This presentation participates in OSPP

Outstanding Student & PhD candidate Presentation Contest

Dynamics of the Earth energy budget with a variable climate feedback parameter

Robin Guillaume-Castel

Benoit Meyssignac, Rémy Roca, Jonathan Chenal

The Earth Energy Budget

$$N = \Delta F + \Delta R$$

- Linear radiative response approximation

$$N = \Delta F + \lambda \Delta T_S$$

- We know that λ varies with time
  - λ depends on the type and magnitude of forcing
  - λ depends on the mean surface temperature
  - λ depends on the pattern of temperature warming: pattern effect

- How to include $\lambda(t)$ in an energy balance model?

In the literature

- Usual approach:

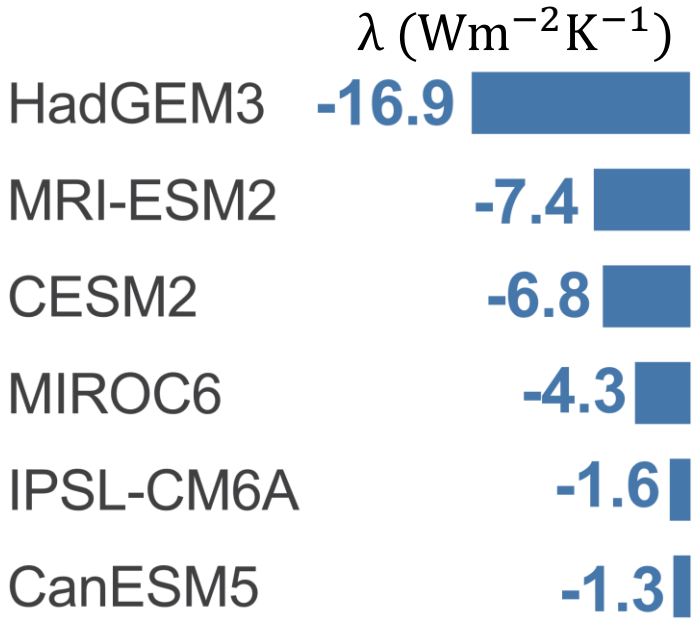
$$N = \Delta F + \lambda(t)\Delta T_S \quad (\Delta R)$$

With $\lambda(t) = \frac{\Delta R}{\Delta T_S}$

$$\Delta R \propto \Delta T_S$$

- What if $\Delta T_S \sim 0$ but λ varies?

~~$\Delta R \sim 0$?~~



Theoretical development

- Going back from Budyko (1968) $\mathrm{OLR} = \mathrm{A} + \mathrm{BT_S}$ with $\lambda(\mathrm{t}) = \lambda_0 + \Delta\lambda(\mathrm{t})$

$$\mathrm{N} \neq \Delta\mathrm{F} + \lambda(\mathrm{t})\Delta\mathrm{T_s}$$

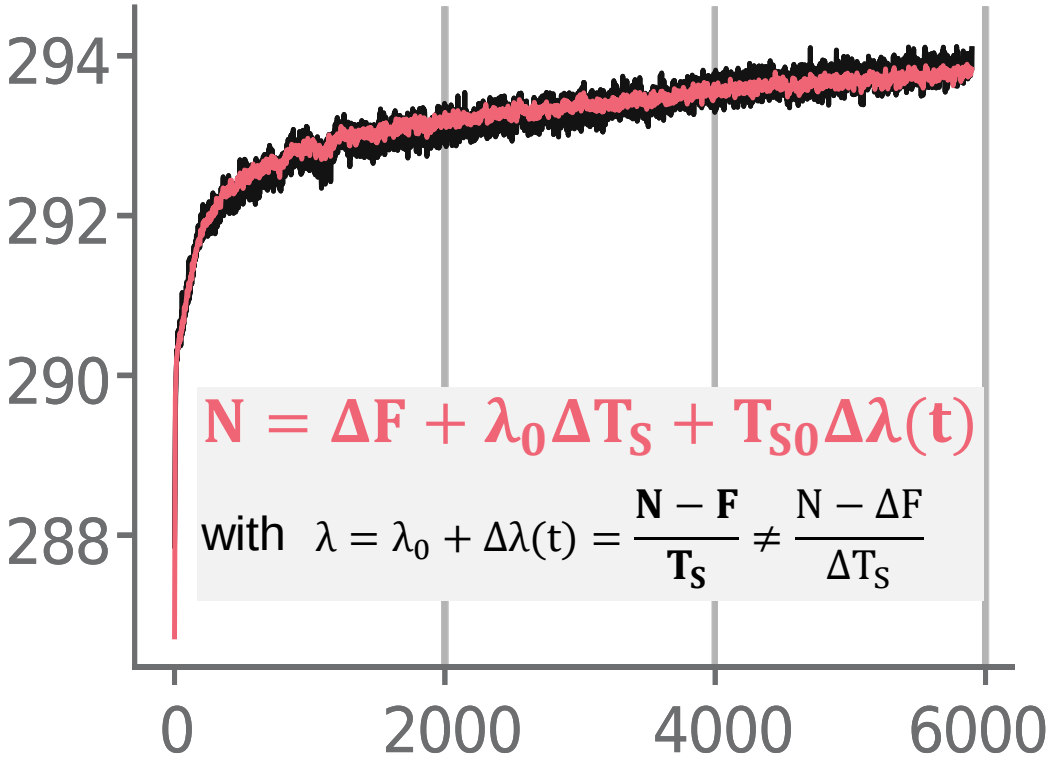
The correct energy balance model with $\lambda(\mathrm{t})$ is:

$$\mathrm{N} = \Delta\mathrm{F} + \lambda_0\Delta\mathrm{T_S} + \Delta\lambda(\mathrm{t})\mathrm{T_{S0}}$$

Validation

- **Reproducing Ts** ✓

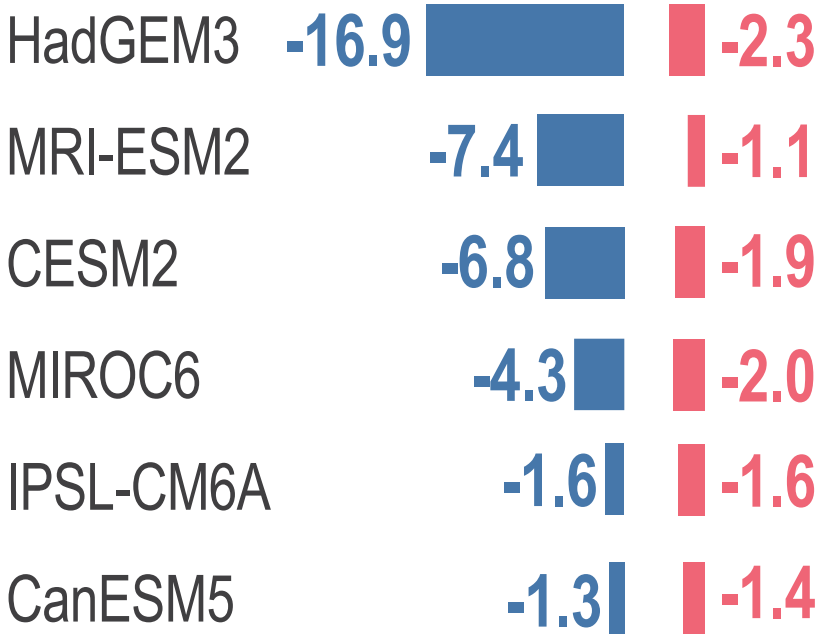
CESM104 abrupt4x CO2



- **Values of λ** (W/m²/K) ✓
  - Simulation with $\Delta T_S \sim 0$

$N = \Delta F + \lambda(t)\Delta T_S$

$N = \Delta F + \lambda_0 \Delta T_S + T_{S0}\Delta\lambda(t)$

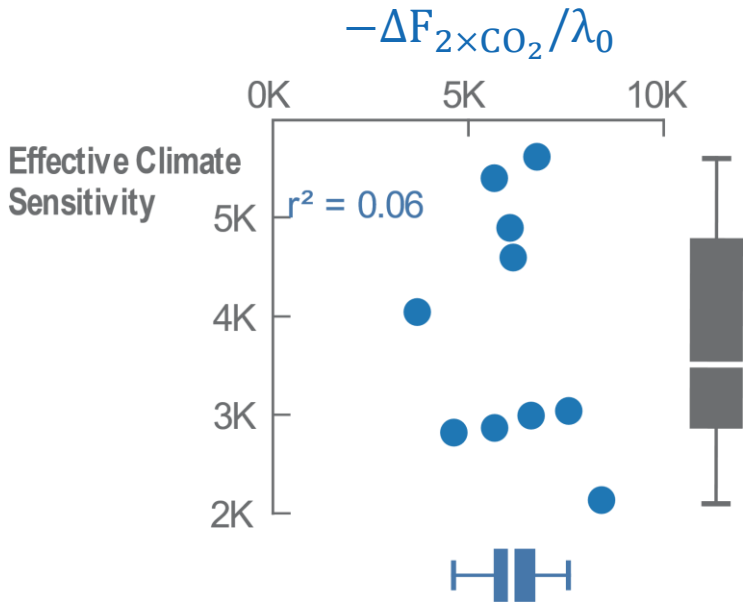


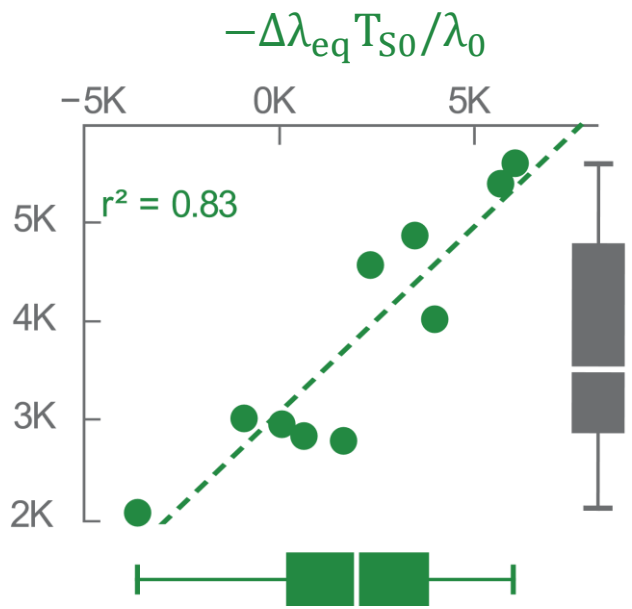
Application to the climate sensitivity

$$N = \Delta F + \lambda_0 \Delta T_S + \Delta\lambda(t) T_{S0}$$

$$ECS = -\frac{\Delta F_{2\times CO_2}}{\lambda_0} - \Delta\lambda_{eq}\frac{T_{S0}}{\lambda_0}$$

- Base state dependence: T_{S0}, λ_0
- Dependence on $\boldsymbol{\Delta\lambda_{eq}}$**: pattern effect**





Take away messages

- The correct EBM with a variable $\lambda(t)$ is $\mathbf{N = \Delta F + \lambda_0 \Delta T_S + T_{S0} \Delta \lambda(t)} \neq \mathbf{\Delta F + \lambda(t) \Delta T_S}$
- This EBM:
  1. Reproduces the T_S dynamics following abrupt-4xCO2 **at all time scales**
  2. Is consistent with experiments where $\Delta T_s = 0$
- We derived a new expression for ECS with an explicit dependence on $\Delta\lambda$:

$$ECS = -\frac{\Delta F}{\lambda_0} - \Delta\lambda_{eq} \frac{T_{S0}}{\lambda_0}$$

- The spread in climate sensitivity is explained by $\Delta\lambda_{eq} \frac{T_{S0}}{\lambda_0}$