OCEA90 Activity: Climate change

1. The following multiple linear regression model explains the global mean surface temperature (GMST) anomalies (°C) as a function of human and natural forcings and natural variability:

$$GMST = -0.22 + 0.25ANTH + 0.08VOLC + 0.18TSI + 0.06ENSO$$

where the intercept is -0.22, ANTH represents the anthropogenic forcing, VOLC represents forcing from volcanic eruptions, TSI represents forcing from solar irradiance (all forcings are in in W/m^2 and MEI is the multivariate ENSO index used to represent the El Nino Southern Oscillation. The R output is shown below, and the important quantities are in bold.

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> summary(model)

Call:
lm(formula = GMST ~ ANTH + VOLC + TSI + ENSO)

Residuals:
      Min          1Q     Median       3Q     Max
-0.154554 -0.040643 -0.003866  0.036346  0.132396

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) -0.22649      0.03035  -7.463 1.44e-09 ***
ANTH         0.25476      0.01232  20.670  < 2e-16 ***
VOLC         0.07909      0.01736   4.556 3.60e-05 ***
TSI          0.17841      0.19006   0.939    0.353
ENSO         0.06175      0.01388   4.448 5.13e-05 ***
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Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1


Residual standard error: 0.06722 on 48 degrees of freedom
Multiple R-squared:  0.9294,    Adjusted R-squared:  0.9235
F-statistic:   158 on 4 and 48 DF,  p-value: < 2.2e-16
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a) What is the coefficient of determination of the model? What does it represent?

The coefficient of determination of the model is 0.9294. It represents the proportion of the variance in the dependent variable (GMST anomalies) that is predictable from the independent variables (ANTH, VOLC, TSI, and ENSO) in the regression model

b) Based on the coefficient of determination entered above, how would you rate the regression model potential for predicting global temperature anomalies (i.e. none, weak, moderate, strong, perfect)?

The independent variables included in the model explain the variations in global temperature anomalies.

c) Based on that model, let's predict the estimated temperature response to different scenarios for a given year (say 2020, the last number on the x-axis), and plot them in the figure below. Note that "GMST" in our equation is the same as "Anomaly" on the graph.

Scenario 1. Increasing human forcing, no volcanoes, no solar irradiance and no interrannual variability (ANTH=3.5, VOLC=0,TSI=0,ENSO=0).

$$GMST=-0.22649+0.89166=0.66517$$

Scenario 2. Increasing human forcing, a large volcanic eruption, no solar irradiance and no interrannual variability (ANTH=3.5, VOLC=-3,TSI=0,ENSO=0).

$$GMST=-0.22649+0.89166-0.23727=0.4289$$

Scenario 3. Increasing human forcing, no volcanoes, no solar irradiance and a large Nino event (ANTH=3.5, VOLC=0,TSI=0,ENSO=2).

$$GMST=-0.22649+0.89166+0.1235=0.78867$$

Scenario 4. Increasing human forcing, a large volcanic eruption, no solar irradiance and a large Nina event (ANTH=3.5, VOLC=0,TSI=0,ENSO=-2).

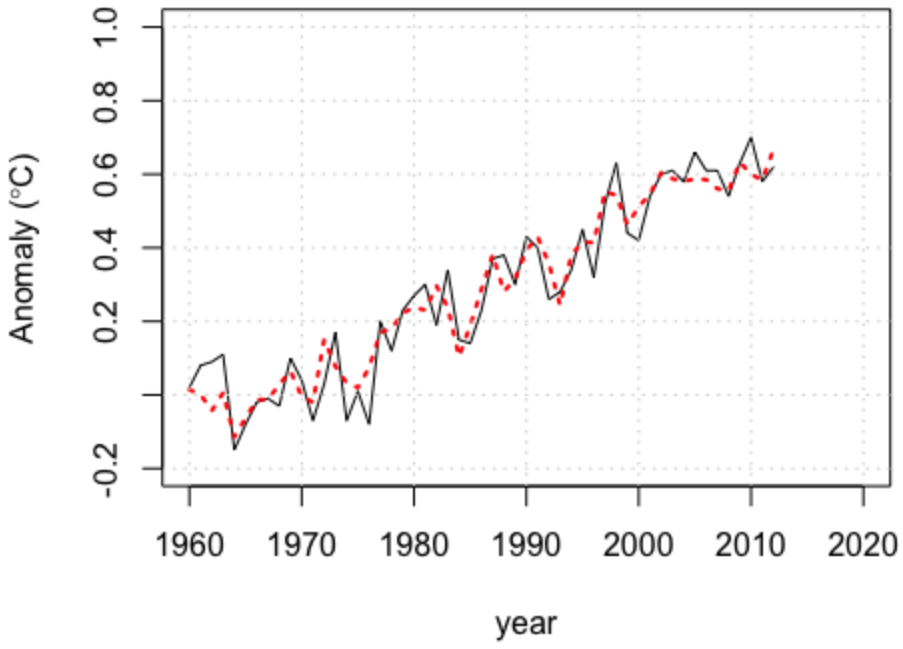
$$GMST=-0.22649+0.89166-0.1235=0.54167$$

Scenario 5. Extreme increasing human forcing, no volcanoes, no solar irradiance and no interrannual variability (ANTH=4.5, VOLC=0,TSI=0,ENSO=0).

$$GMST=-0.22649+1.14642=0.91993$$

Scenario 6. Increasing human forcing, a large volcanic eruption, no solar irradiance and a strong Nino event (ANTH=3.5, VOLC=-3,TSI=0,ENSO=2).

$$GMST=-0.22649+0.89166-0.23727+0.1235=0.5514$$



d) Why is the temperature decreasing following a volcanic eruption? What happens to the Earth's albedo?

I do research online, after a volcanic eruption, temperatures may decrease due to the injection of sulfur dioxide and aerosols into the stratosphere. These particles reflect incoming solar radiation back into space, reducing the amount of solar energy reaching the Earth's surface and temporarily lowering temperatures

e) In terms of latitude, which volcanic eruptions have the most impact on global temperatures and why?

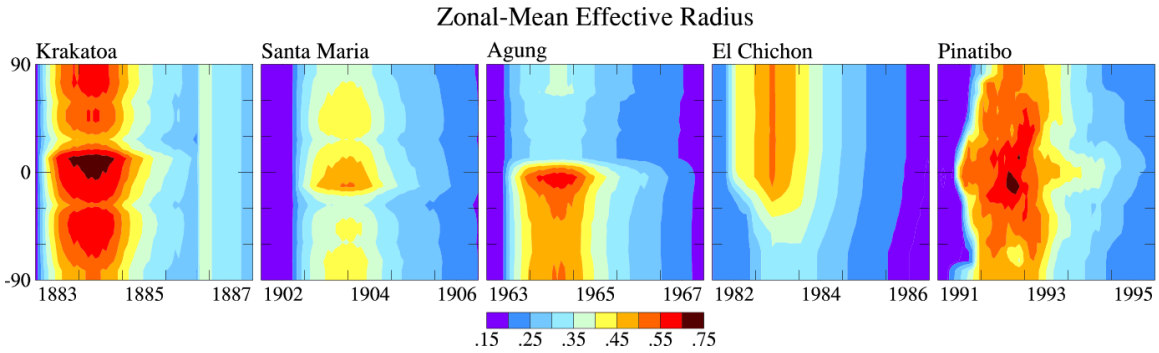
Volcanic eruptions near the equator tend to have the most significant impact on global temperatures. I think it's because eruptions in tropical regions inject sulfur dioxide and aerosols directly into the stratosphere, where they can spread more uniformly around the globe.

f) Say a volcanic eruption takes place in the Northern hemisphere, in which direction do the plume travel? How about in the Southern hemisphere?

In the Northern Hemisphere, the plume from a volcanic eruption would generally travel towards the east or northeast direction due to prevailing westerly winds in mid-latitudes. In the Southern Hemisphere, the plume from a volcanic eruption would typically travel towards the east or southeast direction due to the prevailing westerly winds in the Southern Hemisphere.

The figure below is showing the simulated spread of major volcanic eruptions. The y-axis is the latitude and the x-axis is time around each of these eruptions. The colorbar is a measure

of the resulting aerosols. Think about their effect on local and global temperatures.



g) Why are the global mean surface temperature anomalies increasing during a Nino event? Why are they decreasing during a Nina event?

During El Niño events, global mean surface temperature anomalies increase due to warming sea surface temperatures in the central and eastern tropical Pacific Ocean, altering atmospheric circulation patterns and spreading warm air masses globally. Conversely, during La Niña events, global mean surface temperature anomalies decrease as cooler sea surface temperatures lead to strengthened Walker Circulation, increased upwelling of cold water, and cooler temperatures worldwide.

Note: While the regression model above does a very good job at capturing variability in GMST, it remains a statistical model, which is not based on any physical principles. As such, it is useful and interpretable over that time frame, but cannot be used for long-term prediction.