

Climate Modelling in-class worksheet 5 (week 6)

Group members:

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The focus of Assignment 5 (due after reading week) is on climate changes in the CESM model, and so this worksheet focuses on Lab 15, looking at the transient and equilibrium CO₂ response in the CESM model.

There are many different CO₂ forcing scenarios that can be run with global climate models. These include the SSP/RCP future scenarios of the CMIP (Coupled Model Intercomparison Project) used by the IPCC (Intergovernmental Panel on Climate Change) – these scenarios have been created using assumptions about the social and economic development of the globe, and the implications for greenhouse gas emissions over time (see <https://www.carbonbrief.org/explainer-how-shared-socioeconomic-pathways-explore-future-climate-change/> for more info). These provide our best estimates of possible future climates. But, for more theoretical studies of climate sensitivity, simpler forcing experiments are often used: instantaneous doubling or quadrupling of CO₂ (2xCO₂, 4xCO₂), or steadily increasing CO₂ (e.g. 1% per year). Lab 15 looks at two different CO₂ forcing experiments: 2xCO₂, and 1%/year.

1. Define ‘equilibrium climate sensitivity’ and ‘transient climate response’, and discuss which of the two forcing experiments (2xCO₂ vs 1% per year) can be used to calculate each of these.
2. Of the two metrics you defined above, ‘equilibrium climate sensitivity’ and ‘transient climate response’, which do you think is most useful/relevant for understanding how much the climate has warmed as of this year? Which do you think is most useful for understanding climate warming by 2070? Why?
3. Work through Lab 15 - what are the estimates of the ‘equilibrium climate sensitivity’ and ‘transient climate response’ from the CESM model? Discuss why these are different.
4. The lab reports the two numbers above in units of ‘K’, because the ‘per CO₂ doubling’ is included in the definition, although strictly speaking the units are K/doubling. The lab helps you “Make some pretty timeseries plots, including an **approximate** running annual average” for the global mean surface air temperature in CESM simulations. There are two sub-plots in the figure created in the lab, one of which is relevant for the transient climate response.

- a. Copy the figure relevant to studying transient climate response here, and use this to discuss whether it is valid to scale the transient climate response to different CO₂ forcings, such as 0.8 doublings, or 1.2 doublings (e.g. is the response approximately linear?)
 - b. An approximate annual running mean is calculated for these plots using the following line of code:
`field_running = field.rolling(time=12, center=True).mean()`
Why is this only an approximate annual running mean? How would you make it more exact (you don't have to code it, just explain what you would code, although if you have extra time and want to code it up to see how big/small the errors are, please do!)
5. Using the fact that one doubling of CO₂ is approximately 3.8W/m² of forcing (a bit more accurate than the '4W/m²' given in Hartmann), what is the equilibrium climate sensitivity and transient climate response in units of K/W/m²?
6. The IPCC reports net radiative forcing of 2.72W/m² in 2019. If the CESM model is correct, what is your best estimate of how much global average temperature should have warmed by 2019, relative to pre-industrial times. Explain how you calculated this, and why.
7. Contrast your answer to Q5 to the IPCC reported warming of 1.07C. If this is different from your calculated answer from CESM, discuss possible reasons for this (include at least 2-3 reasons)
8. Lastly, let's do a quick investigation of regional differences and internal variability. Calculate the regional mean (including latitude weighting) temperature in CESM for a relatively small region on the globe of your choice (e.g. BC, approximately 225-245E, 50-60N). Create timeseries of the mean air surface temperature including approximate annual running mean for the 1%CO₂ run and the doubled CO₂ run (e.g. repeat the timeseries created in the lab, but for a small region), and calculate and report the TCR and ECS. Discuss and provide possible explanations for any differences between the global mean and your region, in terms of ECS, TCR, variability (look carefully at the y axis scale), and the difference in magnitude between the trends and the variability.