Project # 3
Multi-model analysis
LPHYS2265 2021

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1 Objectives and steps for this part

This exercise consists in analysing the idealized sea ice projections run from the models you built earlier in this class. In this part, what is expected is to provide a scientific answer to two questions on the future of Arctic sea ice, based on a multi-model analysis. The main steps of this exercise are:

- Read this pdf (1h), make sure you understand what is asked; mark in bold the key science questions. Come back to me in case of any ambiguity or problem.
- Meet your team mate and organise yourselves (30 min);
- Perform analyses and figures (8h)
- Discuss with your team-mate, write report (2 days?)

What to deliver? A $\sim$ 5 page-max pdf **report** (by **groups of 2**). **Deadline: May 19**. Make sure all figures are readable, that axes have readable labels and units.

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2 Scientific questions

This last part of the project is organised around two science questions:

- Will there be more or less Arctic sea ice at the end of this century? (why? what does it depend on? how sure are you?)
- In which season the Arctic sea ice decrease will be the largest? (why? what does it depend on? how sure are you?)

The goal of this project is to understand what type of answer climate models can provide to such questions.

3 Material: model simulations

The material you have at hand are the simulations that every of you have run (the CTL and PR simulations from all models).

I have received your text files by mail (thanks!!!). I **stored all of your output text files within just two mat files** (CTL.mat, PR.mat), in order to spare you some (quite) painful hours crying in your room struggling to read all text files. I also prepared you two python scripts to upload these into python (read_CTL.py, read_PR.py).

Next to your 12/11 models, **I also added three of my own models**. One is just my own Semtner 0-layer model (SUPERN_ICE). The two other (YBLAIRE / BRAILLE_ANE) are a bit different from the Semtner 0-layer model. You should find out they behave a bit differently. So in total, we have 15 models with CTL run and 14 with projections.

The arrays you will work with include a model dependence. For instance, ice thickness in the control simulation will be function of day-of-year AND model: $h_i = h_i(d, i\_mod)$. To plot multi-model output, you can **embed the plotting command line within in a loop over models**, which will save lines of code.

4 Method: multi-model analysis

To work around our two science questions, you will perform **a multi-model analysis** similar to what climate scientists often do.

During your analyses, you could find common treats among different models, and possibly robust relationships between variables, that should help to strengthen your findings.

Often useful is to add the **multi-model mean** as an extra model and to represent it within plots using a thicker line than for individual models. The multi-model mean averages individual model errors. The spread around the mean arguably gives the uncertainty bar.

Keep in mind that your models are much simpler than what is used in reality by climate scientists, but the concepts are the same: 1) you evaluate the skill of the model for some observations, and then 2) you perform projections based on our best understanding of the physics encapsulated in a model (models help you to reason on complex physics). 3) To reduce uncertainties associated with imperfect model physics and understanding, you use multiple models coded by different individuals.

Hereafter, I suggest you a few multi-model analyses that will help you to answer the two questions.

4.1 Control simulations

1. Compare the mean seasonal cycle of ice thickness in the CTL simulation for all models with the "tuning data" of MU71.
2. Add a thicker curve for the multi-model mean
3. Do the same for temperature and snow depth (here you have no data).

You can reach a 3-panel figure with all model outputs for the CTL simulation. With this figure, you can figure to which extent your models are able to reproduce observations, and strengthen confidence in the ability of your models to simulate sea ice. You can see which aspects are consistently simulated, and which are not. Maybe there are links between snow/ice thicknesses and temperature that are worth understanding.

4.2 Projections

1. Compare all models in terms of mean, min and max thickness for the PR03, PR06 and PR12. Do the same for the annual minimum surface temperature.

2. You can play on linestyle / line color to highlight this or that aspect. For instance, you can color lines by model / by warming scenario, which will not convey the same message.

4.3 Extra analyses

What you already have is sufficient and you could stop here and do a nice report. However, thinking in depth at your science questions, you may find that extra analyses are more appropriate / more convincing to address them. This is where you can be creative...

5 Report

The report you have to write is somehow similar to a short scientific article. You have to provide the most convincing and concise piece of text to treat the two science questions, using simple model output.

You can use from 2 to **maximum 4 figures, 1 table and $\sim$ 5 pages. Use 11-point font and avoid single interline (1.2-1.5 are ideal)**. Less is more and we recommend not to exceed 5 pages of text.

You can use **either French or English**.

The standard structure we recommend (you can go alternative though if you think there is a better solution):

1. A summary (5-10 lines) of your study (**abstract**).

2. An **introduction** (1/2 page) with general context, a presentation of the science questions and the methods used to answer these questions.

3. A description of the **material and methods** used (1 page max). Do not go into all technical details, but try to incorporate everything that is

needed for a reader to understand what you are doing (model physics, multiple models, forcing, control simulation, projections)

4. A description of the **results** (2 pages max including figures). Include what you find useful to treat your science question, for instance: 1) evaluate the skill of your model to reproduce observations (CTL simulation), and 2) analyse how sea ice is projected to evolve in the future and why. Avoid presenting data that is not critical to your scientific question.

5. A **discussion** of the results (1/2 page). Here, this is where you discuss a bit more in depth the meaning and implication of your activities. This is where you have a bit of freedom to discuss your answer to the question... You can find tutos online for how doing such a thing. But in a few words, you can 1) reiterate the research problem / state the major findings; 2) explain what is remarkable about the results; 3) acknowledge the study's limitations 4) make suggestions for possible better means to investigate the question you have.

6. **Conclusion** (1-2 small paragraphs, 1/2 page). Where you summarize your answer, give your last word, think of the broad implications.

Throughout the exercise, you will encounter two issues. 1) You don't have lots of culture in the field (you can use the course to strengthen your arguments) and; 2) the models you are using are too simple, which is a limitation. We are aware of that.