Study of the climate feedbacks weights, with the simplified model of an educational software, and comparison with more sophisticated models.

When a forcing is applied on the climate system, for instance by increasing greenhouse gases as it is currently the case, its response is complex. First, the temperature rises, but the various components of our climate (water vapor, clouds, ice, atmosphere, etc.) have their own response to the forcing. Once they are disturbed, these components then influence the global mean state (global temperature, sea level, greenhouse gases, etc.): this is the principle of a climate feedback. To give an example, a part of the ice-sheet melts when the temperature rises; the solar rays previously reflected by the ice are then absorbed by the surface, which will thus warm. In this case, the mechanism makes the planet warm even more: it is a positive feedback. In the contrary, if the feedback damps the main trend, it is a negative feedback.

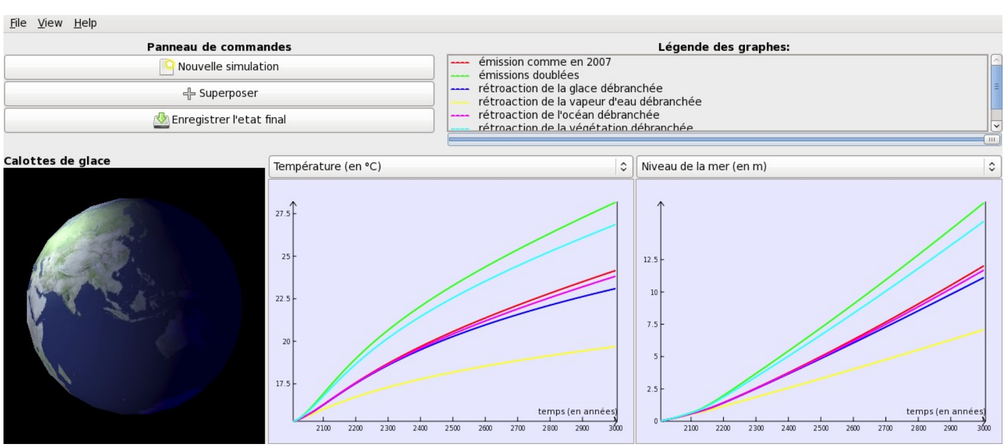
It is very complicated to estimate the role of each feedback in a climate change. Some studies currently try to divide the global warming into the various feedbacks. Moreover, this decomposition may be different in the case of other forcing and other climates. Indeed, during past changes within different contexts from today, the climate components were differently distributed in the system and we can wonder if the corresponding feedbacks played then the same role as today. Consequently, a main issue is to determine the conditions to constrain the future with the past.

The internship is based on the highly simplified climate model from the educational software SimClimat. This tool allows us to easily play with feedbacks and climate changes. The Student will use the software interface to launch simulations, and will also use directly the code to further modify parameters which are not available from the interface. There will be three main steps to constitute the internship:

- Dividing the global warming into the various feedbacks using SimClimat, and studying the sensibility to changing parameters such as the ice reflecting power.

- Determining the role of each feedback in the case of other forcing: cooling as during the last glacial maximum, cooling with the same CO_2 concentration as during the last glacial maximum and the same ice-sheet as today. Studying the feedbacks weights in each context.

- Comparing our results with results from more sophisticated models studies, identifying the differences and their causes.



Supplementary notes for the supervisor

Reference papers:

Dufresne, J-L., and Bony, S., 2008: An Assessment of the Primary Sources of Spread of Global Warming Estimates from Coupled Atmosphere-Ocean Models. *J. Climate*, 21, 5135-5144, doi: 10.1175/2008JCLI2239.1.

Yoshimori, M., T. Yokohata, A. Abe-Ouchi, 2009: A Comparison of Climate Feedback Strength between CO_2 Doubling and LGM Experiments. *J. Climate*, 22, 3374-3395, doi: 10.1175/2009JCLI2801.1.

Primary concepts to be explained to the student:

- Radiative budget (conceptually, as described in SimClimat; see fig.2 of the model documentation (in french): http://www.lmd.jussieu.fr/~crlmd/simclimat/logiciel_documentation.pdf).

- Climate feedbacks, concepts of positive and negative feedbacks.

- The water vapor feedback (including greenhouse effect and Clausius-Clapeyron law), the albedo feedback, the carbon oceanic fluxes feedback (CO_2 pumping and degassing according to the temperature changes, see the documentation for more details), and other feedbacks not included in the model (vegetation, clouds, etc.).

Approximate stages of the internship:

- Introducing the software, the theoretical concepts (see previous section), and how these concepts are turned into equations in the numerical model.

- Introducing the concept of feedback weight according to the current studies (see the reference papers above), and adapted for our model. Starting from the radiative budget of the model (see the documentation):

$S04(1-\alpha)=(1-G)\sigma T4 \quad \rightarrow \quad T4=S0(1-\alpha)4\sigma(1-G)$

considering little variations, that is considering that interactions of second order between the feedbacks (they depend on each other) are negligible, this gives:

$4T3dT=-S04\sigma(1-G)d\alpha+S0(1-\alpha)4\sigma(1-G)2dG$

with $d\alpha=\partial\alpha\partial TdT$

and $dG=dGCO2+dGH2O=dGCO2+\partial G\partial H2O\partial H2O\partial TdT$

- The study in itself, divided into three steps as described in the subject description:

  - Dividing the global warming into the various feedbacks using SimClimat, and studying the sensibility to changing parameters such as the ice albedo.

  - Determining the role of each feedback in the case of other forcing: cooling as during the last glacial maximum, cooling with the same CO_2 concentration as during the last glacial maximum and the same ice-sheet as today. Studying the feedbacks weights in each context.

  - Comparing our results with results from more sophisticated models studies, identifying the differences and their causes.

- If there is enough time, computing a correlation calculation of the part of the temperature change due to each feedback for the warming case versus the cooling case.