Figure S1. Arctic-Boreal Vulnerability Experiment (ABoVE) domain as indicated by black shaded cells.

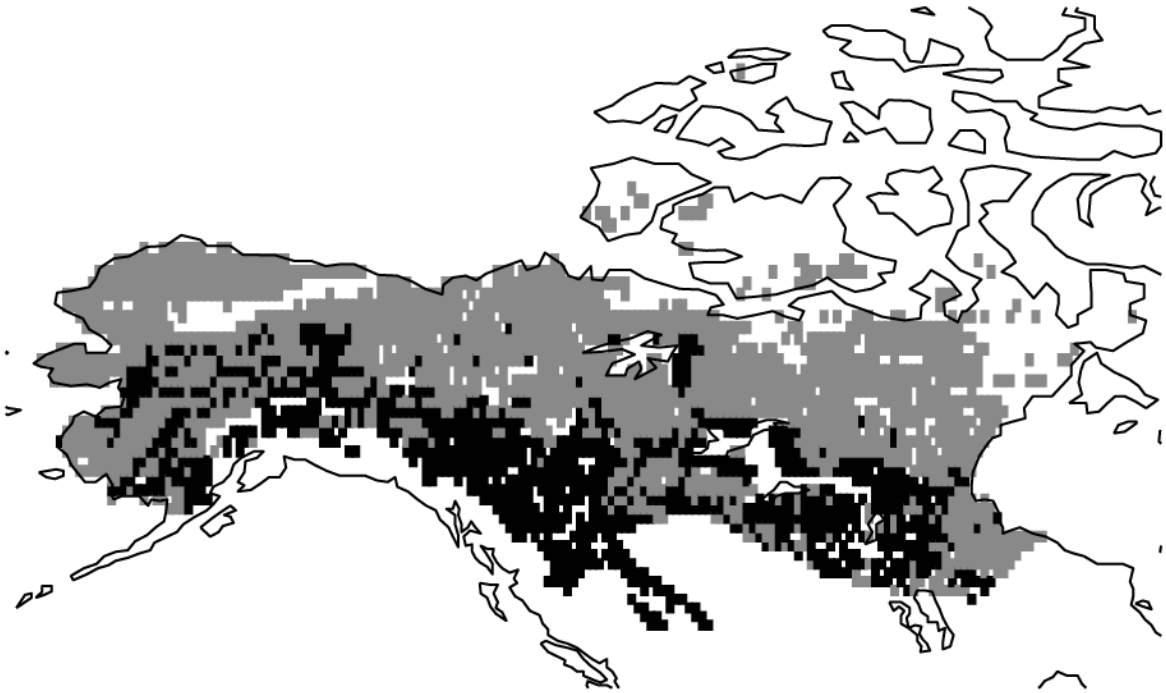

Figure S2. Map of ABoVE that overlaps with the area covered by the Northern Circumpolar Soil Carbon Database (NCSCD). Grey cells indicate regions dominated (≥ 50%) by peat and permafrost soils (histosol, histesl, gelisol, orthel) as defined by the NCSCD. The black cells indicate regions dominated (≥ 50%) by soils other than peat and permafrost (othsoil in NCSCD). Grid cells dominated by other soils (≥ 50%) as defined by the NCSCD are excluded from both regions.

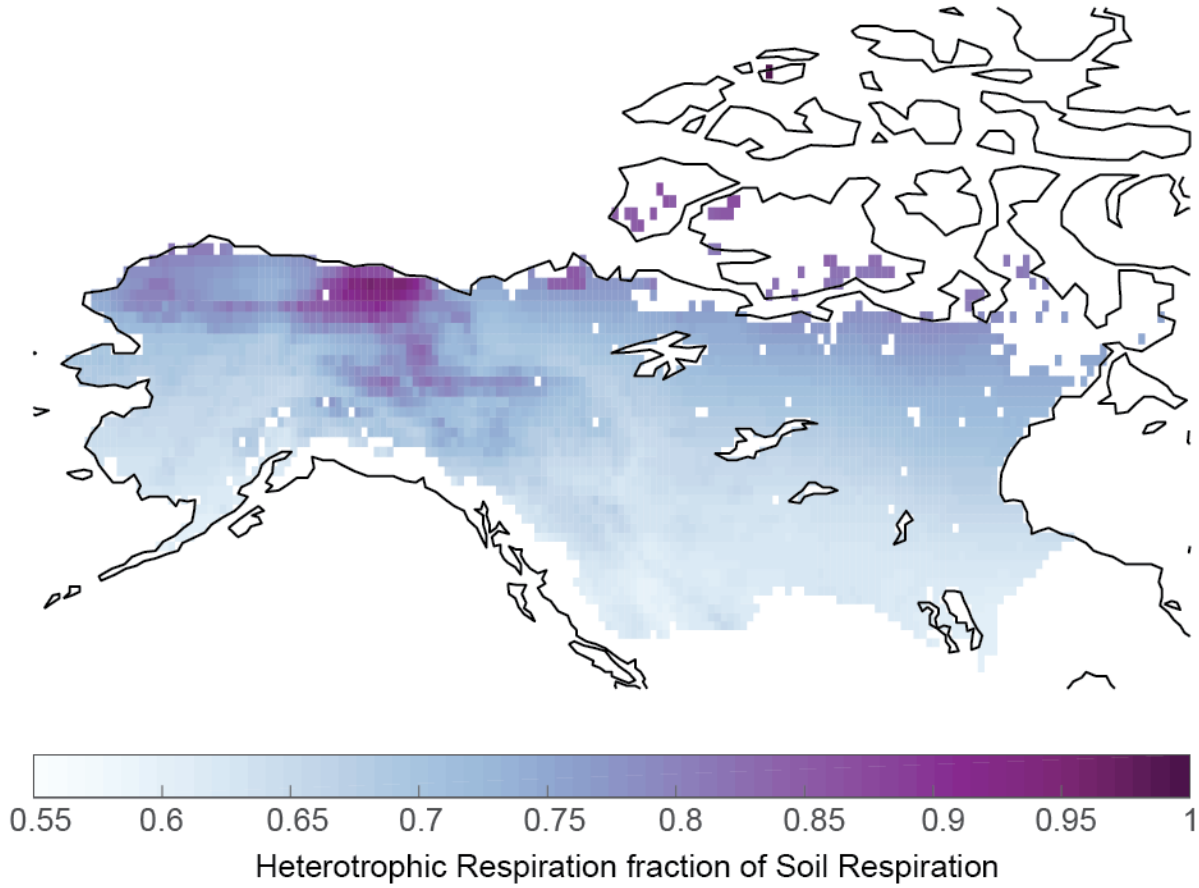

Figure S3. Fraction of soil respiration that is heterotrophic respiration (Rh) based on Hashimoto et al. [2015].

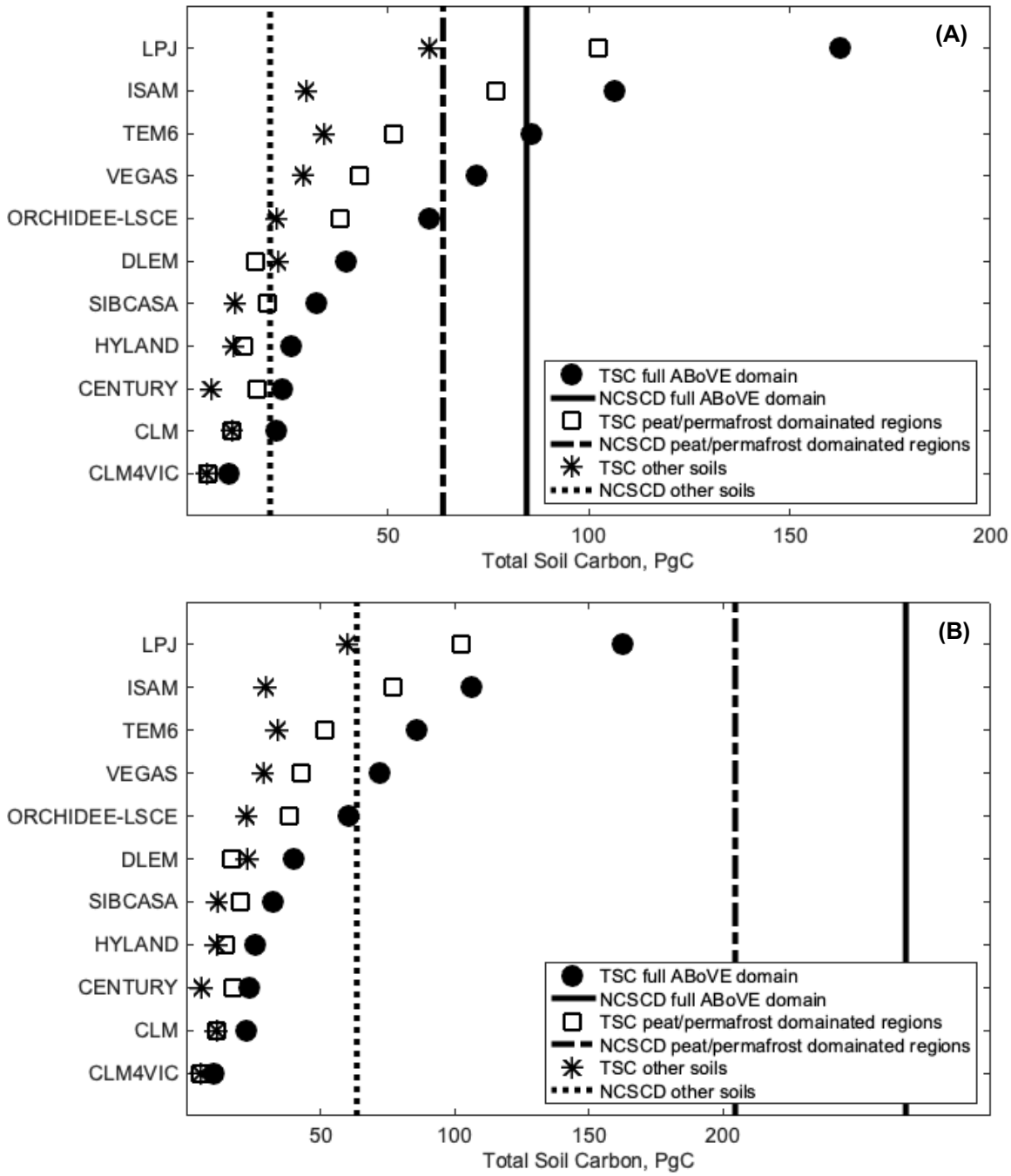

Figure S4. Net soil carbon stocks by model (black circles) for the all land cells within ABoVE domain compared to observationally-constrained estimate from the Northern Circumpolar Soil Carbon Database (NCSCD) (solid black vertical line) for soils (A) between 0 to 1 meter depth, and (B) between 0 and 3 meter depth. In each panel, net soil carbon stocks for the ABoVE domain are shown for both peat/permafrost dominated regions (gridcells with 50% or greater peatland and permafrost soils) and regions dominated (50% or greater) by other soils (non-permafrost or peat soils) for both the modeled and NCSCD values. In all cases, model estimates are shown using symbols; vertical lines show corresponding estimate from NCSCD.

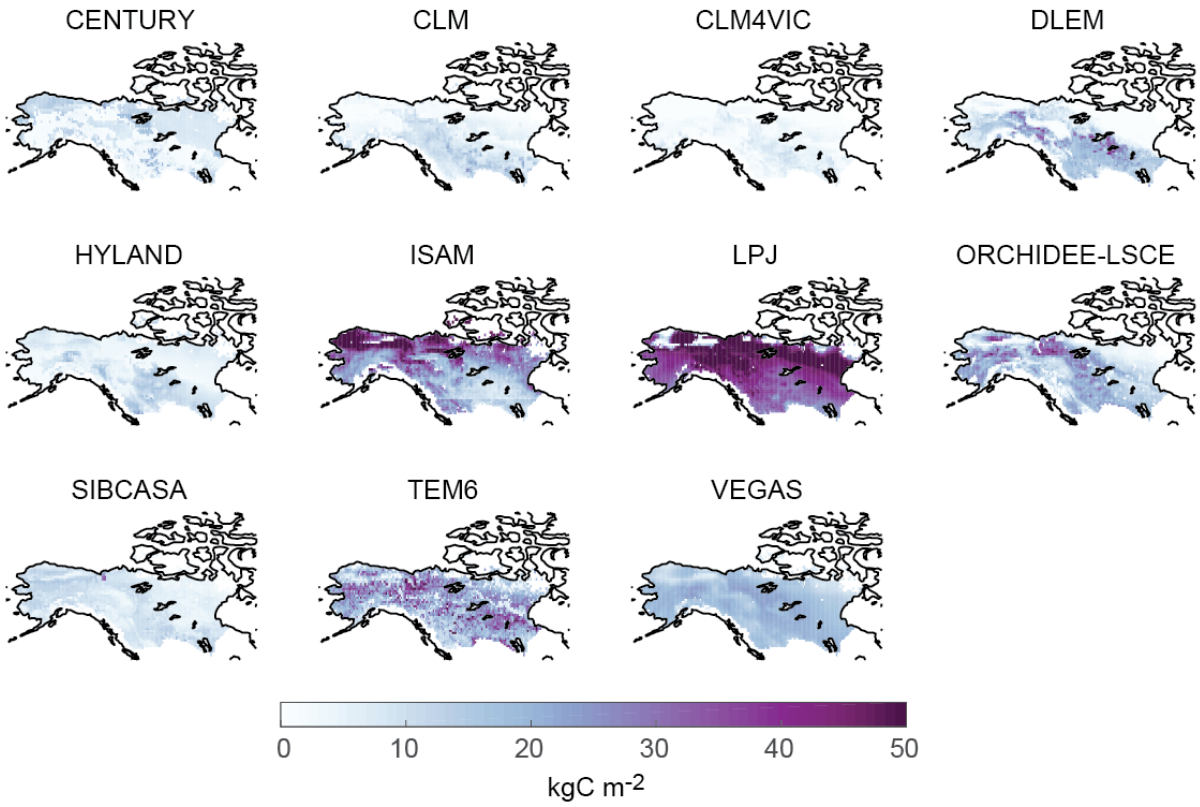

Figure S5. Soil carbon stocks by model averaged over the last decade of simulations (2000 - 2010) for simulation BG1 (all time-varying drivers turned on).

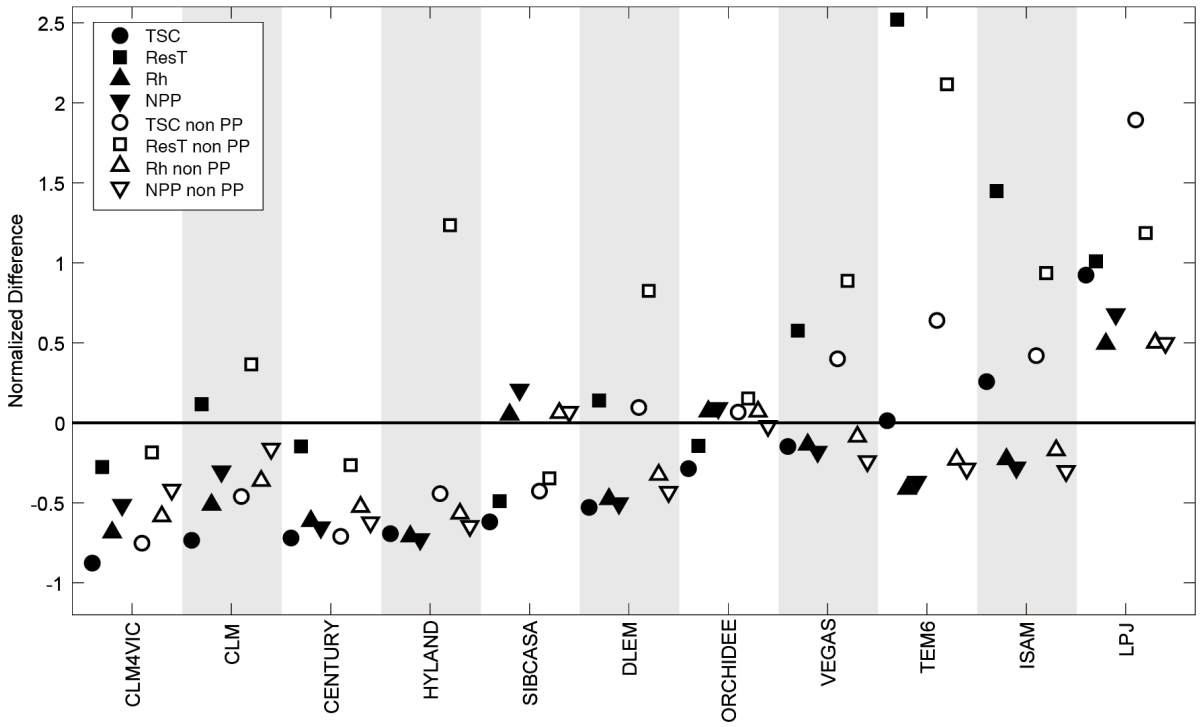

Figure S6 Normalized difference between modeled and observationally-constrained net flux into (net primary productivity, NPP) and out of (heterotrophic respiration, Rh) soil carbon, along with net soil carbon stocks and apparent soil carbon residence time (ResT) across the ABoVE domain for the decade 2000-2010. Filled symbols represent normalized difference for net pools/fluxes across the full ABoVE domain. Open symbols show normalized differences for net pools/fluxes for only non-permafrost and peatland (non PP) dominated regions. Apparent soil carbon residence time is calculated as the ratio of total soil carbon stocks to Rh. Refer to supplemental Table 1 for magnitude of individual model estimates.

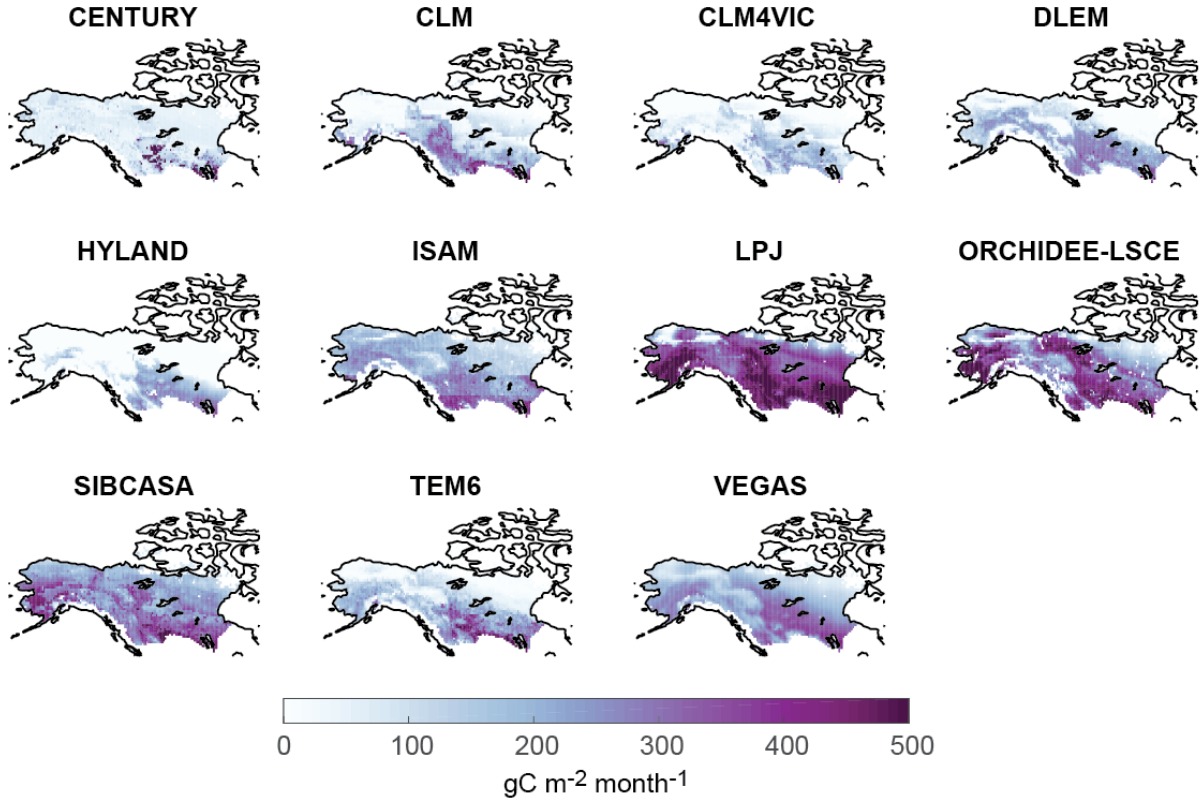

Figure S7. Heterotrophic respiration (Rh) by model averaged over the last decade of simulations (2000 - 2010) for simulation BG1 (all time-varying drivers turned on).

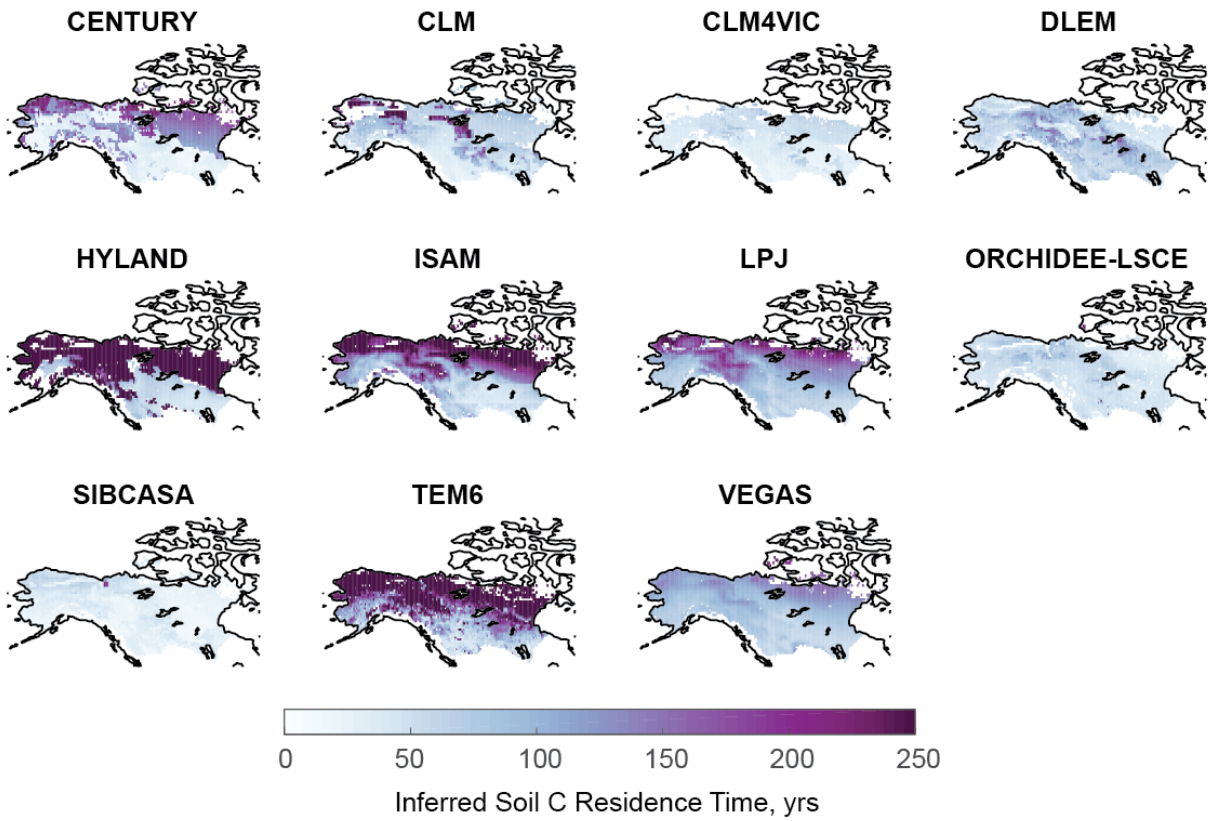

Figure S8. Inferred soil carbon residence time (RT) by model for the last decade of simulations (2000 - 2010) for simulation BG1 (all time-varying drivers turned on).

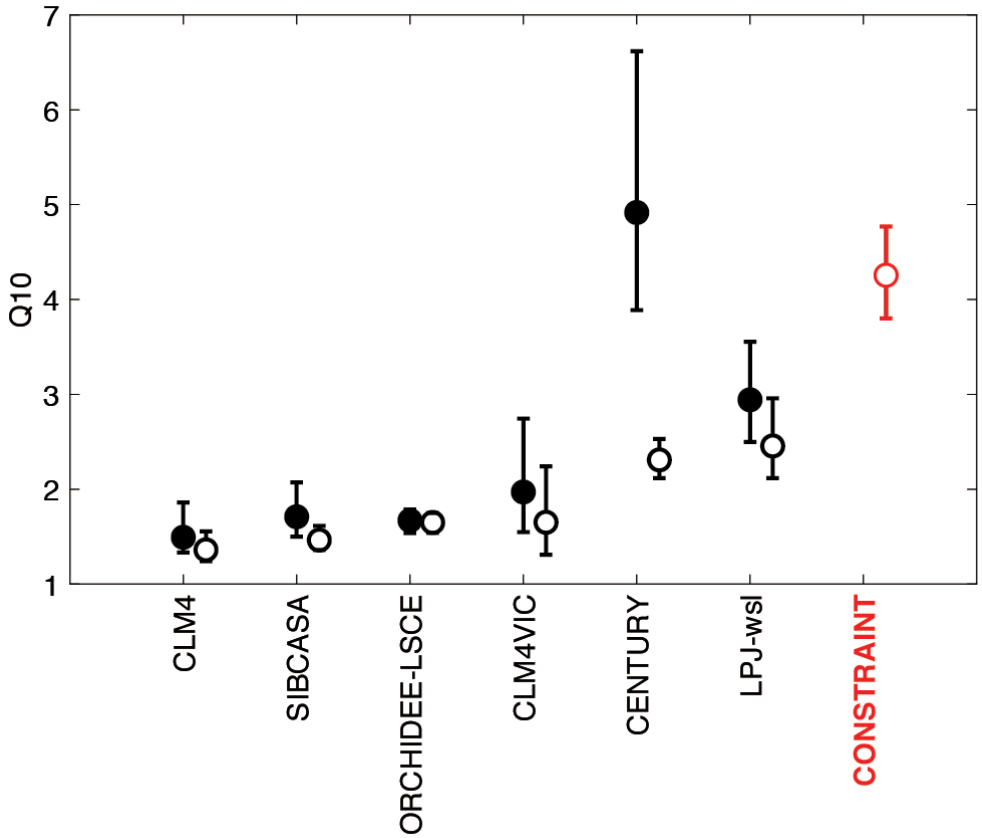

Figure S9. Inferred Q10 for model's that reported soil temperature based on heterotrophic respiration (Rh) as a function of temperature relationship. Circles represent the median inferred Q10 across all land cells within the ABoVE domain for Boreal and Northern Shrubland ecosystem in non-permafrost and peatland dominated regions. Error bars represent the spread (interquartile range) in inferred Q10 values across gridcells. Filled circles show inferred Q10 based on air temperature. Open circles are inferred Q10s based on soil temperature reported by the models. The red open circle and error bars show the inferred Q10 from control sites at warming experiments reported by Carey et al., 2016.

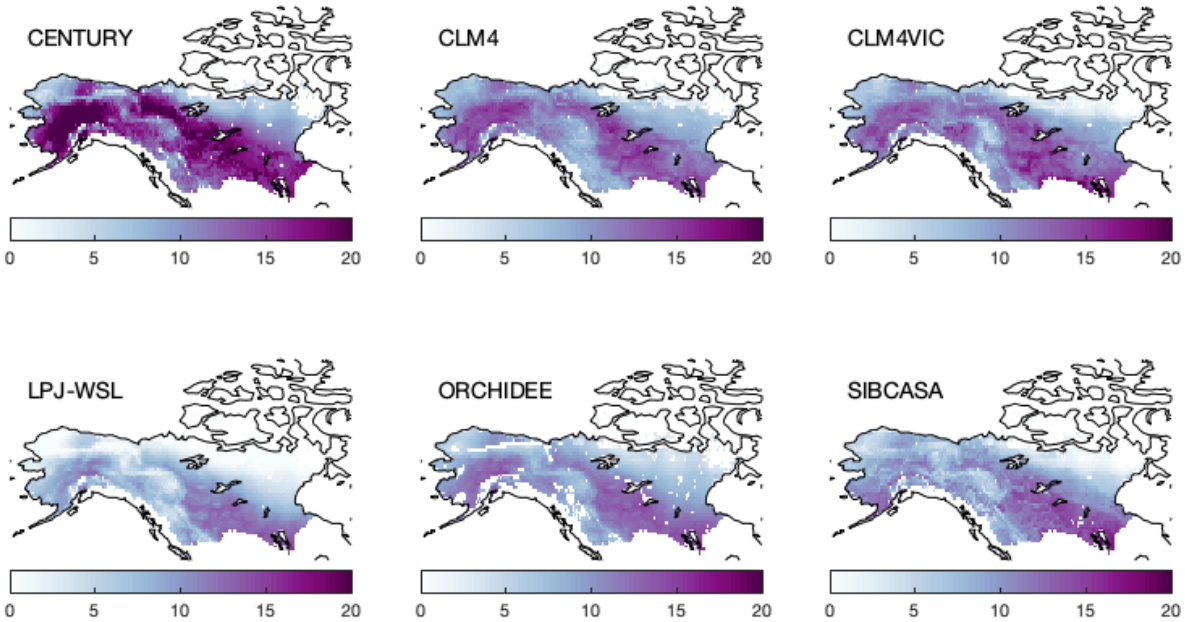

Figure S10. Mean soil temperature for June 2000 for models in MsTMIP ensemble that reported soil temperature.

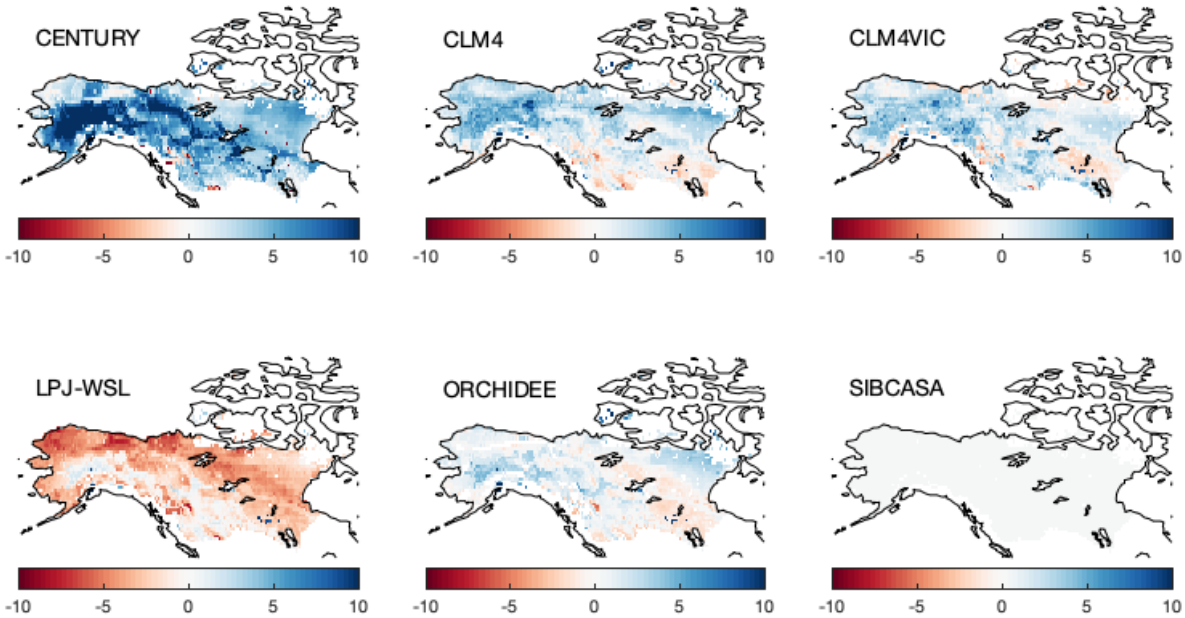

Figure S11. Difference between mean air temperature and mean soil temperature for June 2000 for those models that reported soil temperature. Air temperature is taken from the MsTMIP driver data (Wei et al., 2014) and is based on CRU-NCEP.

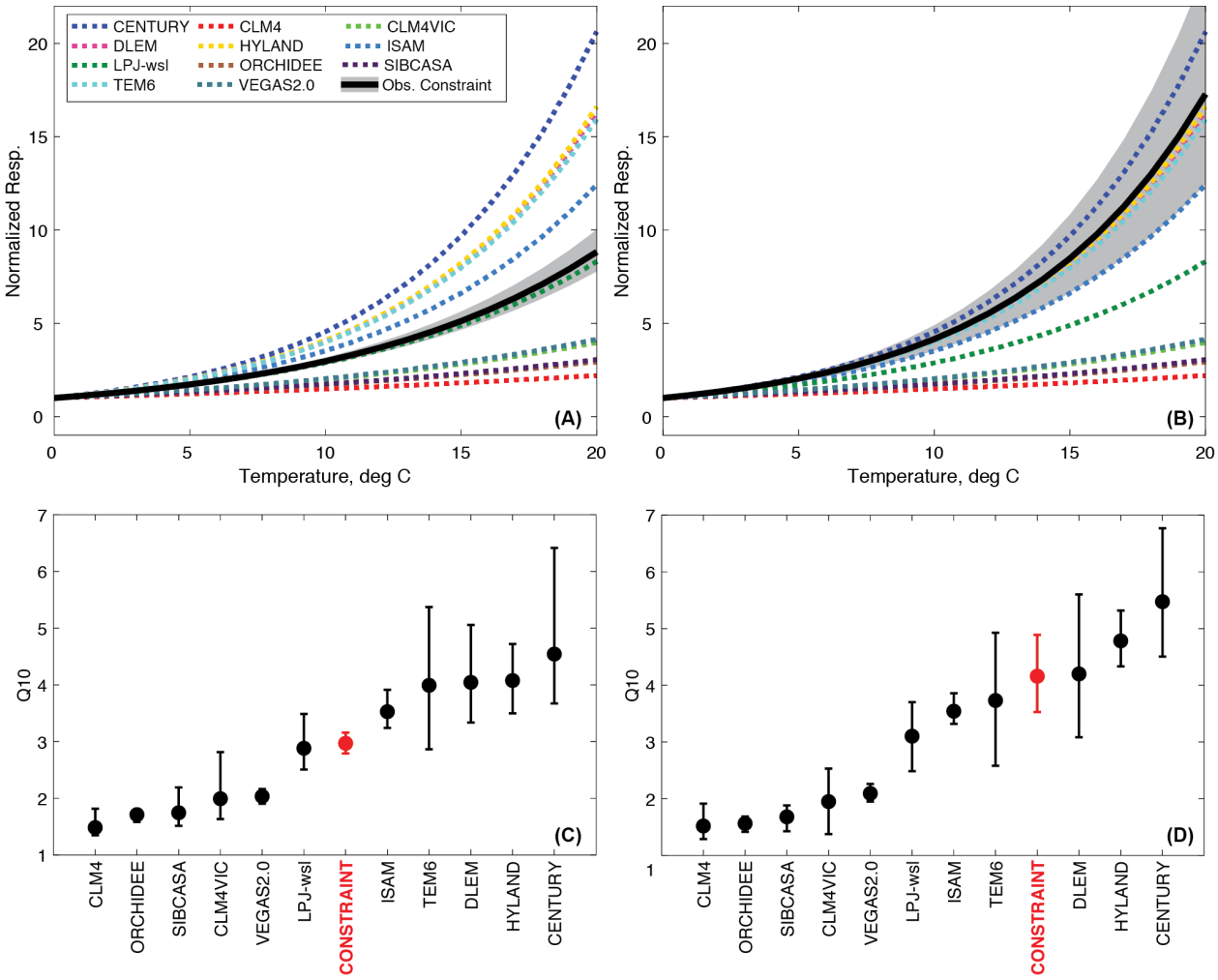

Figure S12. Heterotrophic respiration (Rh) and a function of temperature for (A) boreal forests and (B) northern shrublands for only those land cells not dominated (≥ 50%) by peat and permafrost soils. Colored lines show median of individual modeled relationships. Modeled results are compared to observed Rh as a function of temperature (black line and grey shaded region) derived from control plots at warming sites reported by Carey et al., 2016. Grey shading indicates uncertainty on the observational constraint. Also shown are the inferred Q10 values for (C) boreal forests, and (D) northern shrublands based on the curves in (A) and (B). Black circles represent the median inferred Q10 across all land cells within the ABoVE domain in non-permafrost and peatland dominated regions. Error bars represent the spread (interquartile range) in inferred Q10 values across gridcells. Red circles and error bars show the inferred Q10 from control sites at warming experiments reported by Carey et al., 2016.

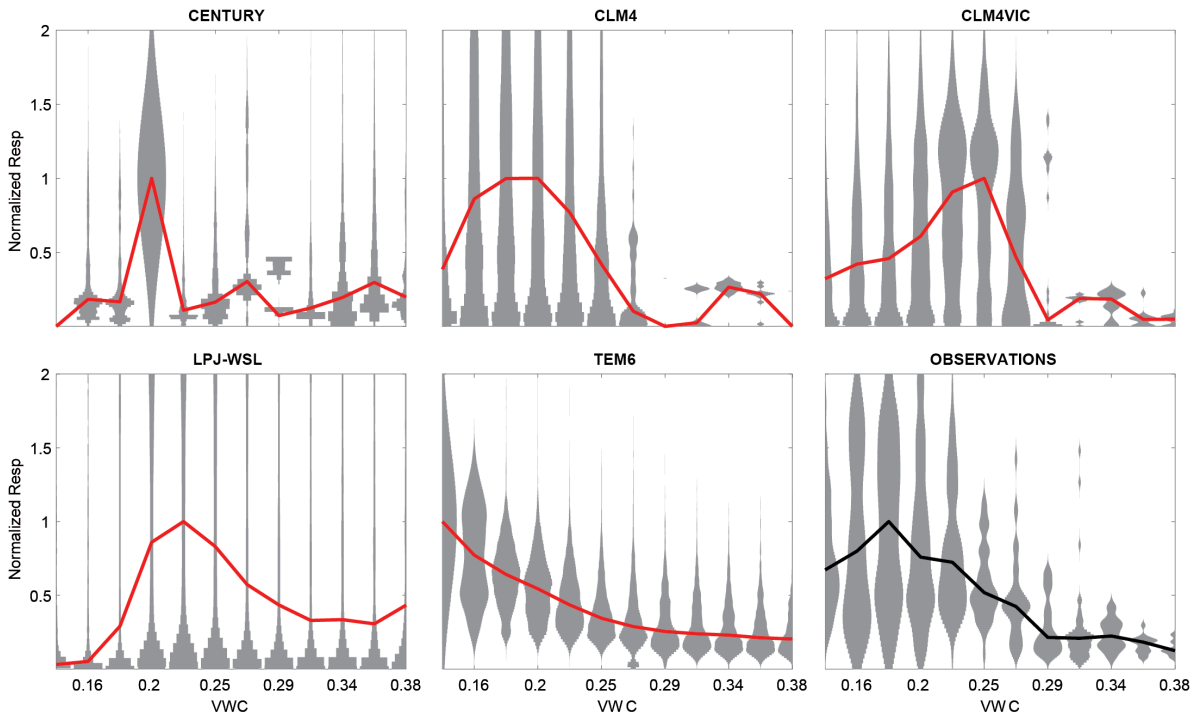

Figure S13. Normalized respiration as a function of volumetric water content (VWC). Violin plots (grey shading) show the distribution of respiration within each VWC bin. In this plot a bin width of 0.045 is used. The red lines show the median respiration within each VWC bin. Respiration is normalized by the maximum median respiration across all bins. The black line shows the median normalized respiration derived from observations using both control and warming sites as reported in Carey et al., (2016).

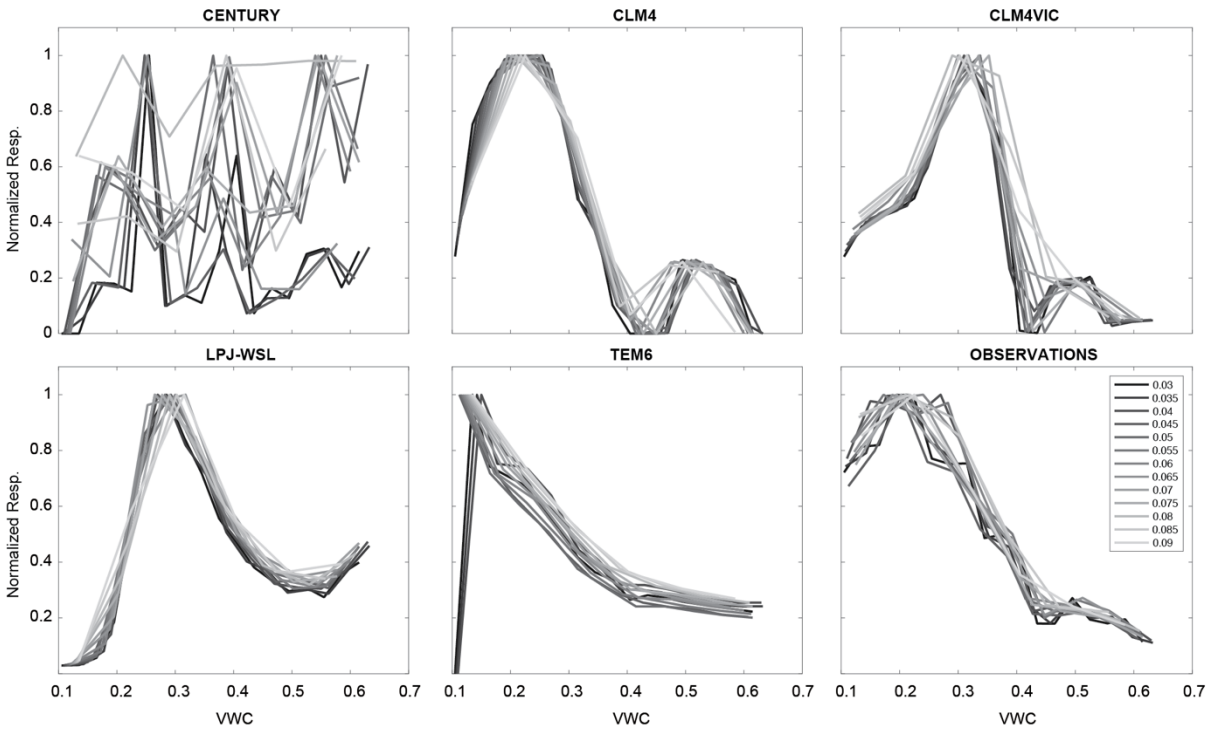

Figure S14. Normalized median respiration curves versus volumetric water content (VWC) for both models and observations. Respiration is normalized by the maximum median respiration across all bins. Different lines show the impact of varying bin width on the position of the peak respiration. The median normalized respiration curves derived from observations are based on data from both control and warming sites as reported in Carey et al., [2016].

Table S1. Semi-factorial design of MsTMIP simulations. For more details refer to Huntzinger et al., 2013.

<table>
<tr><th rowspan="2">Environmental Driver</th><th colspan="5">Simulation</th></tr>
<tr><th>RG1</th><th>SG1</th><th>SG2</th><th>SG3</th><th>BG1</th></tr>
<tr><td>Climate</td><td rowspan="4">Constant</td><td>Time-varying</td><td rowspan="2">Time-varying</td><td rowspan="3">Time-varying</td><td rowspan="4">Time-varying</td></tr>
<tr><td>Land-cover change</td><td rowspan="3">Constant</td></tr>
<tr><td>Atmospheric CO_2</td><td rowspan="2">Constant</td></tr>
<tr><td>Nitrogen deposition</td><td>Constant</td></tr>
</table>

Table S2. Model properties related to soil carbon pool structure, turnover rates in different carbon pools and carbon cycling.

Model	No. of Soil + Litter Pools	Max Soil C Depth (m)	Vertically Resolved Soil BGC	Turnover Active (yr)	Turnover Slow (Yr)	Turnover Passive (yr)	Max Soil Depth (m)	No. Soil Lyrs	Thickness of top soil layer (m)	Soil Moisture Model	Simulate Permafrost
CENTURY	3 + 4	0.9	No	0.5 to 3	20 to 50	400 to 2000	Varies	6	0.15	Bucket model	No
CLM4.0	4 + 3	0.3	No	0.04 to 0.19	1.95	27.4	4.2	10	0.0175	Richard's Eqn.	Yes
CLM4VIC	4 + 3	0.3	No	0.04 to 0.19	1.95	27.4	4.2	10	0.0175	Richard's Eqn.	Yes
DLEM	5 + 4	1	No	0.054 to 0.22	3 to 6	100 to 1500	3	10	0.05	Richard's Eqn.	No
HYLAND	3 + 4	0.8	No	0.22	5	150	0.8	1	0.8	Bucket model	No
ISAM	3 + 4	1	No	0.24 to 0.43	2.11 to 7.60	495	3.5	10	0.0175	Richard's Eqn.	Yes
LPJ-wsl	3 + 2	1.5	No	2.85	33	1000	1.5	2	0.5	Bucket model	No
ORCHIDEE	3 + 4	2	No	0.15	5.5	241	2	2	0.2	Bucket model	No
SIBCASA	13 + 2	3	Yes	0.05 to 0.20	5	222	15	25	0.02	Richard's Eqn.	Yes
TEM6	3 + 0	Varies up to 3	Yes	NA	variable ~31 yrs	NA	36	Varies	Varies	Bucket model	Yes
VEGAS2.0	3 + 3	Varies	No	2	20	1000	1 to 2 m	2	Varies	Bucket model	No

Table S3. Model estimates of total soil carbon (TSC) at steady-state of the year 1901 for the full ABoVE domain, along with the change in TSC between steady-state (1901) and the end of the simulation period (2010).

Model	TSC (PgC)	Change in TSC	
		PgC	TgC yr^{-1}
CENTURY	36.2	3.2	29.3
CLM4.0	34.3	0.02	0.2
CLM4VIC	15.6	-0.1	-1.0
DLEM	54.7	-0.7	-6.5
HYLAND	38.9	0.5	4.9
ISAM	135.2	5.2	47.1
LPJ-wsl	213.1	3.7	33.5
ORCHIDEE	76.6	-2.1	-19.0
SIBCASA	41.3	-2.3	-20.5
TEM6	122.9	11.6	105.5
VEGAS2.0	98.2	1.3	11.5