

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 (τ_{soil}).

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 ($mg\ kg^{-1}$) 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_{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}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 (C_3/C_4 plant or grassland/forest) change of the sample site.

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

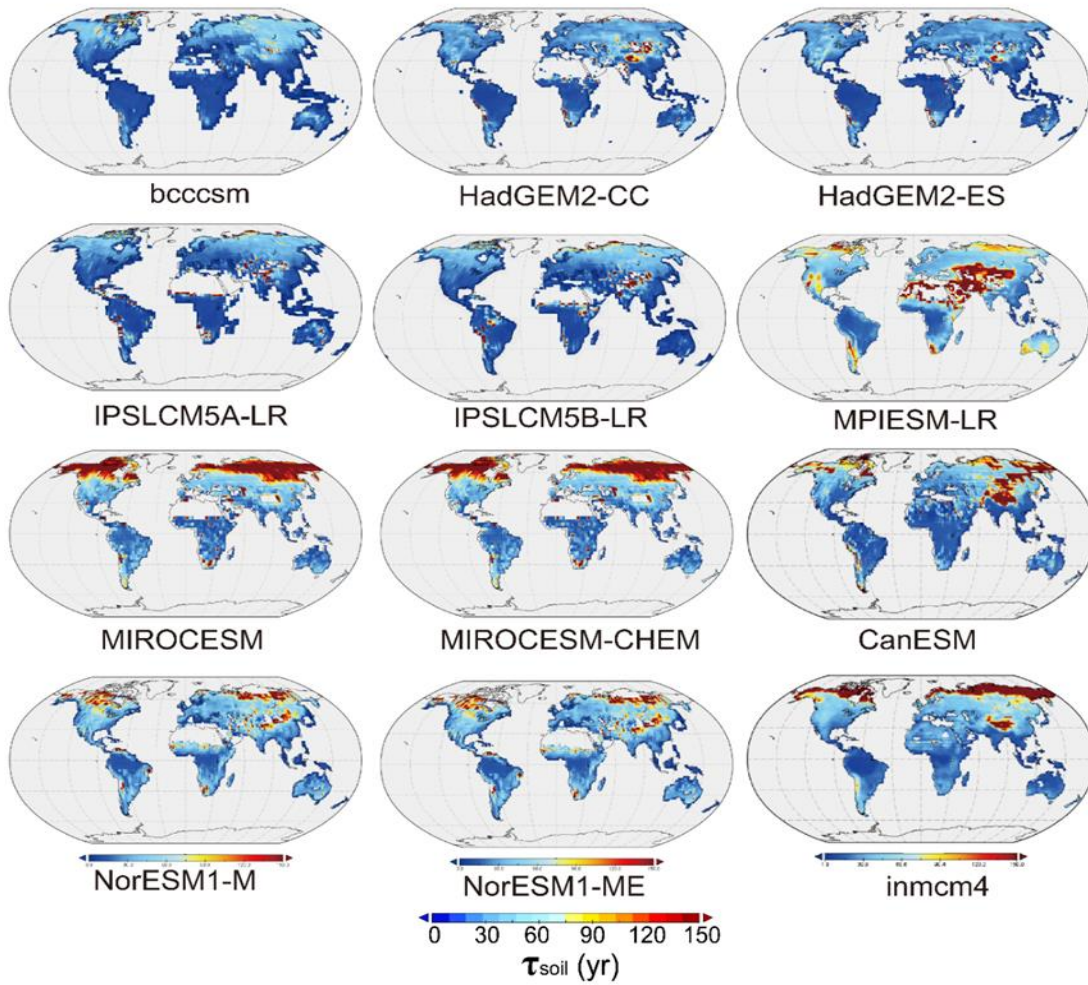


Figure S1. SOC transit time (τ_{soil}) of SOC from Earth system models. These soil carbon densities represent 1995–2005 means from the historical simulations of the Climate Model Intercomparison Project 5 (CIMP5).

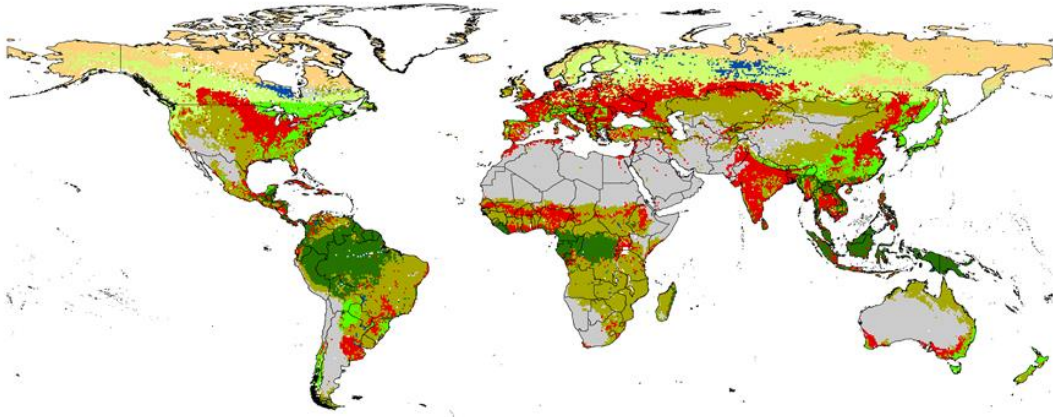


Figure S2. Classification of plant function type. (1) Tropical forest includes evergreen broadleaf forest between 25° N and 25° S; (2) Temperate forest includes deciduous broadleaf, evergreen broadleaf outside of 25° N and 25° S, and mixed forest south of 50° N; (3) Boreal forest includes evergreen needleleaf 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.

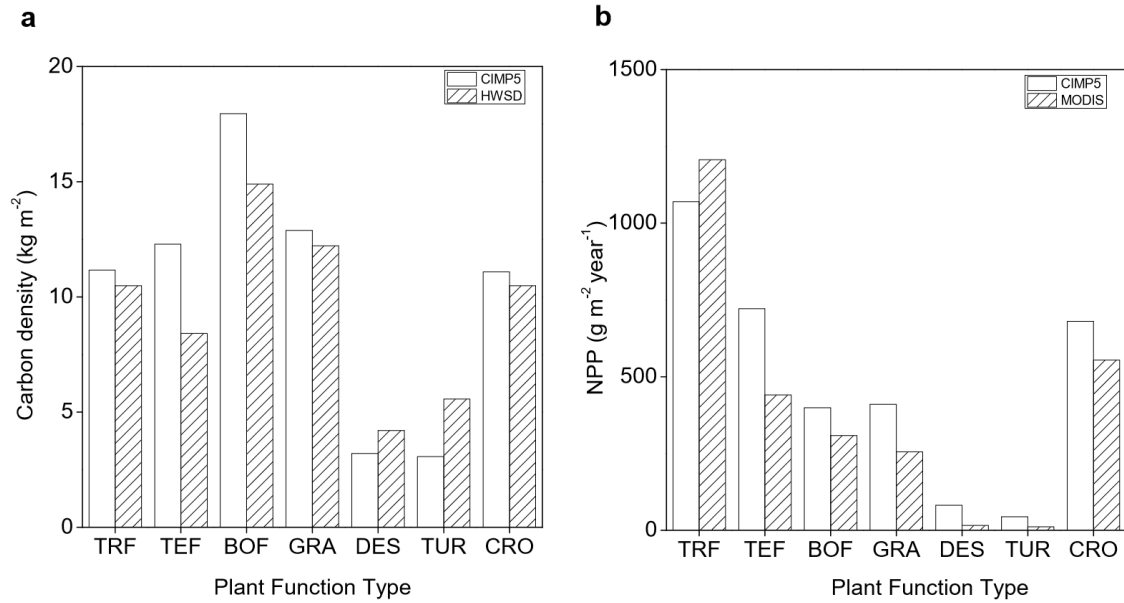


Figure S3. Biases of estimating the transit time (τ_{soil}). a, The CMIP5 models underestimated the SOC stock in tundra (~1.8 times) and desert (~1.3 times) based on the Harmonized World Soil Database (HWSD). b, Overestimated the NPP in tundra and desert by 4 and 5 times comparison with the MODIS product.

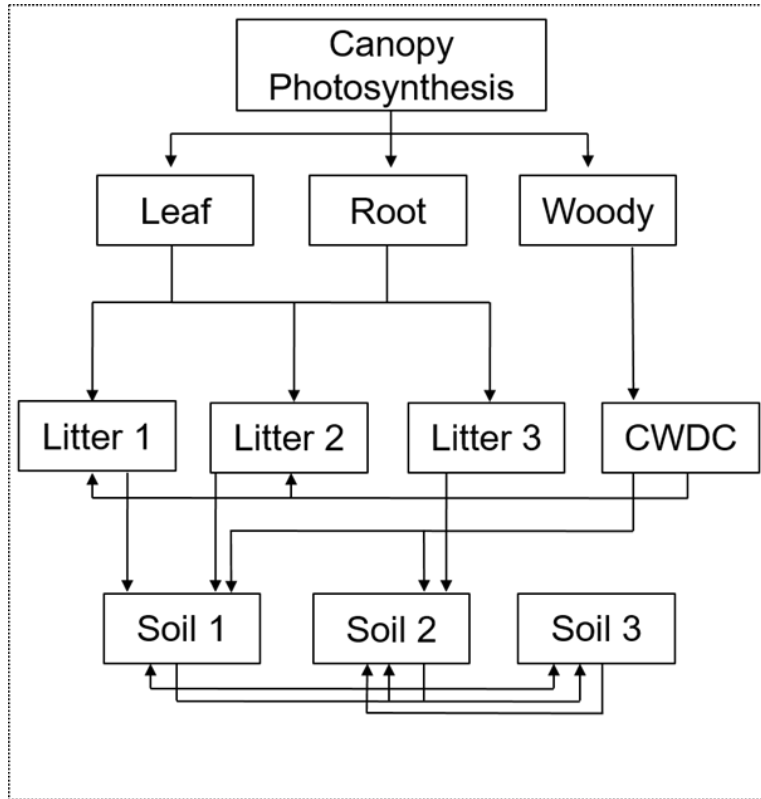


Figure S4. The framework of CLM4.5 and transit time (τ_{soil}) at the ecosystem level. The carbon pools are: leaf, root, wood, metabolic litter (litter1), cellulose litter (litter2), lignin litter (litter3), coarse wood debris (CWD), SOC pool of fast (soil 1), slow (soil 2), and passive (soil 3), respectively.

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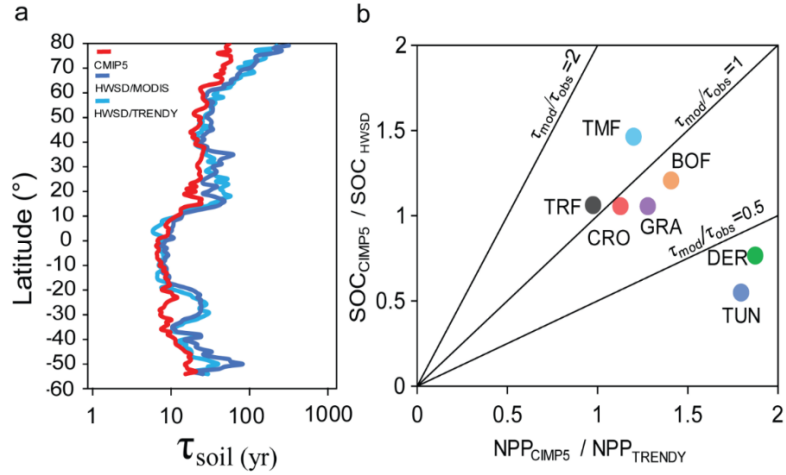


Figure S5. Biases of estimating the SOC transit time (τ_{soil}) in TRENDY models. a, Latitudinal gradients of τ_{soil} . b, the biases of NPP and SOC on estimating τ_{soil} . The SOC data from HWSD, and the NPP data from TRENDY models.

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Biome	Observations (year)			Models (year)		
	Median	Q ₁	Q ₃	Median	Q ₁	Q ₃
Tropical forest	14.67	9.38	129.50	7.64	0.30	12.78
Temperature forest	43.77	13.13	88.59	29.46	11.39	27.02
Boreal forest	57.50	24.55	169.83	27.35	18.21	32.31
Grassland and Savanna	34.85	20.75	56.75	23.70	23.19	29.43
Desert and Shrubland	170.38	58.13	508.19	37.21	14.00	87.69
Tundra	159.00	38.50	648.79	20.71	15.32	30.13
Cropland	61.89	21.00	120.49	27.91	24.96	32.00

Table S1. Median and quartiles of τ_{soil} in the observations and multi-model ensemble.

Model Name	Grid Size (°×°)	Used data in this study	Nitrogen	Modeling Center (or Group)
CESM-BGC	0.94×1.25	SOC, NPP	Yes	Climate and Global Dynamics Laboratory (CGD), American National Center for Atmospheric Research (NCAR).
Can-ESM	2.79×2.81	SOC, NPP, Rh	No	Canadian Centre for Climate Modelling and Analysis
HadGEM2-CC	1.25×1.88	SOC, NPP	No	Met Office Hadley Centre (additional
HadGEM2-ES	1.25×1.88	SOC, NPP, Rh	No	HadGEM2
inmcm4	1.50×2.00	SOC, NPP	No	Institute for Numerical Mathematics
IPSL-CM5A-LR	1.89×3.75	SOC, NPP	No	Institut Pierre-Simon Laplace
IPSL-CM5B-LR	1.89×3.75	SOC, NPP, Rh	No	Institut Pierre-Simon Laplace
MIROC-ESM	2.79×2.81	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	2.79×2.81	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	1.86×1.88	SOC, NPP, Rh	No	Max-Planck-Institut für Meteorologie (Max Planck Institute for Meteorology)
NorESM1-M	1.89×2.50	SOC, NPP	Yes	Bjerknes Centre for Climate Research
NorESM1-ME	1.89×2.50	SOC, NPP, Rh	Yes	Bjerknes Centre for Climate Research

Table S2. Summary of soil carbon models including Earth system model information.

Model name	Grid size (°×°)	Used data in this study	Nitrogen
LPJ	0.5×0.5	SOC, NPP, Rh	Yes
LPJ_GUESS	0.5×0.5	SOC, NPP, Rh	No
OCN	1×1.2	SOC, NPP, Rh	No
TRIFFID	1.25×1.88	SOC, NPP, Rh	No
HYLAND	1.50×2.00	SOC, NPP, Rh	No
CLM4CN	1.89×3.75	SOC, NPP, Rh	Yes
CLM4C	0.5×0.5	SOC, NPP, Rh	No
SDGVM	0.5×0.5	SOC, NPP, Rh	No
VEGAS.2.1	0.5×0.5	SOC, NPP, Rh	No
ORCHIDEE	0.5×0.5	SOC, NPP, Rh	No

Table S3. Summary of soil carbon models including Earth system model information.