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ESYS 104: The Earth System

Assignment #4

Question1:
Climate models make predictions of 2-6 °C increase globally for the end of the century. But they also predict that the temperature increase would be:
-Greater over land than over water;
-Greater at high latitudes and in winter than at low latitudes or in summer;
-Greater at night than during the day.
What processesor phenomenon explain each of these three behaviors? We've talked about at least three feedbacks, one for each behavior. Some of these feedbacks could apply to more than one behavior, but give three.

1- Greater warming over land than water:
Heat capacity differences between land and water: Water has a higher specific heat that slows its warming, so land heats up faster when given the same energy input. Hence, this leads to more temperature increases over continents compared to oceans. Evaporation over water also absorbs heat and cools the surface, which also slows down temperature increases. Over land, there is less evaporation, making it heat more quickly.

2- Greater warming at high latitudes and in winter:
Ice-albedo feedback: Snow and ice have a high surface reflectivity against solar radiation (high albedo), but as temperatures rise, snow and ice melt, which exposes darker surfaces like ocean water or land. Darker surfaces absorb more heat causing positive feedback (more warming -> less ice -> more absorption -> more warming) leading to more pronounced increased warming in polar regions (high latitudes) and during winter than at low latitudes or in summer.

3- Greater warming at night than during the day:
Water vapor and greenhouse gas feedback: As the atmosphere warms, warmer air holds more water vapor (a greenhouse gas). Hence, this increased water vapor and other greenhouse gases trap more heat that would escape to space at night normally. During the day, on the other hand, incoming solar radiation from the Sun overwhelms the effect, which makes it less noticeable. But at night, when the Earth is mainly losing heat, the enhanced greenhouse effect leads to greater warming than during the day.

Question 2:
Chaos theory (or the butterfly effect) relates to the impossibility of predicting weather beyond several weeks.

a) Explain why the weather is scientifically impossible to forecast beyond a certain lead time.
The weather is chaotic. Small changes in initial conditions can lead to very different outcomes over time (the butterfly effect). Weather systems are ruled by nonlinear differential equations with extreme sensitivity to these initial conditions. Even with precise measurements and models, the tiniest errors grow exponentially and make forecast accuracy impossible beyond more than a few weeks.

b) Given your answer above, why do we claim we can nevertheless predict climate several years in advance?

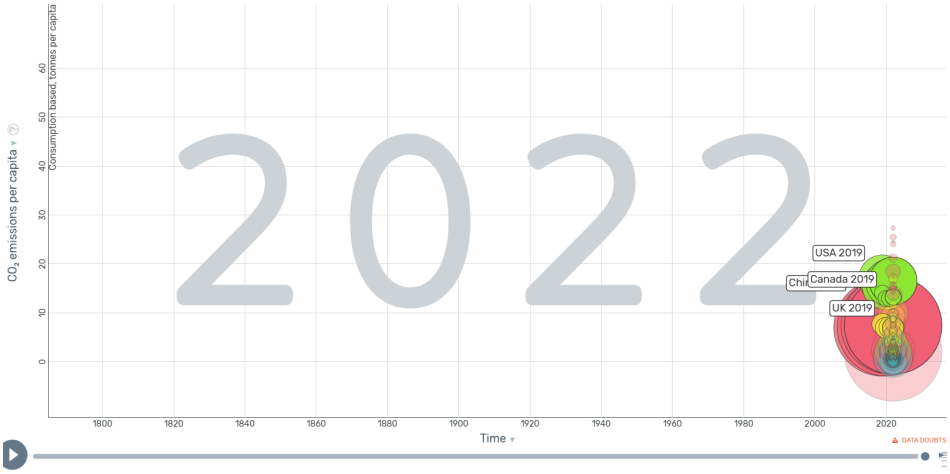
Weather and climate are not the same. Weather is chaotic and unpredictable beyond a few weeks because of its sensitivity to initial conditions (butterfly effect). Climate on the other hand focuses on long-term averages/trends controlled by more predictable factors such as greenhouse gases, ocean currents, or solar radiation. Hence, since climate models focus on large-scale patterns/long-term trends and are less sensible to initial conditions, they help predict changes years in advance, even though daily weather is unpredictable, allowing reliable climate forecasting despite the weather's chaotic nature.

Question 3:
If at a given time birth rates in a population are 45 per thousand and death rates are 25 per thousand,
a)what is the population exponential growth rate r (in percent per year?)
exponential growth rate (r) = Birth Rate−Death Rate = (45 per 1000 = 4.5%/year) - (25 per 1000 = 2.5%/year) = 2.0%/year.
b)What is the doubling time of this population? (justify answer with a simple hand calculation)
Doubling time is estimated using Rule of 70 and exponential growth rate r (in percent per year):
Doubling time = 70/r (where r is in percent)
Doubling time = 70/2.0 = 35 years
c) Between the years 2000 and 2014, the Chinese economy grew an average of 10% per year. How many times has the GDP (Gross Domestic Product, GDP, a measure of wealth) doubled within this timeframe (integer answer)?
Time period = 2014 - 2000 = 14 years
At 10% growth, doubling time = 70/10 = 7 years
Number of doublings = 14/7 = 2
China's GDP doubled 2 times between 2000 and 2014, meaning it grew to 2^2=4 times is original size.

Question 4:
View the two videos on Gapminder.org :(https://www.youtube.com/watch?v=4IkHtTgn3Nk) (https://www.youtube.com/watch?v=Crf0Ev1zoIU)

a) These date from 2008 and 2009: use the Gapminder World app (now located at: www.gapminder.org/tools; use ‘bubble’ charts if it’s not the default) to update the CO_2emissions (tones per person) for China, the US, Canada, and the UK. The value for a data point (colored circle) is displayed on the y-axis when you highlight that point. Selecting a box for the country of interest helps find it, and you can use the ‘log’ or ‘linear’ plotting axes to help separate points.

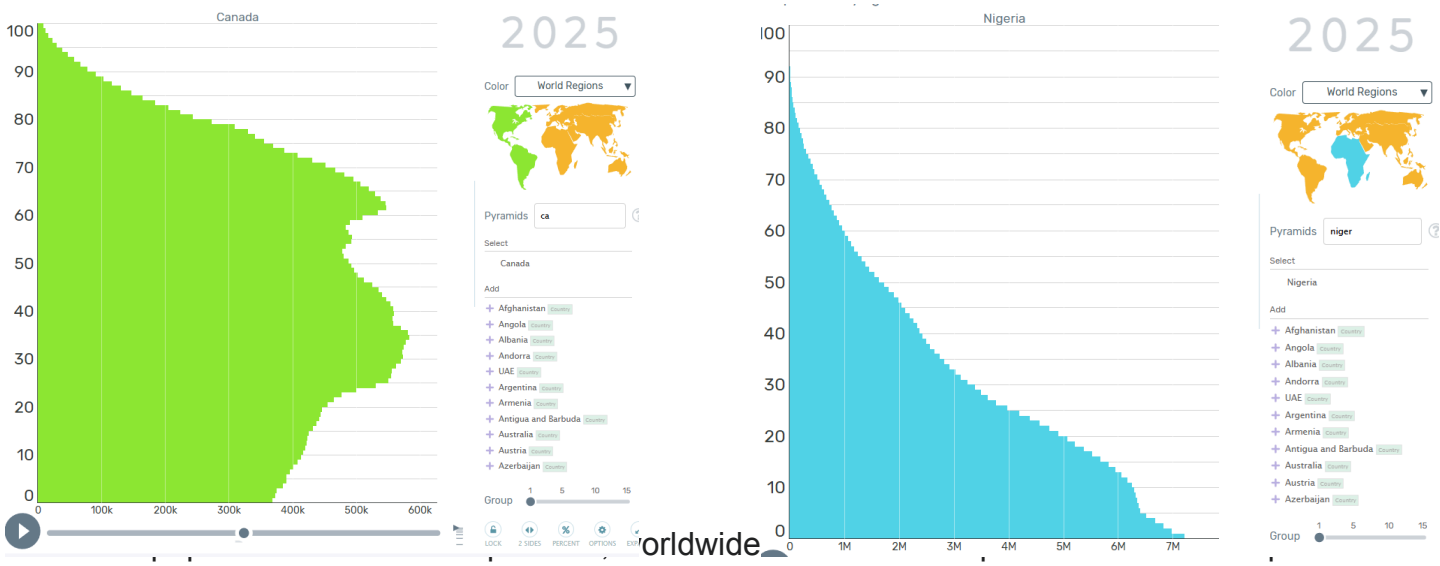
The most recent year available in the timeline for CO2 emissions per capita is 2022, and in this timeline, we get the following for each country:
-China: 7.38 tonnes per capita
-USA: 16.4 tonnes per capita
-Canada: 13.2 tonnes per capita
-UK: 6.93 tonnes per capita



b) Gapminder has been updated to 2023 with health and wealth data. Has China caught up to the UK? What are the latest reported respective life expectancies? What is the life expectancy in the country of your birth (give it and the country)? What do you notice when you compare the US and Canada in the last 50 years?
Yes. China 50 years ago as a comparison had a life expectancy of 66.1 years, while UK had a life expectancy of 74.8 years. In 2023, the latest life expectancy of China is 78.4 years, and that of the UK is 81.7 years, providing insight into a closer difference in life expectancy than 50 years ago between China and the UK, which means that China did caught up to the UK. The life expectancy in my country of birth is Canada, and is 82.8 years in 2023. 50 years behind 2023, life expectancy was 76.1 years for Canada, 74.8 for US. In 2023, its 82.8 years in Canada, 79.5 years in US. Comparing, we see theres been significant increases in life expectancies for both, and that Canada has made more progress, gaining 6.7 years vs 4.7 years in the US, keeping it ahead even after 50 years, and widening their gap.

c) There is an ‘Ages’ button that allows plotting of demographic pyramids. Compare the demographics of Canada with that of Nigeria (describe your screensave).

Nigeria has a pyramid shape with a very wide base, narrowing sharply toward the top, suggesting a rapidly growing population with high birth rates and lower life expectancy. They seem to have an extremely young population with the largest segments being the youngest age groups of 0-10 years old. Canada has more of an even shape that bulges in the middle and narrows at both the top and bottom. Canada has clearly a more evenly distributed population across age groups, with a notable bulge in the 60-70 and 30-40 years old areasl. It is important to recognize that Nigeria's pyramid shows a scale in millions (up to 7M), indicating a much larger overall population than Canada's pyramid using only hundreds of thousands (up to 600K). Hence, we can conclude that Nigeria's pyramid suggests a growing population with high birth rates and lower life expectancy, while Canada's more balanced structure suggests an aging population with lower birth rates and higher life expectancy.



worldwide

person. Therefore, at the current global population if everyone used only 1.6 hectares we would be ecologically sustainable. If people consume more than the equivalent of 1.6 hectares per person we would need more planets to support the population and therefore would be living unsustainably. Examine the degree to which your own living habits are sustainable by calculating your ecological footprint using the simple Ecological Footprint Calculator: http://www.footprintcalculator.org A hectare is 100 square meters (1 acre = 0.4 hectares). Averages are used as defaults; if you click through without changing any values, you'll end up with the footprint of the average person. It's not necessary to give them your email address (you can use test@gmail.com). Add details to improve accuracy is useful.

Also: Montreal is a city of over 1,000,000 people, if you're eating fresh fruit or vegetables in the winter, it's from a long way away, and it's about 5 hours by air coast to coast or to Europe, one way (4000 - 5000 km). 1000 square feet of housing space is equal to 93 square meters, and 30 miles per gallon equals 7.9 litres per 100 km in mileage (20 mpg is 11.8 litres/100 km; higher mpg is lower litres/100 km). Quebec produces about 96% of its electricity by hydroelectric and other low - carbon emission sources, Ontario 92 %, and Alberta 10 %.

a) report your footprint in number of global hectares (gHa) and number of planets.

Number of global hectares (gHa): 8.1 gHa
Number of planets: 4.9 Earths
CO2 emissions in tonnes per year: 10.6 tonnes per year
Carbon Footprint: 46% of my total Ecological Footprint (means that carbon emissions account for nearly half of my overall environmental impact. The Ecological Footprint is said by the site to be comparable to biocapacity).

b) is there any reasonable way for you to reduce your footprint substantially, given how you might want to live in the future? You may have to answer the questionnaire a second time.

There are two major reasonable ways for me to reduce my footprint substantially. I must admit I eat animal-based products extensively, daily and in big quantities for training purposes, from chicken to fish, to eggs. This is the most reasonable and most substantial change I could assess from my lifestyle I believe, with also the lack of purchasing of locally grown products in my household. We don't necessarily look at the provenance of our purchases, which as mentioned in the case of some products like fresh fruits in the winter, has a large impact on transportation emissions and hence CO2 emissions. I believe making these dietary shifts could substantially reduce my footprint based on the questionnaire. Reducing animal protein consumption cuts land and water use while choosing local, seasonal produce can eliminate thousands of food miles and their associated emissions.