20241121 - Differences Between MSc Thesis and Couplet(2024)

Synthesis : Does a publication of my MSc thesis is useful with the publiction Victor "Tipping intereractions and cascades" ?

I think there is a gap and a place for a publication of my MSc thesis. Even if Couplet et al.(2024) version of SURFER (officially called v3.0) is better than the one into which I integrate my AGTCCM module 6 months ago, my version of SURFER with the AGTCCM allows to highlight the specific capacities of using SURFER as an emulator of EMICs in order to better investigate the possible tipping cascade dynamics between the GIS and the AMOC.

The AGTCCM allows to offer an "clef sur porte" module that tells you "if you give me those hysteresis experiments from any EMICs used this accessible experimental procedure, I can emulate you in a relevant manner the response of the AMOC and the GIS in your complex model into a double-fold dynamics. Once coupled in the the SURFER model, this allows to study with a very limited cost the behaviour of the AMOC and the GIS and their interactions with climate change."

I think we should not try to call my work a "new version of SURFER" because it is not based on the latest version of it. Instead my studies and my configuration of the model allows to provide a practical application for studying the cascading collapses of the AMOC and the GIS. In addition to add a significant amount of time to my work for the publication, I don't think there is an utility that I now try the merge again the AGTCCM with the latest version of SURFER. If a publish my code as branch for instance on a SURFER v3.0 GitHub it will already provide the tool in an accessible manner and the results of my paper. If there is an interest of someone in the future it could be interesting to build a proper "SURFER v3.1" that integrates the AGTCCM based on the latest SURFER v3.0.

A very secondary work that has been achieved in the MSc thesis that is not present in Couplet et al.(2024) work is the parameterization on the carbon cycle of an AMOC collapse in SURFER but this alone don't justify the reasons to write a paper based on my MSc thesis.

Questions

- If I publish my MSc thesis results "as it is" without trying to merge the codes based on the latest version of SURFER, to what version of SURFER should I refer when I used to talk in my MSc thesis to "SURFER v3.1" ? Because this version has never been published.

Differences between the Models

In my MSc thesis I say that the "old" structure of the tipping elements module in the version of SURFER on which I started to work was,

$$\frac{dx_i}{dt} = \left\{ \underbrace{-x_i^3 + a_i x_i^2 + b_1 x_i + c_i}_{\text{Internal Dynamics}} + \underbrace{d_i T}_{\text{Temperature Forcing}} - \underbrace{\sum_{j=1}^{8} e_{ij} L_j}_{\text{Couplings with other TE}} \right\} \frac{1}{\tau_i}$$

In my MSc thesis I said that the shortcomings of that version of the tipping element module was that :

① **The method for fitting the coupling coefficients** e_{ij} **:** I wrote that they were determined in an arbitrary manner based on comparing orders of magnitude between the expected coupling effects of the TE and the literature.
   ① They were already a parametrization of the stabilizing effect $AMOC \rightarrow GIS$ but was highlight as being arbitrary.

② **No parameterization of the destabilizing effect** $GIS \rightarrow AMOC$

Based on the version of SURFER on which I work at that time (April 2024) I couldn't say that they were no couplings between TE in Victor's model because they were with the term $e_{ij}L_j$.

Amaury's AMOC-GIS model in MSc Thesis

My simulations either in CONFA or CONFB in the MSc thesis are performed using :

$$cfeedback = 1 \quad , \quad d = 0.5 \quad , \quad \epsilon = 1$$

It couldn't be more exact to let $d = 1$ but the reason why I didn't touch this was to be able to compare with the previous version of SURFER I had in April 2024 ; This emphasize that the results of my model don't have to be take for true but the comparison between the previous version of SURFER I had and the one I have develop remains.

Victor's AMOC-GIS model in Couplet et al. (2024)

$$\frac{d\Psi}{dt} = \left(-\Psi^3 + a_{2,\Psi}\Psi^2 + a_{1,\Psi} + c_{0,\Psi} + c_{1,\Psi}\left(T + d \cdot \sum_j \epsilon_{\Psi j}\delta L_j q_{+,\Psi} \right) \right) \mu(\Psi, H_i)$$

The idea is that each element is forced by the temperature and can also be forced with any other quantity δL_j simulated by SURFER allowing for coupling between the different elements. Most interactions are modelled by taking δL_j as a linear function of element x_j but the formulation allows for more general cases. For instance, Victor already talk about the parameterization of the destabilizing effect of the GIS on the AMOC as being done with $\delta L_j \propto \dot{V}$.

- The calibration of the parameters $a_{2,i}, a_{1,i}, c_{0,i}, c_{1,i}$ are done for uncoupled elements $d = 0$ because in this case $\delta q = T$ which allows to fit base on the literature such as McKay et al.(2021)
- The couplings coefficients ϵ_{ij} give the strength and the sign of the interactions.
  - Victor calibrate these coefficients based on Wunderling et al.(2024)
- The adimensionnal parameter d is introduced for practical purposes and allows to scale the strength of all interactions simultaneously.

Differences between the two models and added value

Couplet's model is more generic and takes into account multiple tipping elements interactions

In my model I only focus on AMOC-GIS tipping cascade interactions so I shut down all the other interactions and I focus on calibrating the AMOC double fold model of AGTCCM based on cGenie experiments.

Monte-Carlo sampling for exploring phase space Vs Emulator of a specific EMIC

- Instead of calibrating one model in particular, Couplet et al. (2024) use a Monte-Carlo sampling for the critical values of $T_+, T_I, \tau_-, \epsilon_{ij}$

Values of the critical bifurcations coordinates

- In my MSc thesis for the AMOC, based on the cGenie experiments on which I want to calibrate the AGTCCM I use that,

$$\Psi^+ = 0.6, \Psi^- = 0.022, \quad T_+^\Psi = 5.5^\circ C, T_-^\Psi = 1.27^\circ C, \quad F_{GIS}^+ = 0.045 Sv, F_{GIS}^- = -0.015 Sv$$

- In Couplet et al.(2024) they performed a Monte-Carlo sampling for T_+^Ψ between $[1.4, 8.0]$

Timescales τ

- For the GIS : Couplet et al.(2024) sample the value of τ_- between 305 and 1978 years where they define that $\tau_+ = 5500$ years. In my MSc thesis I ran simulations defining $\tau_+ = 700 = \tau_-$ years. Those where values given by Victor at that time.
- For the AMOC : Couplet et al.(2024) sample the value of τ_- between 2.1 and 21 years where they define that $\tau_+ = \tau_-$. In my MSc thesis I ran simulations defining $\tau_+ = 10 = \tau_-$ years. Those where values given by Victor at that time.
- For comparing the results as I did in my MSc thesis I realized that I have probably done a mistake because I didn't compare at that time SURFER v3.1 and SURFER v3.2 using the same values of $\tau_\pm$ for the tipping elements. This is a limitation that stress again the fact that my results don't have to be taken as exact prediction but highlights the important differences in terms of tipping elements cascade behaviour and climate trajectories when we change slightly the key parameters of the TE, as I had to do to emulate an EMIC in the case of the AMOC.

F_{GIS} parameterization ?

- In my MSc thesis I used the following parameterization

$$F_{GIS} = \alpha_{GIS}\dot{V}$$

$$\alpha_{GIS} = \kappa S_{pot}^{GIS}$$

$$\kappa = 11.47$$

- In Couplet et al.(2024) the following parameterization is used

$$F_{\text{GRIS}} = \frac{S_{\text{pot,GRIS}} A_O}{3600 \cdot 24 \cdot 365 \cdot 10^6} \cdot \dot{x}_{\text{GRIS}}$$

It has to be check what is the value used for A_O but I think it is the same parameterization. At least we had define the one I use in my MSc thesis during a meeting with Victor last year.

Better carbon cycle model and feedback between tipping element collapsing on climate

The Couplet's model have more complex carbon cycle compare to the one I have used. In both case there a 3 box for the ocean but more parameterization of weathering process were added in the version Victor used.

No impacts on carbon cycle from an AMOC collapse in Couplet's model

It's true that the interaction is quite complex so based on that Victor decide not to try, based on the limited physics include in SURFER to parameterize this.

In my configuration I have implemented a simple linear parameterization of the carbon flux coefficients k_{ij} based on the state of the AMOC. It allows to reproduce at equilibrium the expected $\approx 20\ ppm$ increase in CO_2 concentration in the atmosphere described in certain studies.

Questions

- Does the calibration of the $a_{2,i}, a_{1,i}, c_{0,i}, c_{1,i}$ are done in "idealised" experiments without couplings of the TE and so my AGTCCM calibrate these coefficients base on direct experiments ?
  - Not sure because the expression of the TP in terms of temperature in the literature McKay et al. (2021) are done considering all interactions ?
    - Not sure because them with which models ? Which experiments ?
  - Am I not doing exactly the same thing independent experiments used for fitting in the AGTCCM ?
- Is the AGTCCM already captured in SURFER v3.0 of Couplet et al.(2024) ?

Differences in the results of the two models and added value

Tipping of the AMOC and the GIS

- Global idea that the AMOC is a fast tipping element so even a short overshoot is capable of tipping it whereas it is not the case for the GIS holds in both models.
- Comparison in Couplet et al.(2024) between coupled and uncoupled AMOC and GIS shows the effect of the stabilizing and destabilizing interactions between the two.
- On the importance of considering well the coupling and interactions between the AMOC and the GIS the same results (not in terms of number again) are obtained.

Overshoot without tipping

Also produce in Couplet et al.(2024) due to the differences in the models configuration and version there are differences in the exact response of the TE but the idea is the same. In Couplet et al.(2024) he computes the Ritchie criteria which gives more relevant information.