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Lab 3: Lab Worksheet

Please write your name, cohort, and student number at the top of this page.

All questions must be answered in no more than 5 lines, and most questions should be answered in no more than 3 lines! Be precise but concise in your answers.

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: °C/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.

The UBC temperature anomaly has a slope of 0.47 and y-intercept of 0.47, and oscillates in a period of about 3 years. The maximum and minimum anomaly observed through 1960-2016 is about 5.0C and -3.0C. The mean global temperature anomaly shows a slope of 0.24 and y-intercept of 0.24, and oscillates in a period of about 5 years. The maximum and minimum anomaly observed through 1950-2016 is about 1.1C and -0.4C.

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

Yes, the term global warming is appropriate to describe the temperature time series because the anomalies are increasing overtime. With a value of 0.5 C increase of average global temperature is significant. The trends on both UBC and global mean temperature graphs shows a clear positive slope, so we can be sure to assume the significance of global warming effects.

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?

From observation there is a peak in temperature from oscillation every 3-5 years, this can very possible be associated with natural fluctuations. Some variable I would like to observe are Earth's orbital behaviours as it wobbles on its axis, the sun's temperature throughout the decades, and regular volcanic activities. There are some frequencies that follows a natural pattern, and it will have an effect on the data collected for temperature anomalies.

Section 3

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

In similarity the temperature anomalies experience a positive trend, meaning the warming of Earth, which indicates global warming. There is a difference in seasonal variables as experienced at UBC, and the amount of sunlight is difference for each regions so they will experience different patterns of temperature fluctuations.

Section 4 and 5

a. Fill in table 2 below. Don't forget to give 95% confidence intervals AND units for each slope.

Independent variable	Slope of the global temperature anomaly vs forcing regression for a		
	Simple linear regression		Multilinear regression (R^2= 0.8382)
	Slopes	R^2	Slopes
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?

Linear and multilinear regression are not always compatible because for linear regression only one x and y variable is used. From the data collected, the global temperature anomaly usually has only one x and y variable, so in this case linear regression is more accurate than multilinear regression.

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

A few of the slope does not match my expectations. When looking at the greenhouse gas contents, we are expecting positive slopes which gives an indication of global warming. For instance, we are expecting to a positive slope with one of the SO2 concentration, but instead we get a negative slope in the multilinear regression.

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 CO2 to answer this question. Discuss where disagreement (if any) may come from.

The results of my regression is compatible with such projections, because from analysis we are seeing a steady positive trend throughout the years. Other forces that play a factor could be ozone, albedo, and aerosol levels. These variable would have a positive forcing. I could not find a disagreement because the positive forces are over powering the negative forces.

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.

When it comes to complex problems, a linear regression may not be a suitable analysis because it could over simplify relationships. Such regression analysis has its limitation, it makes the assumption that the two variables are in linear relationship, which makes it ideal to showcase positive or negative trends in data.

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)

Demosfrates 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)

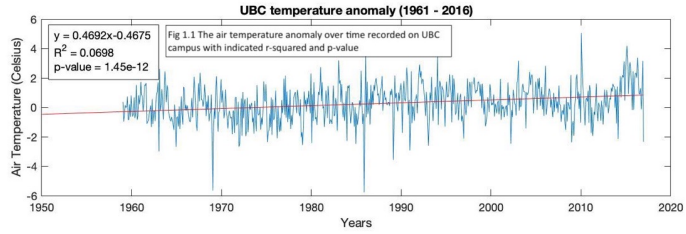
Does not support the statement

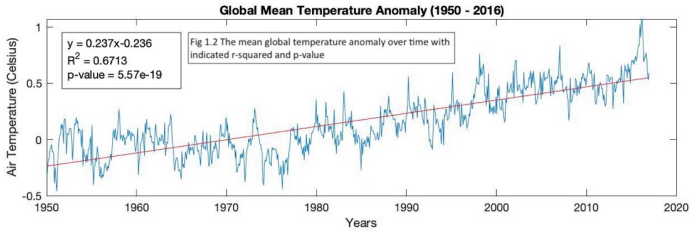
Statement 4: "The Sun is the reason for our warming. SO_2 [from volcanoes] is the 'cure' to put a band-aid on it until it rises again. We are not getting the SO_2 needed [the author means we did not get a major volcanic eruption recently] and that is a problem [i.e., what is causing the warming trend] right now." (southerncaliforniaweatherforce.com)

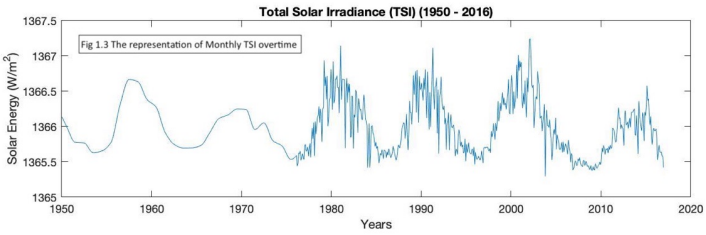
Supports the statement

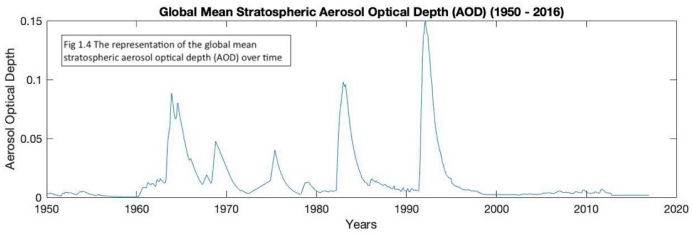
Statement 5: "In recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans." (IPCC AR5)

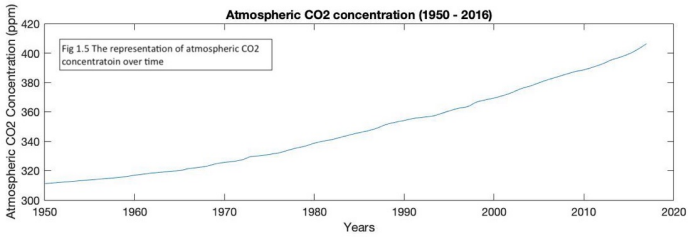
Does not able to comment the statement

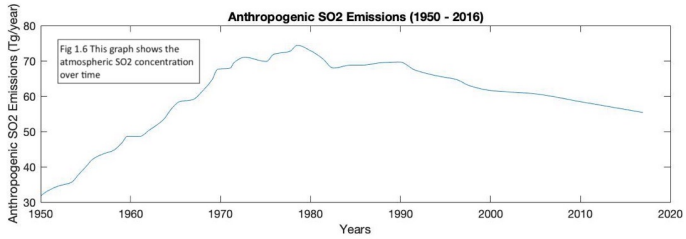

UBC temperature anomaly (1961 - 2016)
y = 0.4692x-0.4675
R2 = 0.0698
p-value = 1.45e-12
Fig 1.1 The air temperature anomaly over time recorded on UBC campus with indicated r-squared and p-value
Air Temperature (Celsius)
Years

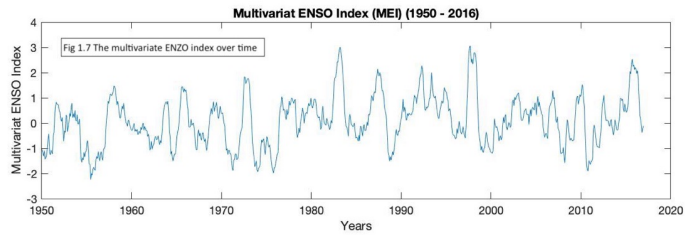

Global Mean Temperature Anomaly (1950 - 2016)
y = 0.237x-0.236
R2 = 0.6713
p-value = 5.57e-19
Fig 1.2 The mean global temperature anomaly over time with indicated r-squared and p-value
Air Temperature (Celsius)
Years

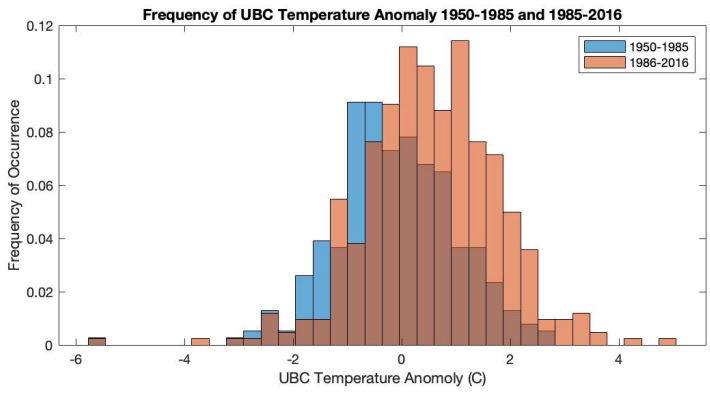

Total Solar Irradiance (TSI) (1950 - 2016)
Fig 1.3 The representation of Monthly TSI overtime
Solar Energy (W/m2)
Years

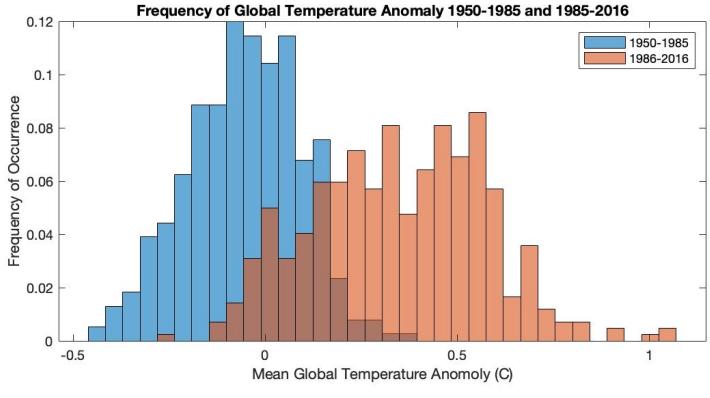

Global Mean Stratospheric Aerosol Optical Depth (AOD) (1950 - 2016)
Fig 1.4 The representation of the global mean stratospheric aerosol optical depth (AOD) over time
Aerosol Optical Depth
Years


Atmospheric CO2 concentration (1950 - 2016)
Fig 1.5 The representation of atmospheric CO2 concentratoin over time
Atmospheric CO2 Concentration (ppm)
Years


Anthropogenic SO2 Emissions (1950 - 2016)
Fig 1.6 This graph shows the atmospheric SO2 concentration over time
Anthropogenic SO2 Emissions (Tg/year)
Years


Multivariat ENSO Index (MEI) (1950 - 2016)
Fig 1.7 The multivariate ENZO index over time
Multivariat ENSO Index
Years


Frequency of UBC Temperature Anomaly 1950-1985 and 1985-2016
1950-1985
1986-2016
Frequency of Occurrence
UBC Temperature Anomoly (C)


Frequency of Global Temperature Anomaly 1950-1985 and 1985-2016
1950-1985
1986-2016
Frequency of Occurrence
Mean Global Temperature Anomoly (C)

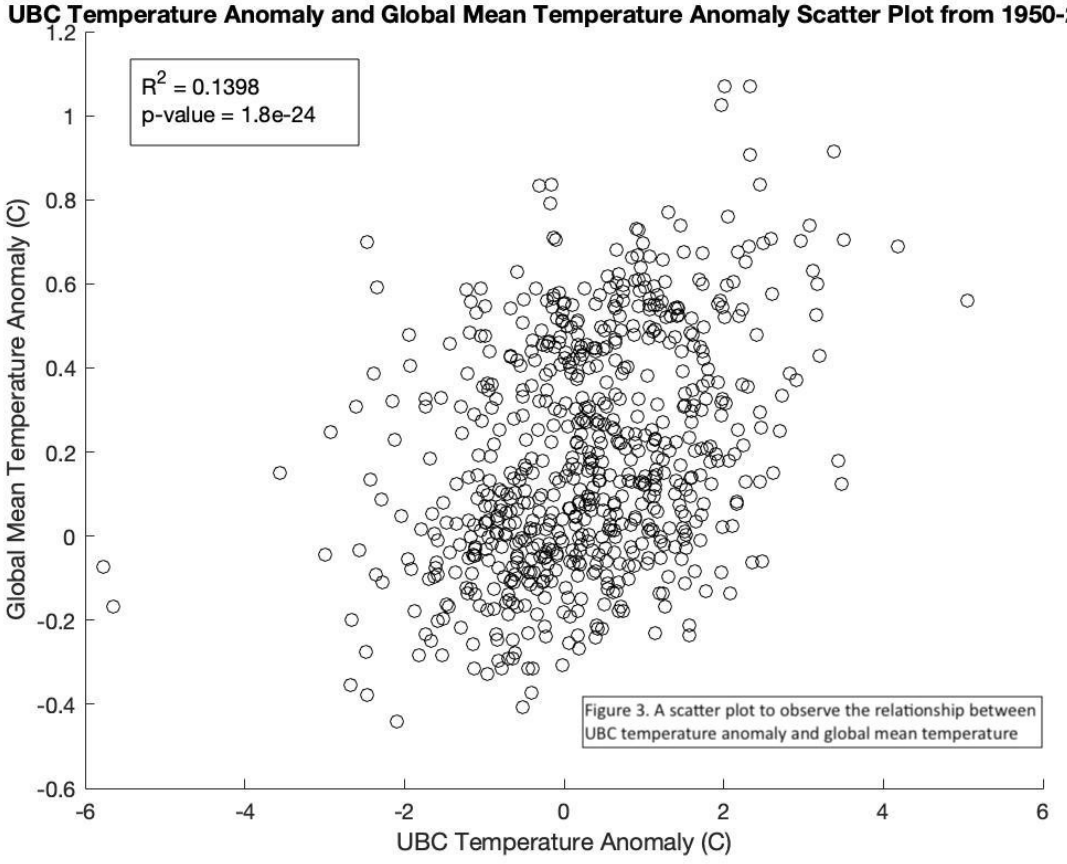
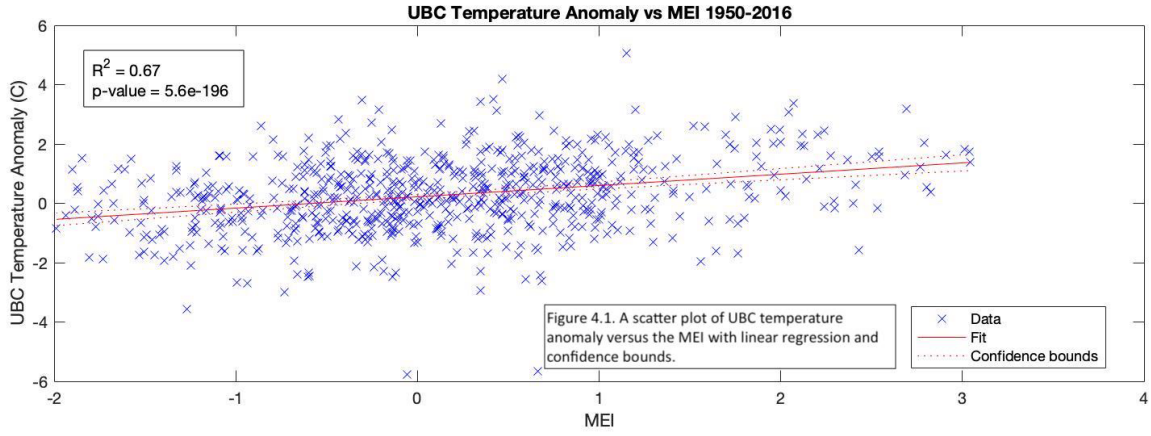
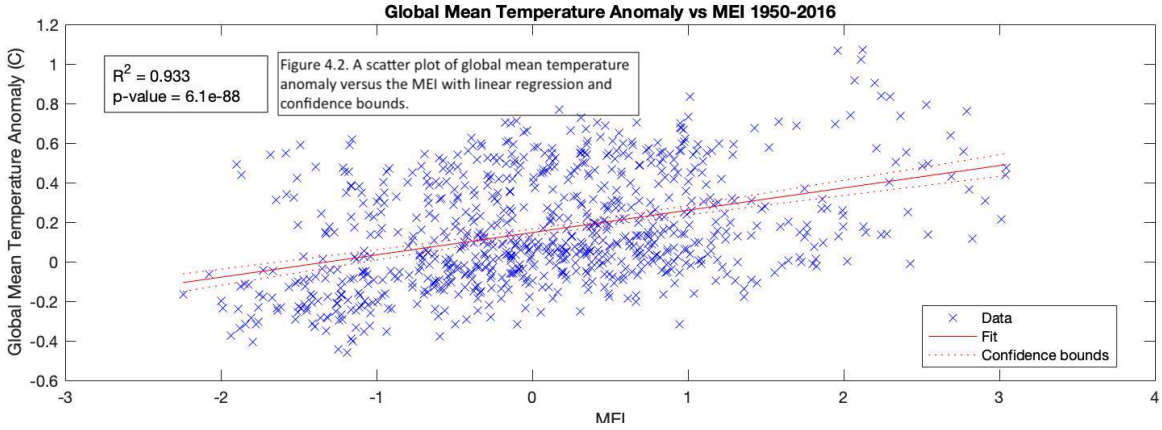
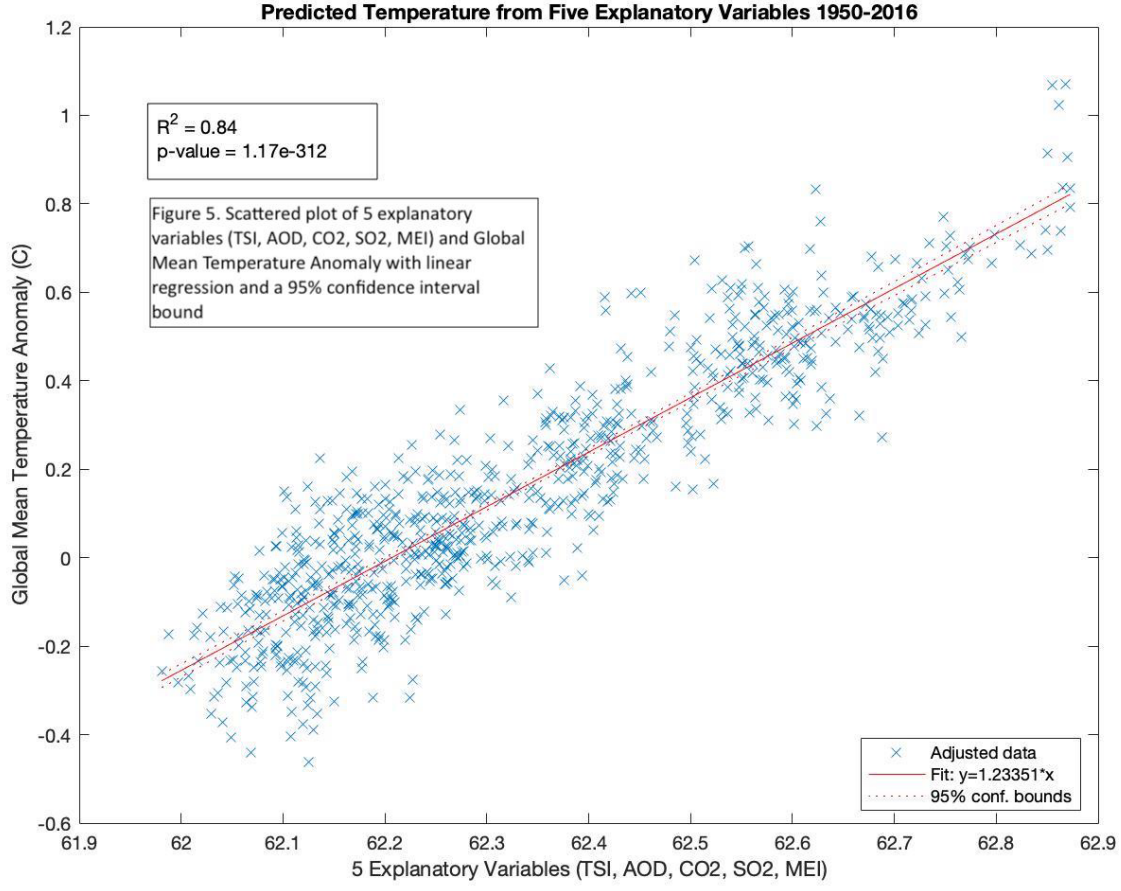


Figure 3. A scatter plot to observe the relationship between UBC temperature anomaly and global mean temperature


UBC Temperature Anomaly vs MEI 1950-2016
R2 = 0.67
p-value = 5.6e-196
Figure 4.1. A scatter plot of UBC temperature anomaly versus the MEI with linear regression and confidence bounds.
Data
Fit
Confidence bounds
UBC Temperature Anomaly (C)
MEI


Global Mean Temperature Anomaly vs MEI 1950-2016
R2 = 0.933
p-value = 6.1e-88
Figure 4.2. A scatter plot of global mean temperature anomaly versus the MEI with linear regression and confidence bounds.
Data
Fit
Confidence bounds
Global Mean Temperature Anomaly (C)
MEI


Predicted Temperature from Five Explanatory Variables 1950-2016
R2 = 0.84
p-value = 1.17e-312
Figure 5. Scattered plot of 5 explanatory variables (TSI, AOD, CO2, SO2, MEI) and Global Mean Temperature Anomaly with linear regression and a 95% confidence interval bound
Adjusted data
Fit: y=1.23351*x
95% conf. bounds
Global Mean Temperature Anomaly (C)
5 Explanatory Variables (TSI, AOD, CO2, SO2, MEI)

```
% Lab 3
clear
% loading the data for this lab
data=xlsread('lab3_data.xlsx');
% Create a vector of monthly dates
dates = data(:,1);

% ***** Section 1 *****

% Create vectors for variables:
UBC_avg_temp_monthly_anom = data(:,2);
CRU_avg_temp_monthly_anom = data(:,3);
TSI_time_series = data(:,4);
AOD = data(:,5);
Atmos_CO2_concentration = data(:,6);
Anthro_SO2_emissions = data(:,7);
MEI = data(:,8);

% Plot each times series in subplots
subplot(4,2,1);
plot(dates, UBC_avg_temp_monthly_anom);
title('UBC temperature anomaly (1961 - 2016)')
xlabel('Years')
ylabel('Air Temperature (Celsius)')
[b,bint,r,rint,stats]=regress(UBC_avg_temp_monthly_anom,[ones(size↙
(UBC_avg_temp_monthly_anom)) dates]);
MeanTemp1 = b(2)*dates + b(1);
hold on
plot(dates,MeanTemp1,'r')
%include lengend...

subplot(4,2,2);
plot(dates, CRU_avg_temp_monthly_anom);
title('Global Mean Temperature Anomaly (1950 - 2016)')
xlabel('Years')
ylabel('Air Temperature (Celsius)')
[b,bint,r,rint,stats]=regress(CRU_avg_temp_monthly_anom,[ones(size↙
(CRU_avg_temp_monthly_anom)) dates]);
MeanTemp2 = b(2)*dates + b(1);
hold on
plot(dates,MeanTemp2,'r')
%...

subplot(4,2,3);
plot(dates, TSI_time_series);
title('Total Solar Irradiance (TSI) (1950 - 2016)')
xlabel('Years')
ylabel('Solar Energy (W/m^2)')
%...

subplot(4,2,4);
plot(dates, AOD);
title('Global Mean Stratospheric Aerosol Optical Depth (AOD) (1950 - 2016)')
xlabel('Years')
ylabel('Aerosol Optical Depth')
%...

subplot(4,2,5);
```

```
plot(dates, Atmos_CO2_concentration);
title('Atmospheric CO2 concentration (1950 - 2016)')
xlabel('Years')
ylabel('Atmospheric CO2 Concentration (ppm)')
%...

subplot(4,2,6);
plot(dates, Anthro_SO2_emissions);
title('Anthropogenic SO2 Emissions (1950 - 2016)')
xlabel('Years')
ylabel('Anthropogenic SO2 Emissions (Tg/year)')
%...

subplot(4,2,7);
plot(dates, MEI);
title('Multivariat ENSO Index (MEI) (1950 - 2016)')
xlabel('Years')
ylabel('Multivariat ENSO Index')
%...

% Display Histograms
figure(2)
subplot(2,1,1)
histogram(UBC_avg_temp_monthly_anom(1:384),linspace(min(UBC_avg_temp_monthly_anom),max↙
(UBC_avg_temp_monthly_anom),35),'Normalization','probability')
hold on
histogram(UBC_avg_temp_monthly_anom(385:804),linspace(min(UBC_avg_temp_monthly_anom),max↙
(UBC_avg_temp_monthly_anom),35),'Normalization','probability')
title('Frequency of UBC Temperature Anomaly 1950-1985 and 1985-2016')
xlabel('UBC Temperature Anomoly (C)')
ylabel('Frequency of Occurrence')
legend('1950-1985','1986-2016')

subplot(2,1,2)
histogram(CRU_avg_temp_monthly_anom(1:384),linspace(min(CRU_avg_temp_monthly_anom),max↙
(CRU_avg_temp_monthly_anom),35),'Normalization','probability')
hold on
histogram(CRU_avg_temp_monthly_anom(385:804),linspace(min(CRU_avg_temp_monthly_anom),max↙
(CRU_avg_temp_monthly_anom),35),'Normalization','probability')
title('Frequency of Global Mean Temperature Anomaly 1950-1985 and 1985-2016')
xlabel('Global Mean Temperature Anomoly (C)')
ylabel('Frequency of Occurrence')
legend('1950-1985','1986-2016')

% ***** Section 2 *****
% Answer on Lab3 worksheet

% ***** Section 3 *****
% Plot UBC temperature anomaly vs Global Mean Temperature Anomaly
figure(3)
scatter(UBC_avg_temp_monthly_anom, CRU_avg_temp_monthly_anom, 'ko')
title('UBC Temperature Anomaly and Global Mean Temperature Anomaly Scatter Plot from↙
1950-2016')
xlabel('UBC Temperature Anomaly (C)')
ylabel('Global Mean Temperature Anomaly (C)')
stats = regstats(UBC_avg_temp_monthly_anom,CRU_avg_temp_monthly_anom);

% ***** Section 4 *****
```

```
% Perform regression of Global Mean Temp against TSI, AOD, CO2, SO2 and MEI
% Which variable is there a large confidence on the sign of the linear
% regression slope?

% Plot Global Mean Temperature anomaly vs MEI and UBC Temperature Anomaly vs MEI
% Perform linear regression for each pair; add regression line and slope
figure(4)
subplot(2,1,1)
mlr = fitlm(MEI,UBC_avg_temp_monthly_anom);
plot(mlr)
title('UBC Temperature Anomaly vs MEI 1950-2016')
xlabel('MEI')
ylabel('UBC Temperature Anomaly (C)')

subplot(2,1,2)
mlr = fitlm(MEI,CRU_avg_temp_monthly_anom);
plot(mlr)
%{
This code also works but NOT using it:
scatter(MEI,CRU_avg_temp_monthly_anom,'kx')
[b,bint,r,rint,stats] = regress(CRU_avg_temp_monthly_anom,[ones(size↙
(CRU_avg_temp_monthly_anom)) MEI]);
RegCRU = b(2)*MEI+b(1);
hold on
plot(MEI,RegCRU,'r')
%}
title('Global Mean Temperature Anomaly vs MEI 1950-2016')
xlabel('MEI')
ylabel('Global Mean Temperature Anomaly (C)')

% ***** Section 5 *****

% 5 Forcing variables: TSI, AOD, CO2, SO2 and MEI
% Multilinear regression of Global Mean Temperature Anomaly against the 5 variables
figure(5)
x = [TSI_time_series, AOD, Atmos_CO2_concentration, Anthro_SO2_emissions, MEI];
mlr = fitlm(x,CRU_avg_temp_monthly_anom);
plot(mlr)
title('Predicted Temperature from Five Explanatory Variables 1950-2016')
xlabel('5 Explanatory Variables (TSI, AOD, CO2, SO2, MEI)')
ylabel('Global Mean Temperature Anomaly (C)')
```