GFDL | GEOPHYSICAL FLUID DYNAMICS LABORATORY

Influence of Forcing Strength on Estimates of ECS in GFDL CM4

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Concept/Motivation:

●Fully Coupled runs of GFDL CM4 (**CMIP6 model**) in response to instantaneous and historical/future changes in greenhouse gases and/or aerosol emissions.

● **Aim is to understand the ECS obtained from a range of radiative forcing strengths** with an emphasis on extending runs beyond the normal CMIP6 150-year period (**up to 450 years**), inspired by Longrunmip findings for CMIP3/CMIP5

Description of Fully Coupled Runs of GFDL CM4

Instantaneous

Run	Length	Description (all agents at 1850 level unless stated	Fixed SST Radiative Forcing (Wm^{-2})
4xCO2	300 years	CO2 fixed at 4 times the pre-industrial level	8.23
2xCO2	450 years	CO2 fixed at 2 times the pre-industrial level	4.10
2014GHG	450 years	Well Mixed Greenhouse Gases (no O3) fixed at 2014 values	3.14
2014AER	200 years	Anthropogenic Aerosol Emissions fixed at 2014 values	-0.73
1975AER	200 years	Anthropogenic Aerosol Emissions fixed at 1975 values	-0.98

Historical/Scenario (3 ensemble members each)

Run	Length	Description
ALL Historical+SSP245	1850-2100	All Forcing agents (Natural + Anthropogenic)
AER Historical+SSP245	1850-2100	Anthropogenic Aerosol Changes
GHG Historical+SSP245	1850-2100	Well Mixed Greenhouse Gas Changes

Control

Run	Length	Description
Control	500 years	All Forcing agents fixed at 1850

Comparing feedbacks across all runs

- The feedback parameter in transient and instantaneous runs can be written as, N-F = λ̄T.
- The AMIP, Historical/SSP245 and first 20-30 years of 2014GHG, 2xCO2 & 4xCO2 all have a feedback parameter of -1.6Wm^{-2}/K, implying a low ECS of ~2.6 K (red line **Fig 2**)
- Compared to this 2.6 K value….
- 2014GHG, 2xCO2 and 4xCO2 all have a higher ECS due to time-dependence of SWCRE (**Fig 3**) independent of forcing strength (**Fig 4**)
- 2014GHG and 2xCO2 have a larger change in ECS with time because of the non-linear SWCLR in 4xCO2 **(Fig 3**)
- 4xCO2 and 2xCO2 have a large ECS than 2014GHG due to the LWCRE being dependent upon forcing strength(**Fig 3**)
- For 2xCO2 the feedback shift from -1.6Wm^{-2}/K to -0.26 Wm^{-2}/K is due to a 1 Wm^{-2}/K in SWCRE, 0.2Wm^{-2}/K in LWCRE 0.1Wm^{-2}/K in LWCLR

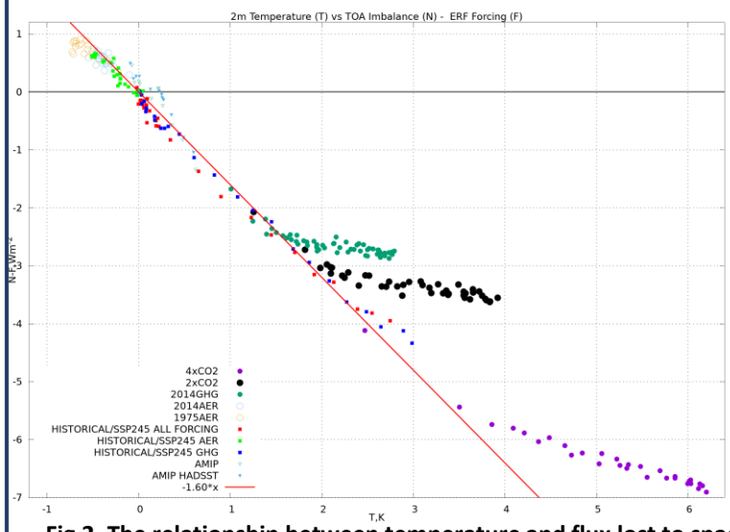

Fig 2. The relationship between temperature and flux lost to space (N-F) for instantaneous and transient runs of GFDL CM4

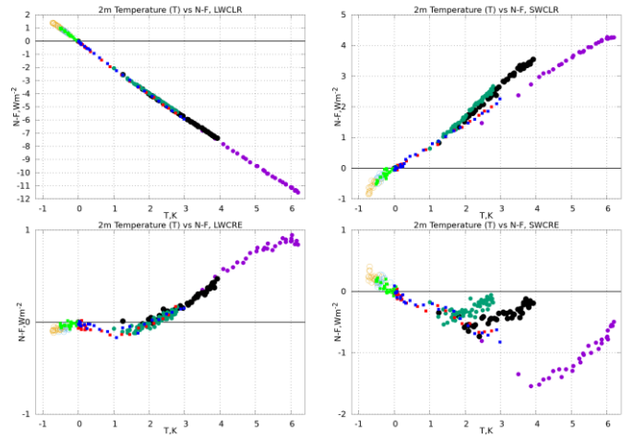

Fig 3. As Figure 2, but for different radiative components

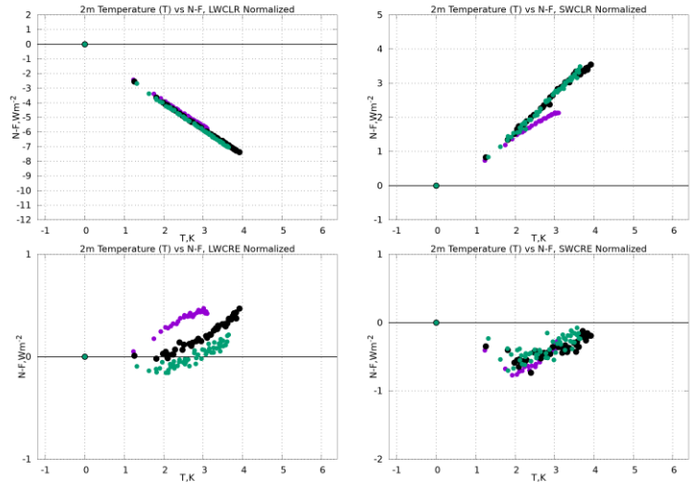

Fig 4. As Figure 3, but normalized by 2xCO2 ERF.

ECS estimated by linear fit

In CM4 estimated ECS shows a strong dependence upon strength of greenhouse gas forcing and time of linear fit

ECS (K)	Period of Linear Fit				
Instantaneous	1-150	31-150	31-200	31-300	31-450
4xCO2	4.0	4.6	4.8	4.9	
2xCO2	3.7	4.5	5.1	6.1	6.1
2014GHG	3.2	4.0	4.1	5.0	5.4
2014AER	3.9	4.2	4.2		
1975AER	4.2	4.5	5.5		
Transient	1850-2020		1850-2100		
HIS-ALL	2.1		2.8		
HIS-AER	3.0		3.0		
HIS-GHG	2.6		2.8		

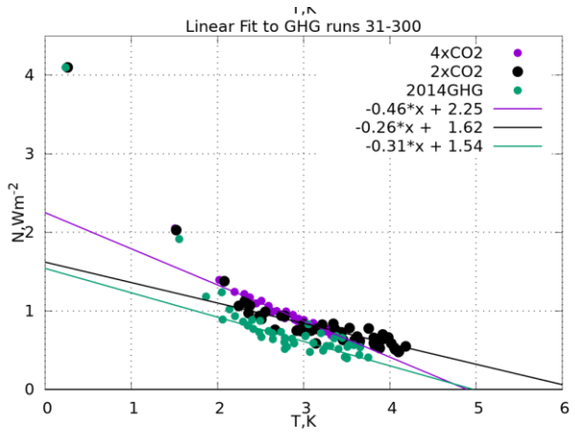

Fig 1. Example of linear fit to 3 of the instantaneous runs normalized by 2xCO2 ERF. Note the very shallow gradients indictive of high ECS

Why are the Historical Estimates of ECS lower? (or why do the feedbacks weaken over time?)

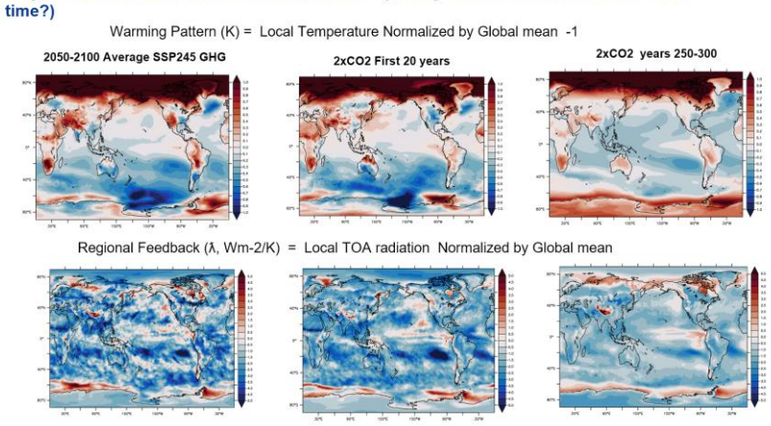

Fig 5. Warming patten and feedback pattern of CM4

Distinct lack of SH warming in CM4 and negative SWCRE is important (fig 5) to explain the low ECS value from the historical period.