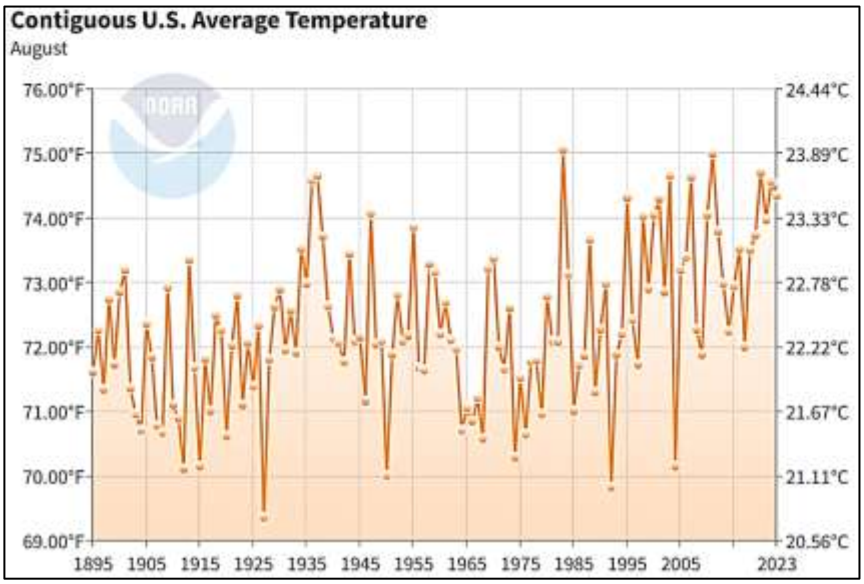
Due: 27 Sept 2023

Energy: Science, Technology, and Society

Homework Set 1

1. Statistical Analysis of U.S. Surface Temperatures



The United States National Oceanic and Atmospheric Administration (NOAA) tracks and publishes climate data, including the changes in mean surface temperatures for the U.S. The graph shows raw data for the average temperature $\boldsymbol{T}(t)$ in the U.S., measured for the month of August of each year, versus time (t). Depicted is a time period from near the start of the heavy industrialization of the U.S. (**t** = 1895) to today (**t** = 2023). The following numerical tasks can be performed with a spreadsheet utility software like MS Excel.

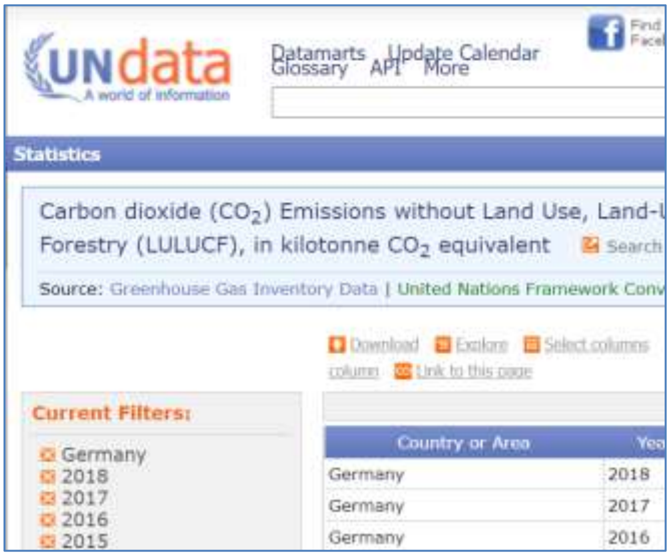
a) Access and down load the actual numerical data shown in the figure from the NOAA web site at URL https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/national/time-series
b) Briefly describe the general trends with time seen in the August U.S. temperature data.
c) Divide the data set into an early 20-year period, 1895≤***t***≤1924, and a late 20-year period 2004≤***t***≤2023. Calculate the statistical mean temperatures <***T***> and the variances σ_T^2 for the two periods.
d) For each of the above periods, sort the data into $\Delta T=0.5^0$-wide bins centered at $T_i = T_0 + i \cdot \Delta T$ ($i=1,2,\ldots$) with a low offset, e.g., $T_0=T(1926)$. In MS Excel, an appropriate sorting function (FREQUENCY) is available for this task.
Normalized the frequency distribution of the temperature data (for a given bin T_i plot the fractional probability $\boldsymbol{P}(T_i)$) vs. T_i.

e) Compare the probability distributions or the two time periods with Gaussian (Normal) functions $G(T)=\left(2\pi\sigma_T^2\right)^{-1/2}\exp\{-\left(T-<T>\right)^2/2\sigma_T^2\}$ with the same mean <*T*>and variance σ_T^2 as the data. You may use the MS Excel function NORMDIST.

f) Are the mean US August temperatures observed in the last 20 years consistent with the profile that was normal in the past? Base your arguments on the data.

2. Study of Comparative CO_2 Emissions

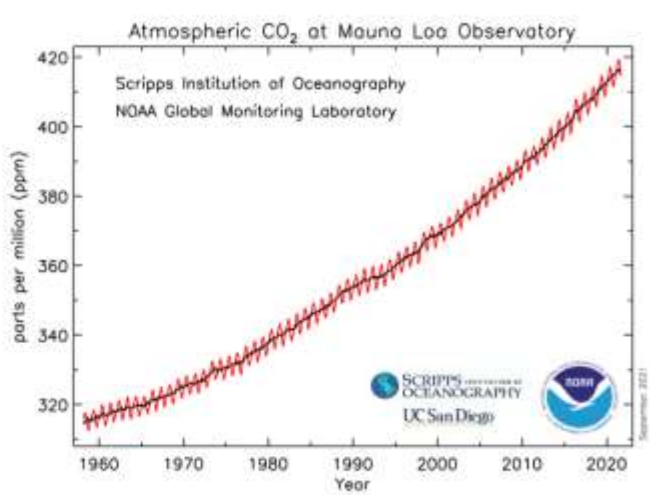
Obtain experimental data (measurements) for the total CO_2 emission rates (in kt CO_2/a) published on line by the U.N. (data.un.org) for China, the U.S., France and Germany, for the years 1990-2020. Populations of the respective countries are 1.33B, 0.33B, 0.06B, and 0.08B. Access data at ([UNdata | record view | Carbon dioxide (CO₂) Emissions without Land Use, Land-Use Change and Forestry (LULUCF), in kilotonne CO₂ equivalent]) More extensive database is available at https://data.worldbank.org/indicator/EN.ATM.GHGT.KT.CE.



a) Use the MS Excel (or similar) data analysis utility to calculate and plot the annual emission rates per capita.

b) Compare the patterns observed for the four countries, i.e., discuss values per capita and the trends in time.

c) Propose some likely qualitative reasons for the observed trends



3. Fitting World Greenhouse Gas Emissions from the Mauna Loa Record

Assuming average time dependent trends C(*t*) in atmospheric CO_2 emission established by accurate measurements at the Mauna Loa Observatory to persist, predict the atmospheric CO_2 concentration expected for the year 2050. The figure displays the actual monthly CO_2 concentration measurements ***C***(*t*) (red line). It illustrates a seasonal variation superimposed on a yearly average trend, the latter shown as a black curve. Sometimes, the data are approximated by an exponential increase with time t (in years) since 1960, i.e., $C(t) = C(t = 1960) \cdot \exp\{r \cdot (t - 1960)\}$.

a) From the NOAA web site (https://gml.noaa.gov/ccgg/trends/gr.html) download the Mauna Loa CO_2 annual mean data published by NOAA.
b) From the data deduce parameters for an analytical function **C**(*t*) that best fits the trend from 1960 to 2014 ("trend line" in Excel). Consider the fit with the above exponential dependence and compare it to one using a simpler, quadratic dependence

$$C(t) = C(t = 1960) + a \cdot (t - 1960) + b \cdot (t - 1960)^2$$

c) Plot the data and the analytical functions vs. time (in years) from 1960 to 2040.
d) Which function better represents the data? What are the predictions for 2040, based on the historical record?

Auxiliary information: Data are reported as a dry-air mole fractions x, i.e., in terms of the number of CO_2 molecules/the number of all molecules-H_2O molecules. Example: x=0.000400 is given as 400 ppm.