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**Problem Set 1 – Airborne Fraction**

**The assignment explores the relationship between human emissions of CO2 from fossil fuel and how much CO2 is staying in the atmosphere. We will use the observed record of CO2 from Mauna Loa as an approximation of average global CO2 concentration. Global fossil fuel emissions estimates come from bottom up estimates reported by each country to the UN, and reported by the Global Carbon Project.**

Data Files:

* Global Fossil Fuel Emissions 1750-2020 from the Global Carbon Project
  + Filename: GCB2021v34\_MtCO2\_flat.csv
  + <https://doi.org/10.5281/zenodo.5569235>
* Annual Mean CO2 concentration at Mauna Loa 1959-2020
  + Filename: co2\_annmean\_mlo.txt
  + <https://gml.noaa.gov/ccgg/trends/data.html>
  + <https://gml.noaa.gov/webdata/ccgg/trends/co2/co2_annmean_mlo.txt>

Python Notebook:

PS1\_AirbrorneFraction.ipynb

References:

IPCC AR6 Ch. 5:

Josep G. Canadell, J. G., P. M. S. Monteiro, M. H. Costa, L. Cotrim da Cunha, P. M. Cox, A. V. Eliseev, S. Henson, M. Ishii, S. Jaccard, C. Koven, A. Lohila, P. K. Patra, S. Piao, J. Rogelj, S. Syampungani, S. Zaehle, K. Zickfeld, 2021, Global Carbon and other Biogeochemical Cycles and Feedbacks. In: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In Press.

**Answer the following questions using the Python Jupyter Notebook:**

PS1\_AirbrorneFraction.ipynb

Read through the notebook to see the notes and code as well as suggestions for calculating the answers below.

Check the “accessing\_JupyterHub.pdf” instructions file for information on how to access and run the code. In brief, you will login to the jupyter hub, and create a folder called “PS1\_AirborneFraction” that contains (at a minimum) the python notebook file and the two data files. This will allow the notebook to run and have access to the data.

Please provide narrative written descriptions and supporting figures or numbers where appropriate. You can make specific calculations using the example code at the bottom of the notebook, or you can approximate answers from the graphs.

1. FF emissions have been increasing over time. Please include the unit you are using!
   1. What is the rate of increase of FF emission in the last decade (FF emission increase/10years)?
   2. Compared to a baseline year of 2000, what percentage increase is this?
   3. How has it varied over the past 30 years? (qualitative or quantitative answer ok).
2. Cumulative Fossil Fuel Emissions
   1. What was the cumulative total of FF emission in 2013? (As in all of the emissions since the beginning of the record up to 2013).
   2. How much of the cumulative total was emitted since 1990?
   3. since 2000?
3. Airborne fraction of CO2. Assume the globally averaged CO2 mixing ratio can be approximated by the concentration at MLO.
   1. Using a pre-industrial value for CO2 of 280ppm. What is the airborne fraction of **cumulative** FF emissions (i.e. all emissions since 1750)?
   2. What is the average annual mean airborne fraction of FF CO2 as measured at MLO for 1980-1990, for 1990-2000, and for 2000 to the present?
   3. What is the standard deviation of the airborne fraction over the MLO record?
4. Does this estimate of the airborne fraction match those from the literature?   
   The IPCC AR6 Ch 5 on the Carbon Cycle has the following high-level statement:  
   *“****Over the past six decades, the average fraction of anthropogenic CO2 emissions that has accumulated in the atmosphere (referred to as the airborne fraction) has remained nearly constant at approximately 44%.*** *The ocean and land sinks of CO2 have continued to grow over the past six decades in response to increasing anthropogenic CO2 emissions (high confidence). Interannual and decadal variability of the regional and global ocean and land sinks indicate that these sinks are sensitive to climate conditions and  therefore to climate change (high confidence). {5.2.1.1, 5.2.1.3, 5.2.1.4.2; Figures 5.7, 5.8, 5.10}”*

Explain some of the contributing factors to any differences. (I have two in mind!). Think about what data we used or didn’t used for both CO2 concentrations and carbon fluxes.