Supplementary Information for manuscript:

The key role of forest disturbance in reconciling estimates of the northern carbon sink

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Figures

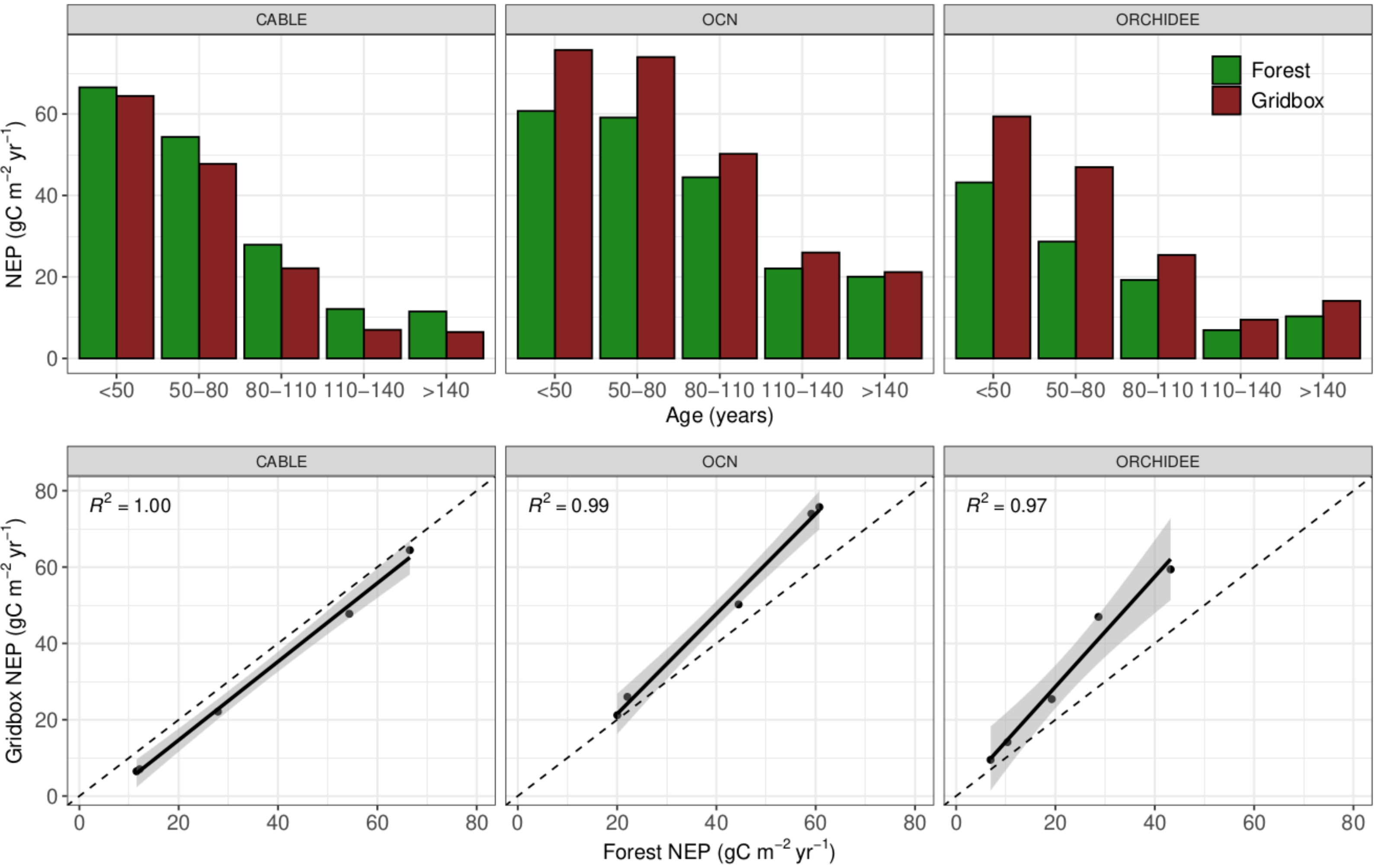

Figure S1 - Forest NEP has a dominant control on gridbox NEP. (Top row) Forest and gridbox NEP for different age classes for the DGVMs that report plant-specific heterotrophic respiration. (Bottom row) Direct comparison between forest and gridbox total NEP. Each point represents an age class. The dashed line is the 1:1 line. Forest NEP is reported as the net flux per area of gridbox, not area of forest to enable a direct comparison with the gridbox total.

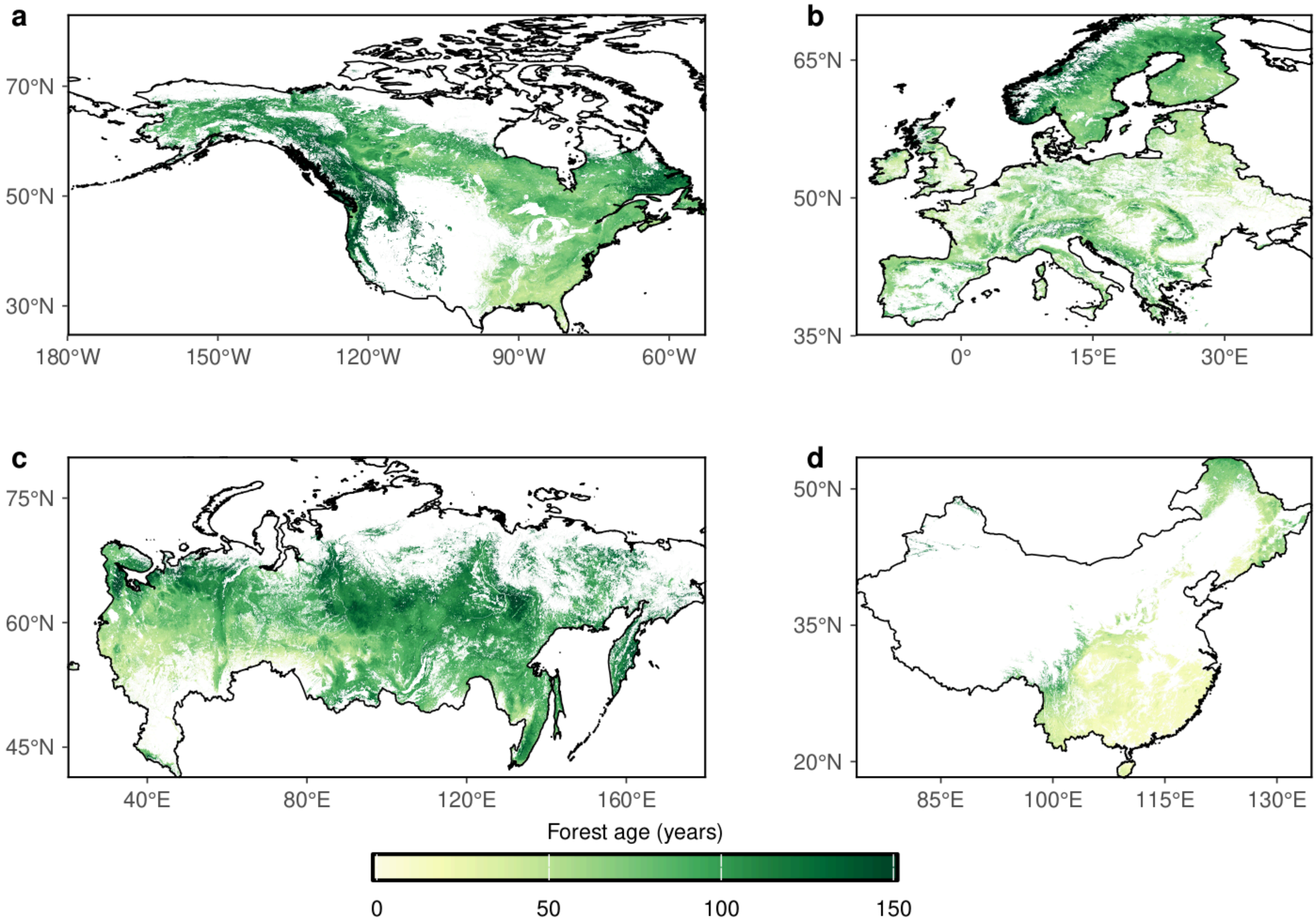

Figure S2 - Forest age (years) map for the year 2010 as found in ref. [1]. Only grid cells with > 30% tree cover are included in the upscaling from 100m to 1km spatial resolution. Trees older than 150 years are truncated for plotting purposes.

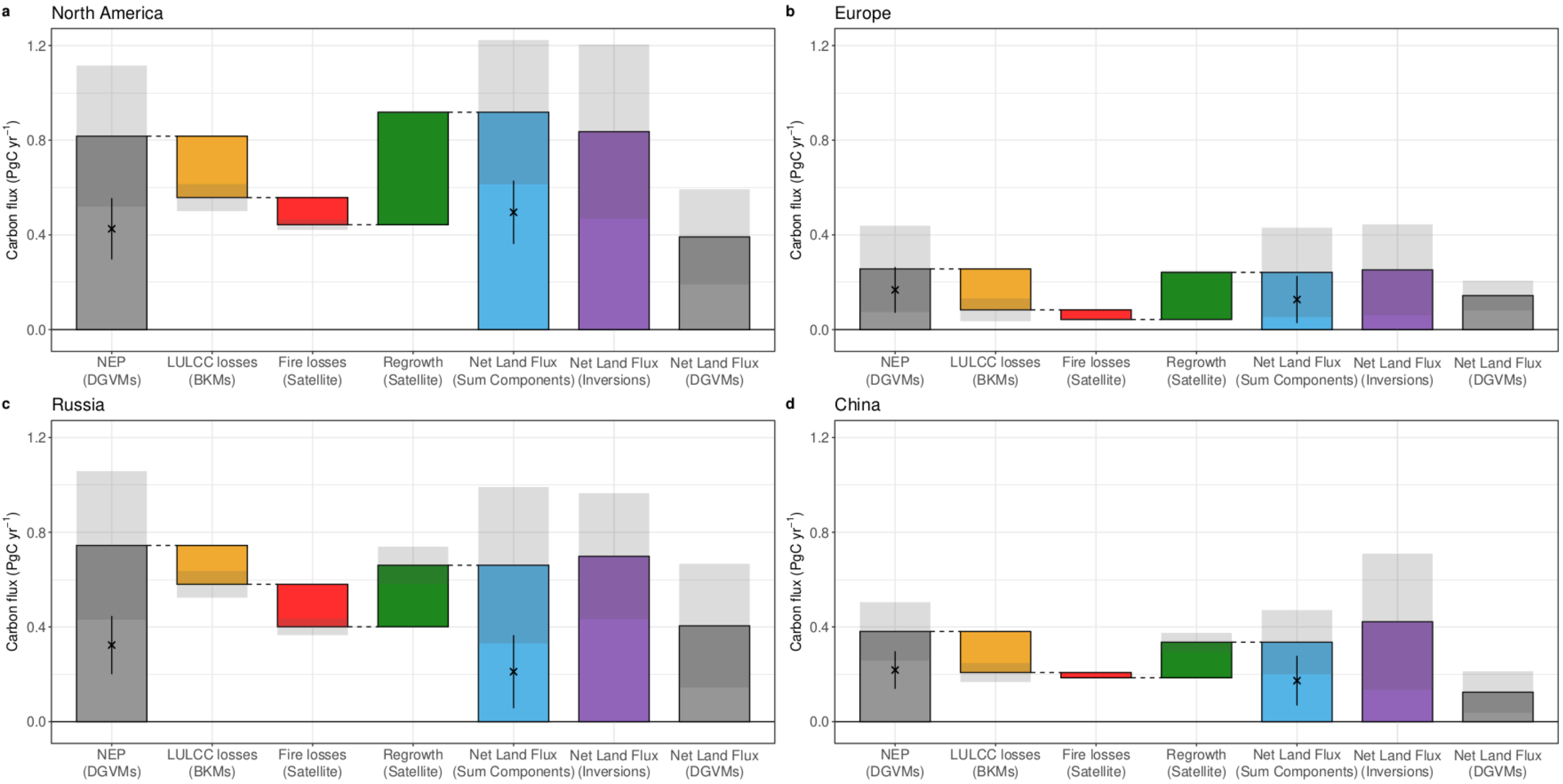

Figure S3 - Regional mean attribution of the northern land carbon sink. Mean carbon flux over the period 2001-2021 for individual components, for (a) North America, (b) Europe, (c) Russia, and (d) China. The carbon sink from rising atmospheric CO2, nitrogen deposition, and climate change is estimated by the DGVMs (only using fire-enabled DGVMs) from the S2 simulation (grey bar). NEP for non-fire-enabled DGVMs is shown as a cross. Land-use and land cover change gross losses (including peat drainage) are estimated from three bookkeeping models, BLUE, OSCAR, and HN (orange bar). Fire carbon losses are estimated by two satellite-derived products; GFAS and GFED4.1s, for the period 2003-2021 (red bar). The forest regrowth carbon flux is estimated from this study (green). The sum of the four components (DGVM NEP, Regrowth, LULCC losses, and fire losses) represents our new estimate of the net land sink (light blue bar). The cross on top of the blue bar shows the sum of four components but with NEP from the non-fire enabled models. The net land sink as estimated by atmospheric inversions (purple) and the original estimate from the DGVMs (S3 simulation; grey bar) are shown. Shading in all panels represents 1σ uncertainty across the models or inversion datasets, respectively.

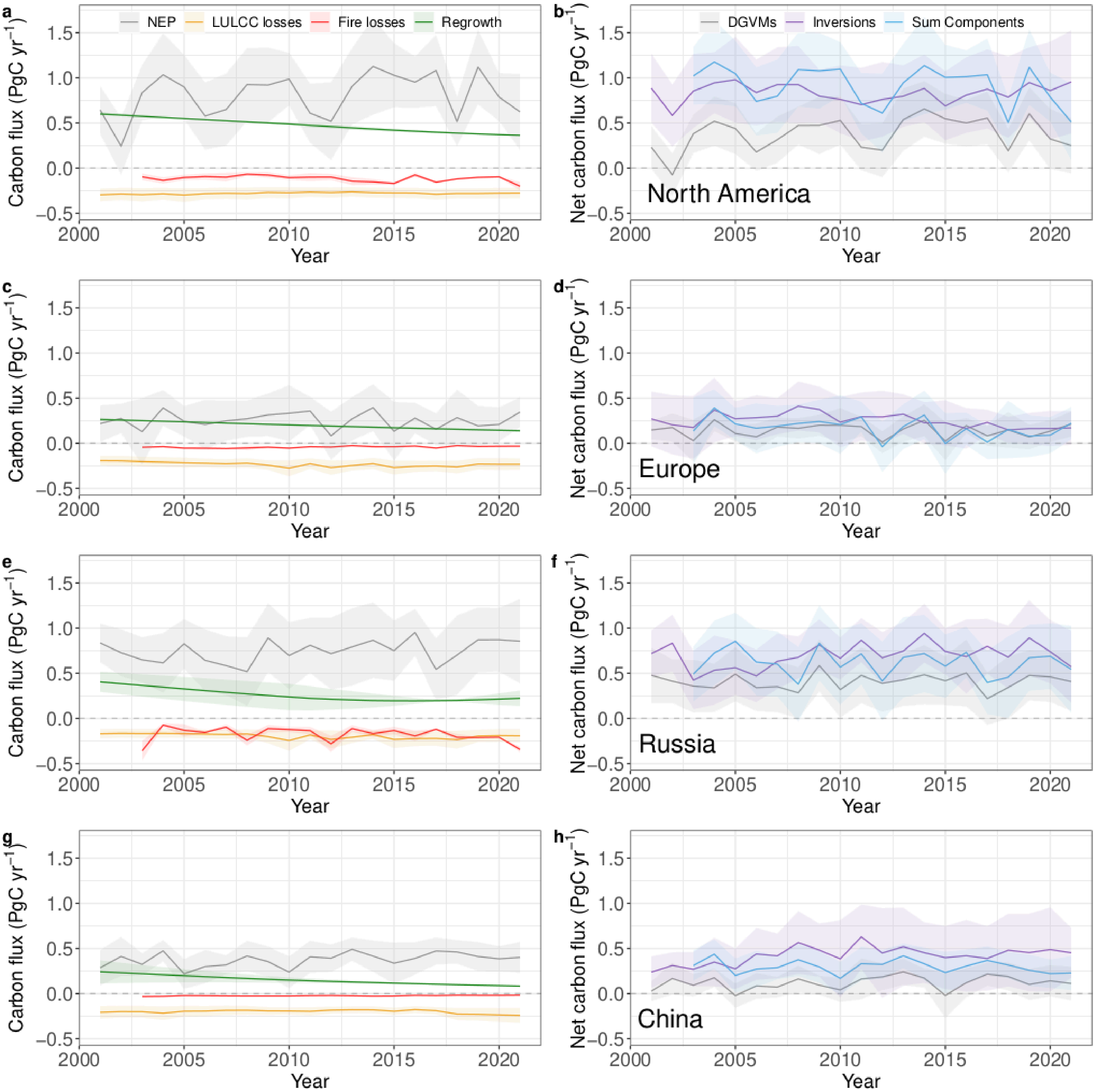

Figure S4 - Regional attribution of the northern land carbon sink. Annual mean carbon fluxes for (a,b) North America, (c,d) Europe, (e,f) Russia, and (g,h) China, for (a,c,e,g) the four component fluxes; NEP (fire-enabled DGVMs only), Regrowth, LULCC losses, and fire losses (positive values mean flux from atmosphere to land), and (b,d,f,h) the sum of the four components (blue), the net land sink as estimated by the inversions (purple), and the original

DGVM estimate (S3 simulation; grey). Shading in all panels represents 1σ uncertainty across the models or inversion datasets, respectively.

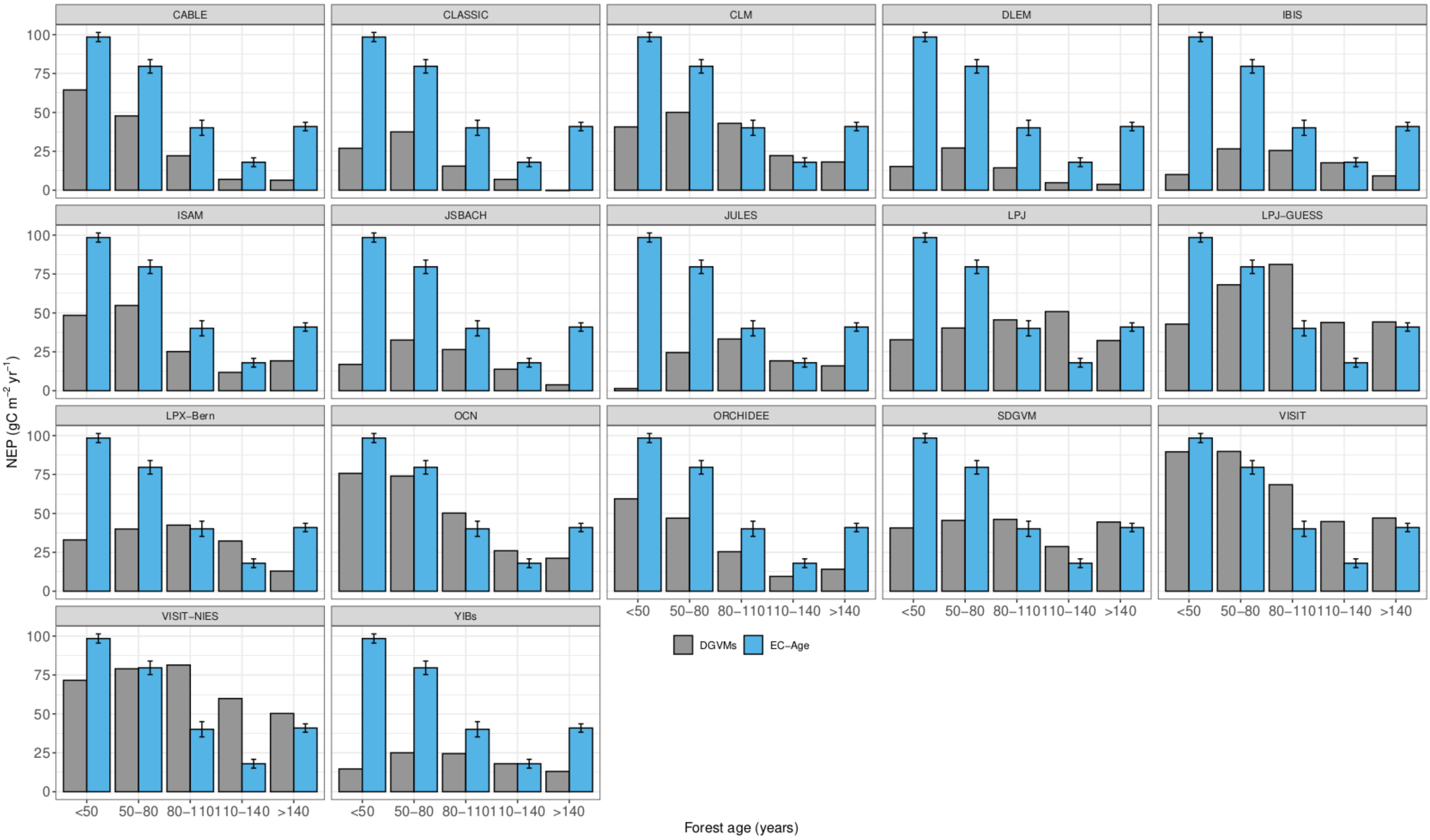

Figure S5 - Large divergence in individual DGVM NEP relation to forest age. Net ecosystem production (NEP) estimates from individual DGVMs (grey) and upscaled eddy covariance data (EC-Age), which has been adjusted for tree age (blue). The NEP fluxes are partitioned into forest age classes. Here we show gridbox mean NEP for the DGVMs, which includes non-forest fluxes.

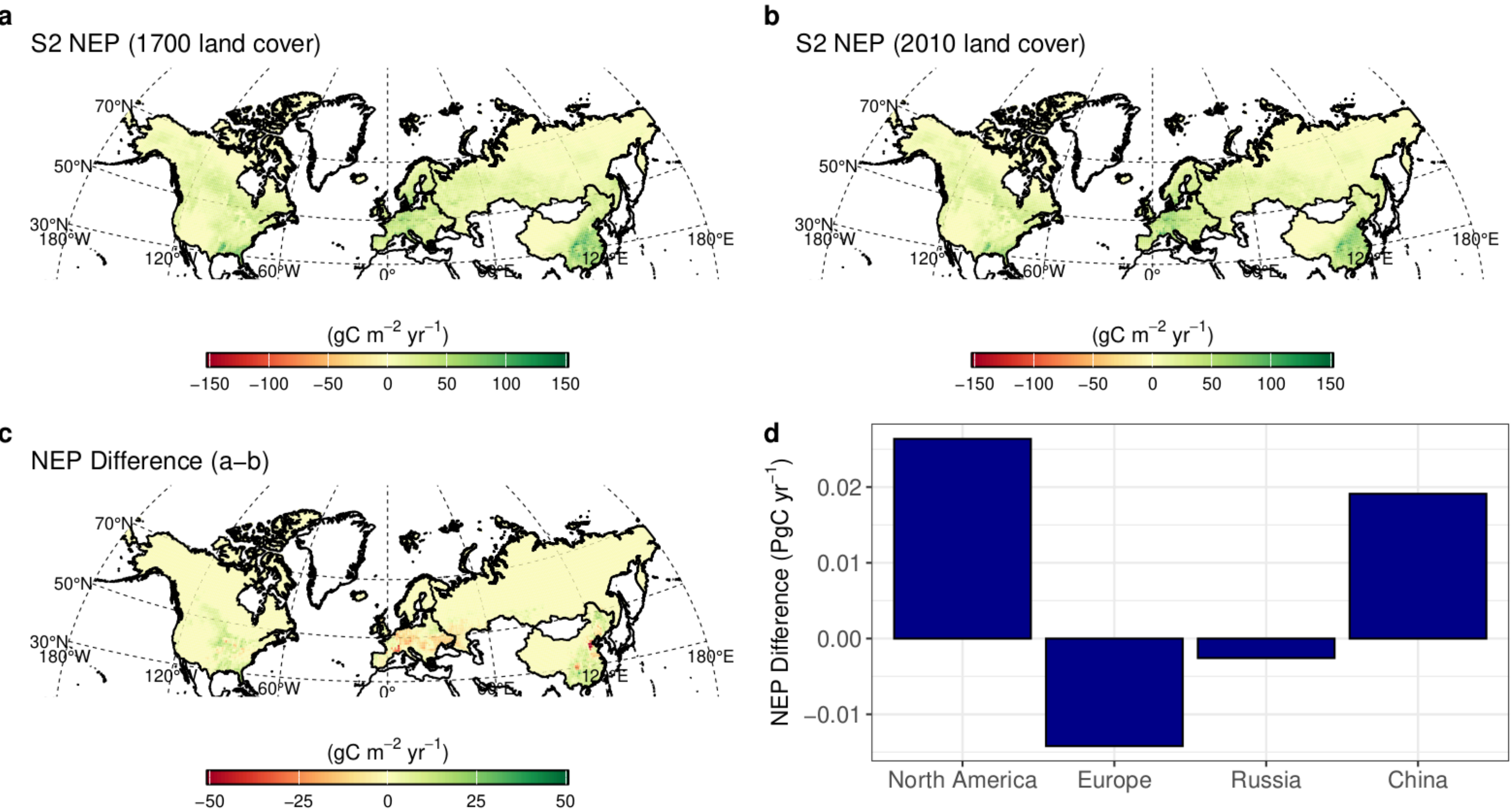

Figure S6 - The bias in ORCHIDEE S2 NEP due to fixed 1700 land cover. (a) Mean NEP (2001-2021) for the standard S2 simulation (transient atmospheric CO2, nitrogen deposition, and climate, and fixed 1700 land cover). (b) S2 NEP bias-corrected for the land cover. Plant-level output for Net Primary Productivity (NPP) and Heterotrophic Respiration (Rh), is combined to calculate plant-level NEP from the S2 simulation. These plant-level NEP rates are then combined with 2010 land cover. (c) Spatial bias in NEP, calculated as panel a) subtract panel b). Green indicates NEP from the S2 simulation is overestimated, and red indicates NEP is underestimated. (d) Regional mean bias for the four study regions.

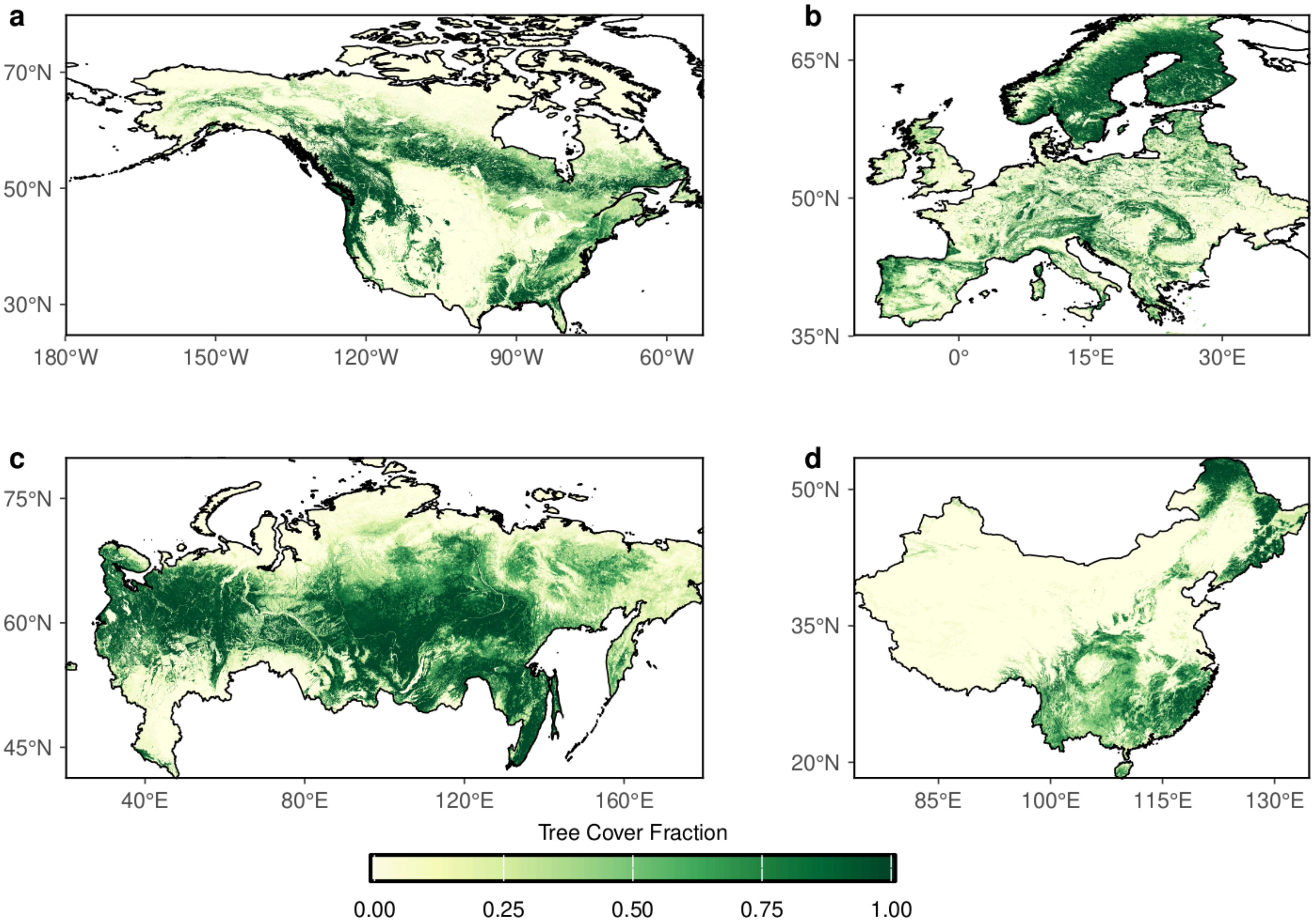

Figure S7 - Tree cover fraction (0-1) at 1km spatial resolution from ref. [2]. This product is used in a final step to convert per area of forest fluxes into per area of grid cell fluxes for forest regrowth (see Methods in main ms). With per area grid cell flux, regional total regrowth carbon fluxes can be calculated.

Tables

Table S1: List of acronyms used in this study.

Acronym	Full Name	Description
DGVM	Dynamic Global Vegetation Model	Models vegetation dynamics and their interactions with the climate and carbon cycle.
ESA CCI	European Space Agency	Program aimed at providing data to monitor climate

	Climate Change Initiative	change and its impacts from space.
ESM	Earth System Model	Integrated models that simulate the physical, chemical, and biological processes of the Earth system.
FAO	Food and Agriculture Organisation	United Nations agency focused on global food security and agriculture.
FRA	Forest Resources Assessment	Global assessment of the state and changes in forest resources conducted by FAO.
GFAS	Global Fire Assimilation System	System that estimates global fire emissions by combining satellite observations with modelling
GFED	Global Fire Emissions Database	Database that provides information on the emissions of trace gases and aerosols from fires globally.
LULCC	Land Use and Land Cover Change	Study of changes in the use and cover of land, impacting ecosystems and climate.
NEP	Net Ecosystem Production	Measure of the net carbon exchange between ecosystems and the atmosphere.
NPP	Net Primary Productivity	Amount of carbon uptake after subtracting plant respiration from total photosynthesis.
OCO-2	Orbiting Carbon Observatory-2	NASA satellite designed to measure atmospheric carbon dioxide concentrations from space.
PgC	Petagrams of Carbon	Unit of measurement used to quantify large-scale carbon stocks and fluxes (1 PgC = 1 billion tons).
Rh	Heterotrophic Respiration	Process where organisms decompose organic material, releasing carbon dioxide.
TRENDY	Trends in the Land Carbon Cycle	Initiative that compiles data and models to study trends in the land carbon cycle.

Supplementary References

1. Besnard, S. *et al.* Mapping global forest age from forest inventories, biomass and climate data. *Earth Syst. Sci. Data* **13**, 4881–4896 (2021).
2. Tuanmu, M.-N. & Jetz, W. A global 1-km consensus land-cover product for biodiversity and ecosystem modelling. *Glob. Ecol. Biogeogr.* **23**, 1031–1045 (2014).