Forced and unforced pattern effects in the climate feedback in MIROC6

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Key points

We estimate relative role of forced and unforced pattern effects in the global temperature change from early 20th century to the end of 21st century, by using 50-member large ensemble simulations with MIROC6.

In MIROC6, unforced pattern effect cause a diversity of EffCS by 1K for 1970-2014. It eventually reduces in the future projection, yet the effect is still significant in weakening the global warming.

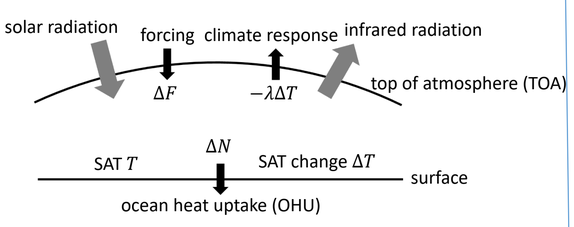
Forced pattern effect varies in its strength by the 1990s, due probably to aerosol forcing, but is nearly identical with that in the 4xCO2 experiment afterwards.

1. Introduction

Energy budget

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

- N is net downward radiative flux at TOA
- F is effective radiative forcing (ERF)
- λ is climate feedback parameter
- T is surface air temperature (SAT)
- Δ means difference from pre-industrial (PI)



Climate sensitivity

- ✓ Equilibrium climate sensitivity (ECS) is the temperature increase when the system reaches equilibrium ($\Delta N = 0$) after CO2 doubling or quadrupling
- ✓ Effective climate sensitivity (EffCS) is calculated by the Gregory method

$\mathrm{EffCS} = -\frac{F_{2x}}{\lambda}$ F_{2x} is ERF due to doubling of CO2

Pattern effect

- ✓ Pattern effect represents processes altering λ in time, depending on the surface warming pattern
- ✓ It consists of *forced pattern effect* arising from the radiatively forced responseand *unforced pattern effect* caused by internal variability in the climate system

2. Data & method

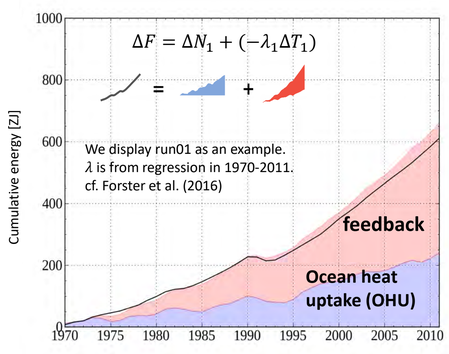
Data

We mainly use 50-member ensemble simulations by MIROC6
ERF is estimated from RFMIP, and assumed to be identical for all members

	MIP	experiment	period	number of members	
CGCM	DECK	historical	1850 - 2014	50	
		abrupt-4xCO2	250 years	1	abrupt CO2 quadrupling
		1pctCO2	1000 years	1	1%/yr CO2 ramping
		piControl	150 years	1	pre-industrial control run
	ScenarioMIP	SSP2-4.5	2015 - 2100	50	medium emission scenario
AGCM	RFMIP	piClim-control	1850 - 1879	1	SST is fixed. Forcing is fixed.
		piClim-histall	1850 - 2100	3	SST is fixed. Forcing varies.
	CFMIP	amip-piForcing	1870 - 2014	1	SST varies. Forcing is fixed.

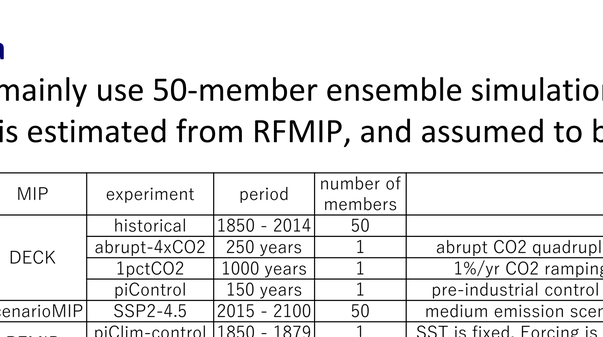
Is historical energy budget closed?

YES → We can use forcing estimated from RFMIP simulations to historical and SSP simulations



How to estimate forced & unforced feedbacks?

(1) We apply the global energy budget equation to each member
(2) The forced component of climate feedback parameter is obtained by applying the energy balance equation to the response of the ensemble mean
(3) Feedback due to internal variability is obtained as their difference



Run01, 1970-2014 $\lambda_1' = -0.42$ W/m²/K

TOA energy budget for ith member

$$\Delta N_i = \Delta F + \lambda_i \Delta T_i$$

TOA energy budget for the ensemble mean

$$\langle \Delta N \rangle = \Delta F + \lambda_f \langle \Delta T \rangle$$

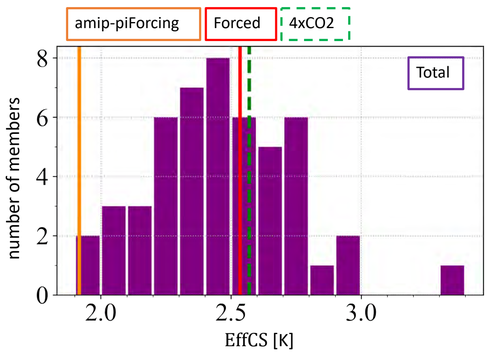
We define λ_f as the forced feedback parameter, and the unforced feedback, λ_i', is simply

$$\lambda_i' = \lambda_i - \lambda_f$$

3. EffCS & feedback

- ✓ EffCS from historical simulations ranges widely by about 1K, due solely to unforced pattern effect
- ✓ A weak climate feedback based on observed SST (amip-PF) can occur as one realization of the ensemble (at least in MIROC6)
- ✓ Forced climate feedback for 1970-2014 is very close to the net feedback estimated from 4xCO2

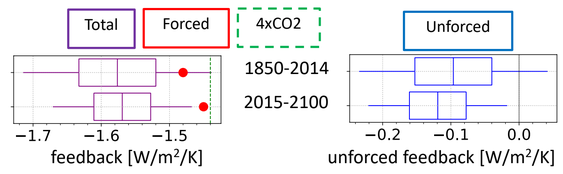
EffCS in 1970-2014 in MIROC6 LE



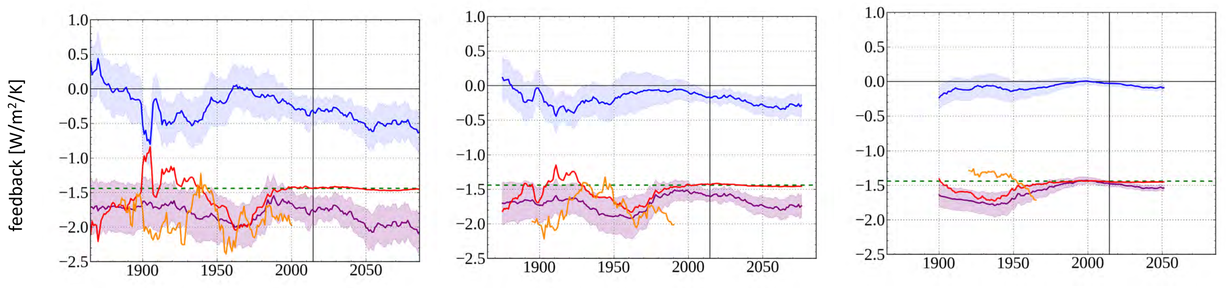
Feedback in 4xCO2 is from regression for 150yrs

- ✓ Total feedback in historical+SSP is more negative than the feedback in 4xCO2 due to a negative unforced feedback

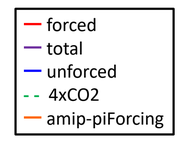
Feedback in historical and SSP2-4.5



30-year window | 50-year window | 100-year window

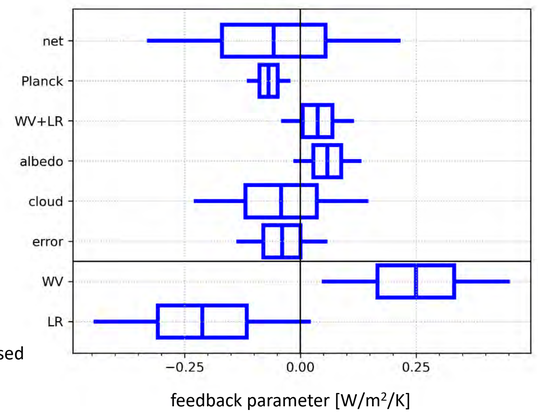


- ✓ Ensemble mean of unforced feedback is negative in most period
- ✓ Forced feedback after the 1990s is constant and nearly equal to the net feedback in 4xCO2, due probably to a weakening of aerosol radiative forcing



Unforced feedback decomposition for 1970-2014

- ✓ Unforced net feedback tends to be negative mainly because unforced Planck and cloud feedbacks are negative
  → Reason not clear

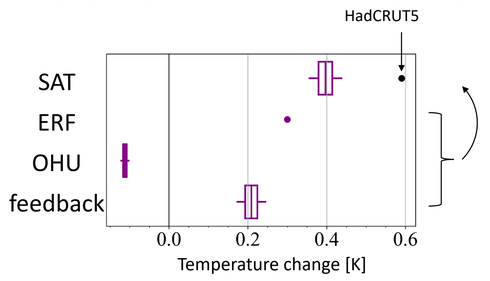


MIROC5 radiative kernel used

4. Contribution of feedback uncertainty

- ✓ MIROC6 underestimates the warming for 1970-2014
- ✓ Diff in warming level is explained primarily by the spread of feedback contribution

contribution to mean ΔT in 1970-2014 [K]



Method is based on Goosse et al. (2018)

5. Implication & future works

- ✓ Observational estimate of the feedback is more accurate using recent data
- ✓ Mechanisms responsible for the unforced feedback is not clear yet
- ✓ Analyses to LEs from other GCMs

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