

Supporting Information for

## **Evaluating the simulated mean soil carbon transit times by Earth System Models using observations**

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### Text S1. Calculation of SOC transit time ( $\tau_{\text{soil}}$ ) with one-pool assumption

The differences of SOC transit time are apparently huge from days to years with incubation methods, decades with stocks and fluxes methods, and stable isotope methods, even centuries with radiocarbon methods. The approach described incubation following equation (1) for estimating the readily decomposition of organic carbon (C) pools and the first-order modeling. To estimate the turnover time ( $1/k$ ) of each organic C pools,  $k$  values were calculated from the slopes of linear segments of fitting curves obtained from plotting the natural log of organic C at time  $t$ .

$$C_t = C_0(1 - e^{-kt}) \quad (1)$$

where  $C_t$  is organic C mineralized ( $\text{mg kg}^{-1}$ ) at specific time  $t$ .

- 10 The common approach used to estimate turnover time is division by stock and flux (equation (2)). To quantify the mineralization rate, SOC pools were divided into different sub-pools so that the flux of each pool could be measured. Where  $C_{\text{pool}}$  is the carbon stock and flux is the flux (NPP or  $R_h$ ) in the same C pool. We also use the ratio of stocks over fluxes to estimate the turnover time on the systematical level.

$$\tau = C_{\text{pool}}/\text{Flux} \quad (2)$$

- 15 The  $^{13}\text{C}$  natural abundance technical provides a new instrument to trace the dynamic of SOC. Where  $A_0$  is a fraction of the initial C stock and  $A_t$  is a fraction of the C stock during  $t$  times with vegetation ( $\text{C}_3/\text{C}_4$  plant or grassland/forest) change of the sample site.

$$k = \ln(A_0/A_t) / t \quad (3)$$

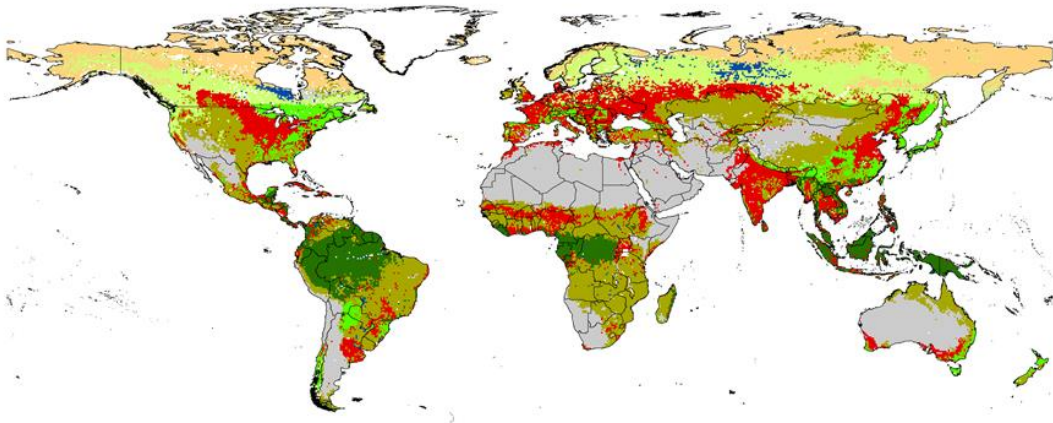


Figure S1. Classification of plant function type. (1) Tropical forest includes evergreen broadleaf forest between 25 °N and 25 °S; (2) Temperate forest includes deciduous broadleaf, evergreen broadleaf outside of 25 °N and 25 °S, and mixed forest south of 50 °N; (3) Boreal forest includes evergreen needleleaf forest, deciduous needleleaf forest, mixed forest north of 50 °N; (4) grassland and shrubland includes woody savanna south of 50 °N, savanna, and grasslands south of 55 °N; (5) Deserts and Savanna includes barren or sparsely vegetated, open shrubland south of 55 °N, and closed shrubland south of 50 °N; (6) Tundra; (7) Croplands. Other land cover types like urban and bare land were not included in this analysis.

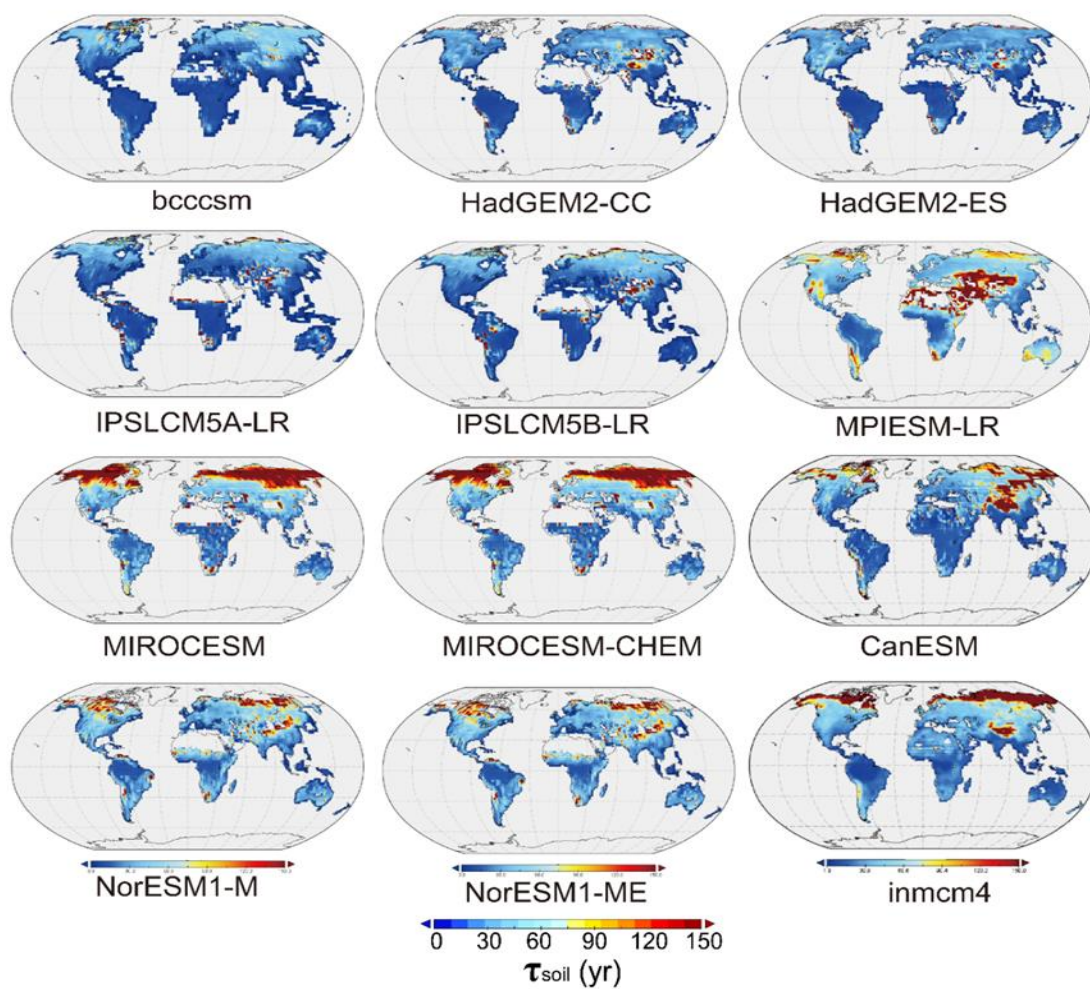


Figure S2. SOC transit time ( $\tau_{\text{soil}}$ ) from Earth System Models. These soil carbon densities represent the means  $\tau_{\text{soil}}$  from the historical simulations of the Climate Model Intercomparison Project 5 (CIMP5).

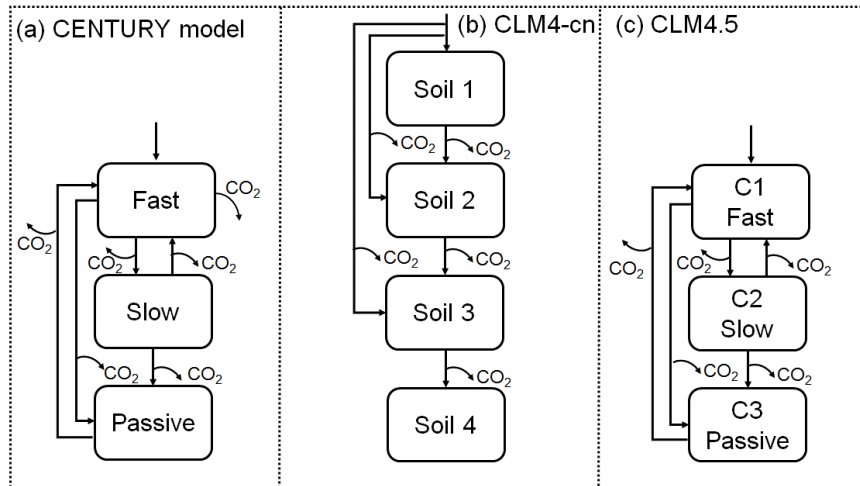


Figure S3. The schematic depiction of the three-pool of soil carbon dynamic model. Boxes indicate three soil organic carbon pools. Arrows indicate decomposition of carbon pools and transfers between three pools.

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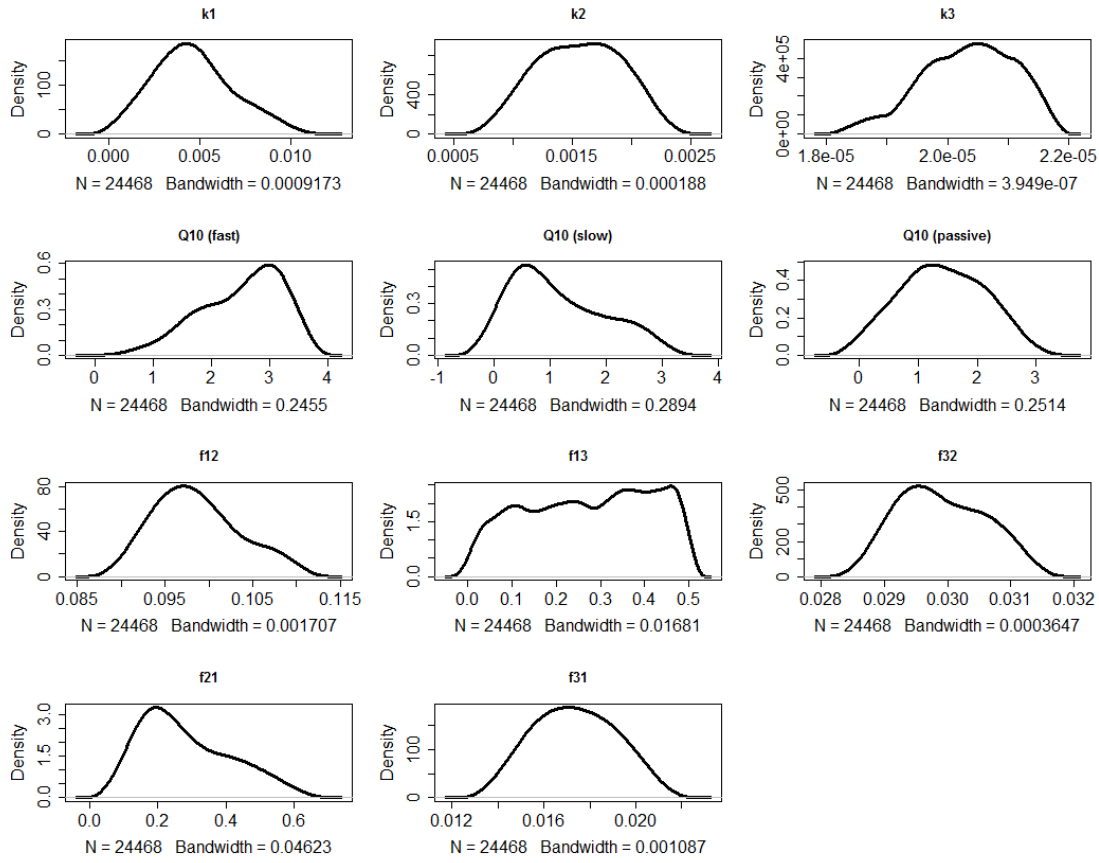


Figure S4. Probability distributions of the parameters in the three-pool model for tropical forest. N indicates the accept number of parameters.

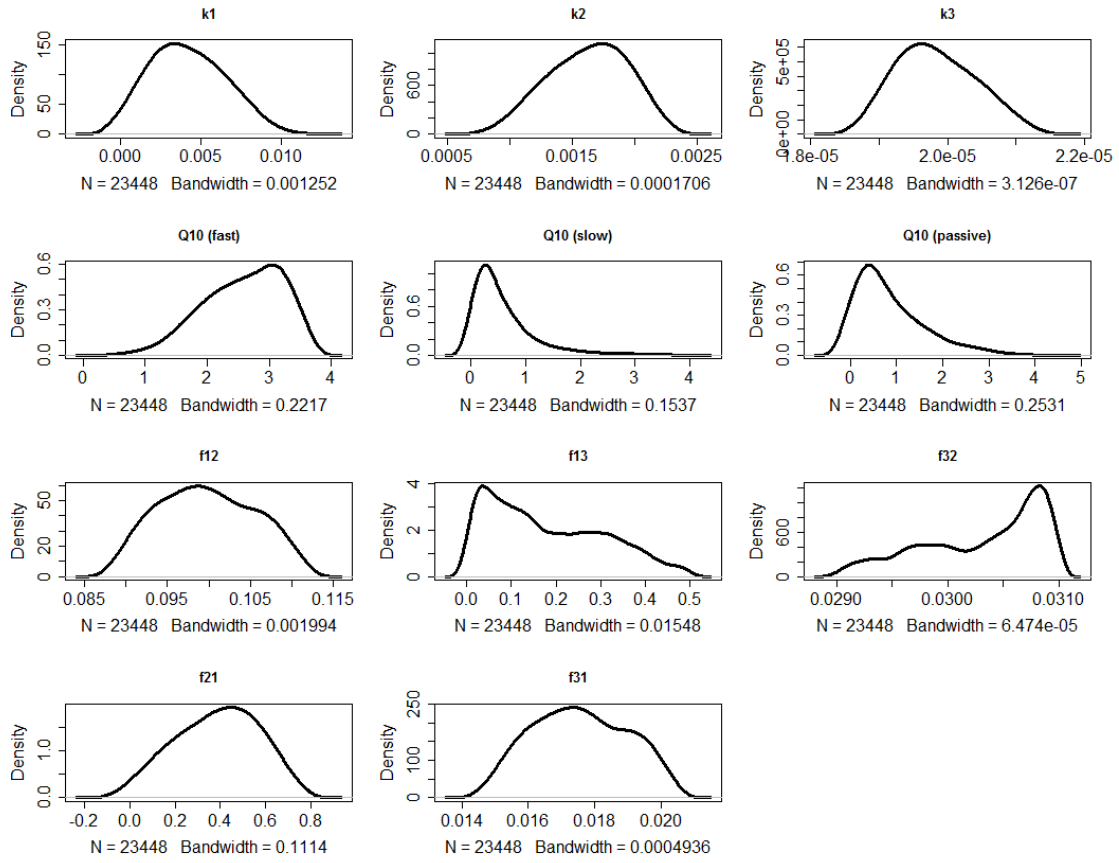


Figure S5. Probability distributions of the parameters in the three-pool model for temperate forest. N indicates the accept number of parameters.

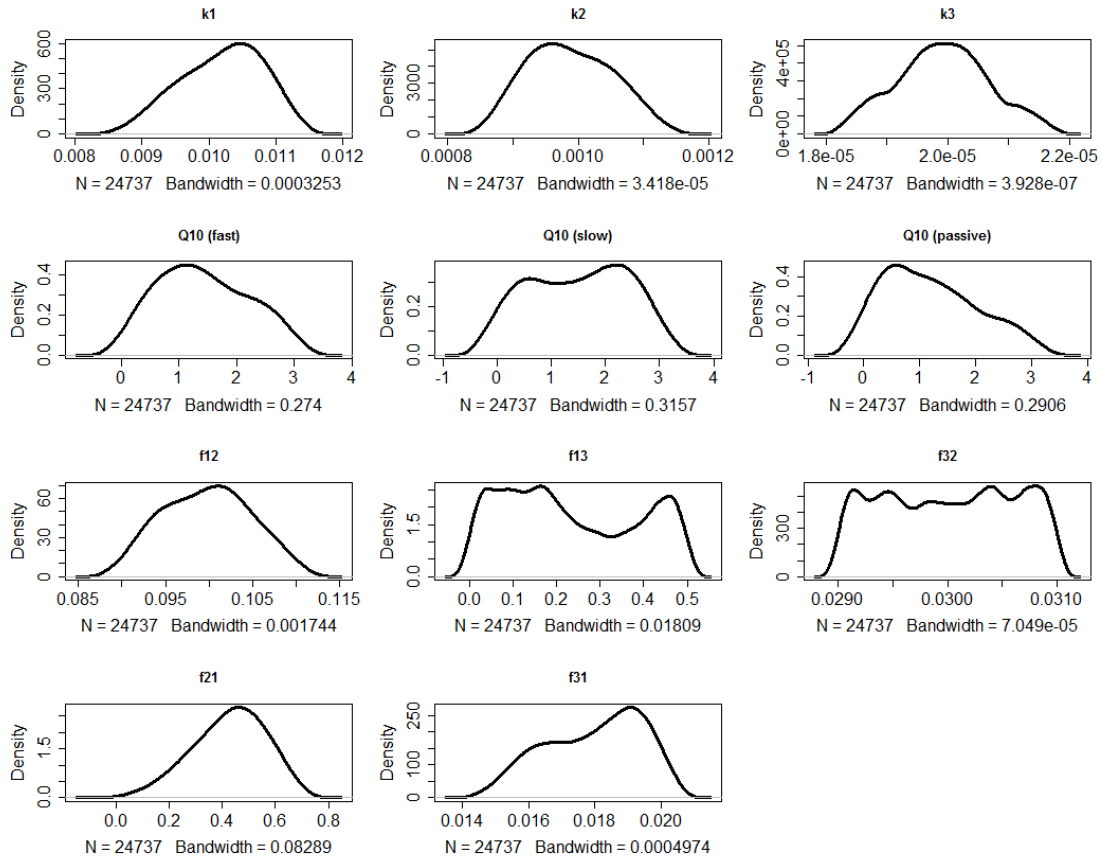


Figure S6. Probability distributions of the parameters in the three-pool model for boreal forest ecosystem. N indicates the accept number of parameters.



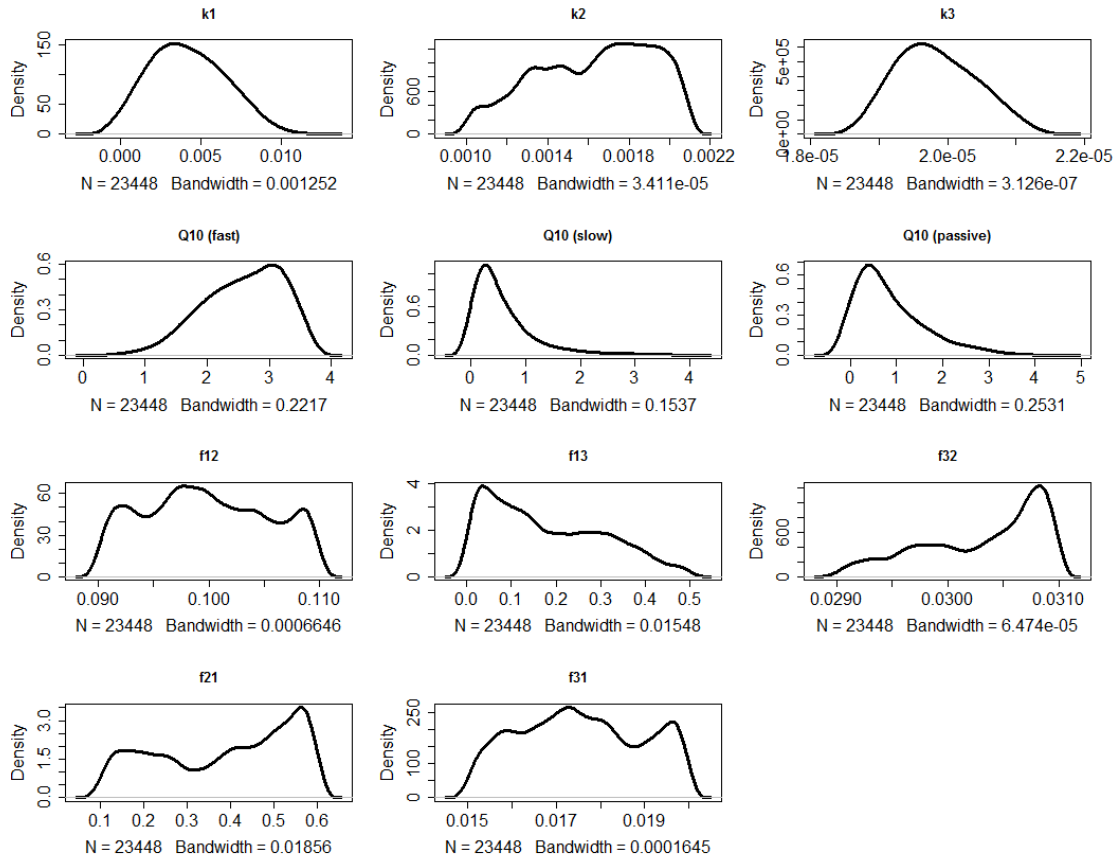


Figure S7. Probability distributions of the parameters in the three-pool model for tundra ecosystem.  $N$  indicates the accept number of parameters.

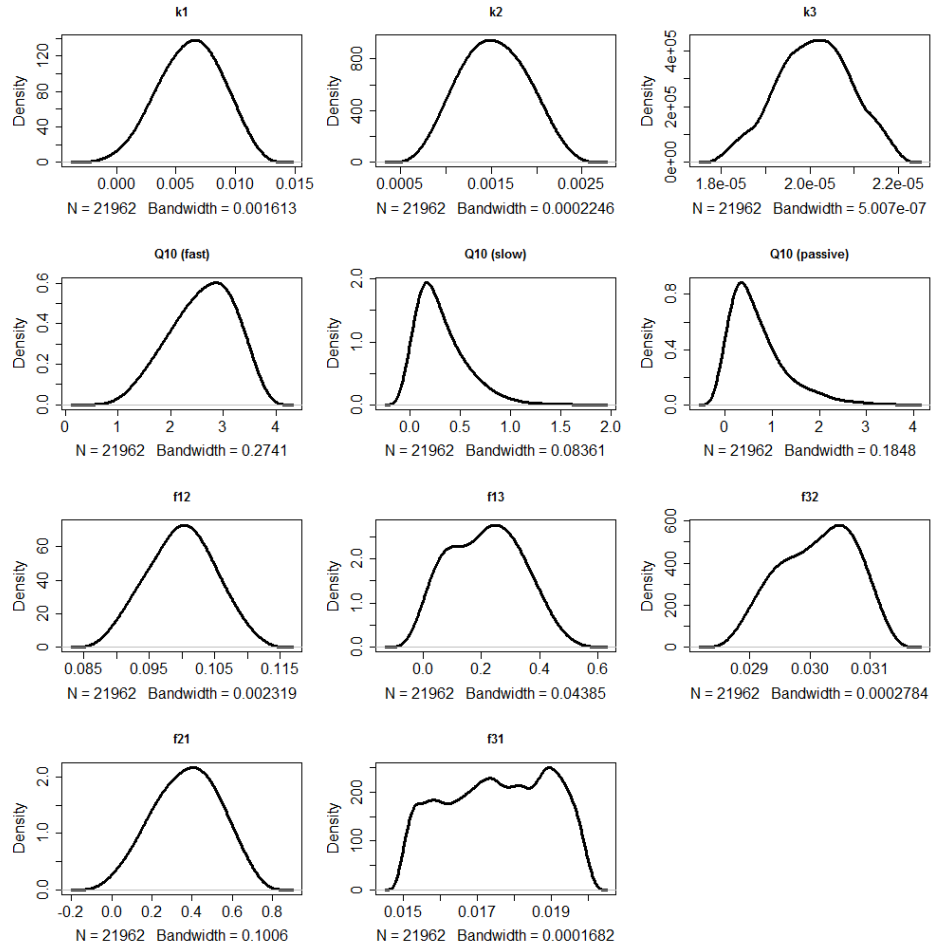


Figure S8. Probability distributions of the parameters in the three-pool model for desert and shrubland. N indicates the accept number of parameters.

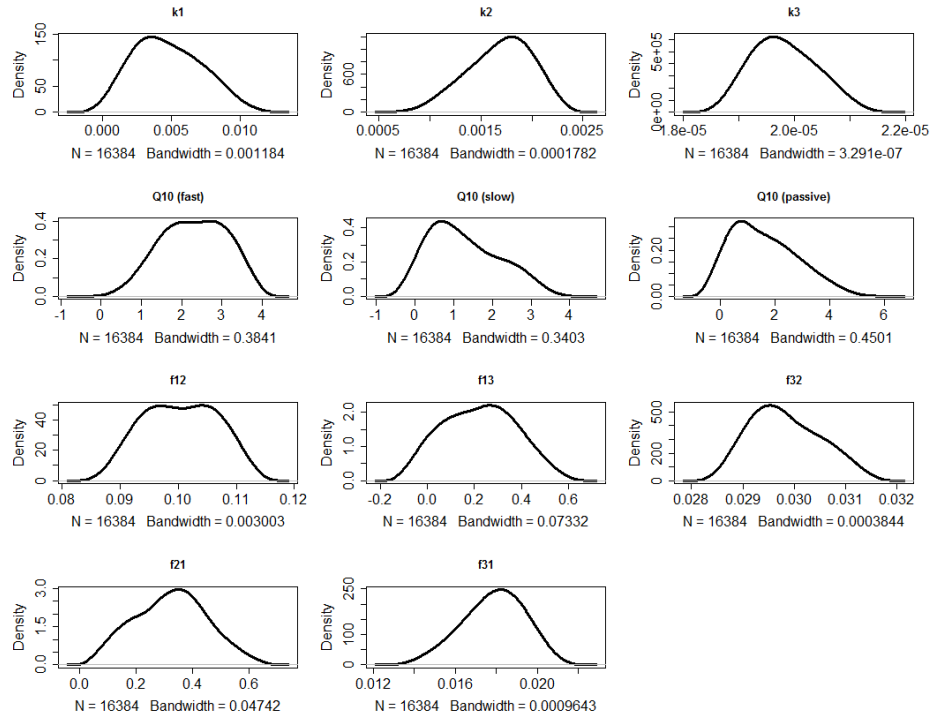


Figure S9. Probability distributions of the parameters in the three-pool model for cropland. N indicates the accept number of parameters.

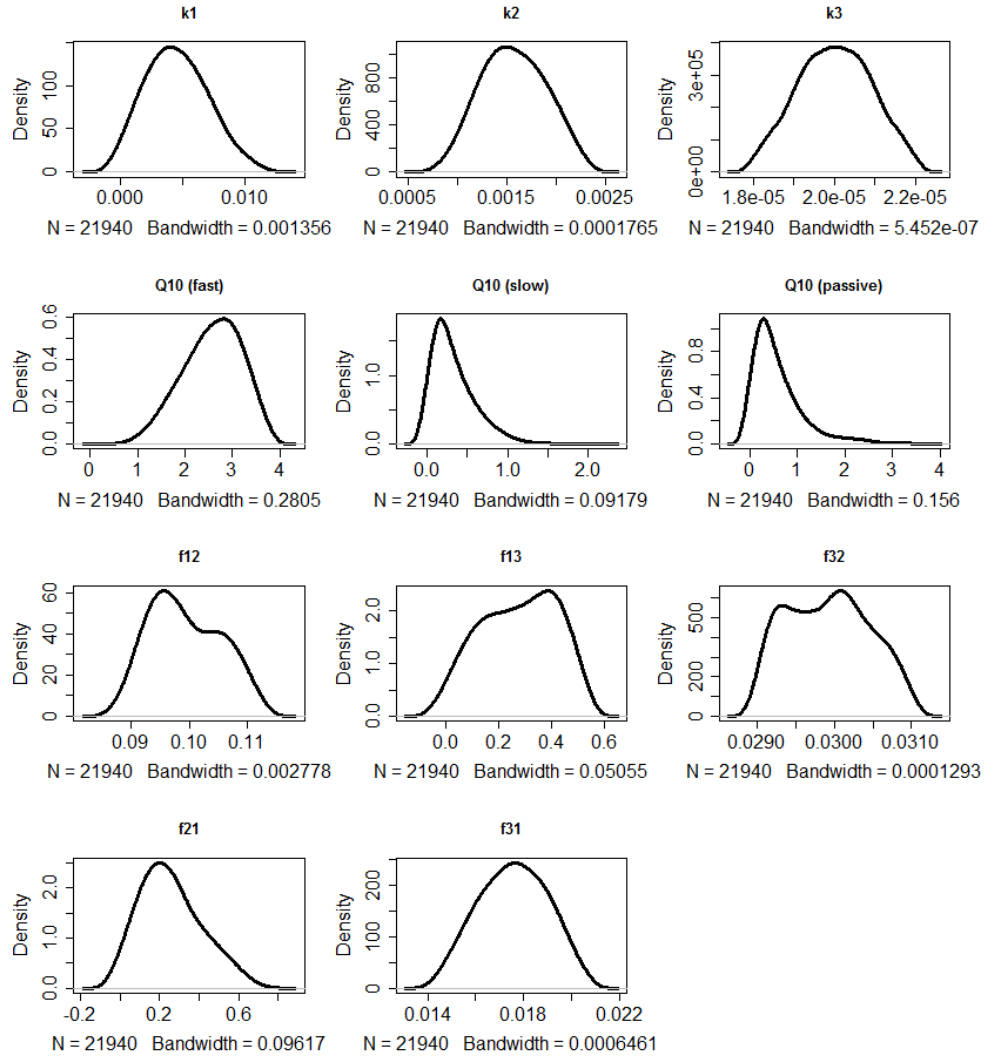


Figure S10. Probability distributions of the parameters in the three-pool model for grassland and savanna.  $N$  indicates the accept number of parameters.

Table S1. Summary of soil carbon models including Earth System Model information.

Model Name	Grid Size ( $^{\circ}\times^{\circ}$ )	Used data in this study	Nitrogen	Modeling Center (or Group)
CESM-BGC	0.94 $\times$ 1.25	SOC, NPP	Yes	Climate and Global Dynamics Laboratory (CGD), American National Center for Atmospheric Research (NCAR).
Can-ESM	2.79 $\times$ 2.81	SOC, NPP, Rh	No	Canadian Centre for Climate Modelling and Analysis
HadGEM2-CC	1.25 $\times$ 1.88	SOC, NPP	No	Met Office Hadley Centre (additional)
HadGEM2-ES	1.25 $\times$ 1.88	SOC, NPP, Rh	No	HadGEM2
inmcm4	1.50 $\times$ 2.00	SOC, NPP	No	Institute for Numerical Mathematics
IPSL-CM5A-LR	1.89 $\times$ 3.75	SOC, NPP	No	Institut Pierre-Simon Laplace
IPSL-CM5B-LR	1.89 $\times$ 3.75	SOC, NPP, Rh	No	Institut Pierre-Simon Laplace
MIROC-ESM	2.79 $\times$ 2.81	SOC, NPP, Rh	No	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies
MIROC-ESM-CHEM	2.79 $\times$ 2.81	SOC, NPP	No	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies
MPI-ESM-LR	1.86 $\times$ 1.88	SOC, NPP, Rh	No	Max-Planck-Institut für Meteorologie (Max Planck Institute for Meteorology)
NorESM1-M	1.89 $\times$ 2.50	SOC, NPP	Yes	Bjerknes Centre for Climate Research
NorESM1-ME	1.89 $\times$ 2.50	SOC, NPP, Rh	Yes	Bjerknes Centre for Climate Research

Table S2. Prior parameters of three-pool simulation.

Parameter	Definition	Value	Range
$Q_{10}$	The temperature scalar in fast, slow and passive carbon pools	2	(0, 6)
$f_{12}$	The fraction of carbon from pool 2 to pool 1	0.1	(0.1, 0.6)
$f_{13}$	The fraction of carbon from pool 3 to pool 1	0.2	(0, 1)
$f_{21}$	The fraction of carbon from pool 1 to pool 2	0.5	(0.1, 0.6)
$f_{31}$	The fraction of carbon from pool 1 to pool 3	0.004	(0, 0.1)
$f_{32}$	The fraction of carbon from pool 2 to pool 3	0.03	(0, 0.03)
$k_1$	The decomposition rate of the fast soil carbon pool	0.01	(0.001, 0.05)
$k_2$	The decomposition rate of the slow soil carbon pool	0.006	(0.001, 0.0021)
$k_3$	The decomposition rate of the passive soil carbon pool	0.00002	( $1.910^{-6}$ , $2.1 \cdot 10^{-5}$ )

Table S3 Maximum likelihood estimates of parameters,  $P$ -value,  $R^2$  and the Akaike information criterion ( $AIC$ ) values in the three-pool model with observations.

Biomes	$Q_{10}$			Transit time (year)				$P$	$R^2$	$AIC$
	fast	slow	passive	fast	slow	passive	Mean			
Boreal forest	1.4	2.8	3.1	4.7	84.2	131.8	66.4	< 0.05	0.95	-158.9
Temperate forest	2.2	1.4	0.8	3.2	28.8	36.8	79	< 0.05	0.96	-167.5
Tropical forest	2.5	1.1	1.4	3	18.7	18.9	28.9	< 0.05	0.95	-224.7
Cropland	2.3	1.3	1.6	3.2	34.5	71.1	77.1	< 0.05	0.99	-209.5
Tundra	2.9	4.2	3.8	47.1	54.9	105.8	166.5	< 0.05	0.96	-106.1
Desert/Shrubland	2.5	1.3	3.7	32.7	55.8	114.8	135.3	< 0.05	0.95	-88.5
Grassland/Savanna	1.9	1.1	2.8	22.6	45.9	88.3	53.8	< 0.05	0.95	-45.8