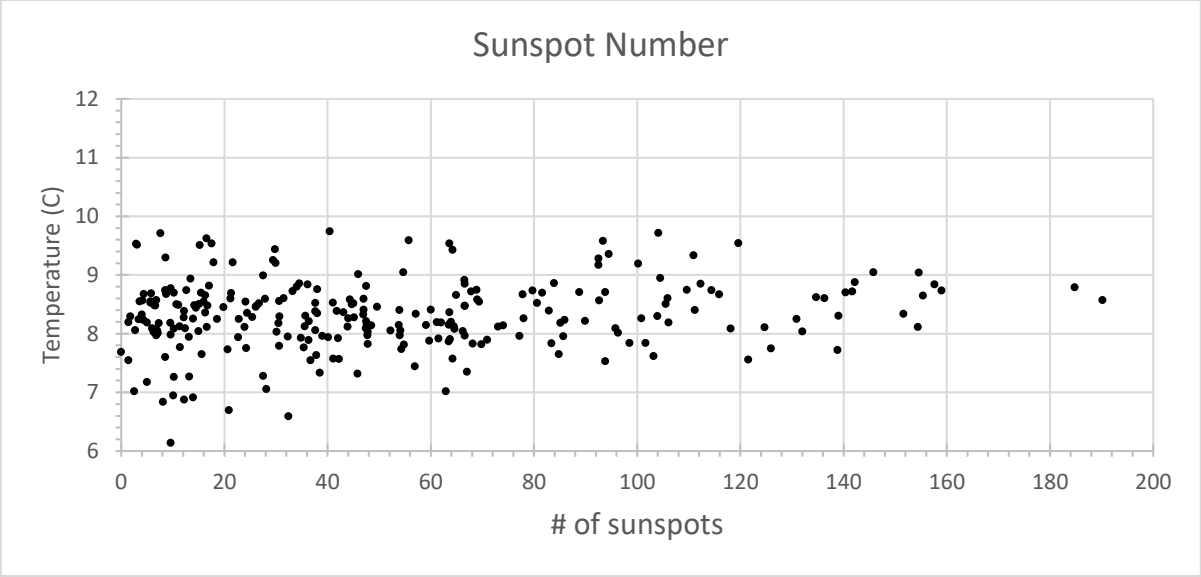
Part 2: Explore Correlation with Temperature

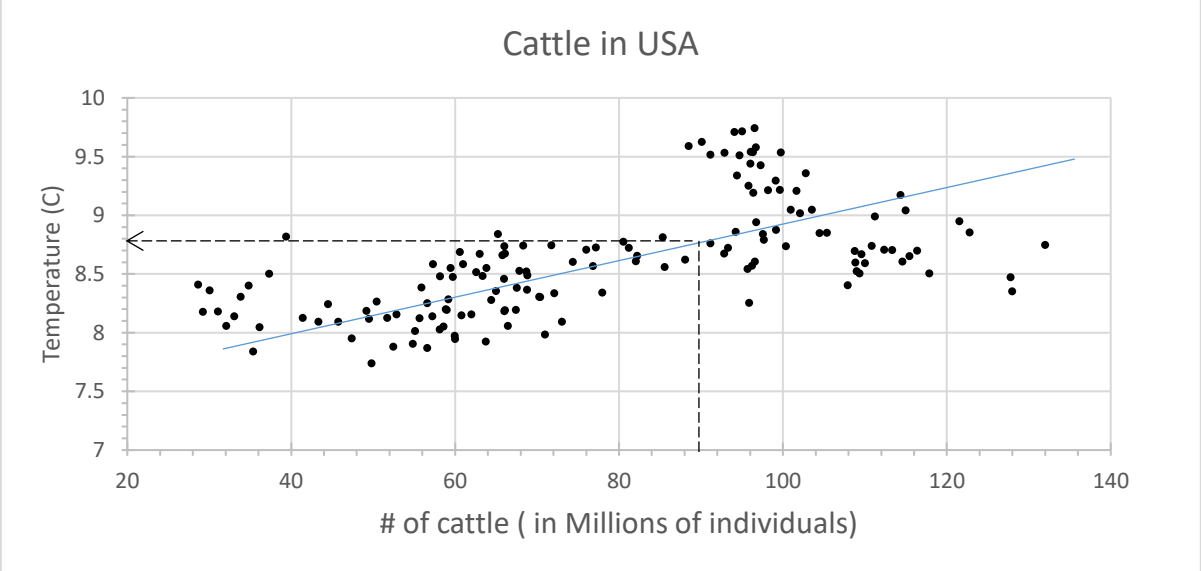
As you were asked to predict change in temperature, it is of interest to explore how each parameter varies with temperature.

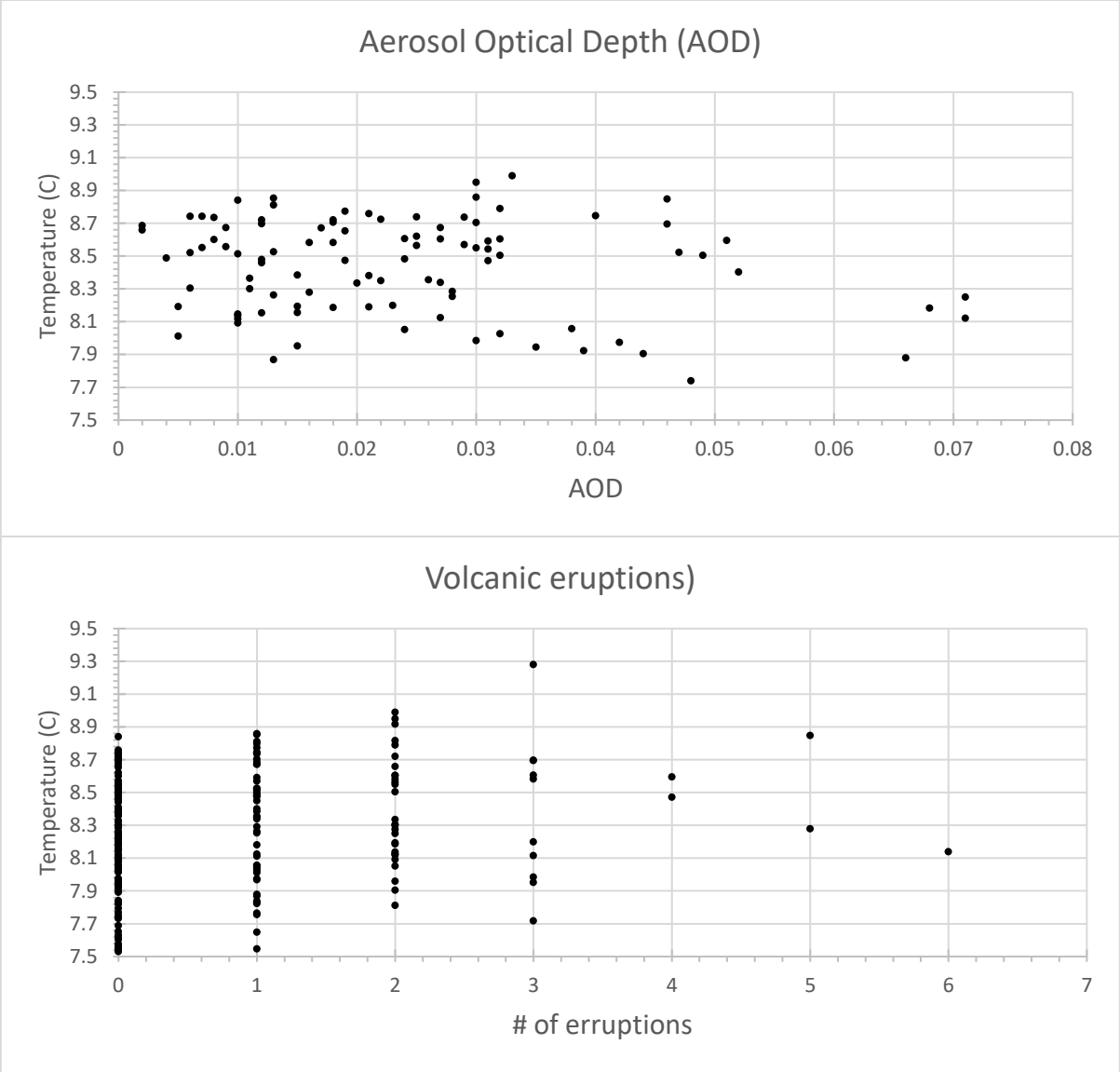
1) Explore the relationship between a parameter and the temperature in the graphs below.
2) Fill in the table below to indicate the relationship between that variable and global temperature (are they positively related, negatively related, or unrelated) and the strength of any relationship (is it a strong relationship or just a weak one with a lot of variation).

Variable	Direction of Relationship	Strength of Relationship	Notes
CO_2 Concentration	positively related	strong	Very strong linear relationship for temperatures higher than 8.5C
Sunspot Number	unrelated	weak	No apparent trend, data just clustered together
Cattle in USA	Weak positive trend	Medium, but with a lot variation	Overall, increasing
Aerosol Optical Depth	unrelated	weak	No apparent trend, data just clustered together
Volcanic Eruptions	unrelated	weak	No apparent trend


CO2 Concentration (ppm)
Temperature (C)
12
11
10
9
8
7
6
250
300
350
400
450
500
550
CO2 Concentration (ppm)


Sunspot Number
Temperature (C)
12
11
10
9
8
7
6
0
20
40
60
80
100
120
140
160
180
200
# of sunspots


Cattle in USA
Temperature (C)
10
9.5
9
8.5
8
7.5
7
20
40
60
80
100
120
140
# of cattle (in Millions of individuals)


Aerosol Optical Depth (AOD)
Temperature (C)
9.5
9.3
9.1
8.9
8.7
8.5
8.3
8.1
7.9
7.7
7.5
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
AOD
Volcanic eruptions)
Temperature (C)
9.5
9.3
9.1
8.9
8.7
8.5
8.3
8.1
7.9
7.7
7.5
0
1
2
3
4
5
6
7
# of erruptions

Part 3: Creating your own Climate Model

T = function (parameter 1, parameter 2, parameter 3…)

a) We are modelling temperature as a function of some parameters. Now, your team needs to decide which parameter to use.

1) Based on the relationship between global temperature and each variable, decide whether or not you think it would be important to include that variable in your model (Circle Yes or No) in the table below. Provide a short rationale why you decided to include and omit some of the parameters:

As we were asked to predict temperature in USA in 2050, I would choose parameters that show correlation with Temperature. Based on Parts 2, only 2 parameters show certain trend: CO2 concentrations and Cattle (this one has a weaker correlation with temperature)

b) For each of the variables you chose to include in your model:

2) From Part1, estimate what the value of the variable going to be in 2050. Record your estimates in the third column ("Estimated Value in 2050")
3) Using Part 2 graphs, determine what temperature is likely to be in 2050 based on 2050 values you determined above. Record your estimates in the fourth column ("Predicted Temp in 2050").
4) Finally, calculate an average of the predicted temperatures from each of the variables above to determine your final prediction.

Variable	Included in the model:	Estimated Value in 2050	Predicted Temp in 2050
CO_2 Concentration	(Y) / N	500ppm	11.7°C
Sunspot Number	Y / (N)		
Cattle in USA	(Y) / N	90 million	8.8°C
Aerosol Optical Depth	Y / (N)		
Volcanic Eruptions	Y / (N)		
Your prediction for average global air temperature in 2050: (Average)			10.3°C

Your prediction for average global air temperature CHANGE since 2014 (Temperature in 2014 is labeled on the graph from Part 1): _____

In 2014 the Temperature was 9.6°C, according to our Model, temperature will rise to 10.3°C by 2050. So, change in temperature is 10.2-9.6 = 0.6°C

NOAA report: By 2050, across high and low emissions scenarios, models project average annual air temperatures in the region will increase between 1.8 to 5.4ºF (1 to 3ºC).

Part 4: Different Policy Scenarios

US Government wants to reduce the warming, and they came up with 2 possible scenarios that can help to achieve their goal. Your team have been asked to explore, using your model how different scenarios will affect the temperature.

Scenario 1:

Adopt stricter CO_2 emissions standards by reducing the rate of increase of atmospheric CO_2 increase by 50%.
Estimated COST $6.6 billion

Scenario 2:

Replace portion of meet protein with a plant-based, thus reducing the number of cattle to 60 million.
Estimated COST $4.0 billion

What would happen to your predicted temperature for 2050 if nations adopted Scenario 1? Explain how you determined your new estimate.

Variable	Included in the model:	Estimated Value in 2050	Predicted Temp in 2050
CO_2 Concentration	**Yes**	450ppm	10.8°C
Cattle in USA	**Yes**	90 million	8.8°C
Your prediction for average global air temperature in 2050: (Average)			9.8°C

Just a slight increase in temperature by 0.2°C by 2050.

What would happen to your predicted temperature for 2050 if nations adopted Scenario 2? Explain how you determined your new estimate.

Variable	Included in the model:	Estimated Value in 2050	Predicted Temp in 2050
CO_2 Concentration	**Yes**	500ppm	11.7°C
Cattle in USA	**Yes**	60 million	8.3°C
Your prediction for average global air temperature in 2050: (Average)			10°C

Increase in temperature by 0.4°C by 2050.

US Government only have money to implement one of the policies. Advice US government on what type of policy should be implemented, give your rationale.

Answers can vary: as cost can be taken into account.
You can argue that scenario 1 would be a better choice despite the high cost as it is reducing the warming significantly.
While you can argue that Scenario 2 will be a more affordable policy and it also reducing the warming compare to "business – as -usual" scenario (i.e. adopt no policies)

Synthesis & Wrap Up

In what ways do you think your model is accurate? In other words, how does your model accurately represent the real world?

Include the parameters that are known contributors to climate change: CO2 and CH4 (that is produced from cattle). In addition, our model contains both anthropogenic (cattle and CO2) factors that are major cause of global warming

Give two limitations of your model. In other words, how is your model not like the real world?

- Averaging of temperatures (i.e. equal weight of different factors)
- The 2050 value of the parameters were estimated by "guessing" or assuming linear relationship between the temperature and a parameter of interest.

What other variables do you think would help your model? What other things could influence global temperatures that could be included?

- Changes in albedo
- Other GHG
- Cloud cover
- Other anthropogenic inputs (agriculture or other sectors)
- Population growth
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