EPFL

Exercise session #5

Science of Climate Change

Indicative Feedback

- Please go to IS-Academia and fill in the indicative feedback
- Thank you!

- Recap from lecture feedback mechanisms, climate sensitivity
- Exercises
- Questions on posters or assignment ?

Join at menti.com | use code 6531 8983

Mentimeter

Feedback mechanisms & Climate sensitivity

Welcome to the quiz !

Recap: Climate sensitivity

- Imagine that your home thermostat is installed very near your kitchen stove.
  - How would this affect the temperature in your home ?
  - Would the heat from the stove be considered a forcing or a feedback?
  - How do you think a home thermostat system might be similar to the way the earth controls its climate system?
  - Why are feedback loops so important in the climate system?

Connect to Memtimeter to answer

Recap: Climate sensitivity

- Imagine that your home thermostat is installed very near your kitchen stove.
  - How would this affect the temperature in your home ?
    - The rest of the house would be too cold as the thermostat would consider the air temperature near the stove as the global house temperature and reduce then the heating system.
  - Would the heat from the stove be considered a forcing or a feedback?
    - Forcing : impact a system (the heaters) from outside of that system (the stove is not designed to regulate the home temperature)
  - How do you think a home thermostat system might be similar to the way the Earth controls its climate system?
    - Forcing as the stove: anthropogenic activities that affect the global Earth temperature
    - Climate feedback as the thermostat : Earth climate system
  - Why are feedback loops so important in the climate system?
    - Feedback loops regulate and moderate earth's climate

Connect to Memtimeter to answer

Recap: Climate sensitivity

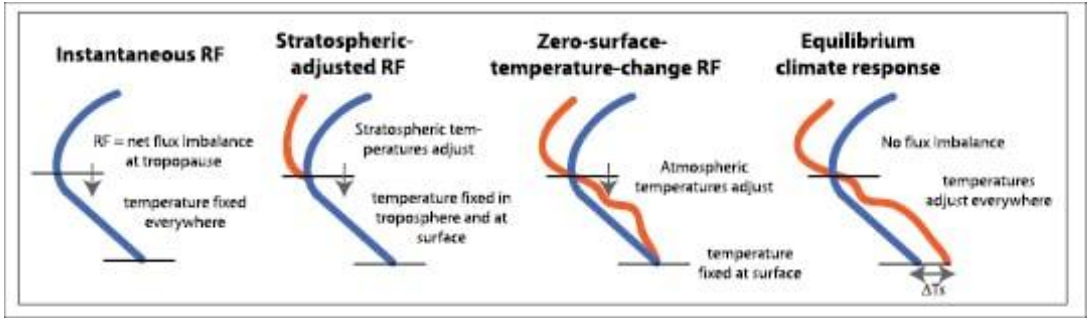
- Forcings affecting the Earth climate systems:
  - External
    - Solar insolation
  - Internal
    - Anthropogenic emissions of excess greenhouse gases
    - Excess aerosols due to fossil fuel burning or human activities (agriculture, forest fire, etc)
    - Human-induced land use change
    - Natural processes such as volcanic eruptions

The climate system reacts to changes in forcing through a response. This response can be amplified or damped through positive or negative feedbacks.

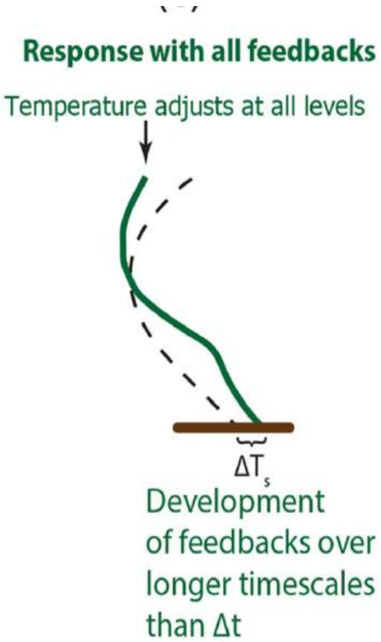
Connect to Memtimeter to answer

Heinze et al., 2019

Recap: radiative forcing and effective radiative forcing



Different definitions of **radiative forcing** depending on what we want to study.



Effective radiative forcing: once all rapid adjustments for temperature, water vapour, surface albedo, and clouds are taken into account in response to a change in a forcing agent (e.g., GHG concentrations.

https://archive.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-2.html

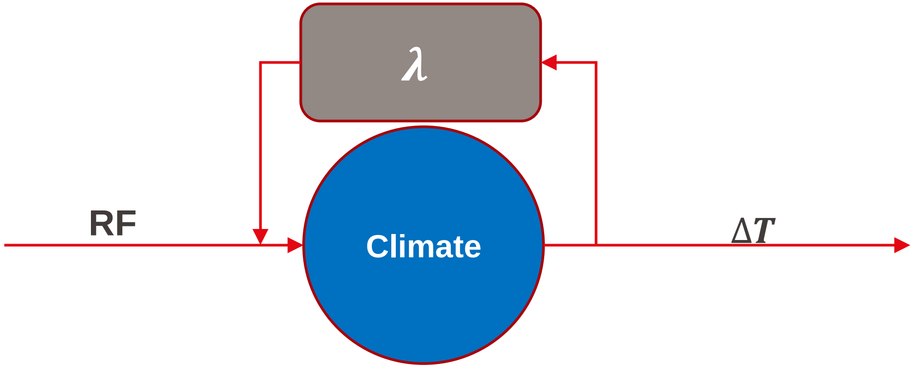
Heinze et al., 2019

Recap: Climate sensitivity and feedback mechanisms

From the lecture:

$$N = RF + \lambda \Delta T$$

N: net top of atmosphere energy balance,
RF: radiative forcing,
ΔT: global surface temperature response, climate sensitivity
λ : feedback factor



A negative feedback will amplify or dampen the response? → Dampen

A positive feedback will amplify or dampen the response ? → Amplify

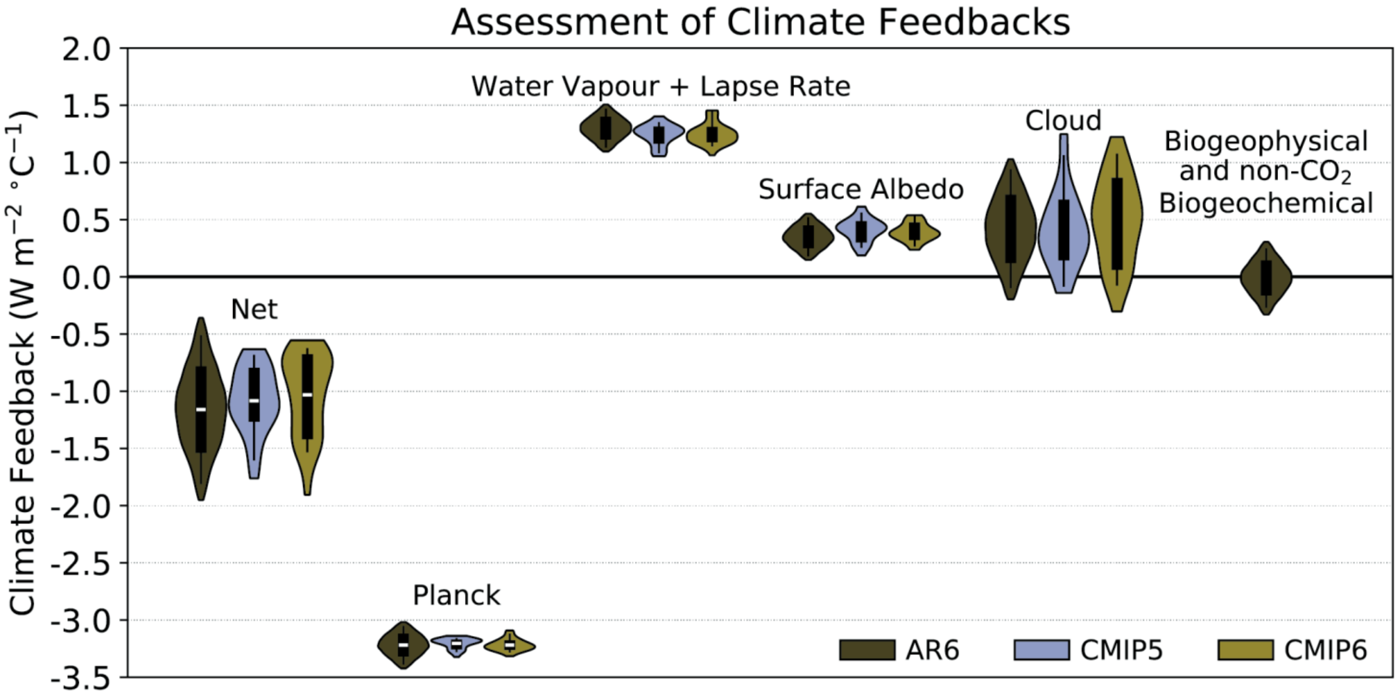
Recap: feedback mechanisms

- The Planck feedback
- The water vapor feedback
- The lapse rate feedback
- Cloud feedback
- The albedo feedback
- The ocean feedback
- Greenhouse gases

Connect to Memtimeter to answer

Summary of physical feedback factors

$$\lambda = \lambda_0 + \lambda_1 + \lambda_2 + \ldots = \sum_{i=0}^{n} \lambda_i$$



IPCC AR6, Fig 7.10

Plank Response

The Plank response is the single largest and negative feedback. It is based on the Stefan-Boltzmann law and tells that the energy radiated by a black body follows the temperature of the black body to the power of four:

$$F_B\,(T) = \sigma\, T^4$$

In other words, the amount of LW radiation emitted by the Earth will increase with temperature producing a negative feedback on the system.

Ex 1: energy balance model: a simple climate model

- At equilibrium of the system (from the lecture)

$$\boldsymbol{RF + \lambda * \Delta T_s = 0}$$

$$\boldsymbol{\Delta T_s = -\frac{RF}{\lambda}}$$

RF : radiative forcing
ΔT_s: global surface temperature response,
$\boldsymbol{\lambda}$: global feedback factor

- If contribution from different feedbacks are taking into consideration:

$$RF + \left(\lambda_0 + \sum_i \lambda_i\right)\Delta T_s = 0$$

λ_i: individual climate feedback (*i:* water vapor, lapse rate, clouds, albedo, etc.)
$\boldsymbol{\lambda_0}$: the Planck feedback
$\boldsymbol{\Delta T_s}$: surface temperature change
$\boldsymbol{RF}$: radiative forcings

Ex 1: energy balance model: a simple climate model

- For this exercise, three forcing types considered

$$F(\phi) = F_{RAD}(\phi) + F_{OHU}(\phi) + F_{AHT}(\phi)$$

ϕ: the latitude

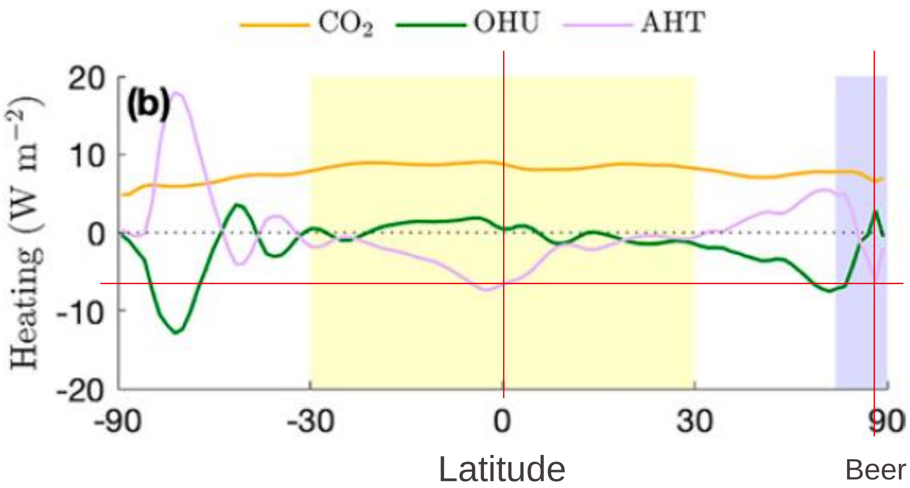
Perturbation in CO_2 forcing

Change in ocean heat uptake

Change in atmospheric heat transport

- Considering only the Planck feedback, calculate heating associated with each forcing
  - At the Equator
  - In the Arctic

- Comments your results.



Beer and Eisenman, 2022

Resp 1: heating associated with Planck response

- Considering the Planck feedback, the equation is :

$$\Delta T(\phi) = -\frac{F(\phi)}{\lambda_0}$$

ϕ: the latitude

- From the lecture $\lambda_0 = -3,3$ W m^{-2} K^{-1}
- From the previous figure

$F_{RAD}(0^{\circ}) = 9.5$ W m^{-2} $\Delta T_{RAD}(0^{\circ}) =$

$F_{RAD}(85^{\circ}) = 8$ W m^{-2} $\Delta T_{RAD}(85^{\circ})$

$F_{OHU}(0^{\circ}) = 0.1$ W m^{-2} $\Delta T_{OHU}(0^{\circ}) =$

$F_{OHU}(85^{\circ}) = 3$ W m^{-2} $\Delta T_{OHU}(85^{\circ})$

$F_{AHT}(0^{\circ}) = -6.5$ W m^{-2} $\Delta T_{AHT}(0^{\circ}) =$

$F_{AHT}(85^{\circ}) = -5.5$ W m^{-2} $\Delta T_{AHT}(85^{\circ}) =$

Calculate the temperature changes.

Resp 1: heating associated with Planck response

- Considering the Planck feedback, the equation is :

$$\Delta T(\phi) = -\frac{F(\phi)}{\lambda_0}$$

ϕ: the latitude

- From the lecture $\lambda_0 = -3{,}3$ W m^{-2} K^{-1}
- From the previous figure

$F_{RAD}(0^\circ) = 9.5$ W m^{-2} — $\Delta T_{RAD}(0^\circ) = 2.9$ °C

$F_{RAD}(85^\circ) = 8$ W m^{-2} — $\Delta T_{RAD}(85^\circ) = 2.4$ °C

$F_{OHU}(0^\circ) = 0.1$ W m^{-2} — $\Delta T_{OHU}(0^\circ) = 0.03$ °C

$F_{OHU}(85^\circ) = 3$ W m^{-2} — $\Delta T_{OHU}(85^\circ) = 0.9$ °C

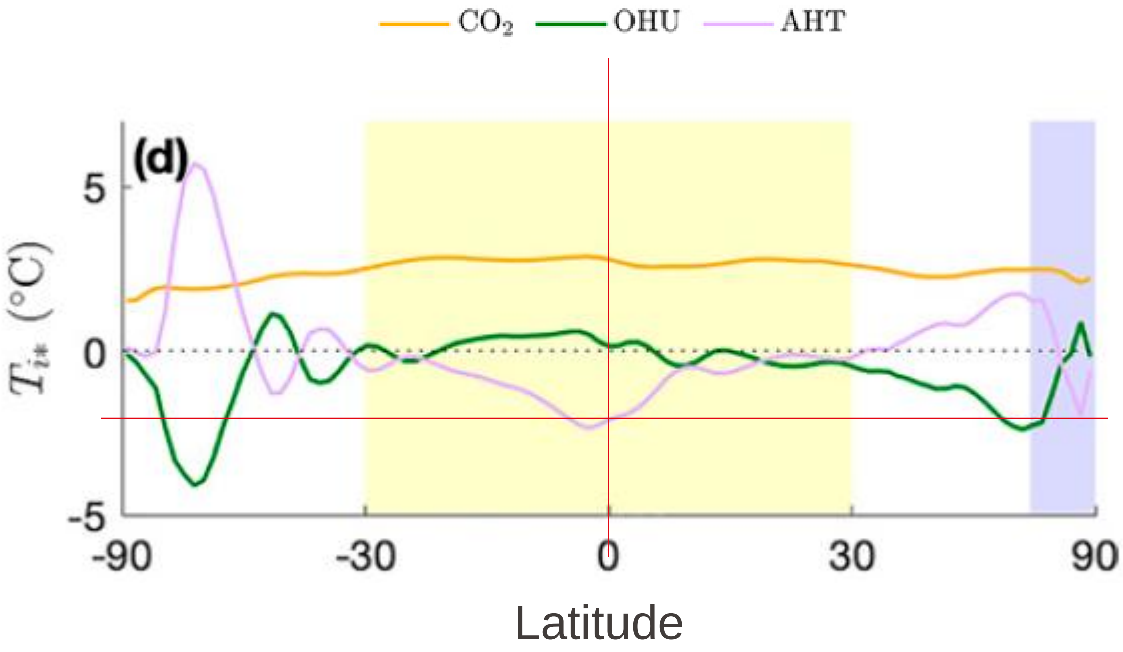
$F_{AHT}(0^\circ) = -6.5$ W m^{-2} — $\Delta T_{AHT}(0^\circ) = -2$ °C

$F_{AHT}(85^\circ) = -5.5$ W m^{-2} — $\Delta T_{AHT}(85^\circ) = -1.7$ °C

Comments:

Radiative forcing from CO_2 is higher than the ocean and atmosphere heat transport at the equator and in the Arctic

Resp 1: verify the calculations on the plot



Beer and Eisenman, 2022

Ex 2: Arctic amplification

- Discuss the physical mechanisms contributing to arctic amplification, and if they are positive, negative, or positive and negative.

Table 1. Synthesis of physical mechanisms. For each of the mechanisms listed, *N* indicates the total number of studies that assessed the contribution of that mechanism to AA. The percentages of *N* that are positive (mechanism contributes to AA), negative (mechanism opposes AA), and positive or negative (mechanism either contributes to or opposes AA) are also given.

Physical mechanism	*N*	% +	% −	% ±
CO_2 forcing	29			
Temperature feedbacks	34			
Planck response	23			
Lapse rate feedback	29			
Surface albedo feedbacks	81			
Sea ice albedo/insulation effects	66			
Other surface albedo feedbacks	35			
Cloud feedbacks	40			
Water vapor feedbacks	37			
Surface evaporation feedbacks	10			
Biosphere feedbacks	8			
Atmospheric PET changes	78			
Oceanic PET changes	28			

Previdi et al., 2021

Resp 3: Arctic amplification

Table 1. Synthesis of physical mechanisms. For each of the mechanisms listed, *N* indicates the total number of studies that assessed the contribution of that mechanism to AA. The percentages of *N* that are positive (mechanism contributes to AA), negative (mechanism opposes AA), and positive or negative (mechanism either contributes to or opposes AA) are also given.

Physical mechanism	*N*	% +	% −	% ±
CO_2 forcing	29	34	48	18
Temperature feedbacks	34	100		
Planck response	23	100		
Lapse rate feedback	29	100		
Surface albedo feedbacks	81	100		
Sea ice albedo/insulation effects	66	100		
Other surface albedo feedbacks	35	100		
Cloud feedbacks	40	55	25	20
Water vapor feedbacks	37	32	62	6
Surface evaporation feedbacks	10	90		10
Biosphere feedbacks	8	88		12
Atmospheric PET changes	78	78	8	14
Oceanic PET changes	28	75	11	14

Previdi et al., 2021