Uncertainties in climate economic models – a machine learning approach

Presentation for GDR Workshop "Interfaces dans le système climatique"

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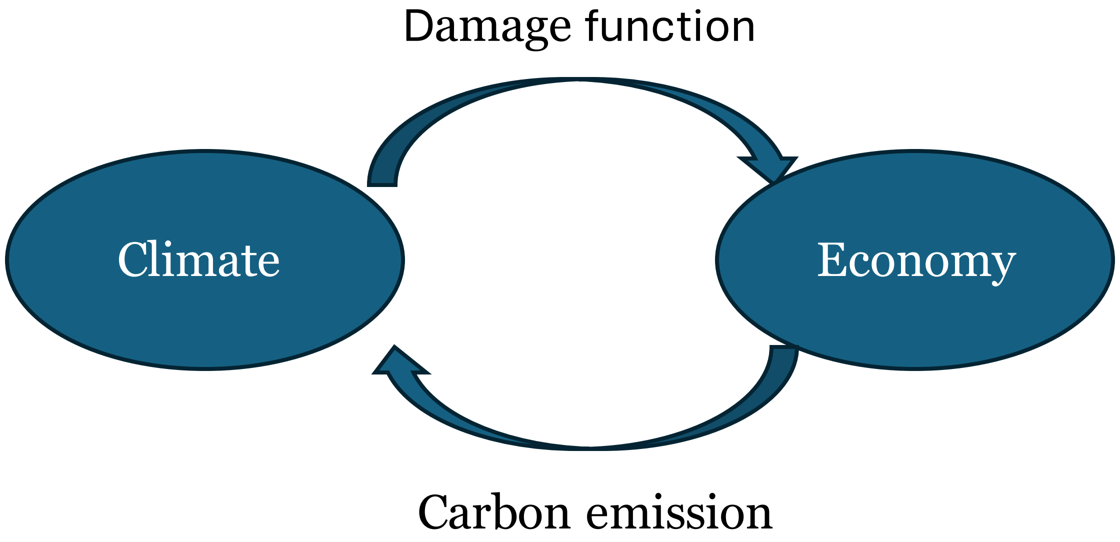
Scopes and Agenda

Context

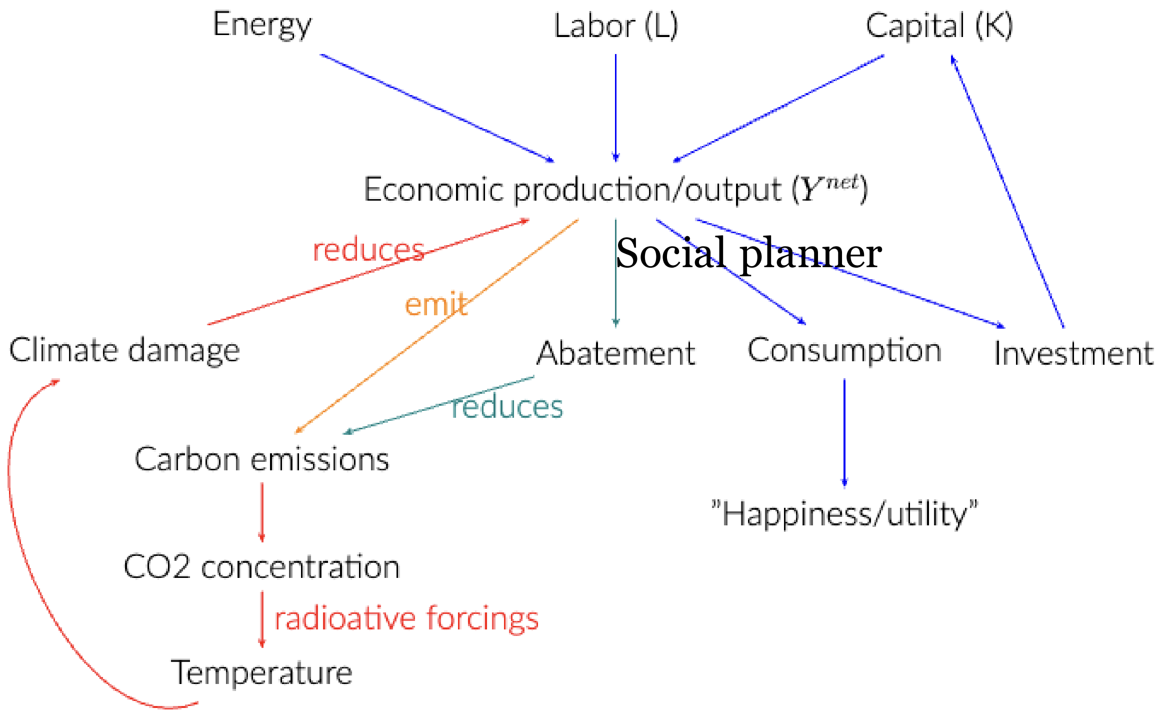
- Global scale modeling and yearly time scale
- Simple Climate Models (SCMs)
- Optimal control problem



Content

- DICE (Dynamic Integrated Climate Eonomic) Model by William Nordhaus
- Update in DICE 2024: From Energy Balance Model to FAIR model
- Bayesian FAIR model
- Conclusion and perspectives

DICE (Dynamic Integrated Climate Eonomic) Model



- 3 boxes for carbon Masses **M**(t)
- 2 layers for temperature **T**(t)

$$\mathbf{M} = \begin{bmatrix} M^{\mathrm{AT}} \\ M^{\mathrm{UO}} \\ M^{\mathrm{LO}} \end{bmatrix}, \mathbf{T} = \begin{bmatrix} T^{\mathrm{AT}} \\ T^{\mathrm{OC}} \end{bmatrix}$$

Continuous-time DICE formulation

$$\max_{C(t),\mu(t)} \int_{t=t_0}^{\infty} \frac{U(t)}{(1+\rho)^t} dt, \quad \text{where} \quad U(t) = L(t) \left(\frac{\left(\frac{C(t)}{L(t)}\right)^{1-\alpha} - 1}{1-\alpha} \right)$$

subject to

$$\frac{\partial \mathbf{M}(t)}{\partial t} = \mathbf{B}\mathbf{M}(t) + \mathbf{B}_E \left(\underbrace{\Gamma(t)(1-\mu(t))Y^{net}(t)}_{\text{Industrial emission}} + E^{LAND}(t) \right), \tag{1}$$

$$\frac{\partial \mathbf{T}(t)}{\partial t} = \mathbf{C}_{\mathrm{T}}\mathbf{T}(t) + \left(F_{2x} \frac{\log\left(\frac{M^{\mathrm{AT}}(t)}{M^{\mathrm{AT}}_{\mathrm{EQ}}}\right)}{\log(2)} + F^{EX}(t) \right), \tag{2}$$

$$\frac{\partial K(t)}{\partial t} = \log(1-\delta_K)K(t) + \underbrace{\left(1 - \Lambda_t \mu(t)^{\alpha_{abate}} - \psi_2 \left(T^{\mathrm{AT}}(t)\right)^2\right) Y^{net}(t) - C(t)}_{\text{Investment}} \tag{3}$$

$$\ldots \tag{4}$$

DICE (Dynamic Integrated Climate Eonomic) Model

- 3 boxes for carbon Masses **M**(t)
- 2 layers for temperature **T**(t)

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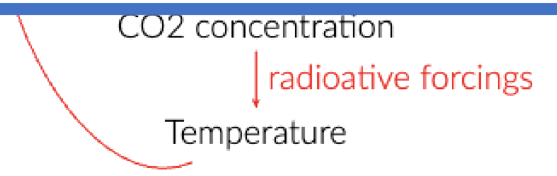
PREVIOUS ARTICLE NEXT ARTICLE

Are Economists Getting Climate Dynamics Right and Does It Matter?

Simon Dietz, Frederick van der Ploeg, Armon Rezai, and Frank Venmans



Industrial emission

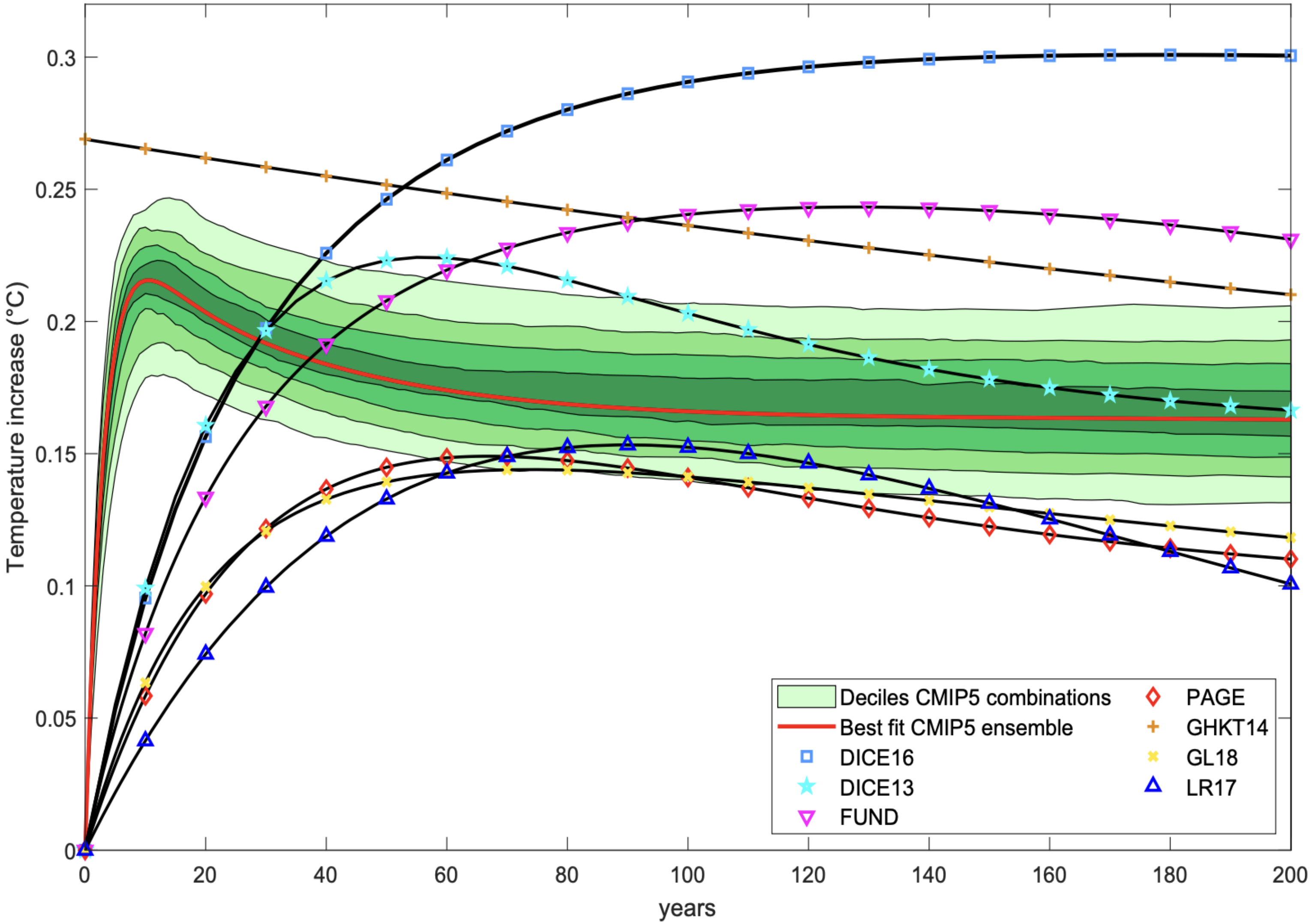
$$\frac{\partial \mathbf{T}(t)}{\partial t} = \mathbf{C}_T \mathbf{T}(t) + \left(F_{2x} \frac{\log\left(\frac{M^{AT}(t)}{M^{AT}_{EQ}}\right)}{\log(2)} + F^{EX}(t) \right), \quad (2)$$

$$\frac{\partial K(t)}{\partial t} = \log(1-\delta_K)K(t) + \underbrace{\left(1 - \Lambda_t \mu(t)^{\alpha_{abate}} - \psi_2 \left(T^{AT}(t)\right)^2\right) Y^{net}(t) - C(t)}_{\text{Investment}} \quad (3)$$

$$\ldots \quad (4)$$

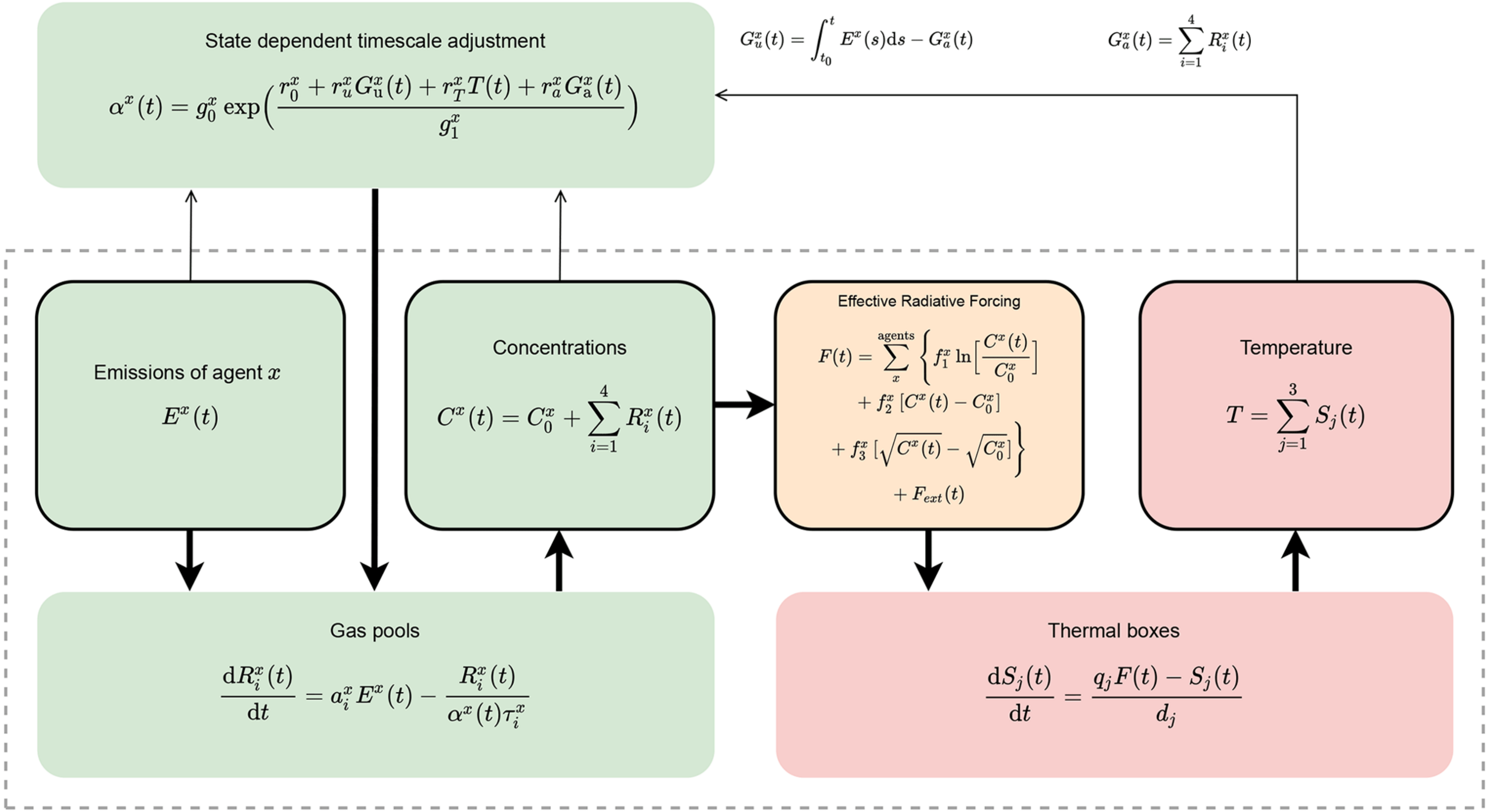
Dietz, S., van der Ploeg, F., Rezai, A., & Venmans, F. (2021). Are economists getting climate dynamics right and does it matter?. *Journal of the Association of Environmental and Resource Economists*, *8*(5), 895-921.

Are Economists Getting Climate Dynamics Right?



Dietz, Simon & Ploeg, Frederick & Rezai, Armon & Venmans, Frank. (2020). Are Economists Getting Climate Dynamics Right and Does it Matter?. SSRN Electronic Journal. 10.2139/ssrn.3545718.

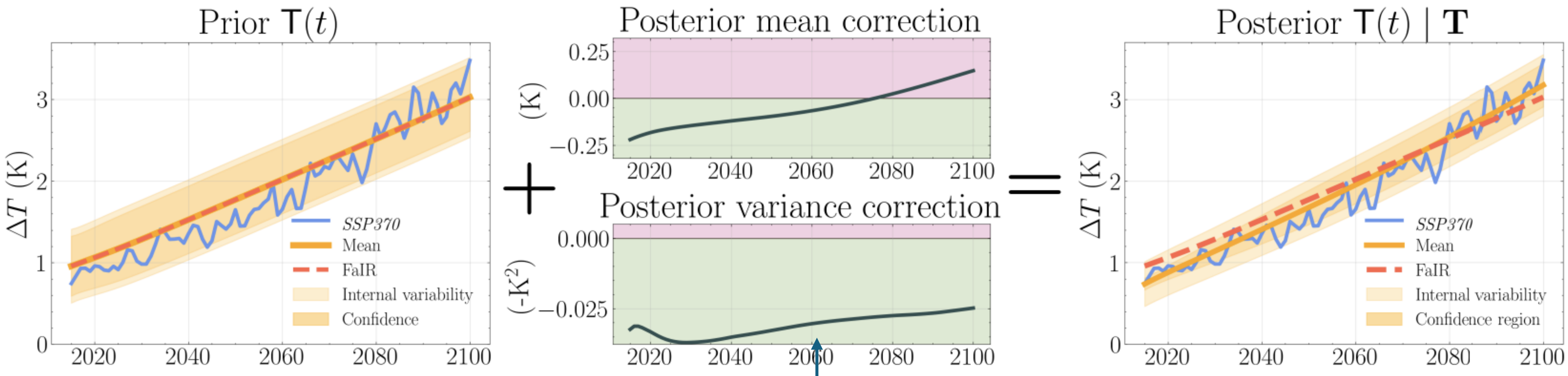
Update in DICE 2024: From Energy Balance Model to FAIR model

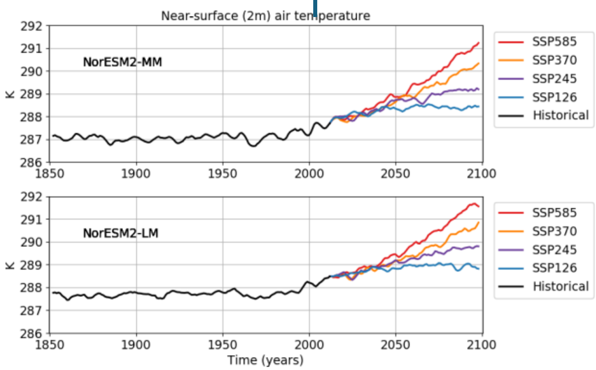


Leach, Nicholas & Jenkins, Stuart & Nicholls, Zebedee & Smith, Chris & Lynch, John & Cain, Michelle & Walsh, Tristram & Wu, Bill & Tsutsui, Junichi & Allen, Myles. (2021). FaIRv2.0.0: A generalized impulse response model for climate uncertainty and future scenario exploration. Geoscientific Model Development. 14. 3007-3036. 10.5194/gmd-14-3007-2021.

Bayesian FAIR model: Using Gaussian processes

$$\begin{bmatrix} \mathsf{f}(t_1) \\ \mathsf{f}(t_2) \end{bmatrix} \sim \mathcal{N}\left(\begin{bmatrix} m(t_1) \\ m(t_2) \end{bmatrix}, \begin{bmatrix} k(t_1, t_1) & k(t_1, t_2) \\ k(t_2, t_1) & k(t_2, t_2) \end{bmatrix} \right).$$

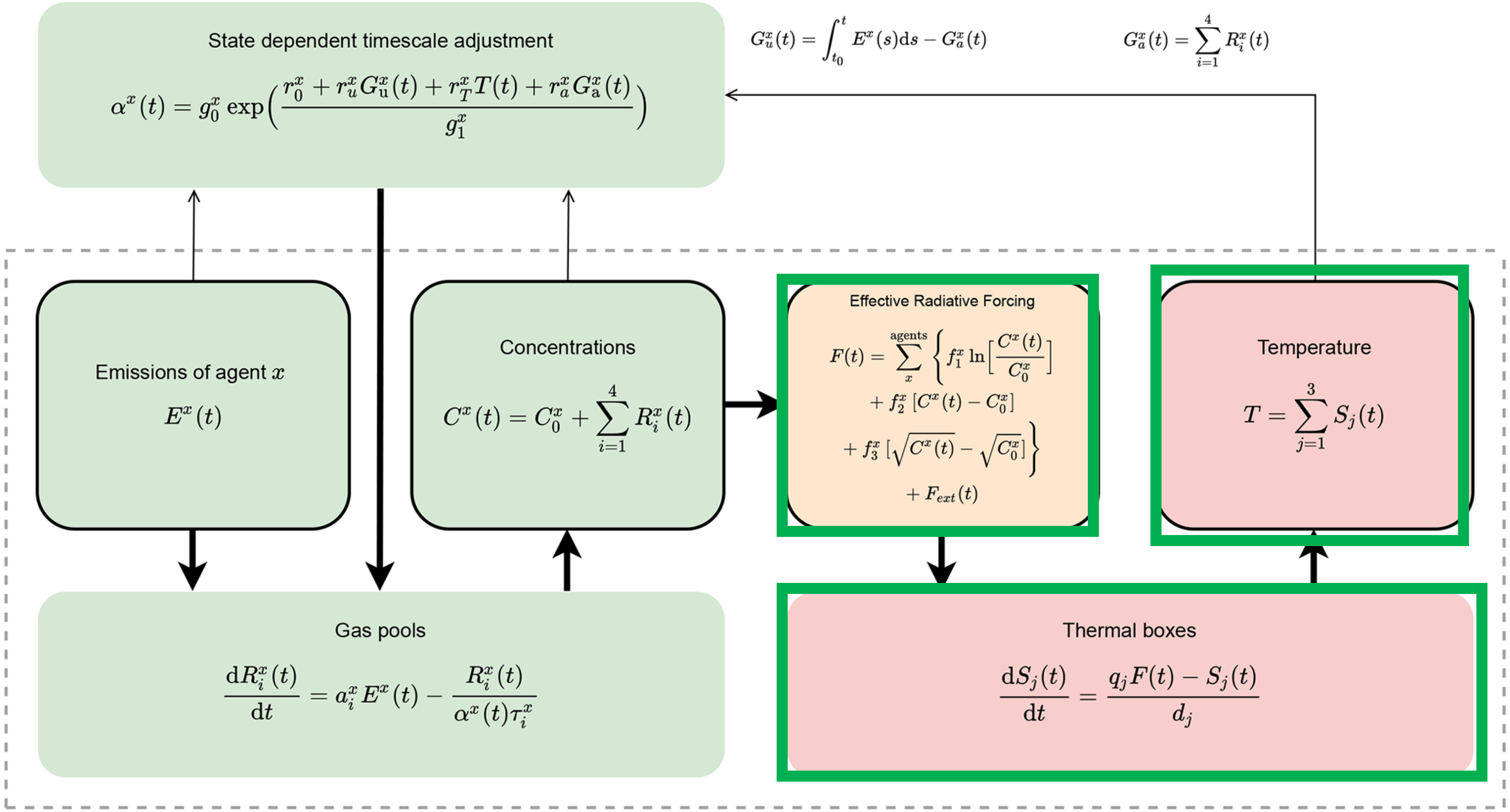




Bouabid S, Sejdinovic D, Watson-Parris D. FaIRGP: A Bayesian Energy Balance Model for Surface Temperatures Emulation[J]. arXiv preprint arXiv:2307.10052, 2023.

Summary

- Epistemic uncertainty in climate models used for climate-economic models need to be quantified
- Bayesian approach is already implemented for FAIR model uncertainty quantification but only partially



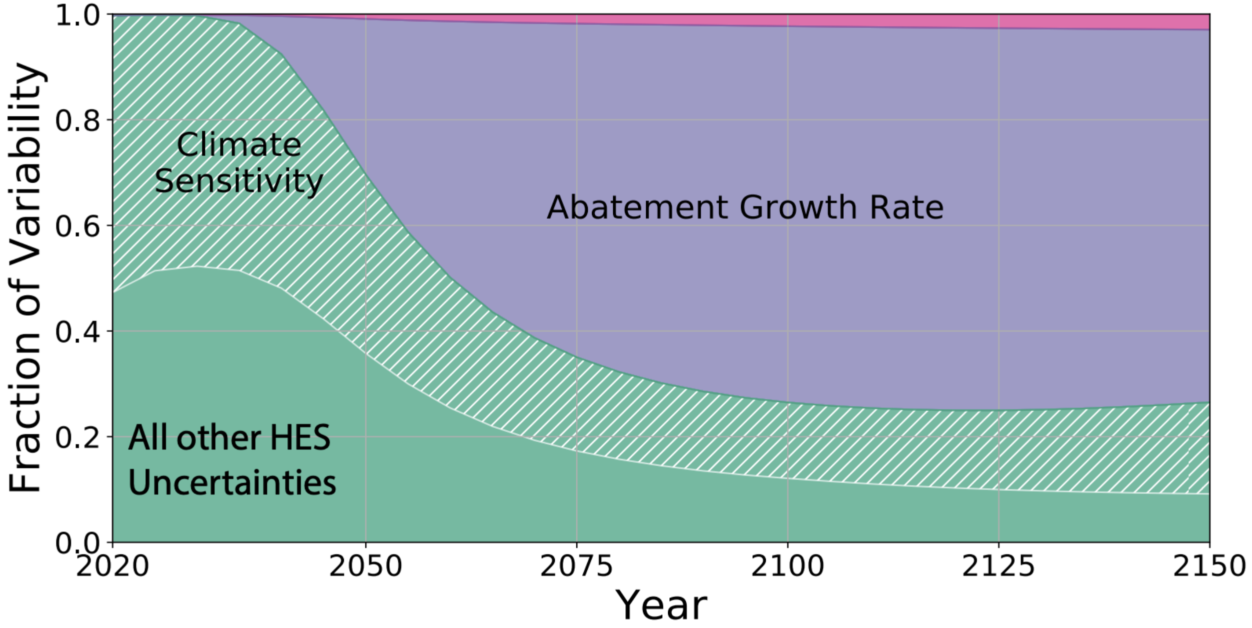
Thank you for your attention! Questions?

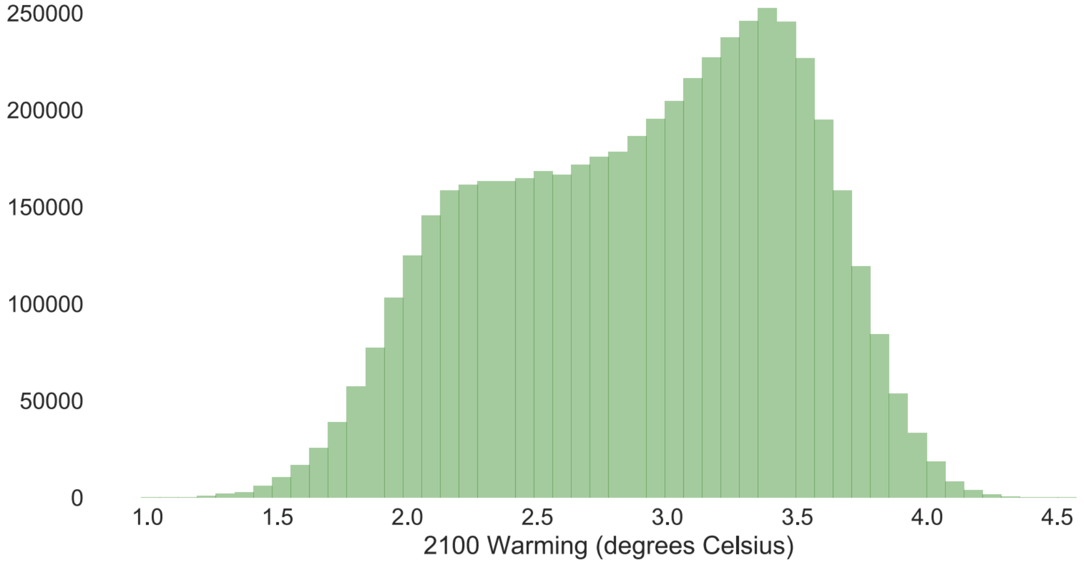
And Does it Matter?

nature climate change
LETTERS
https://doi.org/10.1038/s41558-019-0426-8

Robust abatement pathways to tolerable climate futures require immediate global action

J. R. Lamontagne[1*], P. M. Reed[2], G. Marangoni[3,6], K. Keller[3,4] and G. G. Garner[5]





- How to study parameter uncertainties of the climate model?
- Simulations vs Stochastic Optimal control?

Appendix

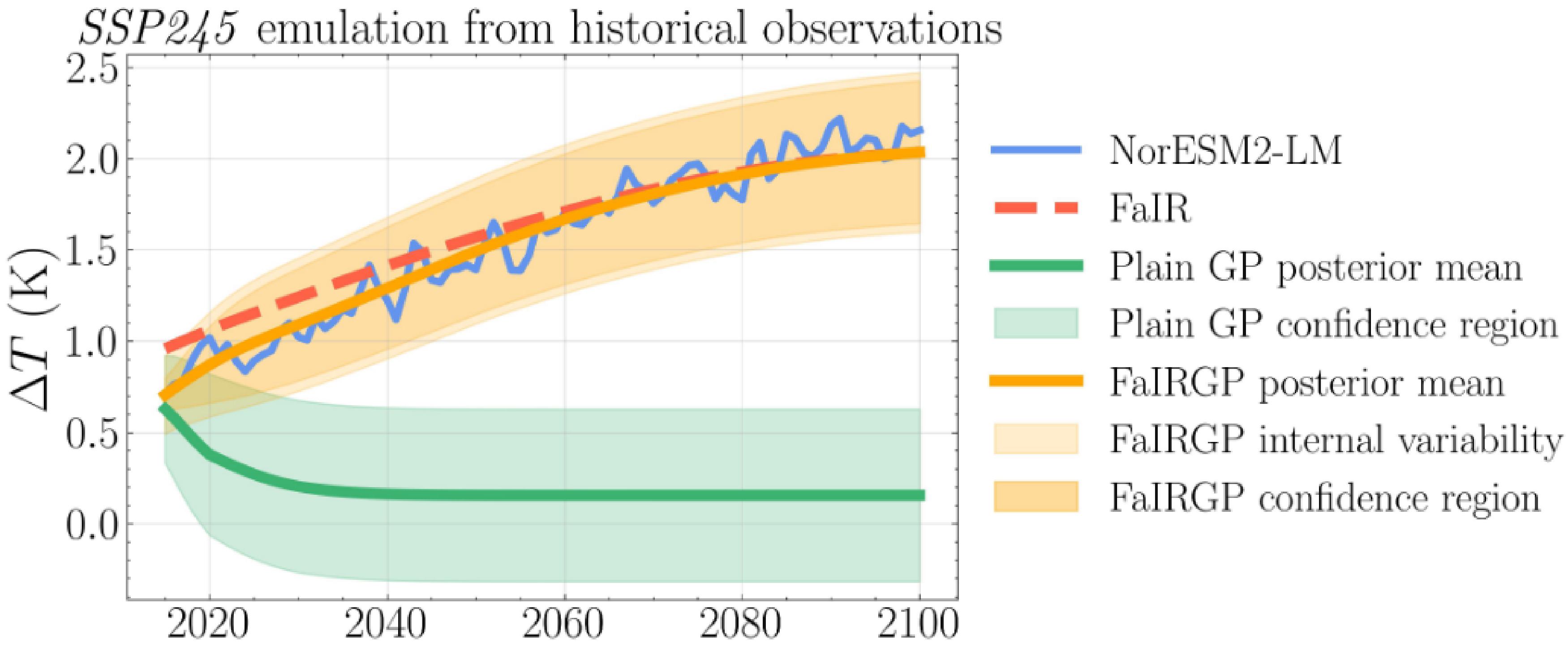


Figure 13: Emulated global mean surface temperature anomaly over 2015-2100 for the *SSP245* scenario with emulators trained over historical temperatures only.

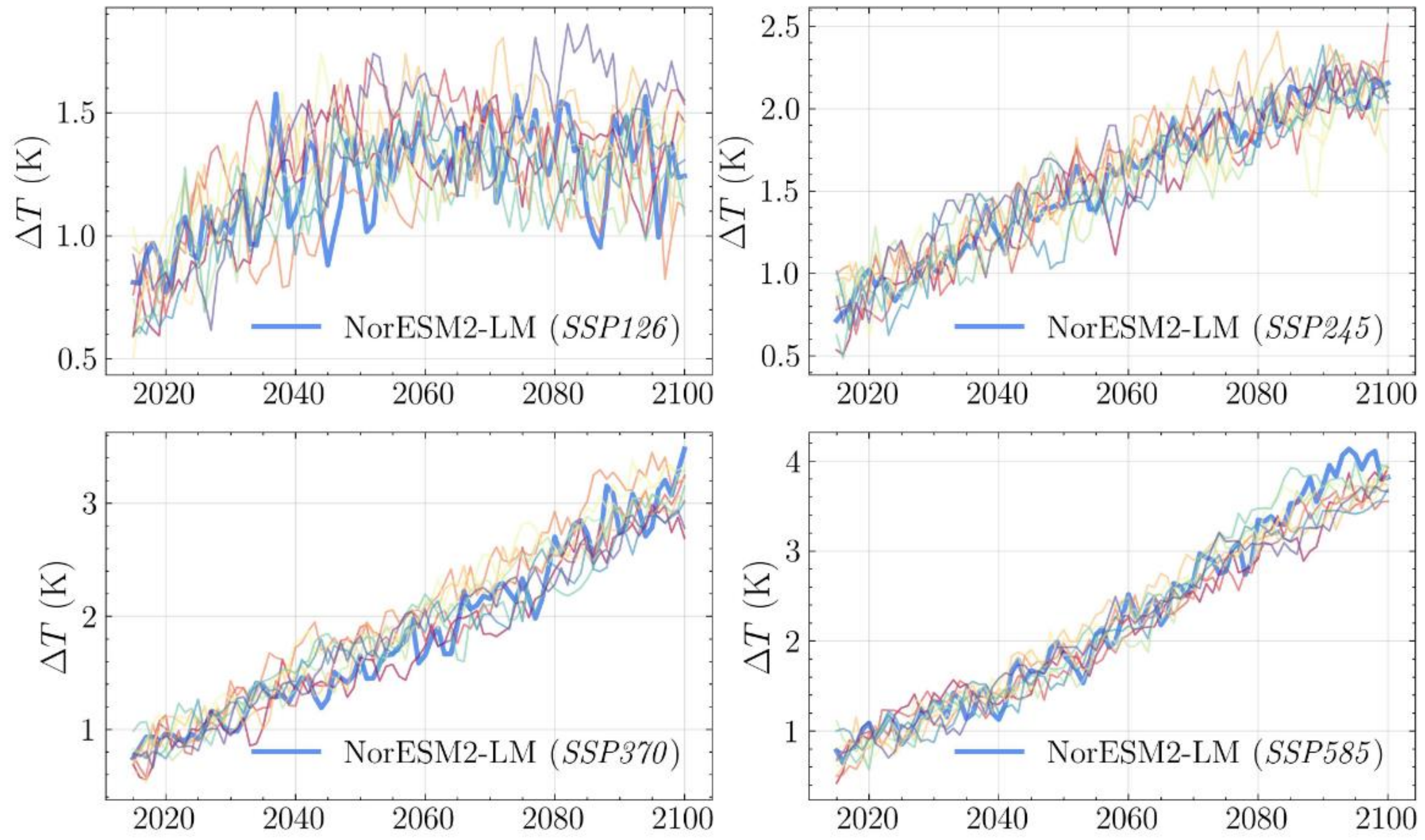


Figure 12: Example of sample paths from the FaIRGP posterior for the emulation of *SSP126* (top-left), *SSP245* (top-right), *SSP370* (bottom-left) and *SSP585* (bottom-right) global mean surface temperature anomaly over the 2015-2100 period.