A newly developed approach to estimate aboveground autotrophic respiration in global forest ecosystems

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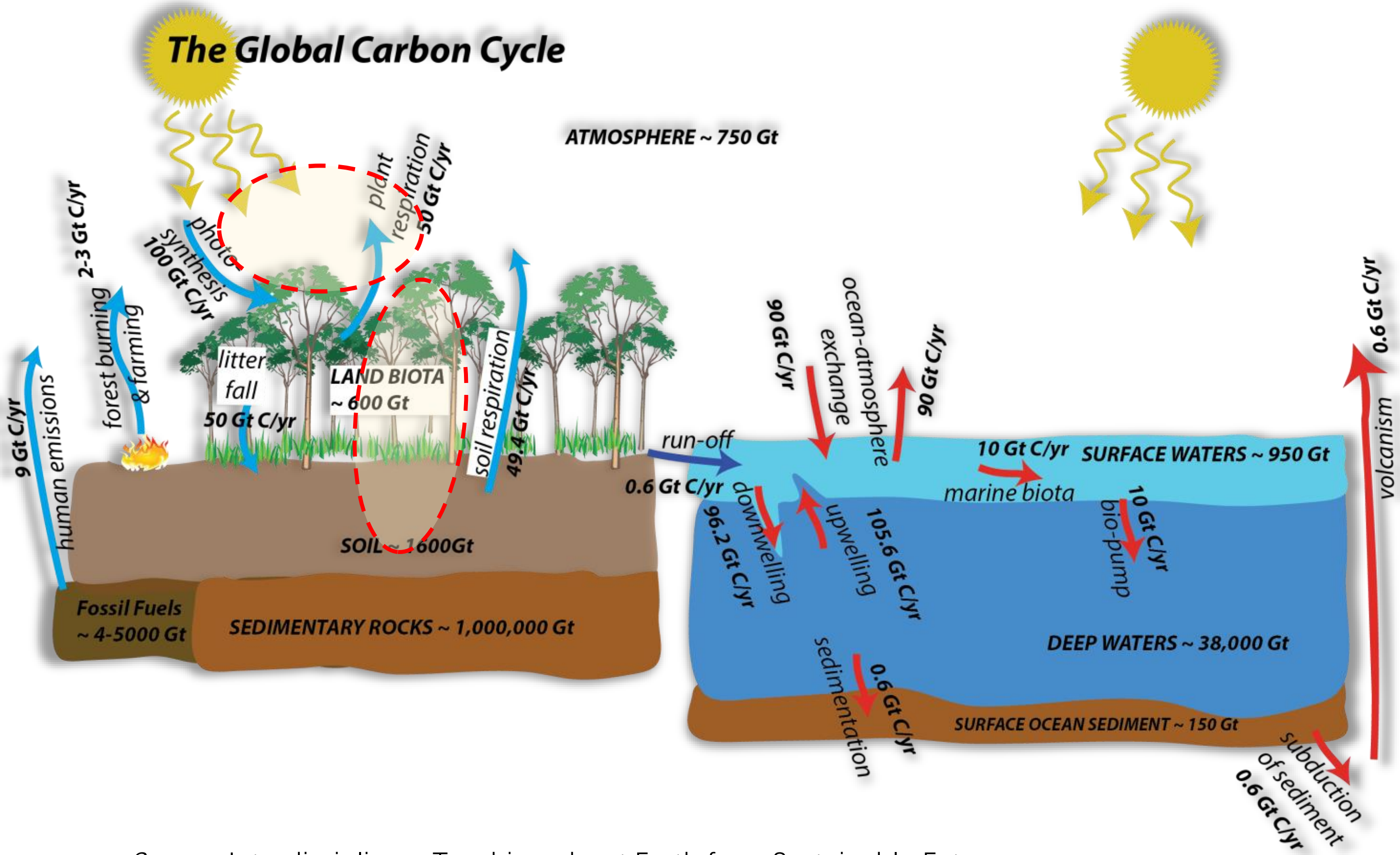
Table of Content

Background

Respiration is the largest outflux from terrestrial ecosystem to the atmosphere

Terrestrial ecosystem release carbon to the atmosphere through respiration:

- Plant respiration: 50 Pg C yr^{-1} (1 Pg = 10^{15} g)
- Soil respiration: up to 108 Pg C yr^{-1}



Source: Interdisciplinary Teaching about Earth for a Sustainable Future

Background

Measuring respiration at scales is challenging due to large spatial and temporal variabilities and complex compositions.

- **特定的尺度**
- **特定的对象**
- **各有优势**
- **各有局限性**

Background

Measuring respiration at scales is challenging due to large spatial and temporal variabilities and complex compositions.

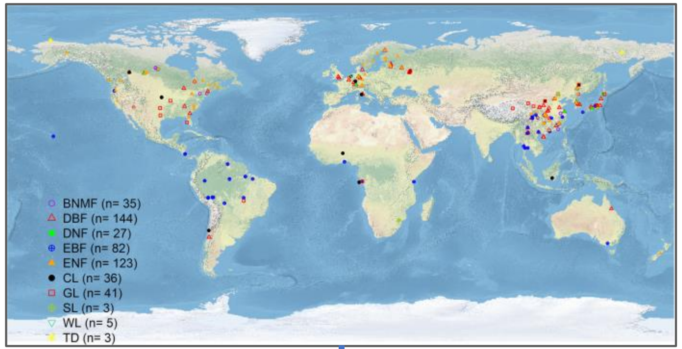
土壤呼吸
箱式法面积：0.5× 0.5 m
自动：动态箱
人工：静态箱-气相色谱

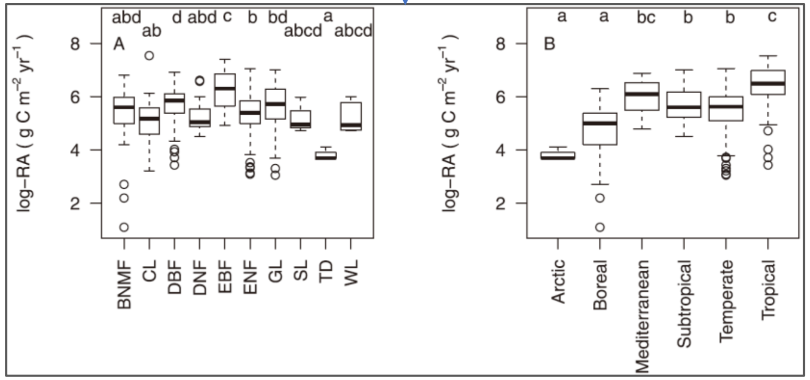
树干流液
单株
自动

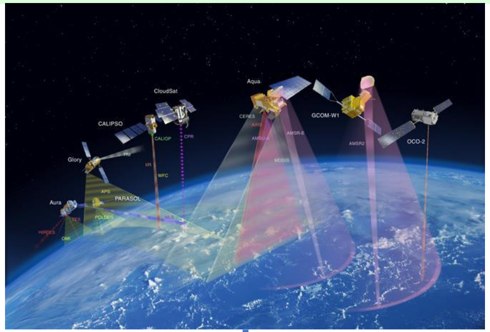
树干呼吸
箱式法面积：直径10 cm
自动：动态箱
人工：静态箱-气相色谱

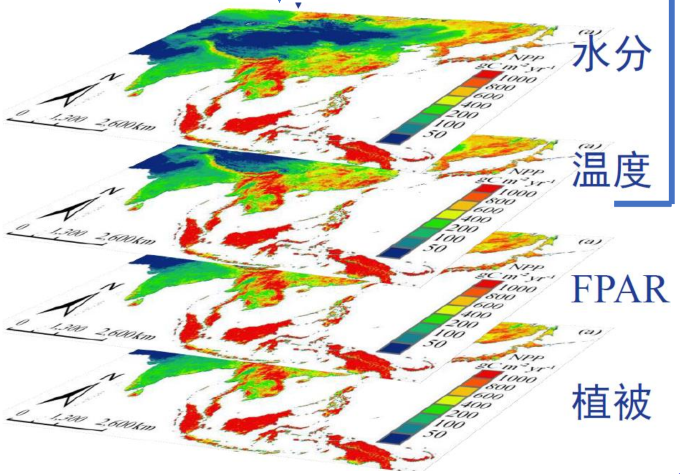
Background

Respiration can divided into belowground (soil) and aboveground respiration, and soil respiration has been widely studied from site level to global level.

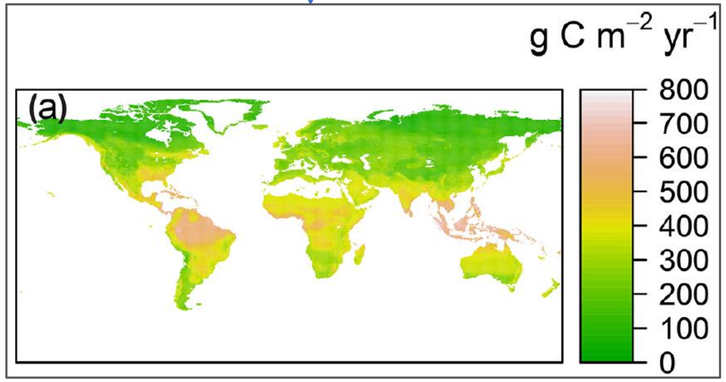








Machine learning algorithms:
RF、ANN……
Models：IBIS、CLM5……



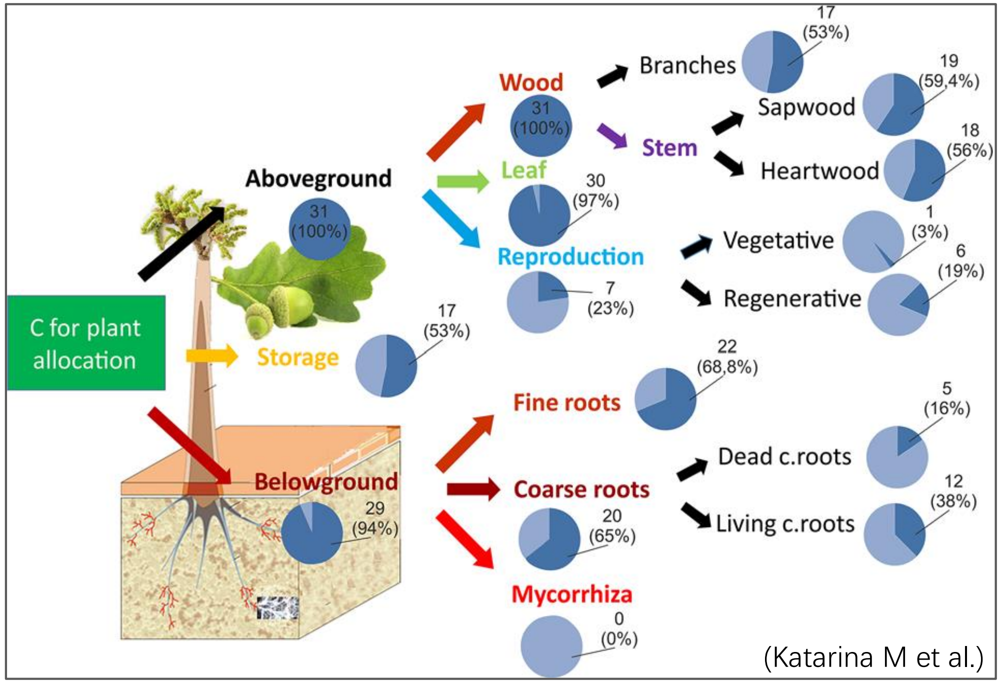
Source: (Tang et al,. 2020) **Site level**

Global level

Background

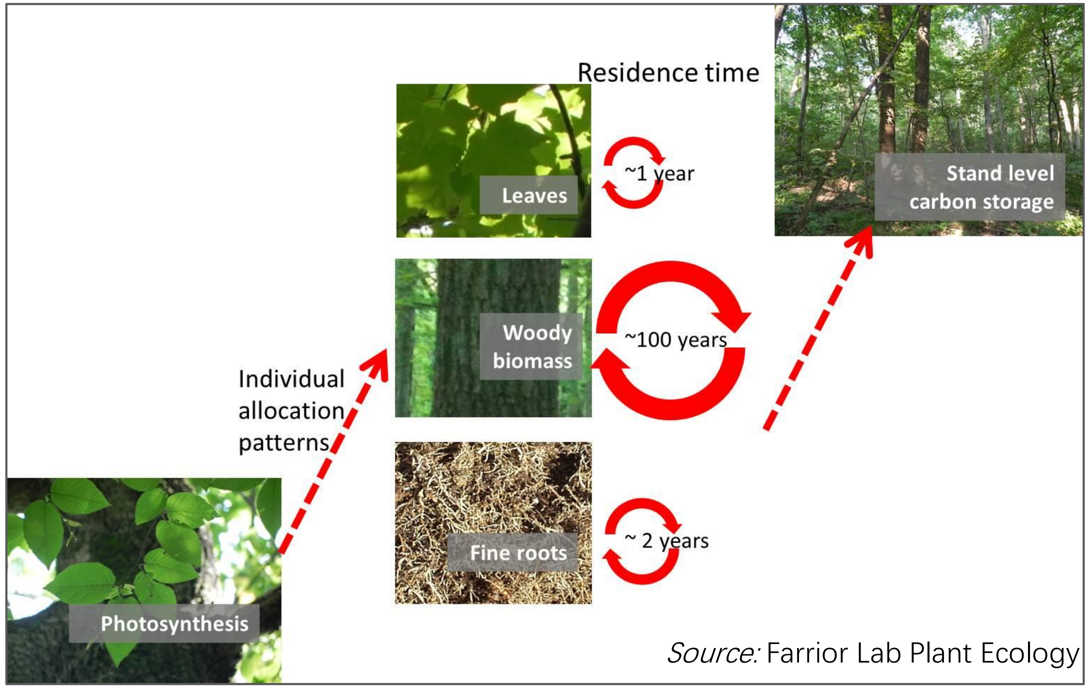
Carbon allocation from GPP to belowground (soil) and aboveground respiration is still unknown.

C for plant allocatiom



(Katarina M et al.)

Carbon allocation in forests

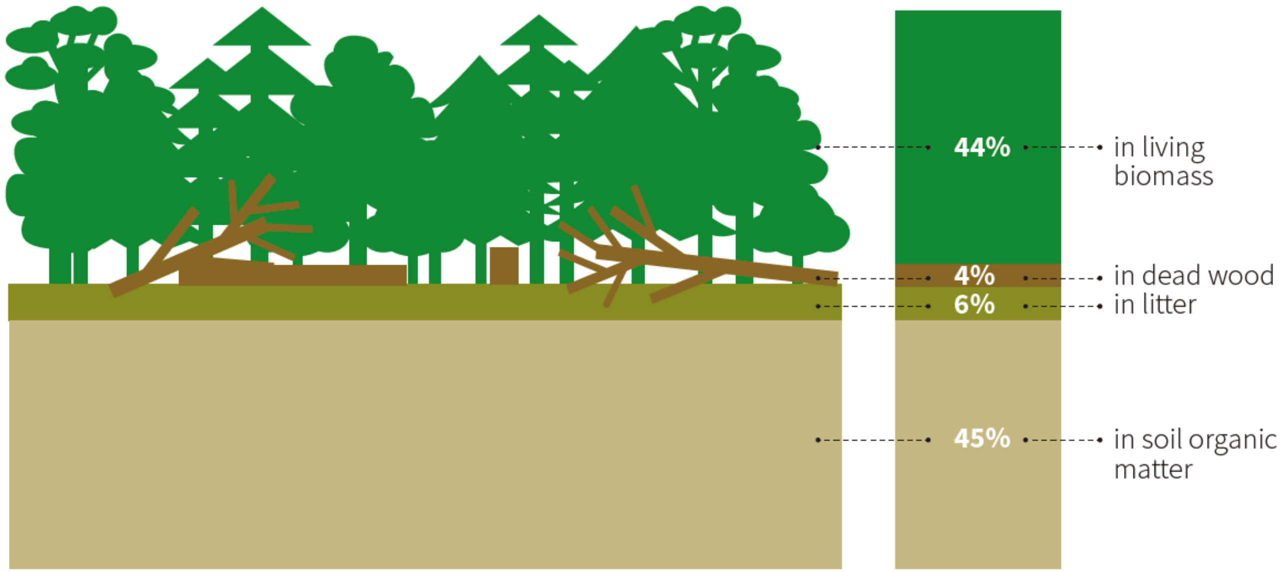


Source: Farrior Lab Plant Ecology

Background

Forests contain the largest carbon pool in soil and biomass, but forest is one of the most complex ecosystems, acting as a critical role in global climate mitigation and adaptation.

Proportion of carbon stock in forest carbon pools, 2020



Source: Global Forest Resources Assessment, 2020

- **The total carbon stock in forests decreased from 668 Gt C in 1990 to 662 Gt C in 2020;**
- **Carbon density increased slightly over the same period, from 159 t ha^{-1} to 163 t ha^{-1} .**

Objectives

- **Estimating the temporal trend of RA_{soil} and examining its spatial distribution pattern;**
- **Carbon allocation from GPP to belowground RA (CA_B);**
- **Developing a new approach to estimate aboveground $RA_{aboveground}$ in forest ecosystems.**

Methodology

Data Sources

Global Soil Respiration Database
(https://github.com/bpbond/srdb, Bond-Lamberty et al., 2010)

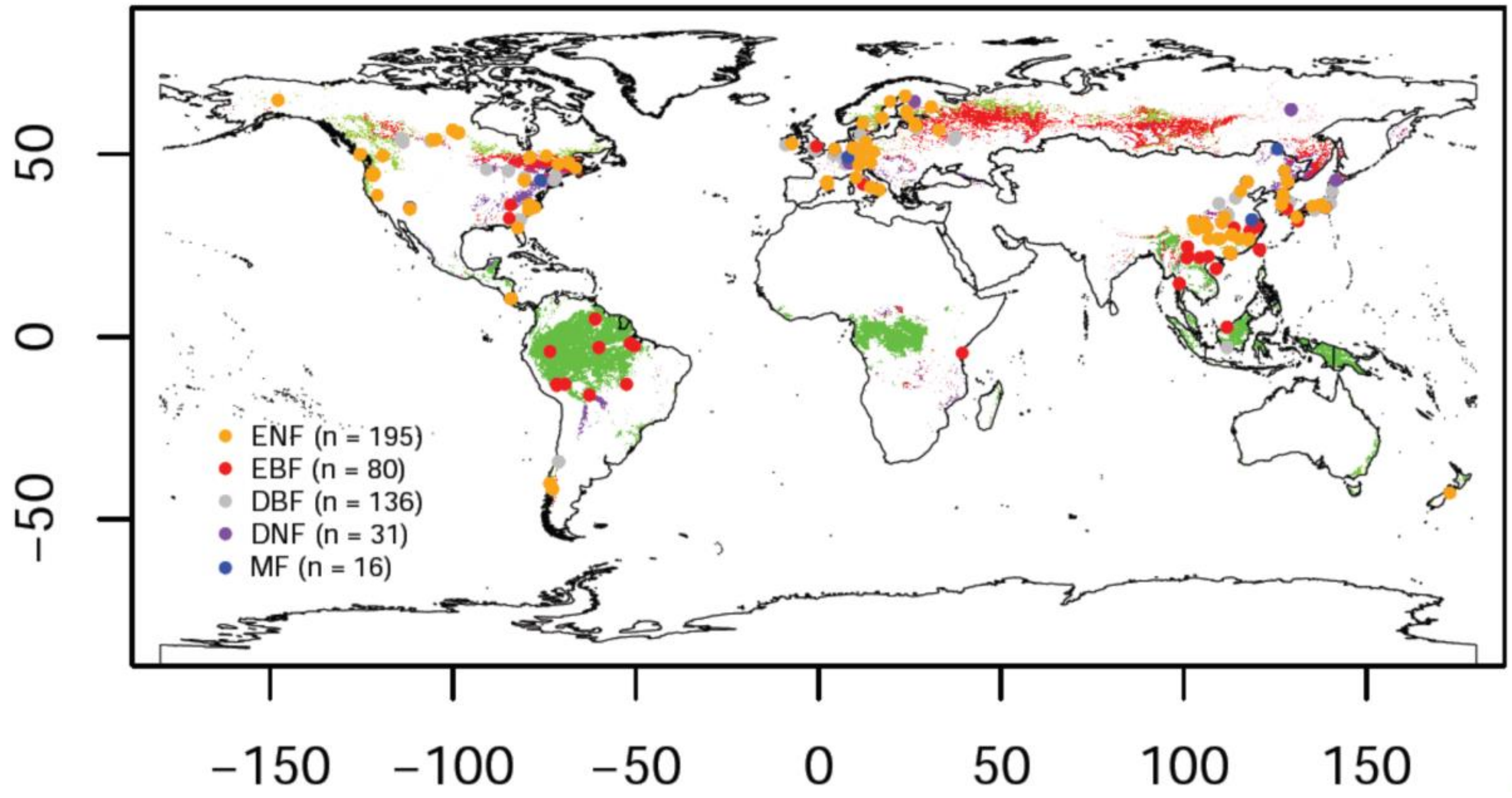
- ISI
- Updated from CNKI
- Updated in April 2020

Selecting criteria

- Annual RA >= 1 year;
- Start and end years reported or extracted from "years of data";
- Gas infra measurements only;
- Without treatment/management

Methodology

Data Sources



Forests from MODIS land cover

458 observations;

Uneven distributed globally;

Lacking in tropical areas, Australia, southeast Asia, and Russia.

Methodology

Global variables

21 global variables at 0.5°

Climate
- Mean annual temperature
- Mean annual precipitation
- Diurnal temperature range
- ....

Soil
- Soil carbon content
- Soil nitrogen content
- Soil water content
- ......

Vegeation
- NDVI
- LAI
- FAPAR
- ....

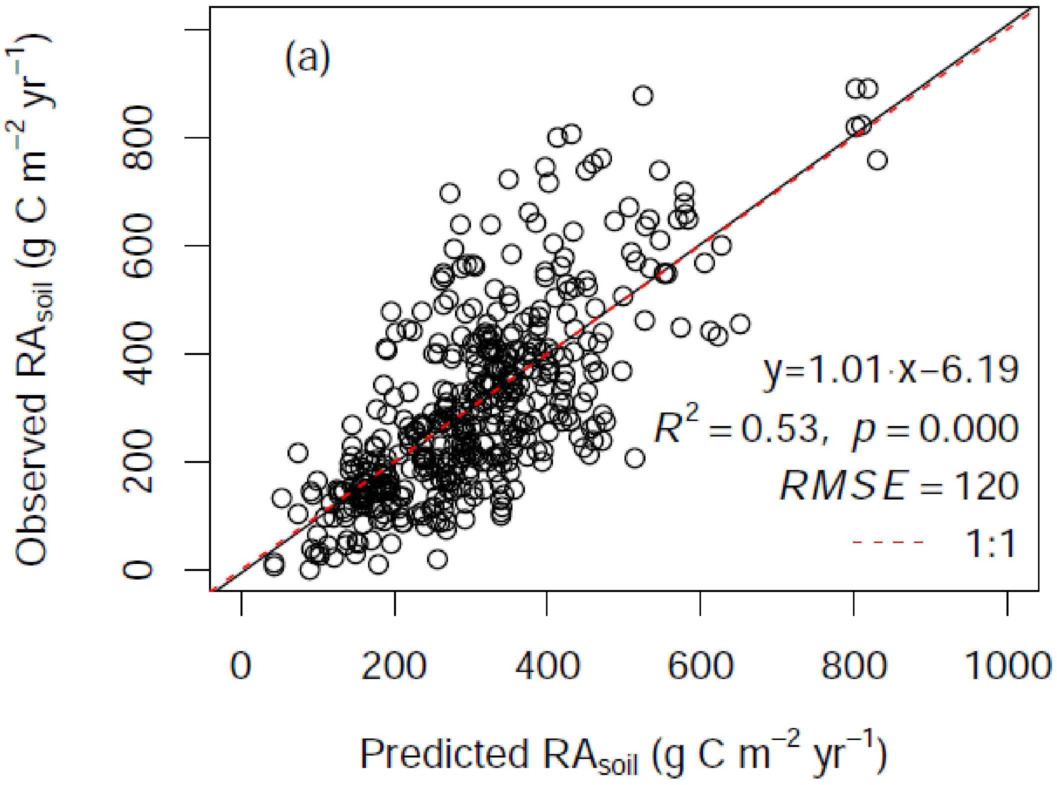
Methodology

- Random Forest-based RA Modelling – a machine learning method;
- Trend analysis — Theil-Sen linear regression and tested with the Mann-kendall non-parametric test;
- All processes conducted in R.

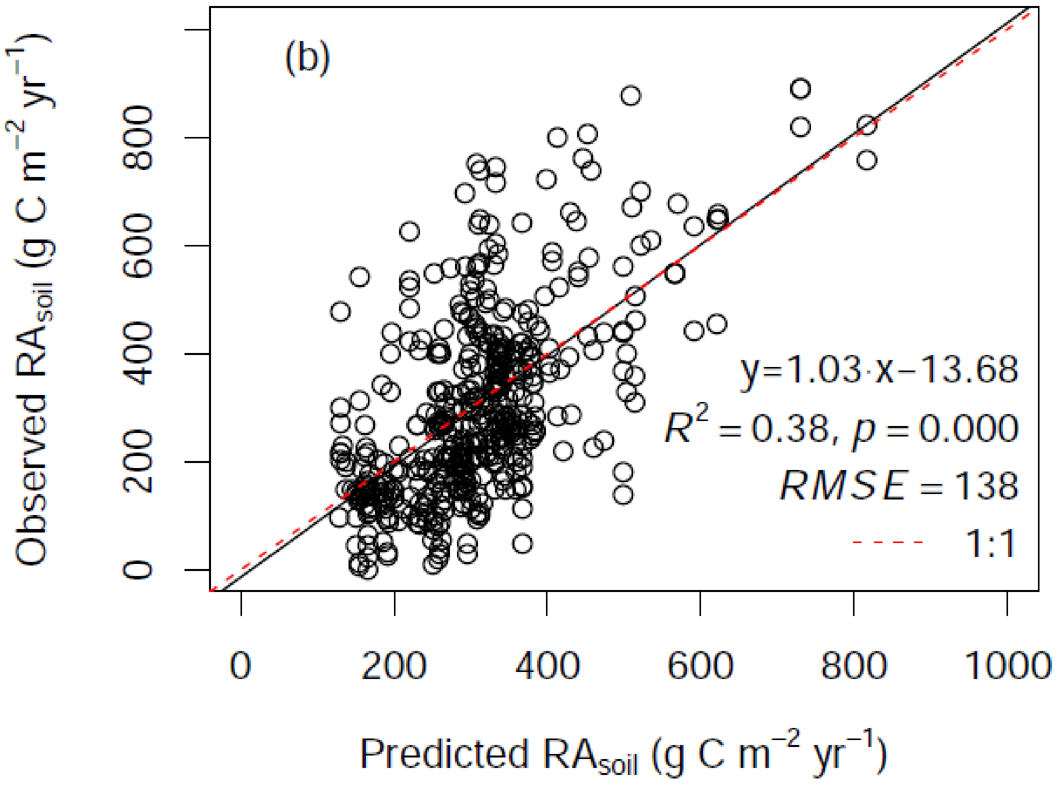
Results

Good model performance

10-fold cross validation



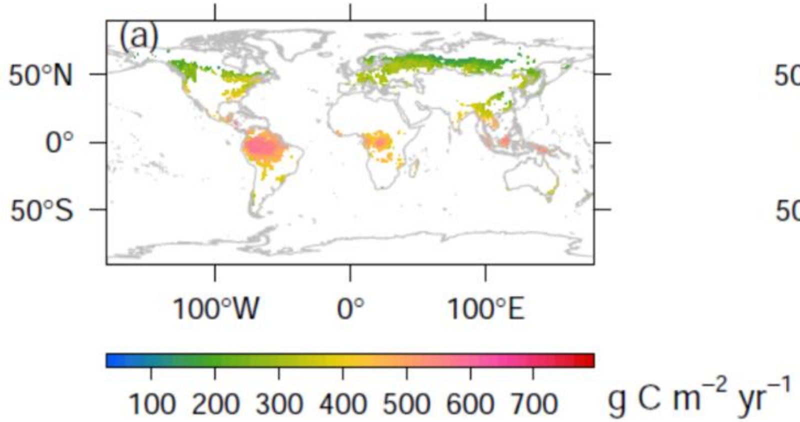
Leave one year out cross validation



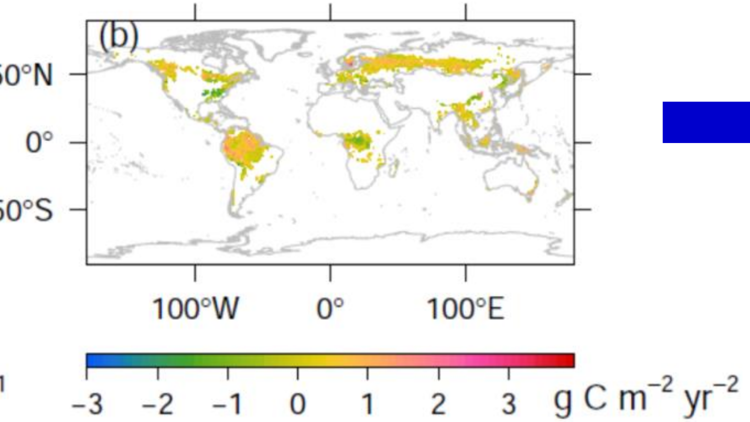
Results

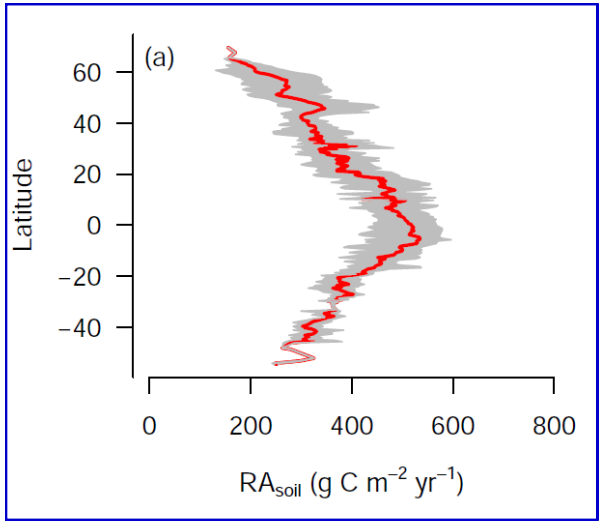
Strong spatial and temporal variabilities

Spatial pattern of RA

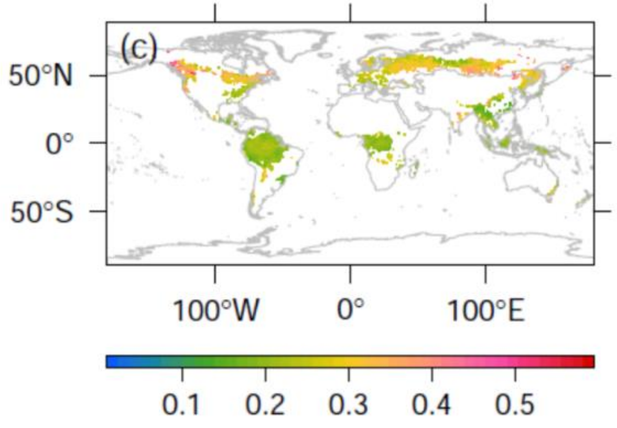


Temperal trend of RA

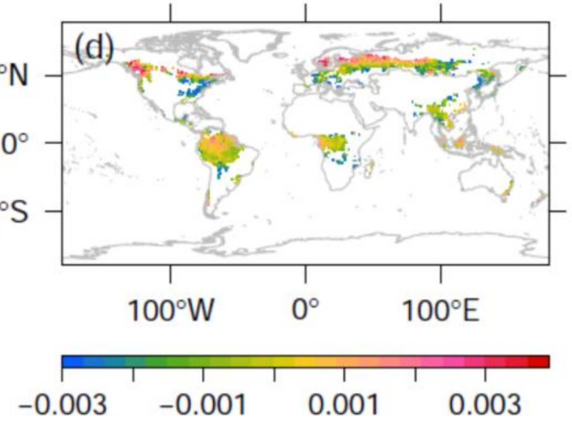


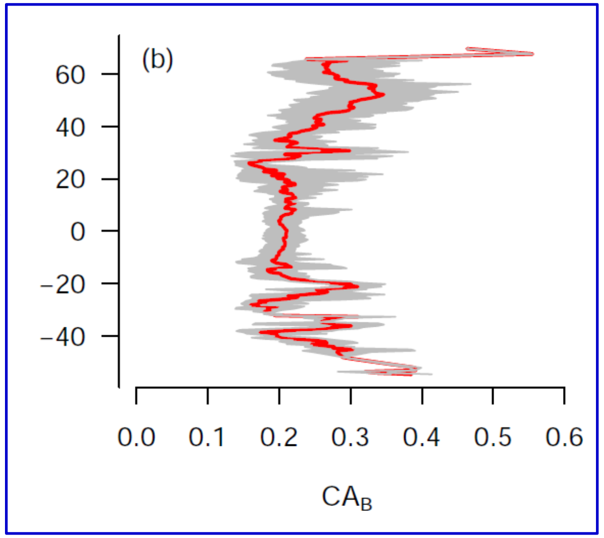


Spatial patterns of CA_B



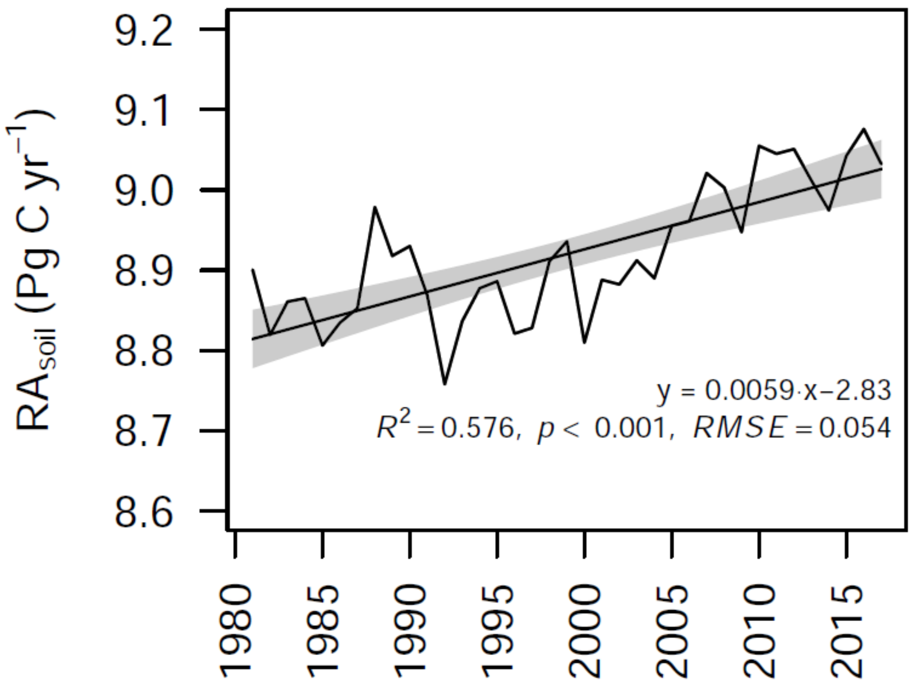
Temporal patterns of CA_B

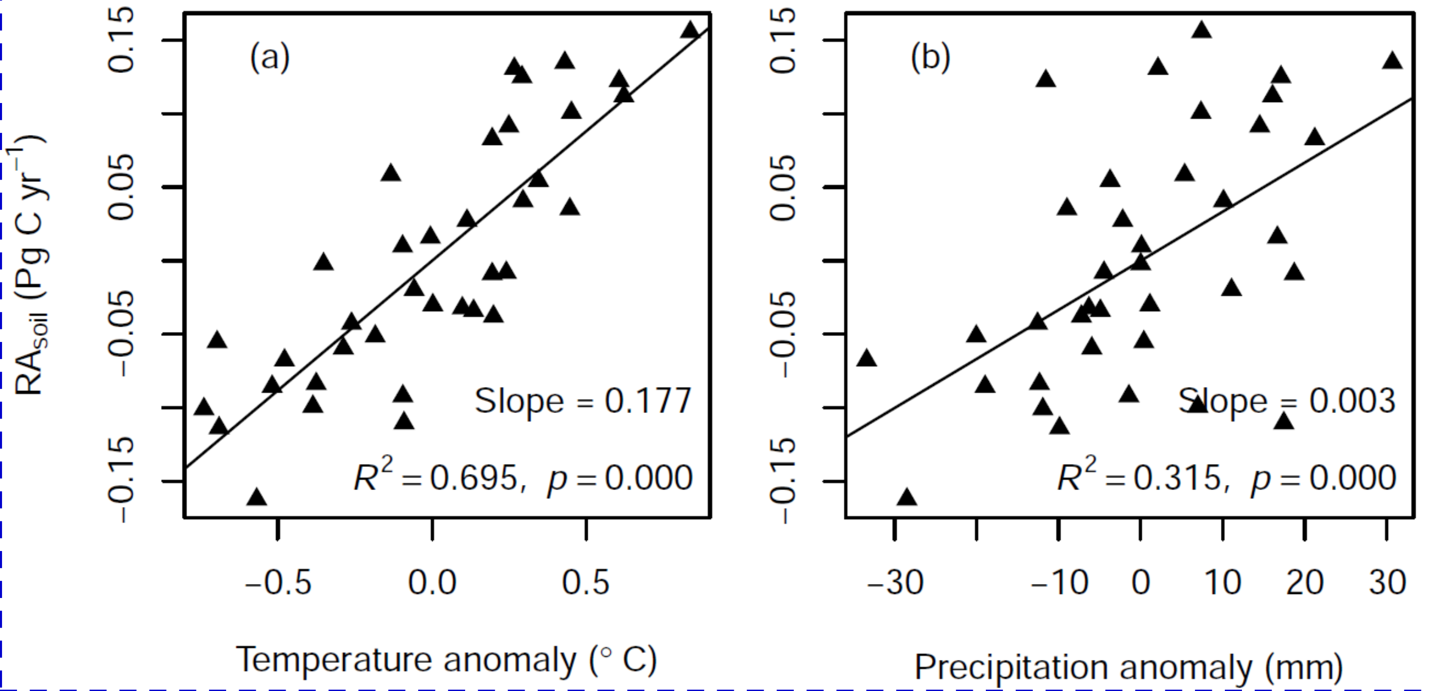




Results

Increase in RA_{soil}





RA_{soil}: 8.9 ± 0.08 Pg C yr^{-1}.

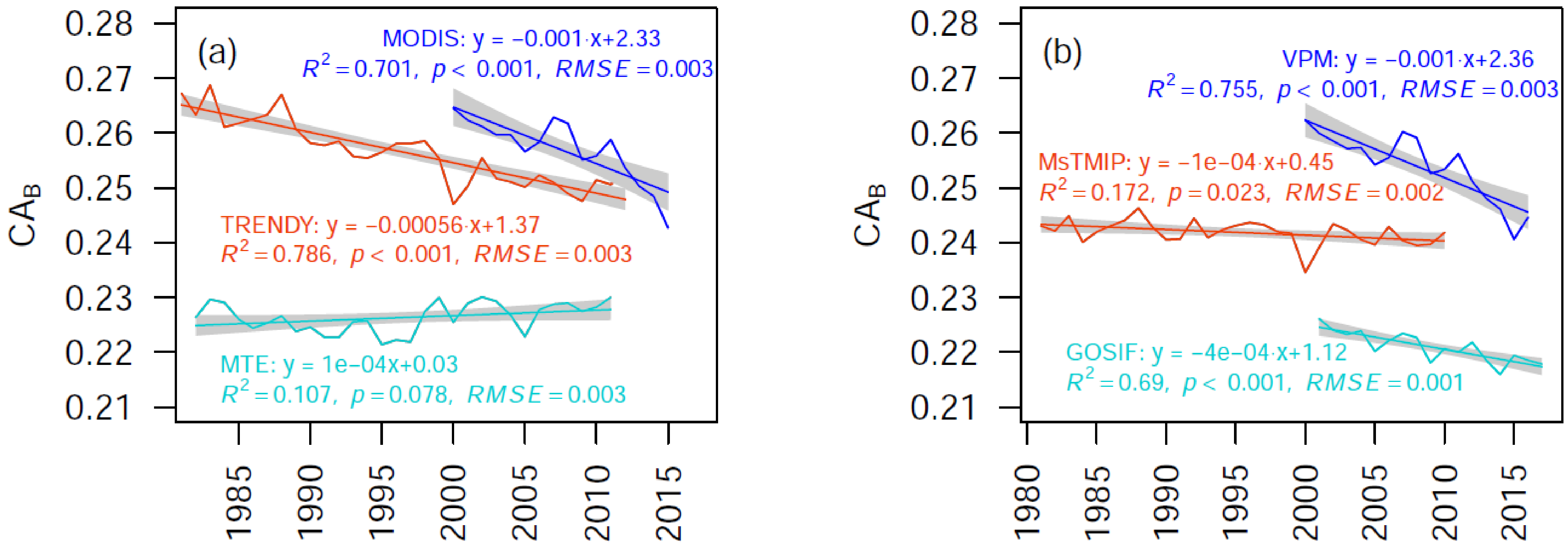
Increasing trend of 0.006 Pg C yr^{-2}.

RA_{soil} increase: 0.18 Pg C yr^{-1} → 1 °C increase in MAT

0.03 Pg C per year yr^{-1} → 10 mm increase in precipitation.

Results

Decrease in CA_B

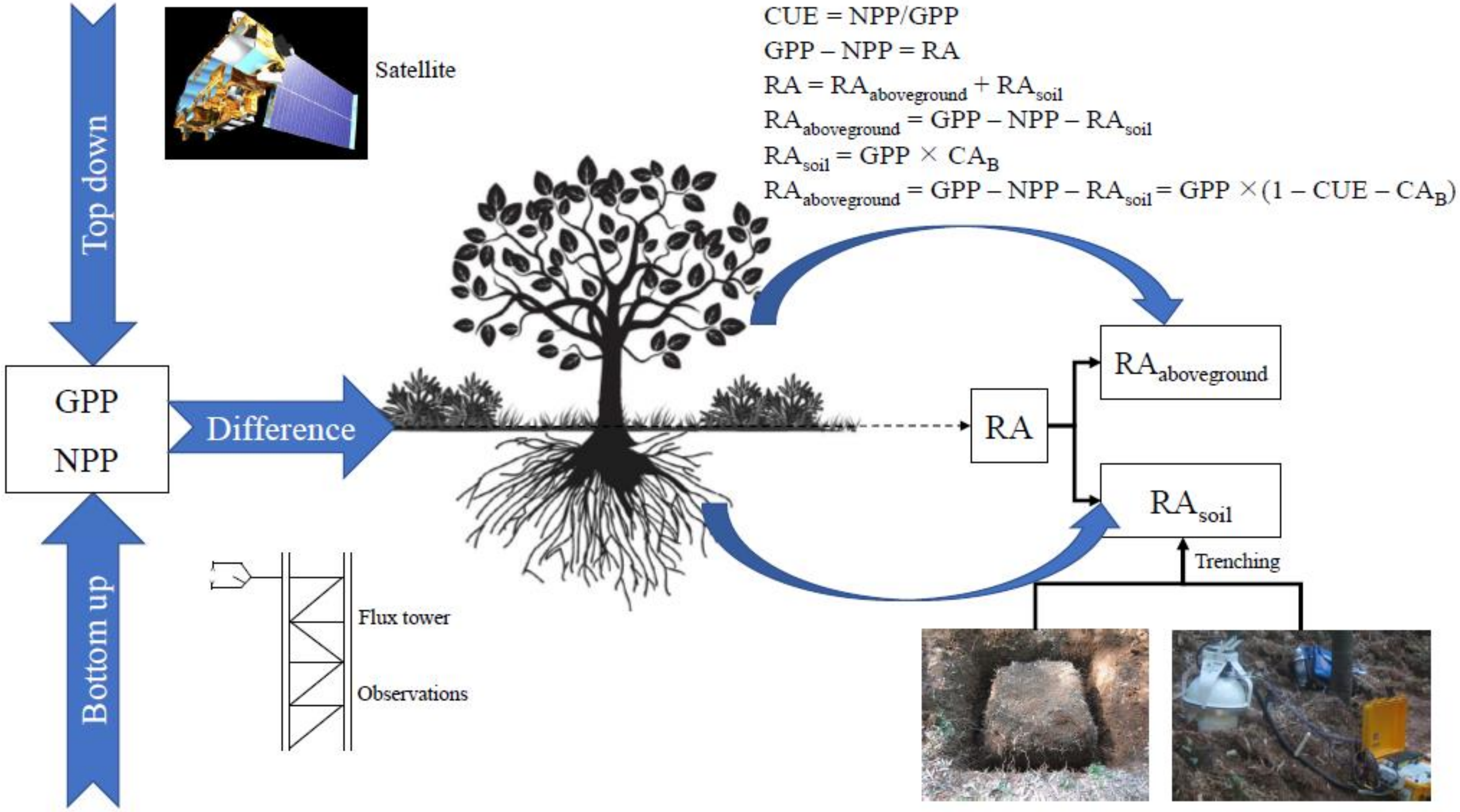


CA_B decreased, varying with GPP products

Mean CA_B: 0.243

Results

• Development of $RA_{aboveground}$



$$RA = RA_{aboveground} + RA_{soil} = GPP - NPP$$

$$RA_{aboveground} = GPP - NPP - RA_{soil}$$

$$NPP = GPP \times CUE$$

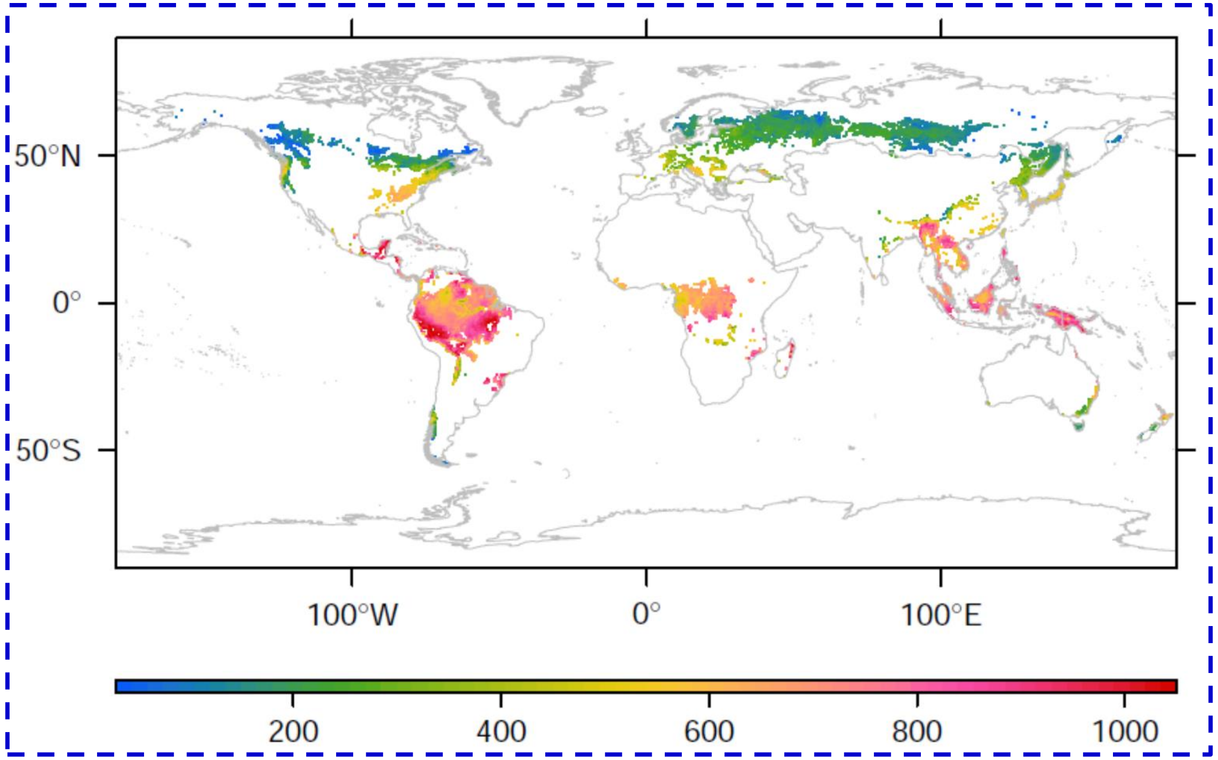
$$RA_{soil} = GPP \times \mathbf{CA_B}$$

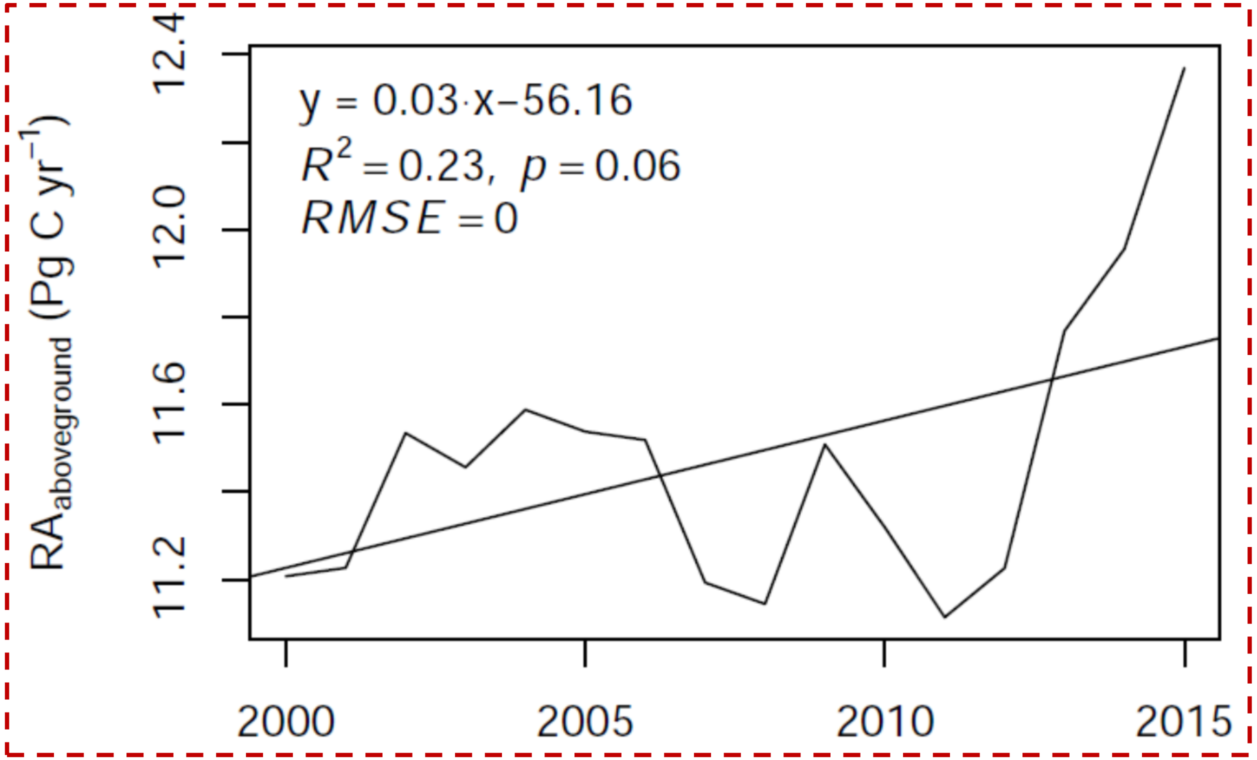
$$RA_{aboveground} = GPP \times (1 - CUE - CA_B)$$

$CUE \approx 0.5$

Results

Spatial and temporal patterns of $RA_{aboveground}$





Strong spatial and temporal patterns

Mean $RA_{aboveground}$: 11.5 Pg C yr^{-1}

No significant trend (p = 0.06)

Results

- Global forest RA_{soil} and CA_B, $RA_{aboveground}$ products at 0.5° 1982 to 2017 were developed;
- Annual mean RA: 8.9 Pg C yr^{-1}, increasing by 0.006 Pg C yr^{-2};
- Mean CA_B: 0.243 with a decreasing trend;
- A new approach to estimate $RA_{aboveground}$ was developed;
- Mean $RA_{aboveground}$: 11.5 Pg C yr^{-1}, no significant temporal trend.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