CESM2 (TSMLT) Feedforward and Feedback Estimates

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Table 1: Temperature Targets

	T0	T1	T2
Member 1	288.62	2.60	-29.52
Member 2	288.61	2.57	-29.55
Member 3	288.68	2.74	-29.30
Member 4	288.65	2.59	-29.50
Member 5	288.62	2.63	-29.38
Ensemble average	**288.64 ± 0.01**	**2.63 ± 0.03**	**-29.45 ± 0.05**

Targets are defined as the average over the 2020-2039 period in the SSP 245 runs (CESM2, full chemistry).

Table 2: Sensitivity Estimates (includes significant digits)

	My CESM 2			My CESM 1			GLENS CESM 1		
	ℓ_0^{-1}	ℓ_1^{-1}	ℓ_2^{-1}	ℓ_0^{-1}	ℓ_1^{-1}	ℓ_2^{-1}	ℓ_0^{-1}	ℓ_1^{-1}	ℓ_2^{-1}
T_0	-7.95			-6.66			-5.2		
T_1	-4.8	-7.6		-2.43	-3.7		-3.7	-4.4	
T_2	-2.6	0.0	-2	-2.29	-2.0	-2.49	-2.4	-2.2	-1.6

My estimates for CESM2 sensitivities are drawn from the data of Tilmes et al 2020.

Table 3: Temperature increase seen in SSP 245 relative to temperature targets, beginning from ~0 in 2030 (in other words, how much temperature increase needs to be offset)

Metric	Behavior	Forcing required to offset
T_0	+0.0276 K per year	enough ℓ_0 to offset this change
T_1	erratic - assume no detectable change	enough ℓ_1 to cancel out whatever ℓ_0 is doing to T_1
T_2	+0.0080 K per year	enough ℓ_2 to offset this change, minus the influence of ℓ_0 (neglect influence of ℓ_1 on T_2 - see table 2 above)

Feedforward calculations

- ℓ_0:
  - -0.0276 K/yr ÷ -7.95 K/ℓ_0 = **0.0035 ℓ_0 per year**
- ℓ_1:
  - -4.8 K/ℓ_0 × 0.0035 ℓ_0/yr = -0.0165 K/yr to offset
  - 0.0165 K/yr ÷ -7.6 K/ℓ_1 = **-0.0022 ℓ_1 per year**
- ℓ_2:
  - -0.0080 K/year required in total
  - -2.6 K/ℓ_0 × 0.035 ℓ_0/yr = -0.0091 K/yr from ℓ_0
  - 0.0011 K/yr of T_2 leftover → the desired ℓ_0 already overcompensates T_2 by a small amount
  - 0.0011 K/yr ÷ 2.14 K/ℓ_2 = **-0.0005 ℓ_2 per year**

Table 4: Injection rates

Latitude	Equation	**ℓ_0 and ℓ_1 feeds**	**ℓ_0 feed only**
30N	$20\ell_1^N + 40\ell_2$	0	0
15N	$30(\ell_0 - \ell_1^N - \ell_1^S - \ell_2) + 45\ell_1^N$	0.0388*(t-2030) Tg/yr	0.1041*(t - 2030) Tg/yr
15S	$30(\ell_0 - \ell_1^N - \ell_1^S - \ell_2) + 45\ell_1^S$	0.1367*(t-2030) Tg/yr	0.1041*(t - 2030) Tg/yr
30S	$20\ell_1^S + 40\ell_2$	0.0435*(t-2030) Tg/yr	0

Table 5: Feedback gains

Metric	Old Gain	GLENS sens.	New sens.	Ratio	New gain
ℓ_0	0.028	-5.2	-7.95	0.66	0.0183
ℓ_1	0.13	-4.4	-7.6	0.58	0.0753
ℓ_2	0.39	-1.6	-2	0.8	0.3120