Investigating the '**hothouse** narrative' with dynamical systems

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fnrs
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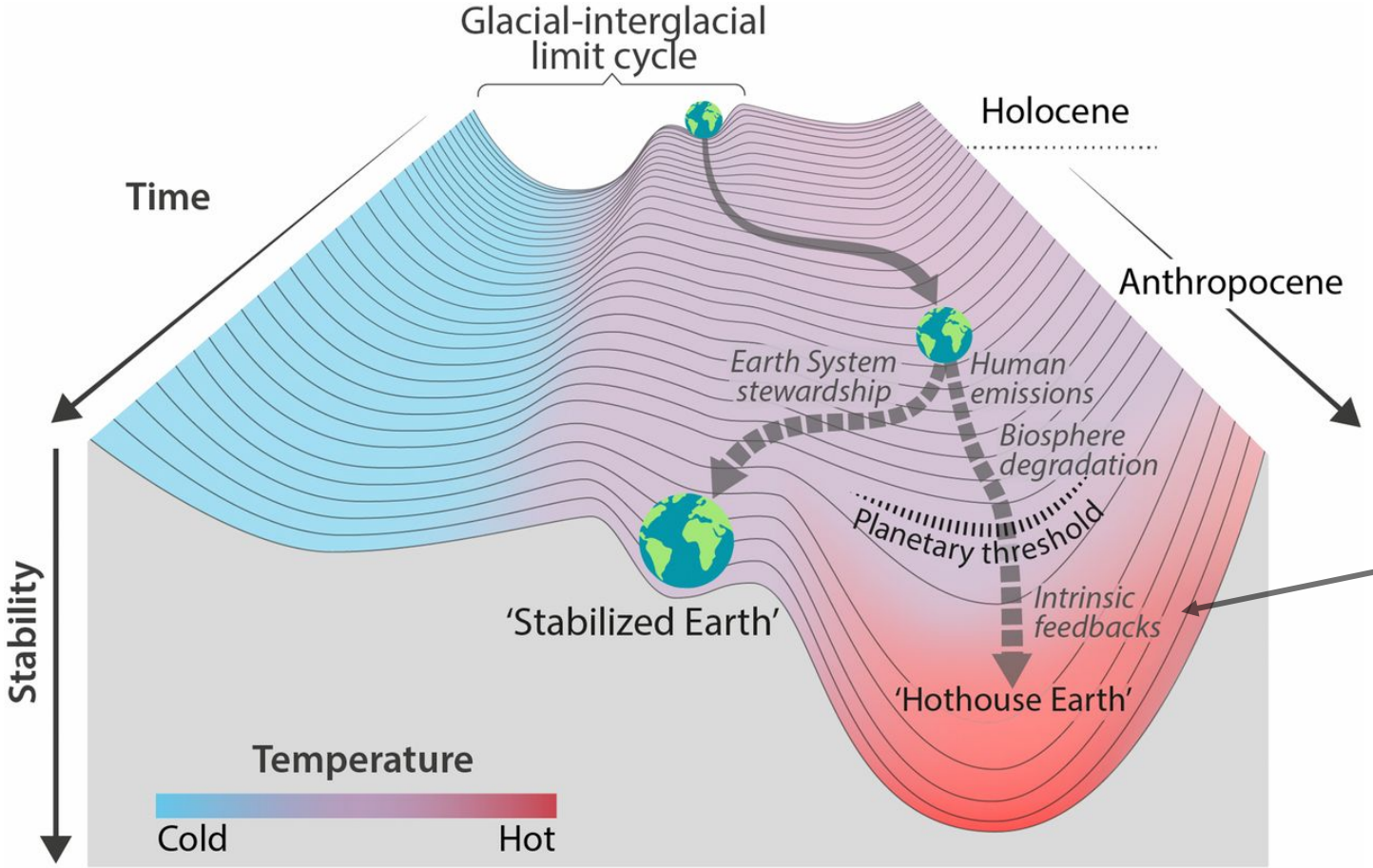
Hothouse narrative : there exists a planetary threshold beyond which tipping cascades lead the Earth to a Hothouse state

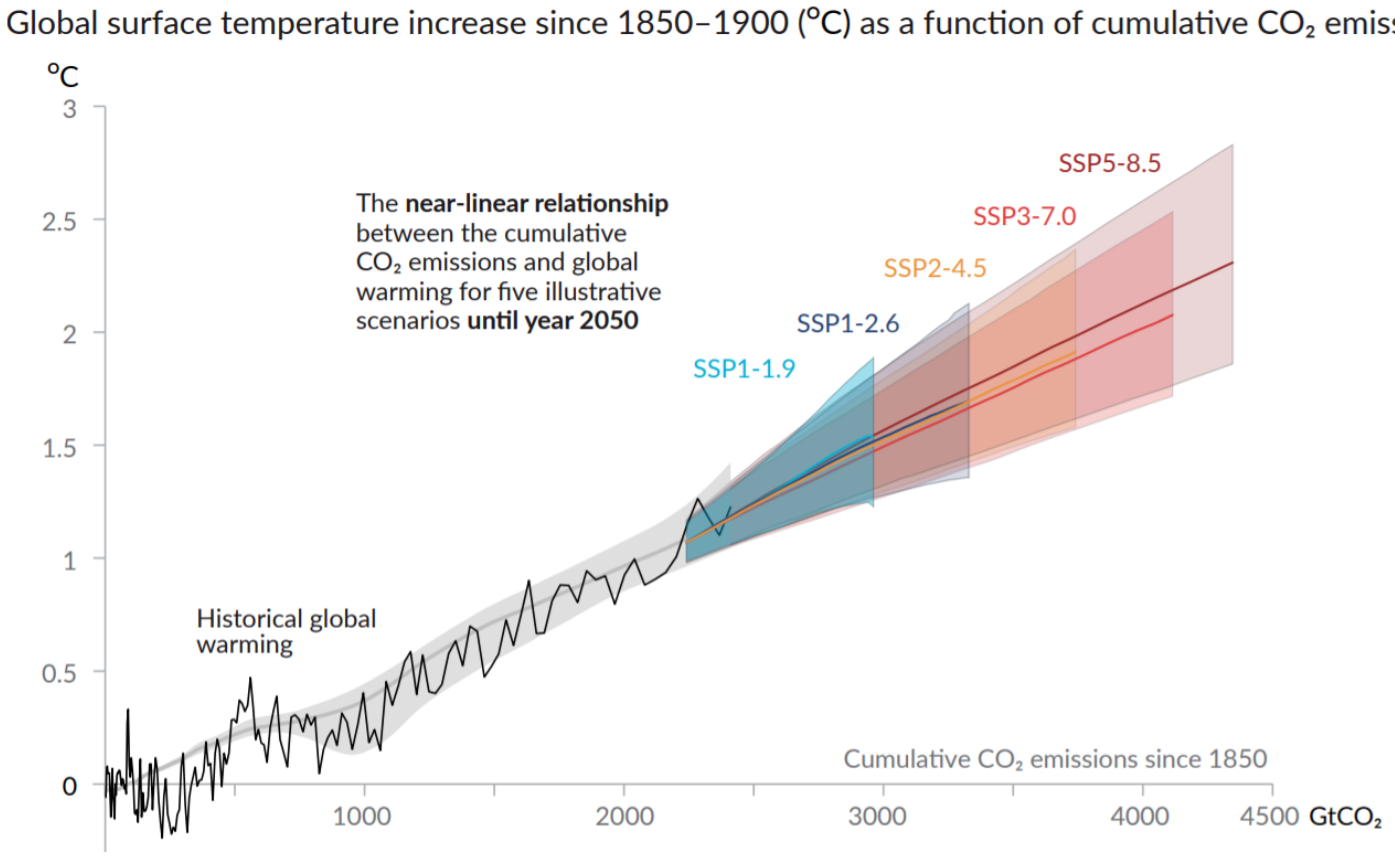


Tipping cascades

Steffen et al. (PNAS, 2018). Link to the paper : click here

IPCC AR6 : "There is no evidence of such non-linear responses at the global scale in climate projections for the next century [...] "

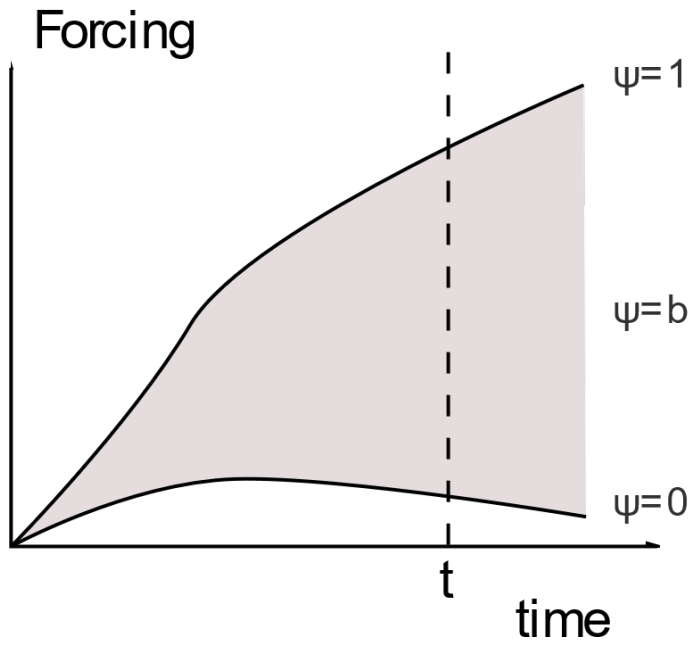
Quote in the tilte of slide is from Chen et al, (2021)
(→ IPCC AR6 WG1 Chapter 1, pg 202. Link : click here).

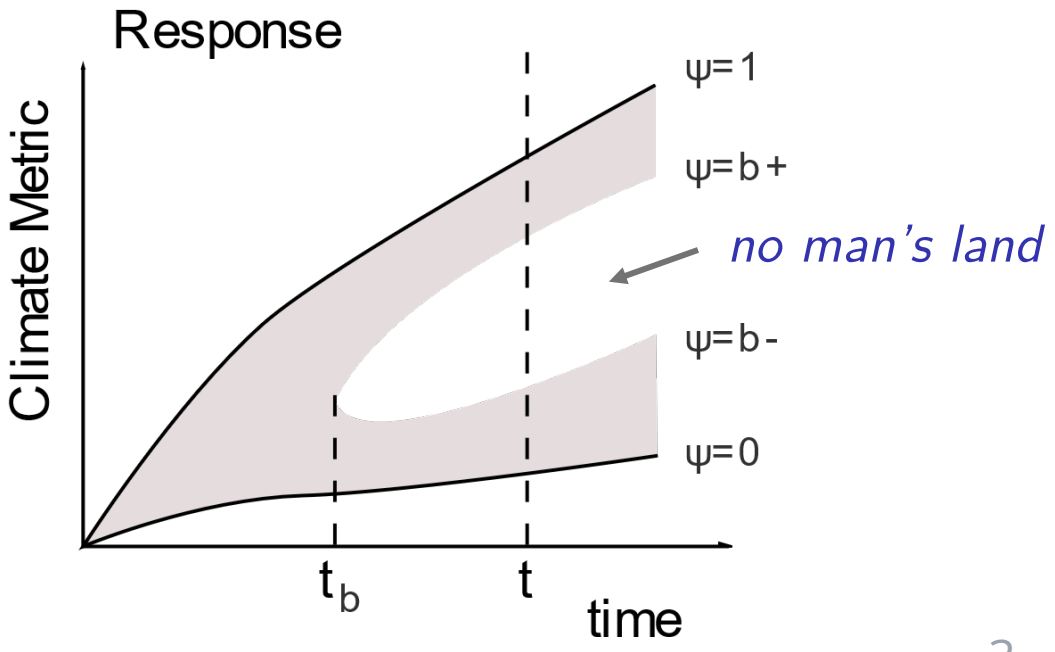


IPCC, 2021: Summary for Policymakers.
Upper part of fig 10. Link to the original : click here.

In my work, I investigate the hothouse narrative with low order dynamical systems

Conceptual model with interacting tipping elements





A toy model of interacting tipping elements with feedbacks on temperature

Anthropogenic CO_2 emissions

↓

Response function fitted to experiences performed with the cGENIE model of intermediate complexity

(Lord et al., 2016)

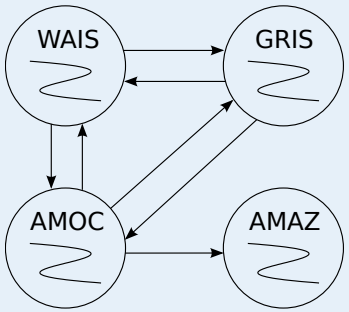
Atmospheric CO_2 concentration

↓

Climate 2-box model

⇄

Conceptual model of interacting tipping elements



(Wunderling et al., 2021)

A toy model of interacting tipping elements with feedbacks on temperature

Anthropogenic carbon emissions *E(t)*

$$CO_2(t) = 280 + \int_{t_0}^{t} E(t') \left(\sum_{k=1}^{n} A_k(\mu) \exp^{-(t-t')/\tau_k(\mu)} \right) dt'$$

(Lord et al.,2016)

$$c \cdot h_u \frac{d\Delta T_u}{dt} = \lambda \Delta T_u + \Delta F_{CO_2} + \sum_i \Delta F_{x_i} - \gamma(\Delta T_u - \Delta T_d)$$

$$c \cdot h_d \frac{d\Delta T_d}{dt} = \gamma(\Delta T_u - \Delta T_d)$$

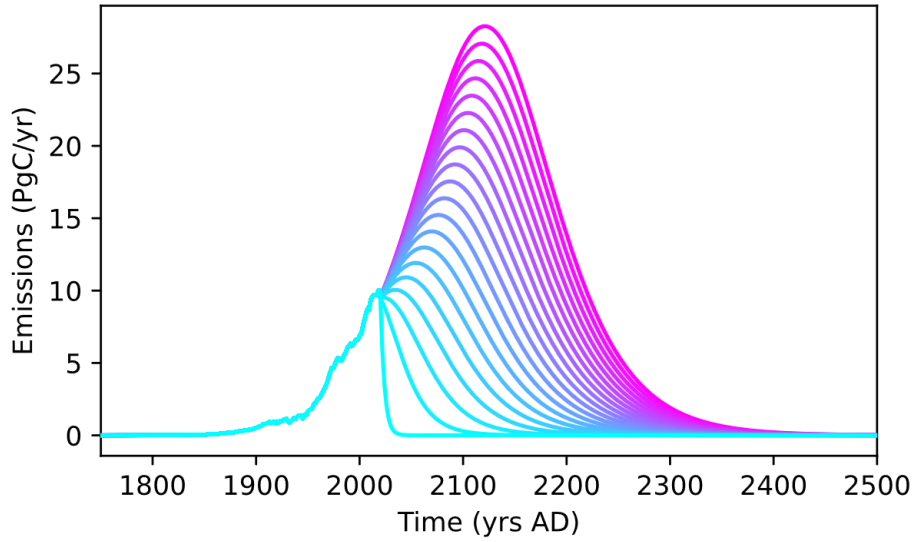
$$\Delta F_{CO_2} = 5.35 \ln \left(\frac{CO_2(t)}{280} \right)$$

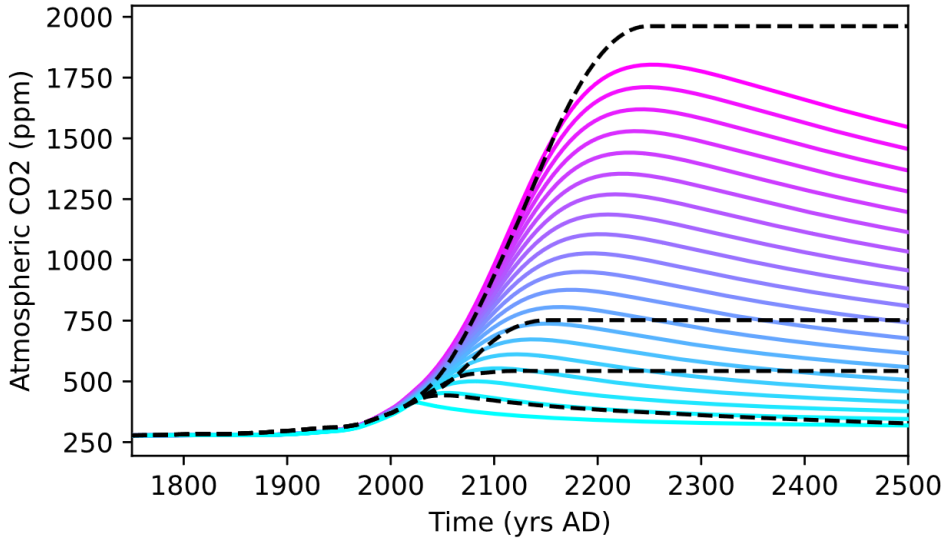
$$\Delta F_{x_i} = \xi_i \frac{1}{2}(1 + \tanh kx_i)$$

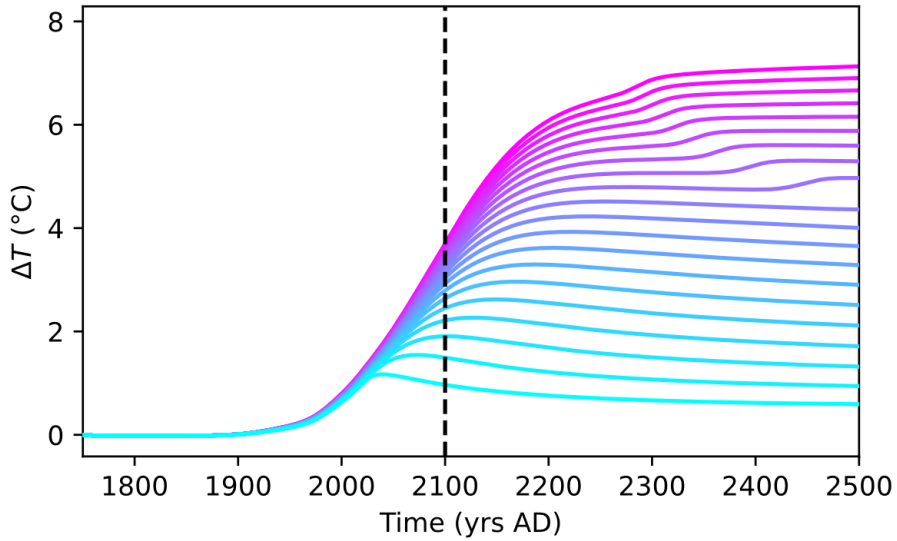
(Wunderling et al.,2021)

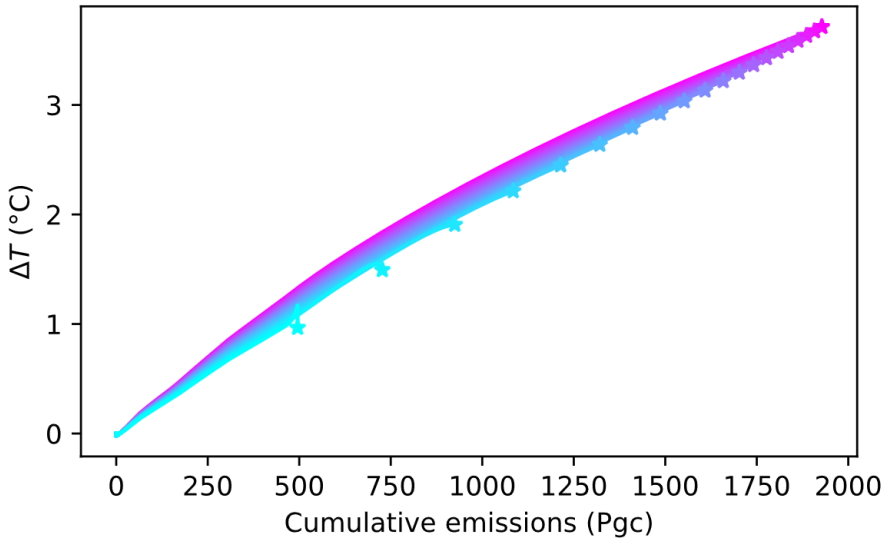
$$\frac{dx_i}{dt} = \left[-x_i^3 + x_i + \frac{\sqrt{4/27}}{T_{\text{limit, i}}} \cdot \Delta T_u + d \cdot \sum_{\substack{j \\ j \neq i}} c_{ij} \, (x_j + 1) \right] \frac{1}{\tau_i}$$

On short time scales, we have a rather linear behavior, and we don't observe a no man's land

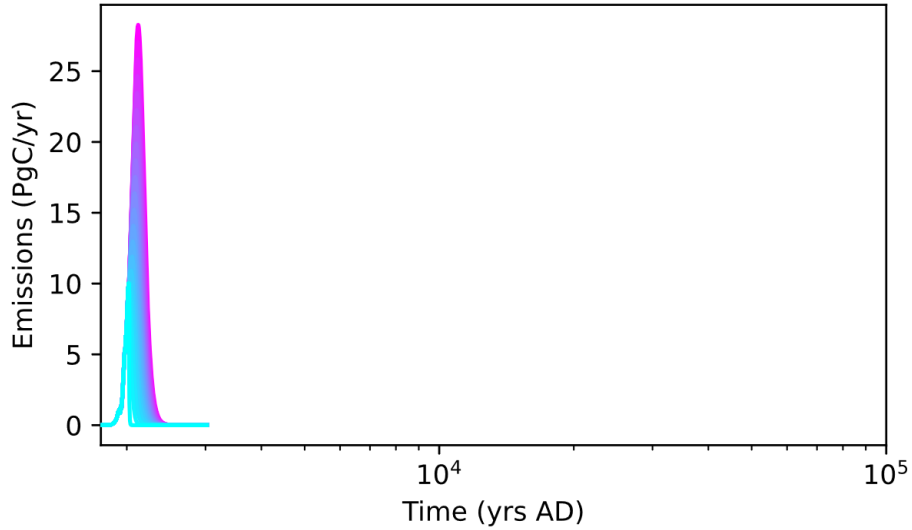


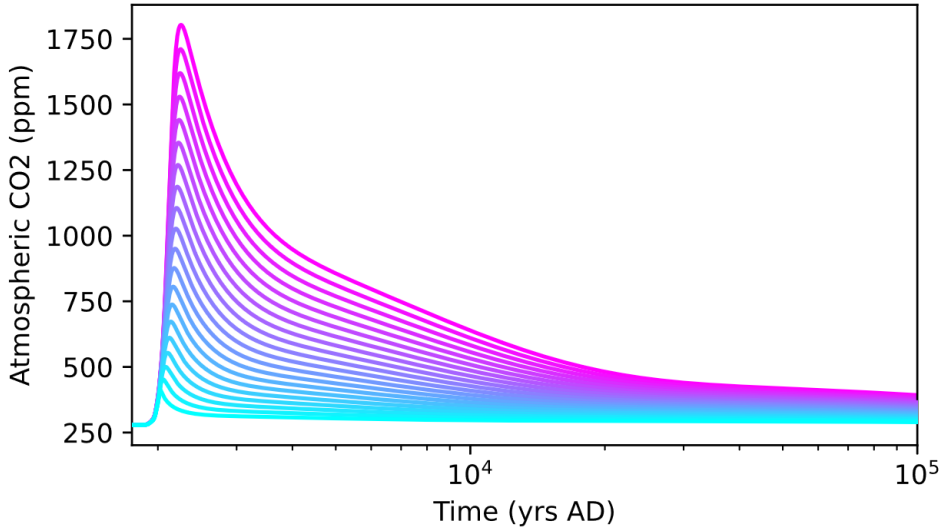


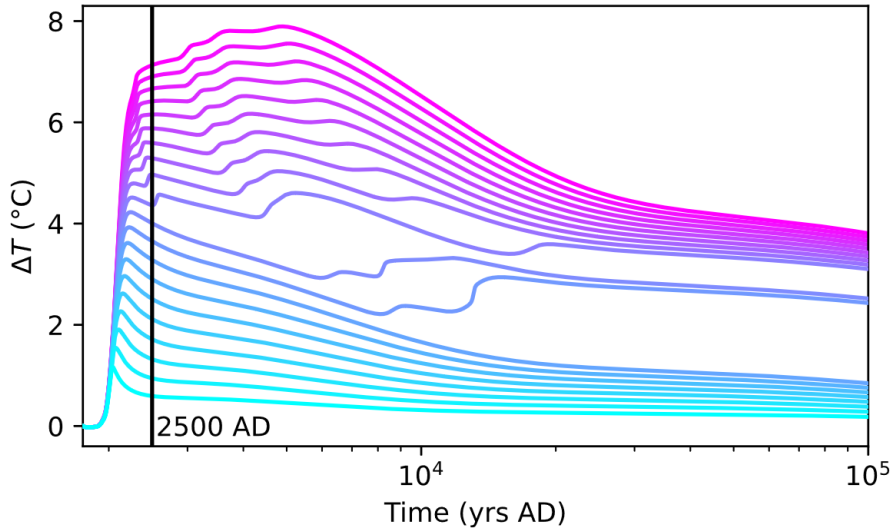


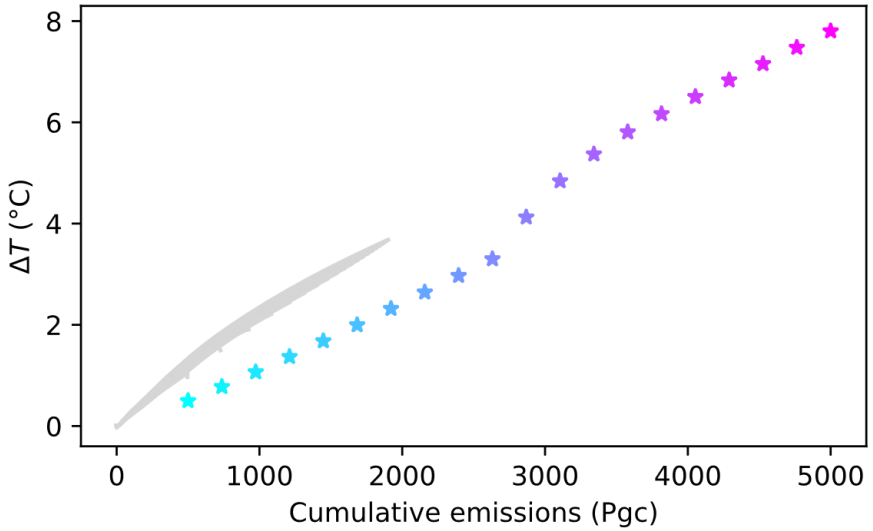


On longer time scales, nonlinearities kick in, and we can observe a no man's land









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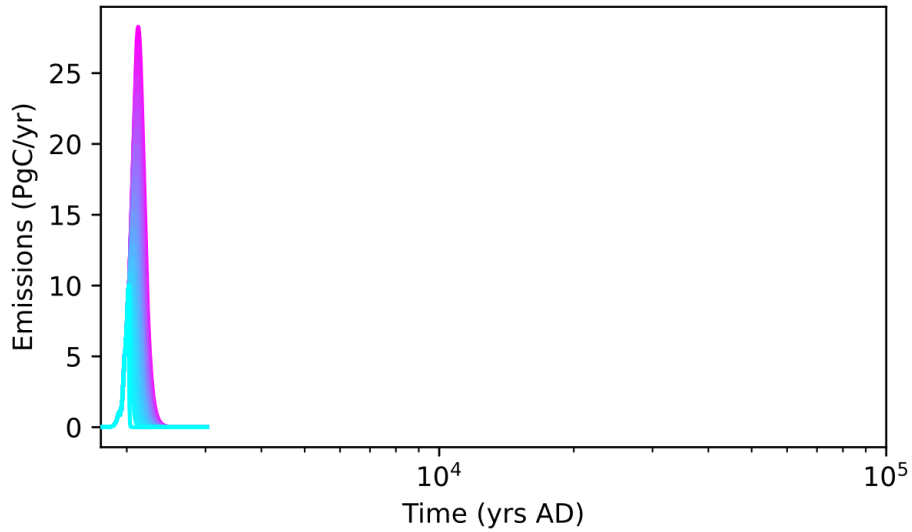

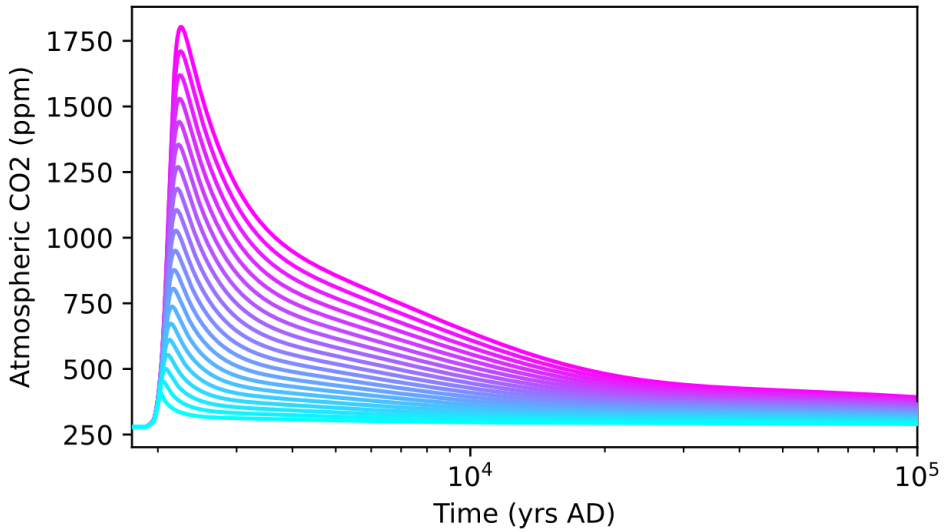

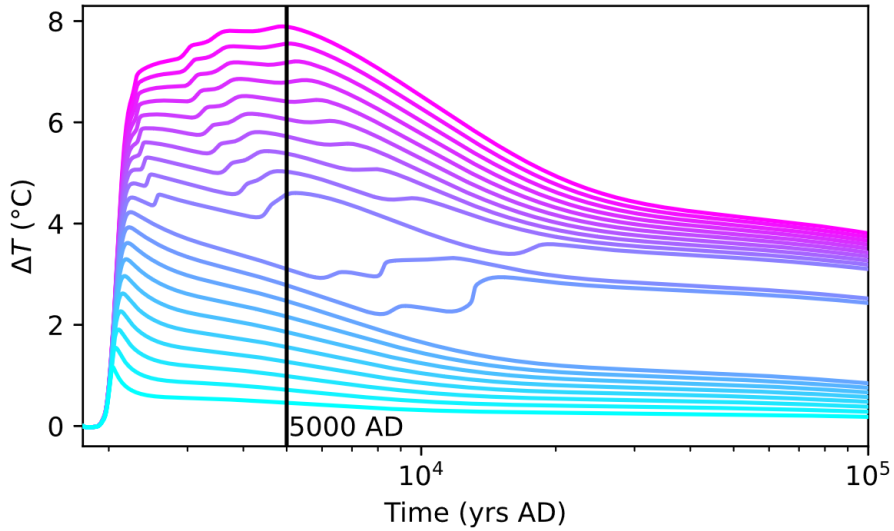

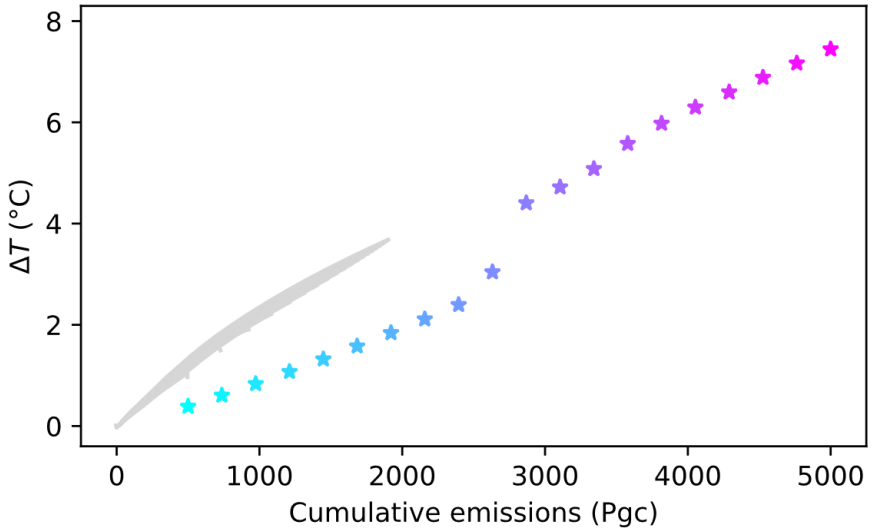

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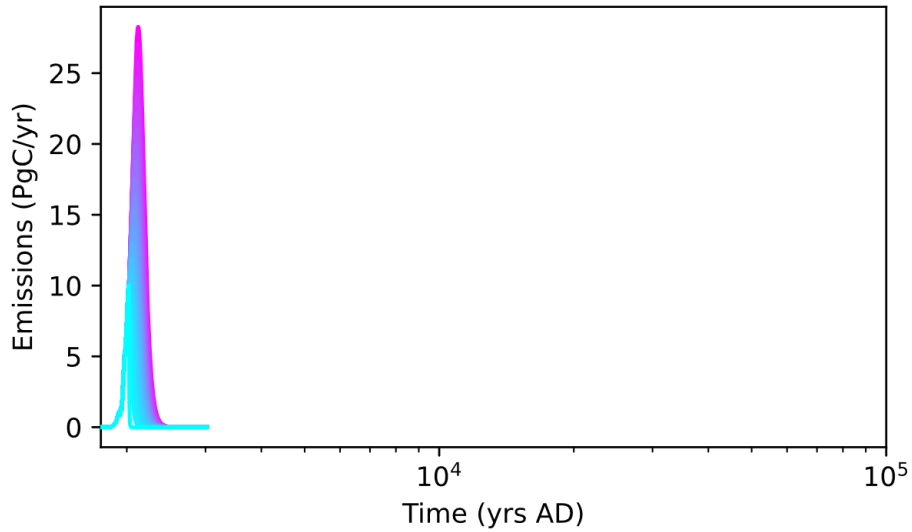

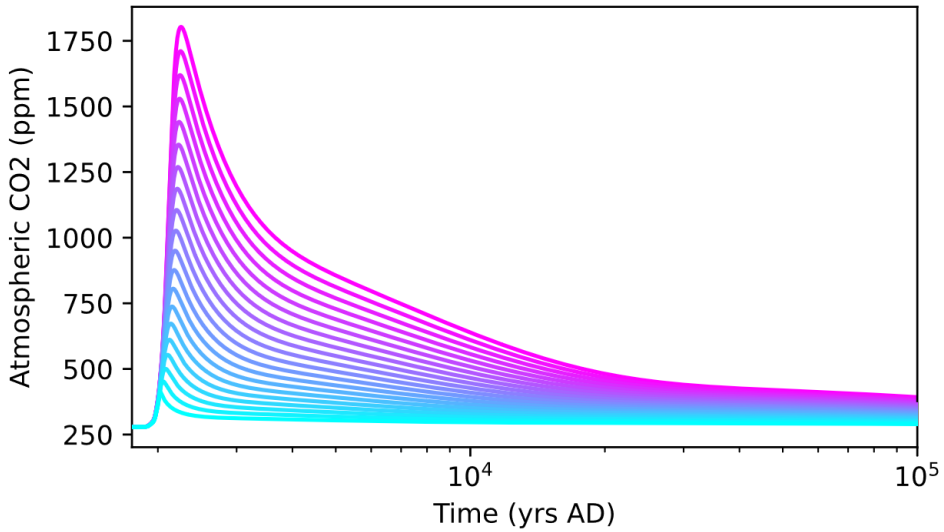

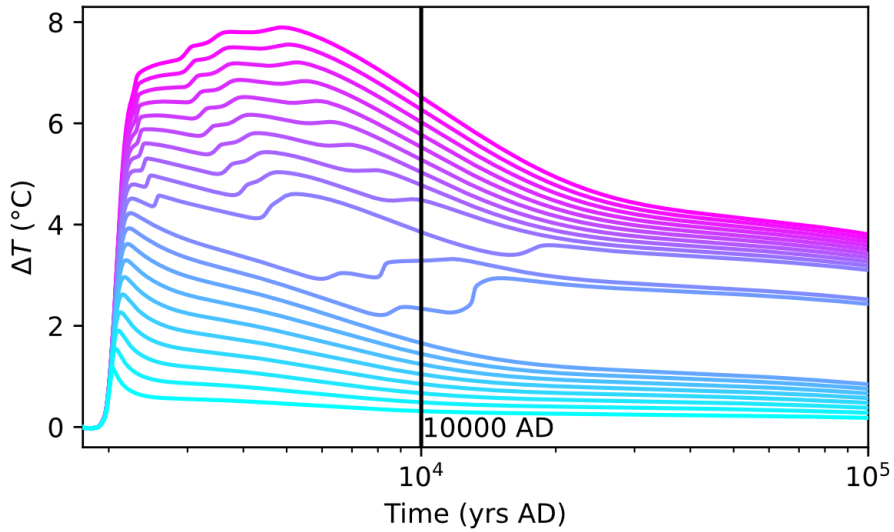

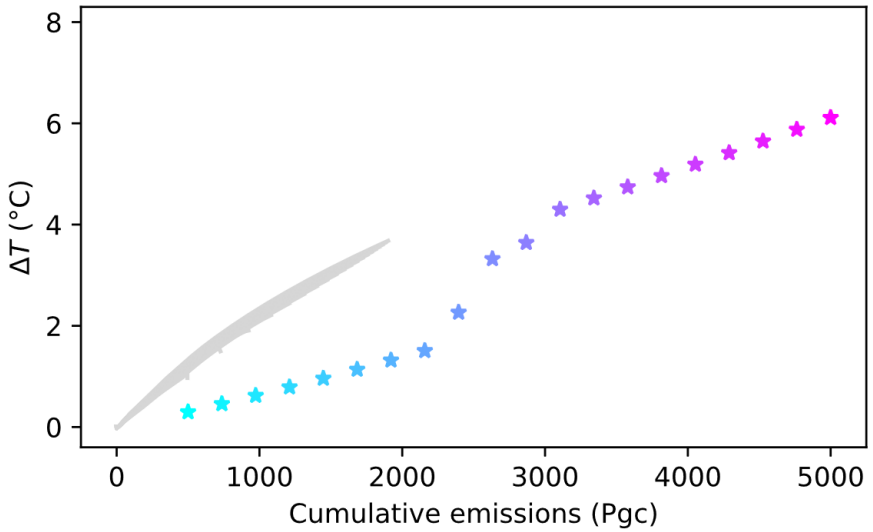

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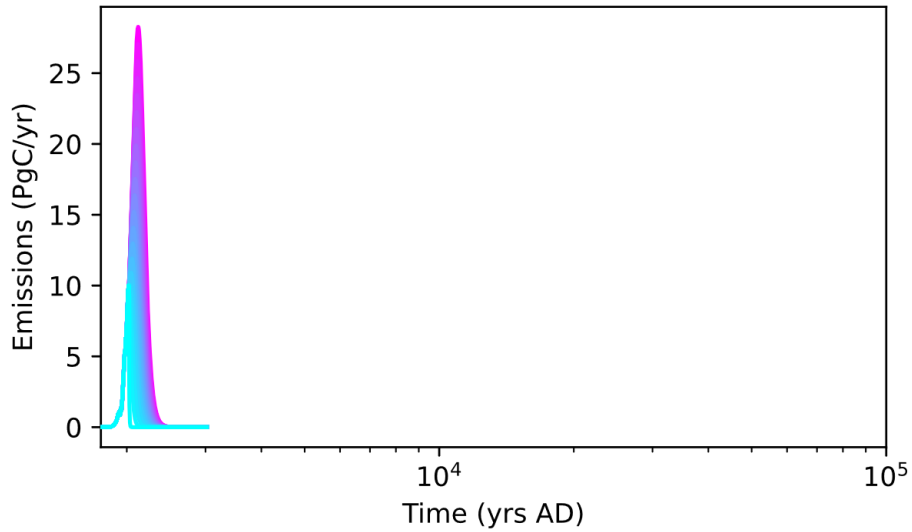
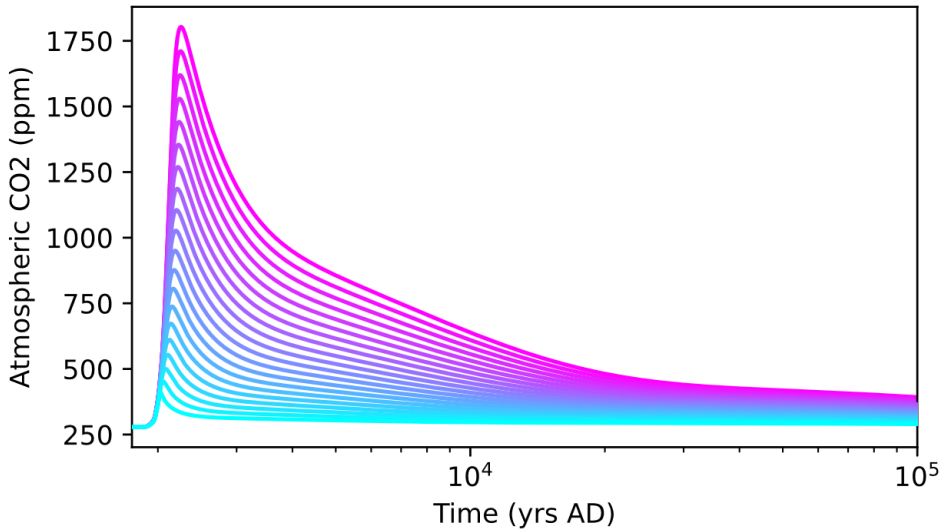
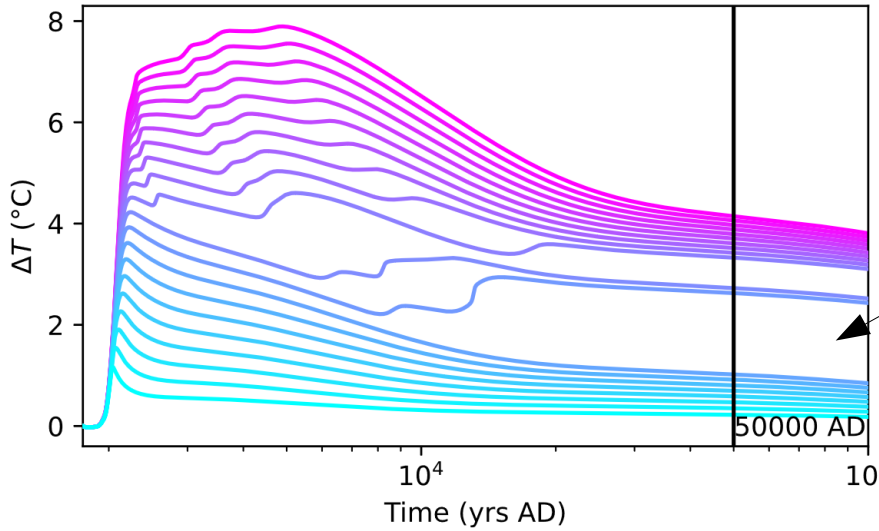
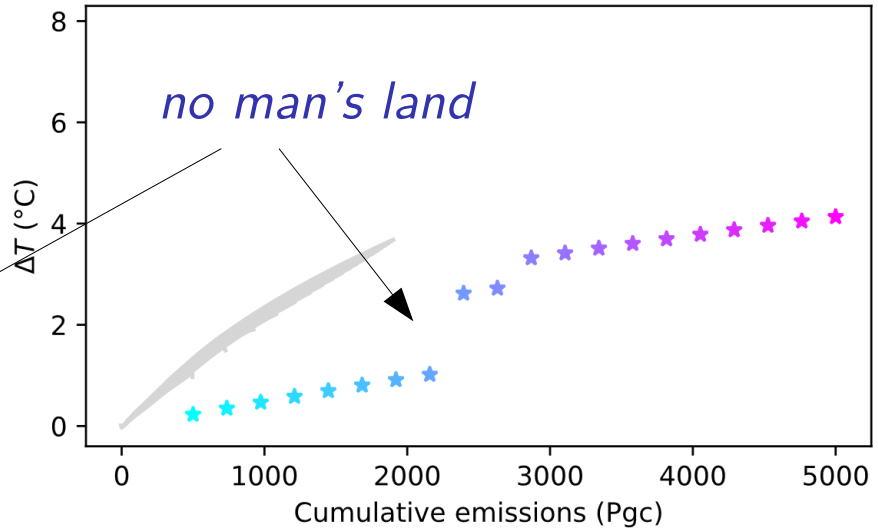
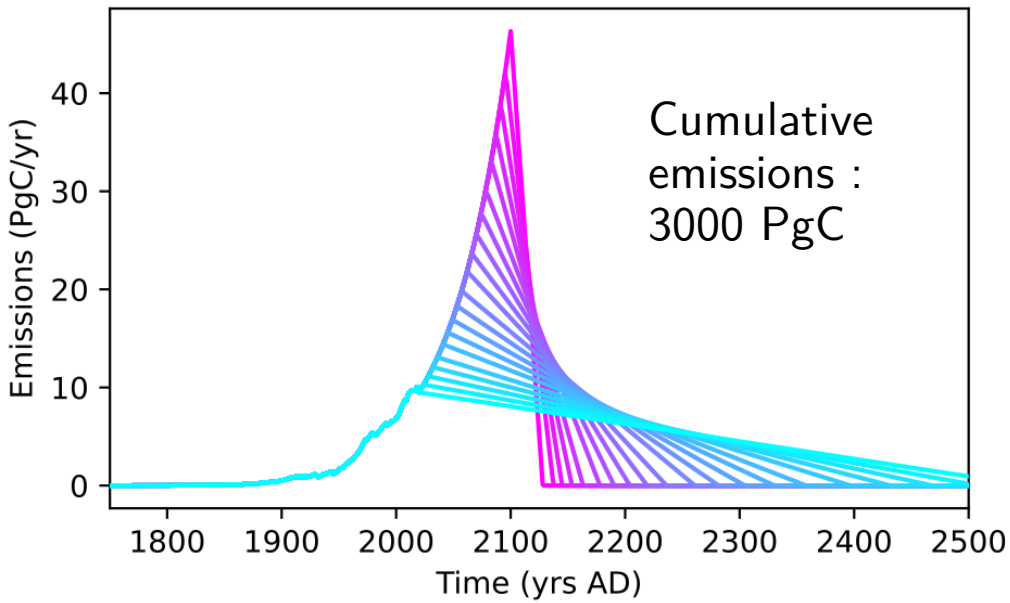


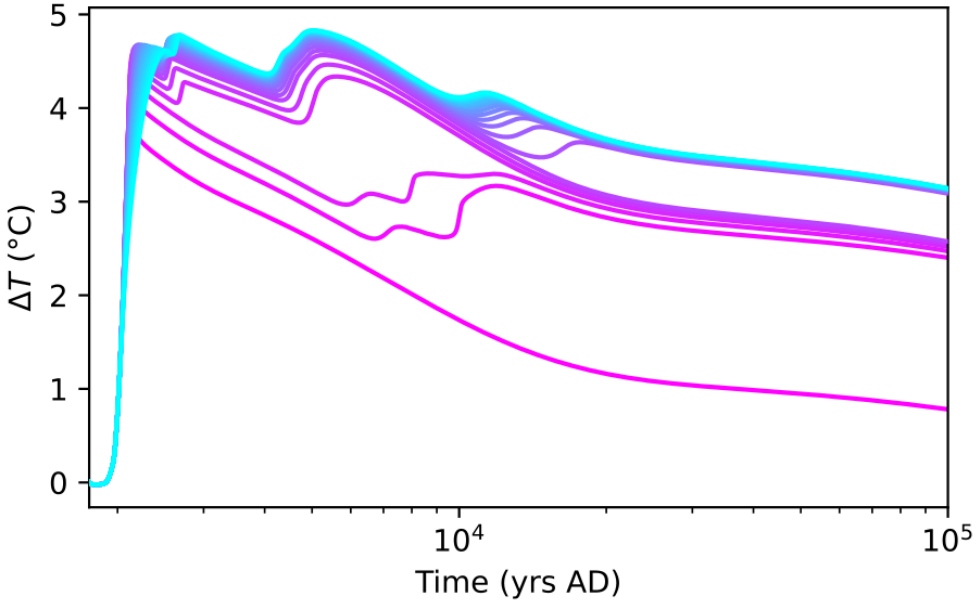






The longer-term trajectory also depends on the shape of the forcing scenario





What have we learnt from this toy model of interacting tipping elements ?

- Tipping cascades could lead to a *no man's land* in the long term temperature response of the climate.
- This is compatible with the predicted near linear relationship between GMT increase and cumulative emissions for the next century.
- The same carbon budget spent differently could lead to different tipping cascades.

Thank you !

Abstract and contact details

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