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Supplement of

Nitrogen cycling in CMIP6 land surface models: progress and limitations

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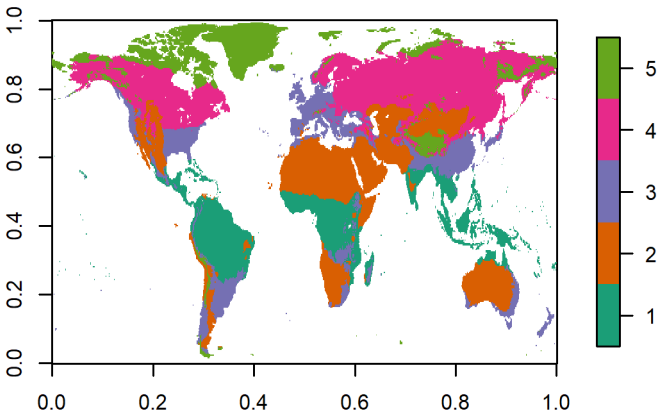

Figure S1. Climate region areas acting as a proxy for biomes, from to Köppen-Geiger climate classification (Kottek et al., 2006; Rohli et al., 2015). 1 = equatorial (tropical), 2 = arid, 3 = warm temperate, 4 = snow (boreal) 5 = polar (tundra).

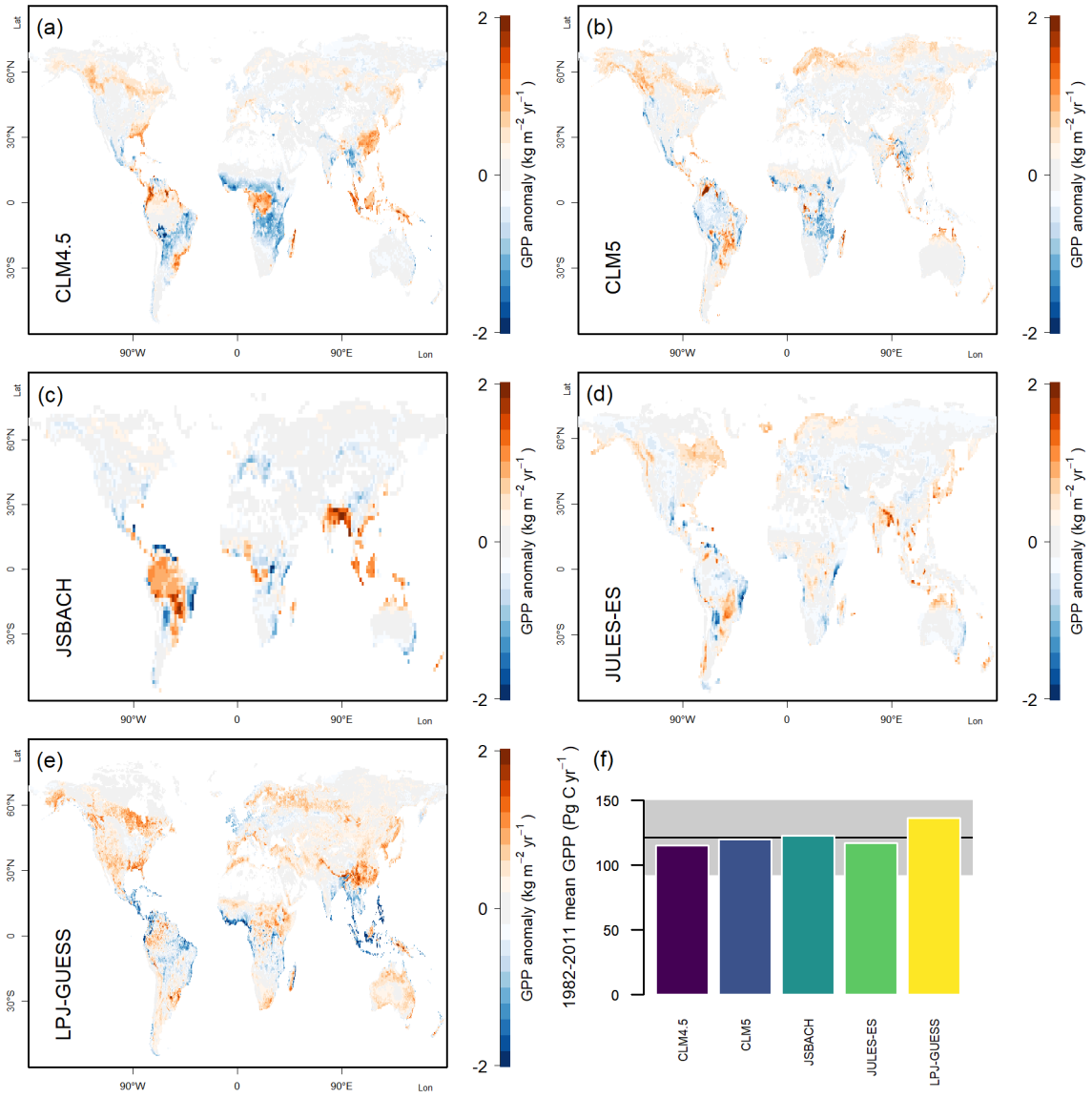

Figure S2. Model output of 1982-2011 mean gross primary productivity (GPP). (a) – (e) Model estimates, shown as the anomaly of the corresponding observation-based estimate (MTE) (i.e. model minus observations) published by Jung et al. (2011). (f) Globally integrated estimates. Black line indicates the global average from the observation-based source; grey area indicates the globally integrated standard deviation from the global average in the model tree ensemble applied to obtain the global average.

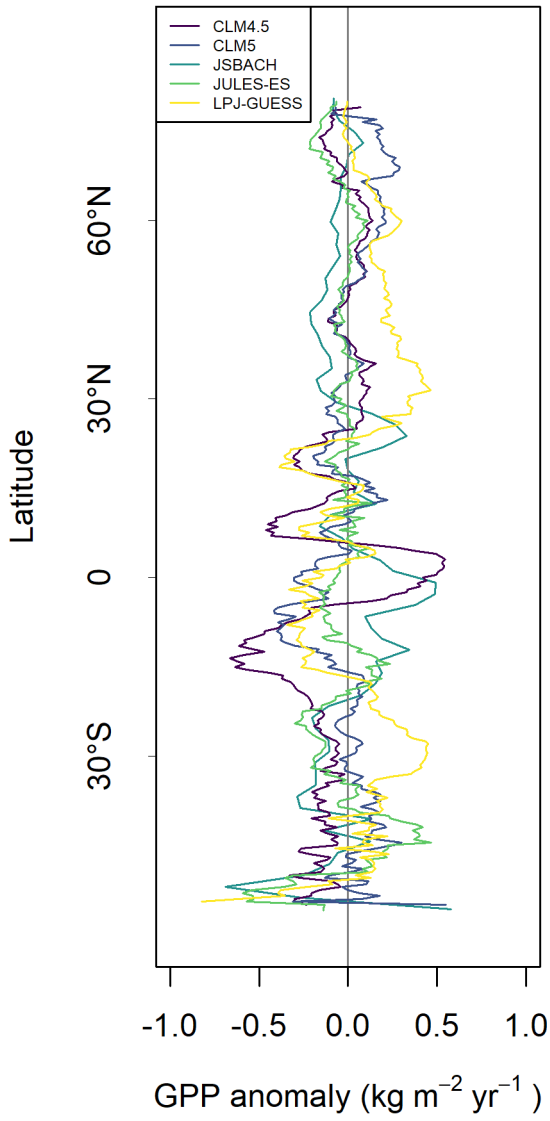

Figure S3. Model output of 1982-2011 mean gross primary productivity (GPP) averaged by latitude, shown as the anomaly of the corresponding observation-based estimate (MTE) published by Jung et al. (2011).

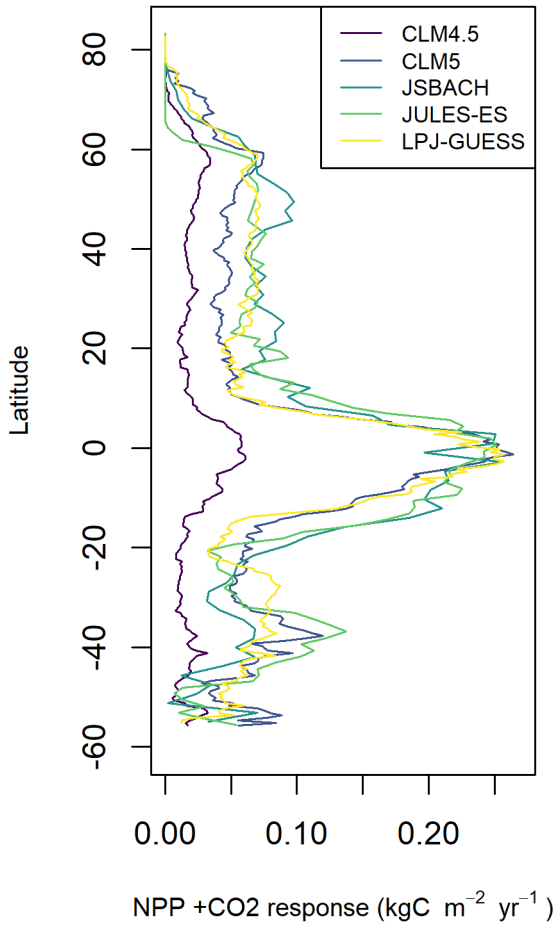

Figure S4. Model estimates of 1996-2005 mean NPP response to +CO2, averaged by latitude.

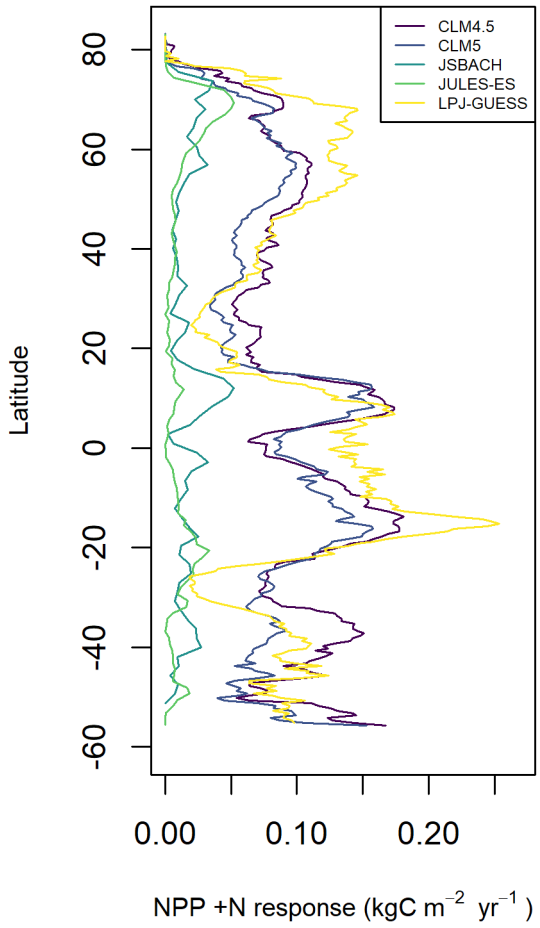

Figure S5. Model estimates of 1996-2005 mean NPP response to +N, averaged by latitude.

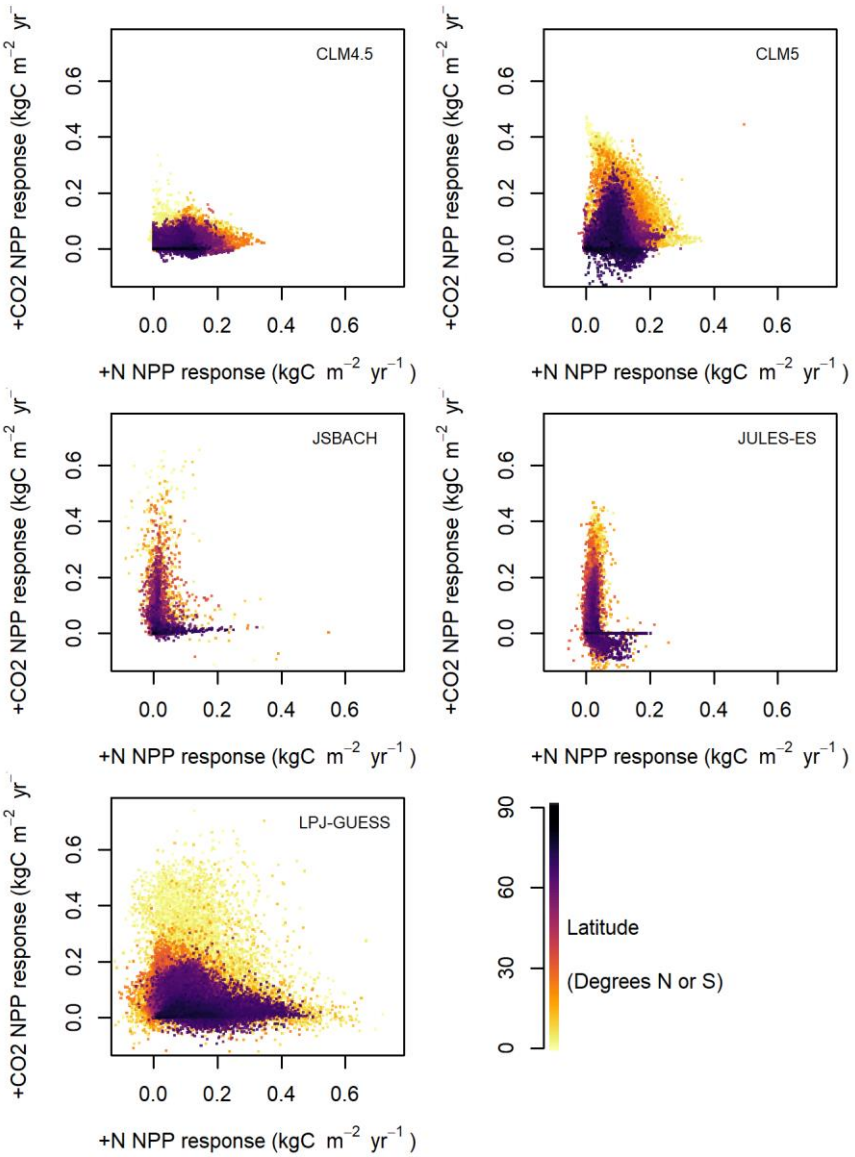

Figure S6. Model estimates of 1996-2005 mean net primary productivity (NPP) response to +N vs +CO2 as the anomaly of the control scenario. Each grid box is plotted against the corresponding grid box for the other variable. The colour of the points indicates the latitude, either North or South.

Table S1. Summary of model simulations.

	Control	**+CO2**	**+N**
Atmospheric CO_2	Time varying	Time varying + 200 ppm	Time varying
N deposition	ACCMIP	ACCMIP	ACCMIP + 50 kg N ha^{-1} yr^{-1}

Table S2. Observational datasets used for comparison with model results

Variable/effect	Dataset	Reference	Number of measurements
+CO2 effect on NPP	meta-analysis of total above ground biomass of woody plants	Baig et al., (2015)	16
	meta-analysis for whole plant NPP and aboveground NPP (ANPP)	Song et al., (2019)	unspecified, maximum of 103
+N effect on NPP	meta-analysis on NPP changes	LeBauer and Treseder, (2008)	126, incl. tundra (10), tropics (8), arid land (3)
	meta-analysis for whole plant NPP and aboveground NPP (ANPP)	Song et al., (2019)	unspecified, maximum of 429
BNF responses to +CO2	global meta-analysis estimate	Liang et al. (2016).	89
BNF responses to +N	meta-analysis	Zheng et al., (2019),	tropical forest (92), temperate forest (52), boreal forest (37)
Biomass response to +N	aboveground forest biomass C change per added N from meta-analysis	Schulte-Uebbing and Vries, (2018)	tropical (17), temperate (41), boreal (12)
GPP (SI Fig. 2)	Flux tower data model tree ensemble	Jung et al., (2011)	unknown
Biome allocation (SI Fig. 1)	Köppen-Geiger climate classification	Kottek et al., 2006)	n/a

Table S3. Percent (%) change in mean NPP from +N or +CO2. Areas where the Control scenario NPP is less than 100 gC m^{-2} yr^{-1} are excluded as the very high percent changes from these grid boxes skew the analysis. Climate regions refer to those shown in SI Fig. 1.

	CLM4.5		CLM5		JSBACH		JULES		LPJ-GUESS	
	+CO2	**+N**	**+CO2**	**+N**	**+CO2**	**+N**	**+CO2**	**+N**	**+CO2**	**+N**
Equatorial (Tropical)	4.9	17.1	22.7	16.8	17.1	1.4	19.5	0.4	18.6	19.4
Arid	6.7	52.3	17.2	63.2	31.7	9.1	7.7	5.8	17.3	14.3
Warm Temperate	5.1	24.1	19.3	19.3	23.7	2.1	18.5	0.8	20.3	19.7
Snow (Boreal)	6.6	28.5	15.4	23.9	18.6	3.8	13.4	3.1	14.5	27.8
Polar (Tundra)	4.4	58.4	14.0	28.1	10.7	7.9	4.1	13.2	13.7	58.7
Global	5.4	24.1	19.6	22.1	19.3	2.5	16.7	1.8	17.5	21.7