LAB 3

Youngsub Lee 22755152

Section 1 and 2

a. Fill in Table 1 below. Don't forget to highlight (e.g. circle) trends which are positive within the 95% confidence interval AND to fill in the unit of the trends you give.

Period	Temperature anomaly trend (unit: Celsius/Month)	
	UBC	Global
1950-1959	(not enough data)	0.0069
1960-1969	-0.0237	-0.006
1970-1979	0.0176	0.0083
1980-1989	0.0522	0.0059
1990-1999	-0.0059	0.0211
2000-2009	-0.0265	0.0096
2010-2017	0.2554	0.0502
1950-2017	0.0196	0.0117

b. Describe the variability in local (UBC) and global temperature anomalies time series.

UBC temperature anomaly indicates a slope of 0.46 with y intercept of -0.46. There is a peak in anomaly in approximately period of 3 years. The maximum and minimum amplitude that can be observed between the time period of 1960-2016 is approximately 2.5 C and -3.0 C respectively

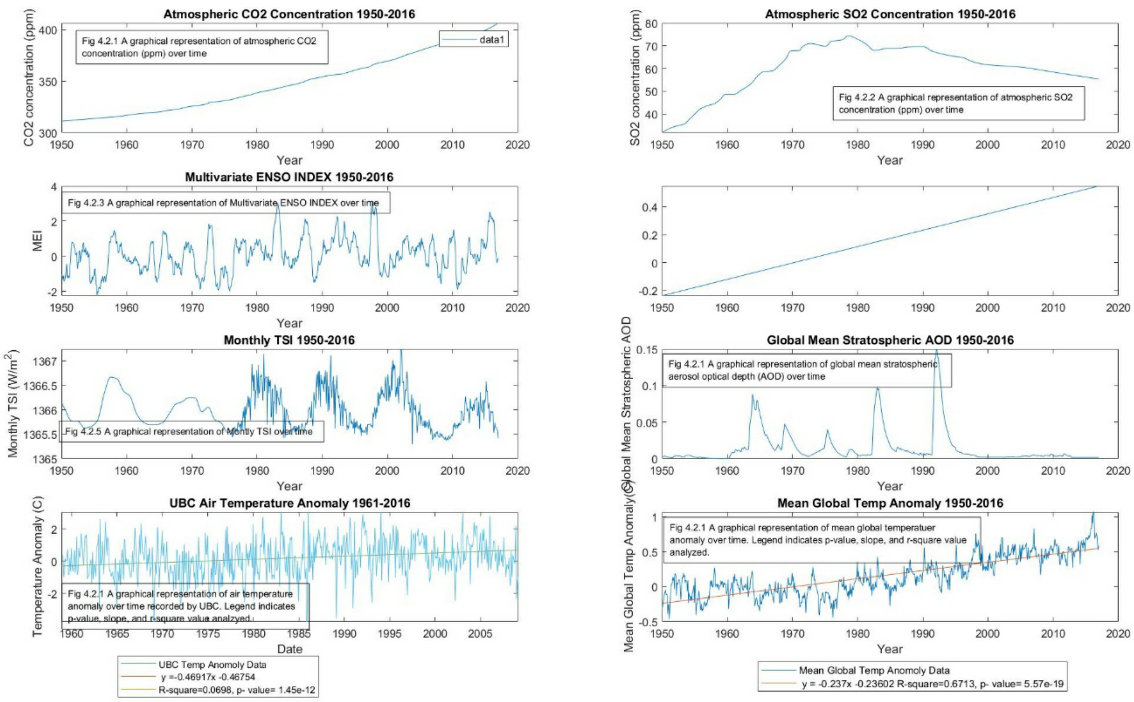
The mean global temperature anomaly indicates a slope of 0.23 with y intercept of -0.23. There is reoccurring peaks in approximately period of 5 years. The maximum and minimum amplitude that can be observed between the time period of 1960-2016 is approximately 0.8 C and -0.5 C respectively

c. Do you think that the term "global warming" is appropriate to describe the time series you plotted? Why?

Yes, the temperature anomaly timeseries indicate that the temperature is increasing over time. Even 0.5 C increase in the global mean temperature is significant. The positive trend of temperature over time with a observable obvious positive slope, one can surely assume the significance of global warming.

d. Do you think that the trend you see in global temperature (if any) is a natural fluctuation? If so, do you think it happen often? What additional data would you like to have to answer these questions?

Considering there is a peak in temperature every 3-5 years, I think this is associated with natural fluctuation. For example, solar radiation from the sun is not received at same rate every year as the Earth is rotating and tilting. Therefore, in some years, we will receive more sunlight that contribute to fluctuation. We would have to consider TSI data specifically to answer these question



Section 3

What reasons could explain the differences and the similarities between UBC and global temperature anomalies?

Similarity: positive trend of temperature indicating global warming (general trend of warming earth)
Diff: climates, seasons, longitude (amount of solar radiation reaching and thus some region may be more significantly experience temperature fluctuation/warming.

Section 4 and 5

a. Fill in table 2 below. Don’t forget to give 95% confidence intervals AND units for eachslope.

Independen t variable	Slope of the global temperature anomaly vs forcing regression for a		
	Simple linear regression		Multilinear regression (R^2=0.8382)
	Slope s	R2	Slop e
TSI	0.0108 W/m/yr	0.0002	0.05 W/m/yr
AOD	-2.4183 AOD/yr	0.04	-1.2 AOD/yr
CO2	0.009 ppm/yr	0.0007	0.009 ppm/yr
SO2	0.002 ppm/yr	0.006	-0.005 ppm/yr
MEI	0.1 MEI/yr	0.16	0.07 MEI/yr

b. Are the results of the simple linear and the multilinear regression always compatible? Why? Which method do you think give the most accurate idea on the dependence of the global temperature anomaly on each forcing?

Looking at the collected data, the results of simple linear and multilinear regression are not always compatible since simple linear regression has only one x and y variable. Therefore, I think global temp anomaly that usually has only one x and y variable, simple linear regression is more accurate

c. Briefly explain if/why the sign of each slope match/does not match your expectations.

Most, if not all, of the slope match my expectations. For example, most people would anticipate that there will be increasing atmospheric GHG which contribute to the global warming. Therefore, I expect that most of slope will end up showing a positive trend.

d. In its AR5 report (2014), the International Panel on Climate Change (IPCC) uses various greenhouse gases emissions scenario to forecast future temperature. In particular, for three scenarios, the atmospheric CO_2 in 2100 is assumed to be 400, 500 and 950 ppm respectively. Corresponding temperature anomalies, relative to 1986-2005, would be 1 ± 0.4, 1.8 ± 0.5 and 3.7 ± 0.7 degree Celsius respectively. Are the results of your regression compatible with such projections? Explain any assumptions made on forcing other than CO_2 to answer this question. Discuss where disagreement (ifany) may come from.

Some forcing I could think of are albedo, ozone and aerosol other than greenhouse gases like CO_2. I think albedo and aerosols may act as a positive forcing. However I could not find disagreement because the negative forcing is outscaling the positive forcing.

Section 6

Briefly summarize the main limitations of an approach based on linear regression to establish a causality between two time series and make prediction for the dependent variable.

Linear regression may over simplify complex problems such that it may fail to fit complicated datasets. It assumes a linear relationship between the input and output variables that it is great for showing some positive or negative trend, but the limitation is clear.

Wrap-up

For each of the statements below, indicate whether your work in this lab: -demonstrate the statement -support the statement -does not enable to comment the statement -does not support the statement -proves the statement wrong Choose only one option. Briefly explain your choice, and make clear whether it applies to the entire statement, or only part of it.

Statement 1: “Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia.” (IPCC AR5)

Demonstrate the statement

Statement 2: “[the main problem for climate scientists is] the fact that there has now been no “global warming” for 18 years and six months.” (Breitbart, 2015)

Does not support the statement

Statement 3: “[greenhouse gases] are extremely likely to have been the dominant cause of the observed warming since the mid-20th century.” (IPCC AR5)

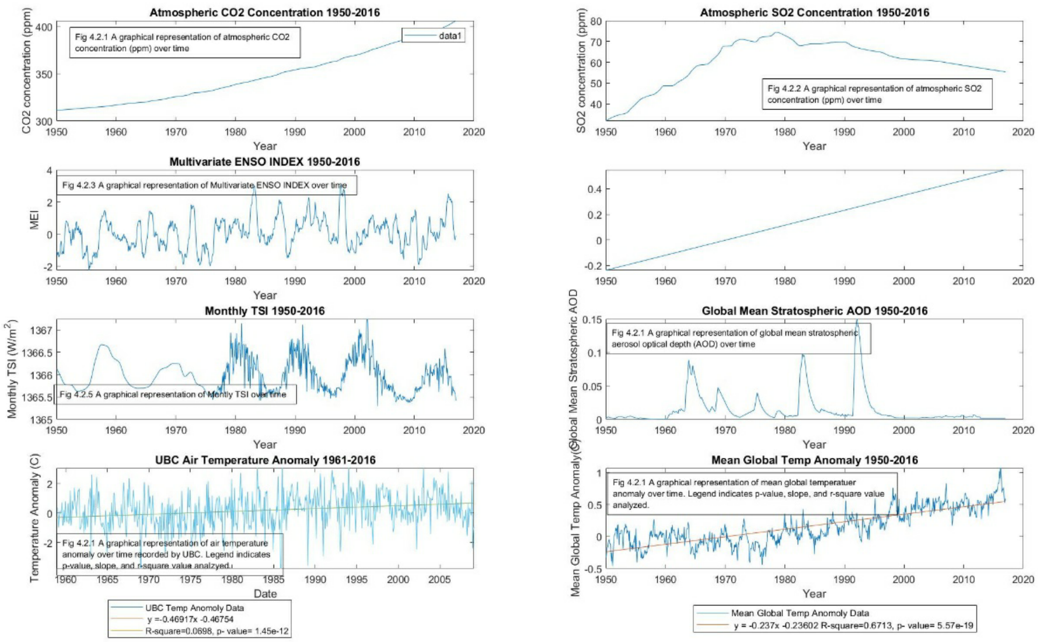
Does not support the statement

Statement 4: “The Sun is the reason for our warming. SO2 [from volcanoes] is the ‘cure’ to put a band-aid on it until it rises again. We are not getting the SO2 needed [the author means we did not get a major volcanic eruption recently] and that is a problem [i.e., what is causing the warming trend] right now.” (southerncaliforniaweatherforce.com)

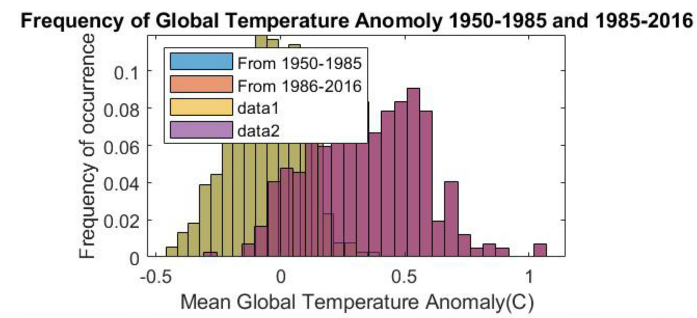
Supports the statement

Statement 5: “In recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans.” (IPCC AR5)

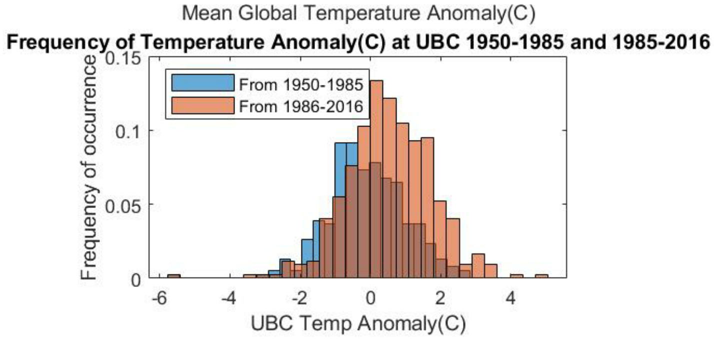
Not able to comment the statement



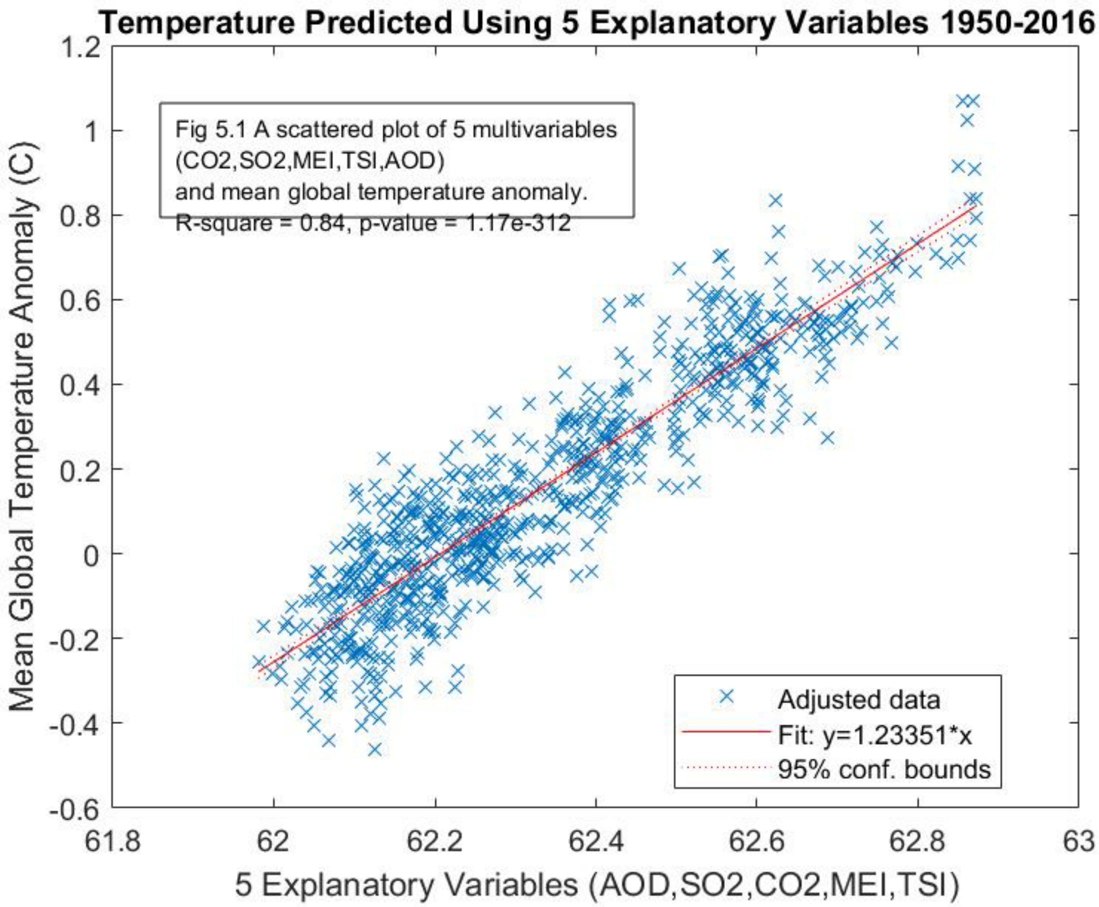
Atmospheric CO2 Concentration 1950-2016
CO2 concentration (ppm)
Fig 4.2.1 A graphical representation of atmospheric CO2 concentration (ppm) over time
data1
Year
Atmospheric SO2 Concentration 1950-2016
SO2 concentration (ppm)
Fig 4.2.2 A graphical representation of atmospheric SO2 concentration (ppm) over time
Year
Multivariate ENSO INDEX 1950-2016
MEI
Fig 4.2.3 A graphical representation of Multivariate ENSO INDEX over time
Year
Monthly TSI 1950-2016
Monthly TSI (W/m2)
Fig 4.2.5 A graphical representation of Montly TSI over time
Year
Global Mean Stratospheric AOD 1950-2016
Global Mean Stratospheric AOD
Fig 4.2.1 A graphical representation of global mean stratospheric aerosol optical depth (AOD) over time
Year
UBC Air Temperature Anomaly 1961-2016
Temperature Anomaly (C)
Fig 4.2.1 A graphical representation of air temperature anomaly over time recorded by UBC. Legend indicates p-value, slope, and r-square value analzyed.
Date
UBC Temp Anomoly Data
y =-0.46917x -0.46754
R-square=0.0698, p- value= 1.45e-12
Mean Global Temp Anomaly 1950-2016
Mean Global Temp Anomaly (C)
Fig 4.2.1 A graphical representation of mean global temperatuer anomaly over time. Legend indicates p-value, slope, and r-square value analyzed.
Year
Mean Global Temp Anomoly Data
y = -0.237x -0.23602 R-square=0.6713, p- value= 5.57e-19



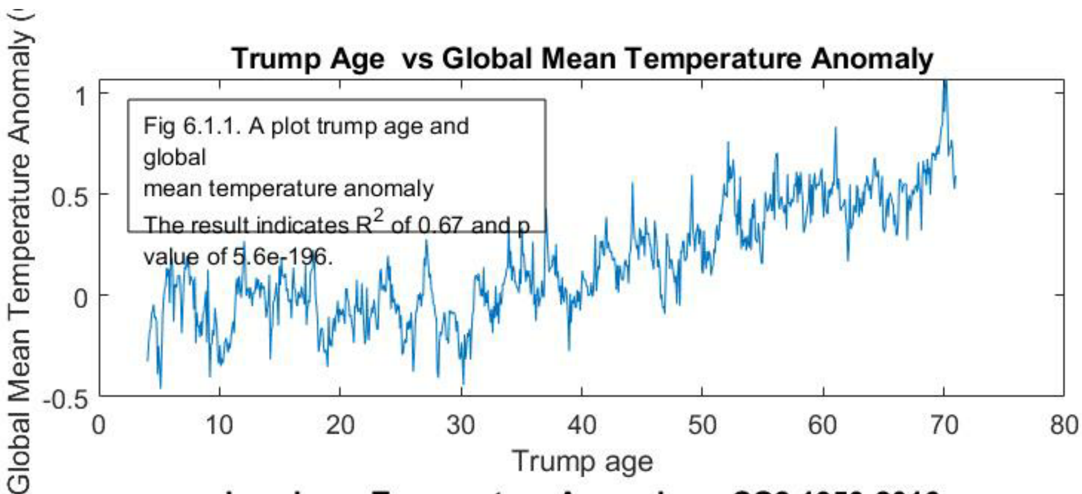
Frequency of Global Temperature Anomoly 1950-1985 and 1985-2016
Frequency of occurrence
From 1950-1985
From 1986-2016
data1
data2
Mean Global Temperature Anomaly(C)



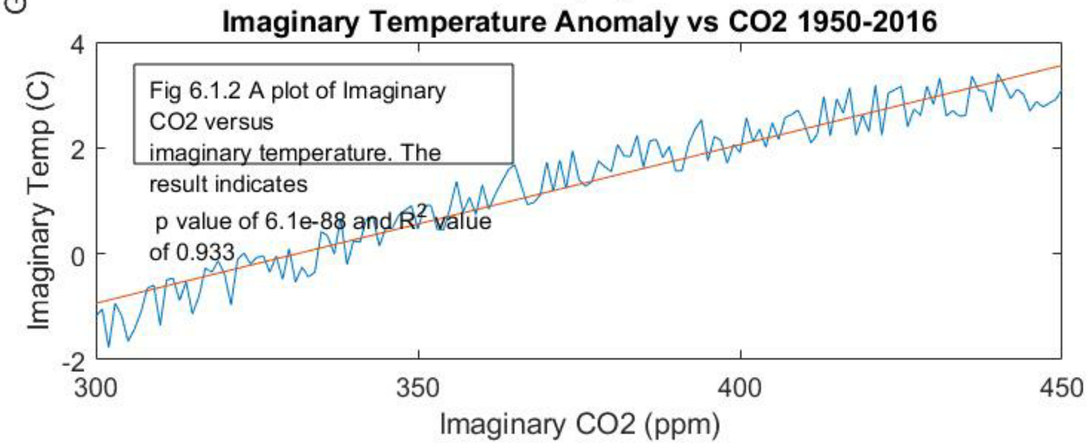
Frequency of Temperature Anomaly(C) at UBC 1950-1985 and 1985-2016
Frequency of occurrence
From 1950-1985
From 1986-2016
UBC Temp Anomaly(C)



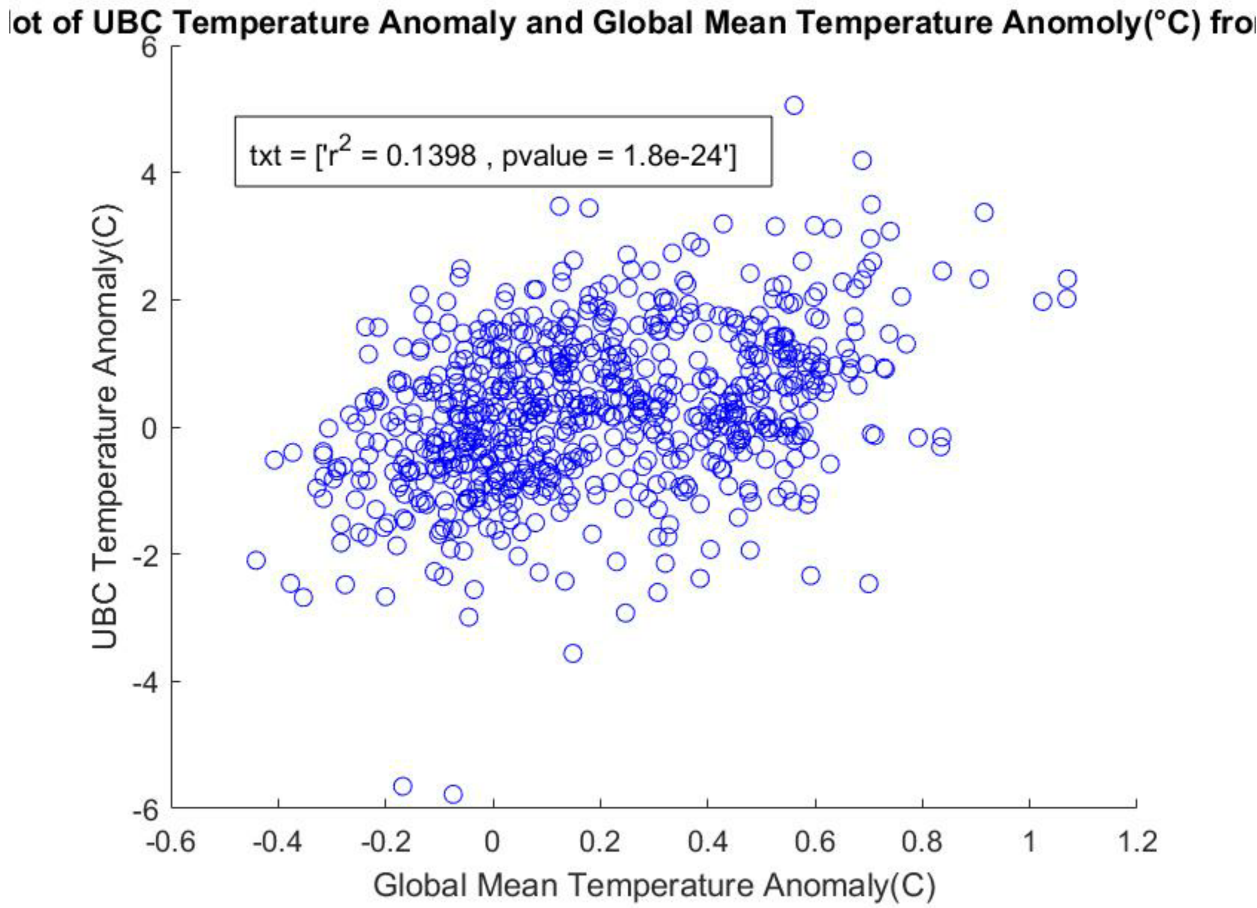
Temperature Predicted Using 5 Explanatory Variables 1950-2016
Fig 5.1 A scattered plot of 5 multivariables
(CO2,SO2,MEI,TSI,AOD)
and mean global temperature anomaly.
R-square = 0.84, p-value = 1.17e-312
Mean Global Temperature Anomaly (C)
5 Explanatory Variables (AOD,SO2,CO2,MEI,TSI)
Adjusted data
Fit: y=1.23351*x
95% conf. bounds
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
61.8
62
62.2
62.4
62.6
62.8
63



Trump Age vs Global Mean Temperature Anomaly
Fig 6.1.1. A plot trump age and global
mean temperature anomaly
The result indicates R^2 of 0.67 and p value of 5.6e-196.
Global Mean Temperature Anomaly (
Trump age



Imaginary Temperature Anomaly vs CO2 1950-2016
Fig 6.1.2 A plot of Imaginary CO2 versus
imaginary temperature. The result indicates
p value of 6.1e-88 and R^2 value of 0.933
Imaginary Temp (C)
Imaginary CO2 (ppm)


lot of UBC Temperature Anomaly and Global Mean Temperature Anomoly(°C) fro
txt = ['r2 = 0.1398 , pvalue = 1.8e-24']
UBC Temperature Anomaly(C)
Global Mean Temperature Anomaly(C)
6
4
2
0
-2
-4
-6
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
1.2

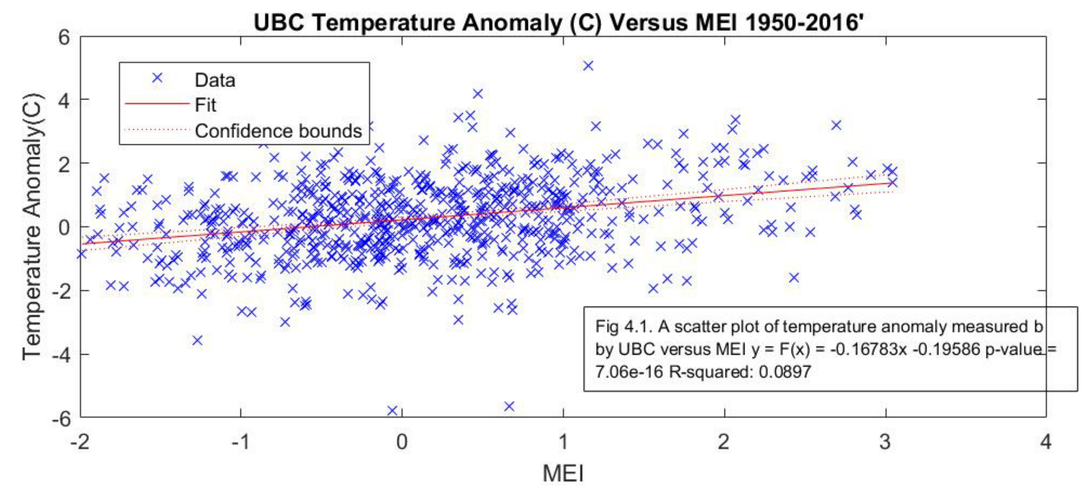
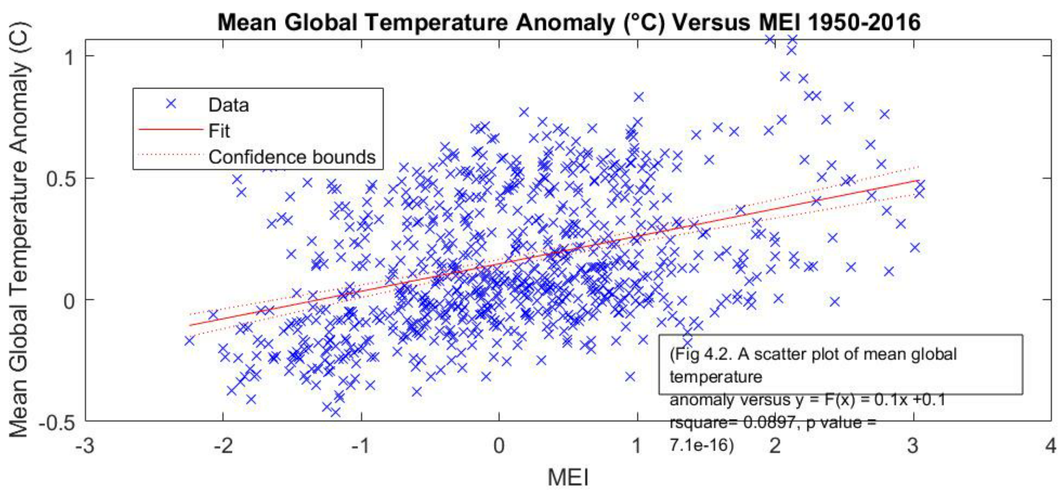
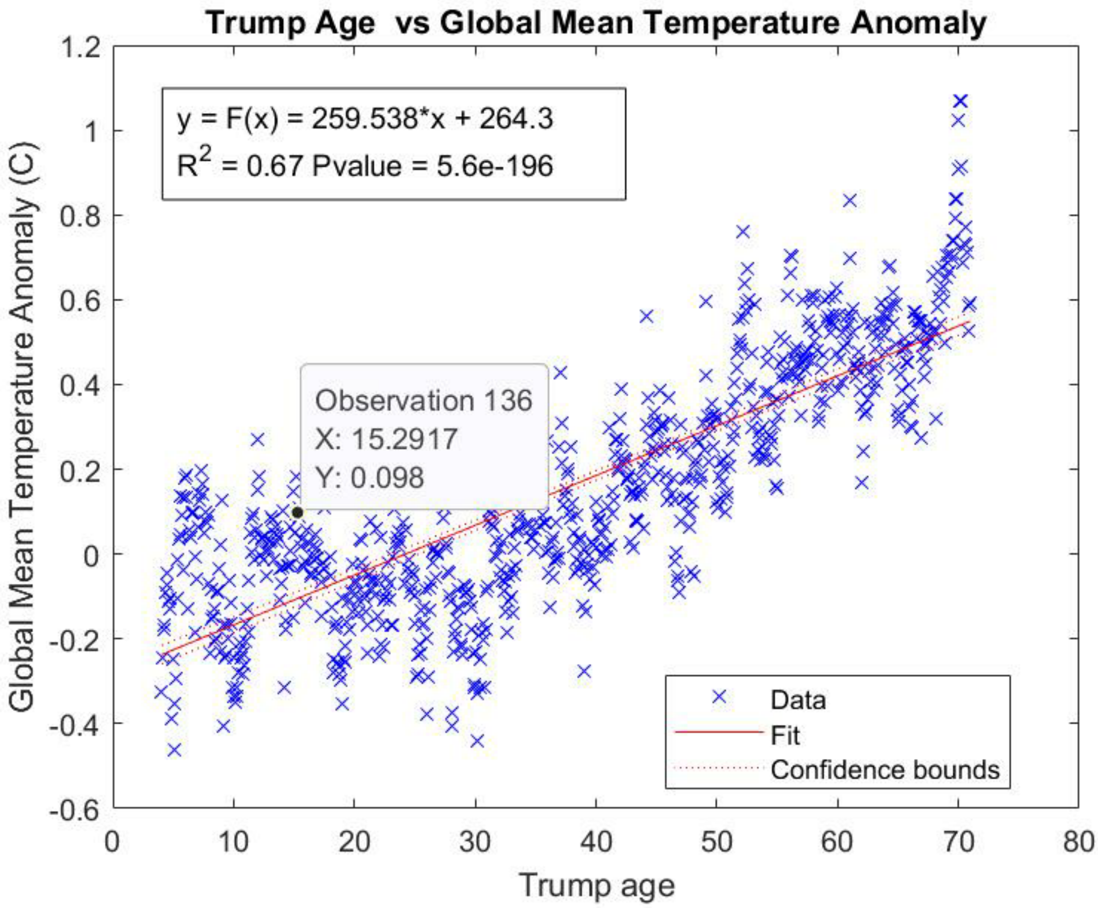


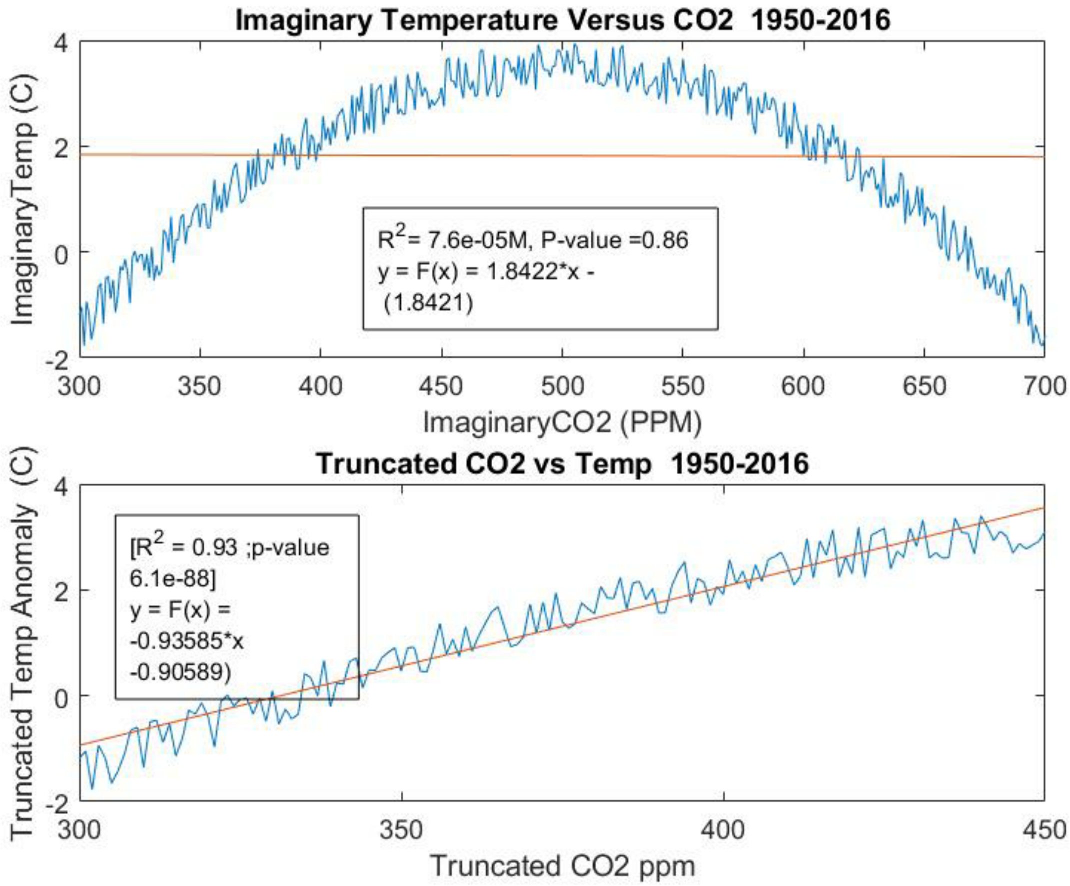
Fig 4.1. A scatter plot of temperature anomaly measured b by UBC versus MEI y = F(x) = -0.16783x -0.19586 p-value = 7.06e-16 R-squared: 0.0897



(Fig 4.2. A scatter plot of mean global temperature anomaly versus y = F(x) = 0.1x +0.1 rsquare= 0.0897, p value = 7.1e-16)



Trump Age vs Global Mean Temperature Anomaly
y = F(x) = 259.538*x + 264.3
R^2 = 0.67 Pvalue = 5.6e-196
Observation 136
X: 15.2917
Y: 0.098
Data
Fit
Confidence bounds
Global Mean Temperature Anomaly (C)
Trump age
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
0
10
20
30
40
50
60
70
80



% Process of importing data home -> import data -> lab3_data
% column vector -> generate script -> CLICK RUN

Variables renamed by shortening and containing initials
CO2, SO2, MeanAnom, MeanTempAnom, MEI, TSI, UBCtemp

```
>> Untitled2

>> figure(1)

subplot(4,2,1)

>> subplot(4,2,1)

>> plot(date1, CO2)

>> xlabel("Year")

>> ylabel('CO2 concentration (ppm)')
```

```
>> title('Atmospheric CO2 Concentration 1950-2016')

>> subplot(4,2,2)

>> plot(date1, SO2)

>> xlabel("Year")

>> ylabel('SO2 concentration (ppm)')

>> title('Atmospheric SO2 Concentration 1950-2016')

>> subplot(4,2,3)
>> xlabel("Year")

>> ylabel("MEI")

>> title('Multivariate ENSO INDEX 1950-2016')

>>>> subplot(4,2,5)

>> plot(date1,TSI)

>> xlabel("Year")

>> ylabel('Monthly TSI (W/m^2)')

>> title('Monthly TSI 1950-2016')

>> subplot(4,2,6)

>> plot(date1,MeanAnom)

>> xlabel("Year")

>> ylabel("Global Mean Stratospheric AOD")

>> title('Global Mean Stratospheric AOD 1950-2016')


%% Perform linear regression and multilinear regression, calculate correlation coefficients,
%%[ b , bint , r , rint , stats ] = regress( y , X ) also returns a vector stats that contains the R2 statistic, the F-statistic and its p-value, and an estimate of the error variance

>> subplot(4,2,7)
>> [b,bint,r,rint,stats]=regress(UBCtemp, [ones(size(UBCtemp)) date1])
UBC = b(2) * date1 + b(1);
```

```
plot(date1,UBC)
>> hold on

>> plot(date1, UBCtemp)

>> xlabel('Date')

>> ylabel('Temperature Anomaly (C)')

>> title('UBC Air Temperature Anomaly 1961-2016')
disp(['y = F(x) = ',num2str(UBC(1)),'*x + ','(',num2str(UBC(2)),')'])
%y = F(x) = -0.46917*x + (-0.46754)


%stat = regstats(date1, UBCtemp) finding p-value and rsquared
[p value = 1.45e-12 rsquare: 0.0698]
>>legend('UBC Temp Anomoly Data',' y =-0.46917x -0.46754','R-square=0.0698, p- value= 1.45e-12','Location','northwest');

>> subplot(4,2,8)

>> plot(date1, MeanTempAnom)
>> xlabel("Year")
>> ylabel("Mean Global Temp Anomaly (C)")
>> title('Mean Global Temp Anomaly 1950-2016')
>> [b,bint,r,rint,stats]=regress(MeanTempAnom, [ones(size(MeanTempAnom)) date1])
>> MeanTemp = b(2)*date1 + b(1)
hold on
>> plot(date1, MeanTemp)
>>disp(['y = F(x) = ',num2str(MeanTemp(1)),'*x + ','(',num2str(MeanTemp(2)),')']);
regstats(date1, MeanTempAnom) , p value 5.57e-19 = r^2 = 0.6713
>>legend('Mean Global Temp Anomoly Data',' y = -0.237x -0.23602 R-square=0.6713, p- value= 5.57e-19','Location','northwest');


%% All captions on graph added manualy using "text box" function

>> figure (2) %Histogram

>> subplot(2,2,1)

>>
histogram(MeanTempAnom(1:384),linspace(min(MeanTempAnom),max(MeanTempAnom),35),'Normalization','probability')
```

```
>> hold on
histogram(MeanTempAnom(385:804),linspace(min(MeanTempAnom),max(MeanTempAnom),35),'Nor
malization','probability')
>> xlabel('Mean Global Temperature Anomaly(C)')
>> title('Frequency of Global Temperature Anomoly 1950-1985 and 1985-2016')
>> ylabel('Frequency of occurrence')
>> subplot(2,2,3)
>> ylabel('Frequency of occurrence')
>>histogram(UBCtemp(1:384),linspace(min(UBCtemp),max(UBCtemp),35),'Normalization','probability')
hold on
>>histogram(UBCtemp(385:804),linspace(min(UBCtemp),max(UBCtemp),31),'Normalization','probability
')
>> legend('From 1950-1985','From 1986-2016','Location','northwest');

>> xlabel('UBC Temp Anomaly(C)')

ylabel('Frequency of occurrence')

>> title('Frequency of Temperature Anomaly(C) at UBC 1950-1985 and 1985-2016')

figure(3) %scatter plot
scatter(UBCtemp,MeanTempAnom,'bo')
xlabel('Global Mean Temperature Anomaly(C)')
ylabel('UBC Temperature Anomaly(C)')
title('Scatter Plot of UBC Temperature Anomaly and Global Mean Temperature Anomoly(°C) from 1950-
2016')

% use regstats(UBCtemp,MeanTempAnom) to find r^2 and pvalue rsquare: 0.1398 p value = [1.8e-24]
txt = ['r^2 = 0.1398 , pvalue = 1.8e-24']

>>figure (4) % scatterplots of UBC temperature against MEI index and global temperature against MEI
index, and associated linear regressions
>> subplot(2,1,1)
>> scatter(MEI,UBCtemp,'bo')
>> reg=b(2)*MEI+ b(1)
>> [b,bint,r,rint,stats]=regress(MEI, [ones(size(MEI)) UBCtemp])
%find out the slope >> disp(['y = F(x) = ',num2str(reg(1)),'*x + ','(',num2str(reg(2)),')'])
%y = F(x) = -0.16783x -0.19586 p-value = 7.06e-16 R-squared: 0.0897


%Find statistic values >>regstats(MEI, UBCtemp,'linear')
p-value = 7.06e-16 R-squared: 0.0897
```

```
>> xlabel('MEI')
>> ylabel("Temperature Anomaly(C)")
```
caption txt(Fig 4.1. A scatter plot of temperature anomaly measured by UBC versus MEI y = F(x) = -0.16783x -0.19586 p-value =7.06e-16 R-squared: 0.0897)

```
%Just repeat what I did
>> [b,bint,r,rint,stats]=regress(MEI, [ones(size(MEI)) MeanTempAnom])
>> reg=b(2)*MEI+ b(1)
>> disp(['y = F(x) = ',num2str(reg(1)),'*x + ','(',num2str(reg(2)),')'])
>>regstats(MEI, UBCtemp,'linear')
```
txt (Fig 4.2. A scatter plot of mean global temperature anomaly versus y = F(x) = -0.1x +0.18 rsquare= 0.0897, p value = 7.1e-16)

figure (5) % scatterplots of global mean temperature anomaly against temperature predicted by a multilinear regression (using 5 explanatory variables, part 5)

```
>> x=[CO2,SO2,MEI,MeanAnom,TSI]

mdl=fitlm(x,MeanTempAnom)

plot(mdl)

xlabel('5 Explanatory Variables (AOD,SO2,CO2,MEI,TSI)')

ylabel('Mean Global Temperature Anomaly (C)')

title(‘Temperature Predicted Using 5 Explanatory Variables 1950-2016')
```

figure (6) % (Two figures containing, respectively, global temperature anomaly as a function of Donald Trump’s age,

```
%Import Data of dummyvariables , generate script, run.
>>subplot(2,1,1)
>>[b,bint,r,rint,stats]=regress(TrumpAge, [ones(size(TrumpAge)) MeanTempAnom])
plot(TrumpAge,MeanTempAnom)
>>regstats(TrumpAge, MeanTempAnom) (%findout p-value and rvalue)
>> disp(['y = F(x) = ',num2str(ta(1)),'*x + ','(',num2str(ta(2)),')'])
>> ta=b(2)*TrumpAge + b(1)
>> plot(fitlm(TrumpAge,MeanTempAnom))
%y = F(x) = 259.538*x + (264.3)

>> xlabel('Trump age')
>> ylabel('Global Mean Temperature Anomaly (C)')
>> title ('Trump Age  vs Global Mean Temperature Anomaly')
% like other figures, the caption was added manually on the plot using textbox function.
```

```
fig (6b) %made-up global temperature against CO2 time series
%Rename variable made up global temp and co2 to ImaTemp and ImaCO2
respectively.
>>[b,bint,r,rint,stats]=regress(ImaTemp, [ones(size(ImaTemp)) ImaCO2])
>> rr=b(2)*ImaCO2 +b(1)
>> regstats(ImaCO2, ImaTemp)
>> xlabel('Imaginary CO2 (ppm)')
>> ylabel('Imaginary Temp (C)')
>> title('Imaginary Temperature Anomaly vs CO2 1950-2016')
% like other figures, the caption was added manually on the plot using
textbox function.

%Rename variable to ImaTemp, ImaCO2, T(ImaTemp, ImaCO2)

subplot(2,1,1)

[b,bint,r,rint,stats]=regress(ImaTemp, [ones(size(ImaTemp)) ImaCO2])

rr=b(2)*ImaCO2 +b(1)

plot(ImaCO2, ImaTemp)

hold on

plot(ImaCO2, rr)

 xlabel('ImaginaryCO2 (ppm)')

ylabel('ImaginaryTemp (C)')

title('Imaginary Temperature Versus CO2  1950-2016')
>> a1=b(2)*ImaCO2 + b(1)
% regstats to find p value and R2
>> disp(['y = F(x) = ',num2str(a1(1)),'*x + ','(',num2str(a1(2)),')'])


subplot(2,1,2)


>> plot(TImaCO2, TImaTemp)

>> hold on

>> plot(TImaCO2, rrr)

xlabel('Truncated CO2 ppm')

ylabel('Truncated Temp Anomaly  (C)')

title('Truncated CO2 vs Temp  1950-2016')
```

```
>> a2=b(2)*TImaCO2 + b(1)
[b,bint,r,rint,stats]=regress(TImaTemp, [ones(size(TImaTemp)) ImaCO2])

rrr=b(2)*TImaCO2 +b(1)

>> disp(['y = F(x) = ',num2str(a2(1)),'*x + ','(',num2str(a2(2)),')'])
```