Processes Linked to Uncertainty Modelling Ecosystems
the PLUME Model Intercomparison Project

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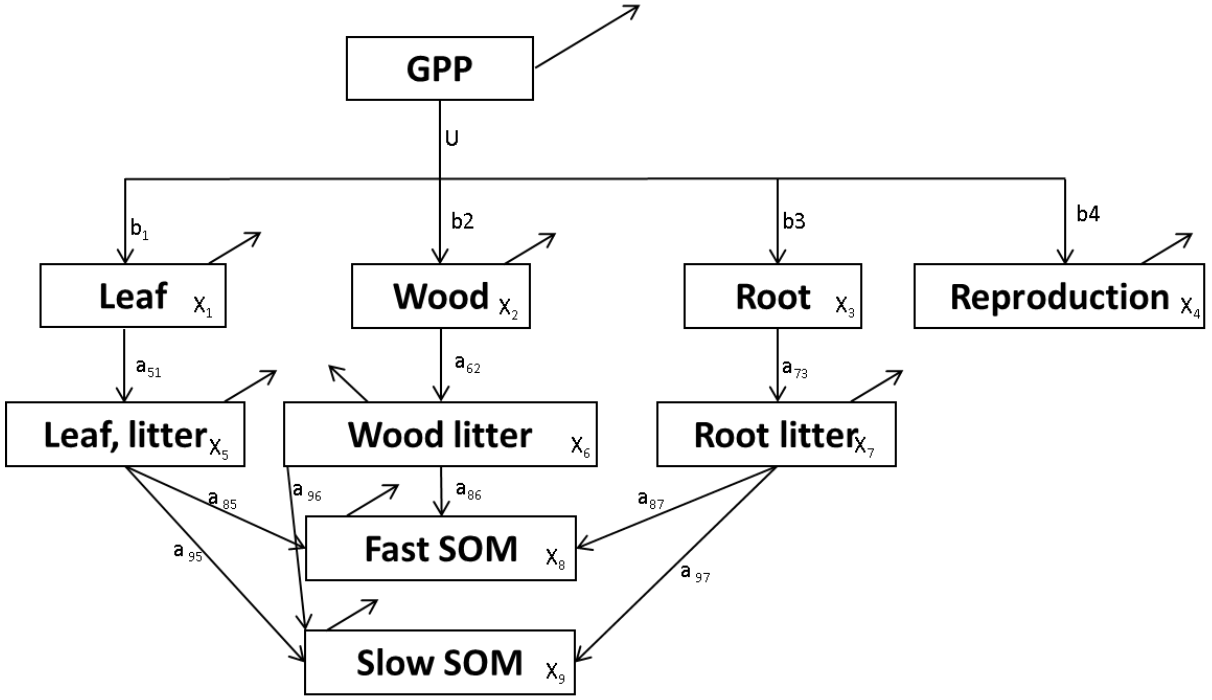
A transparent analysis of model differences between models and identification of uncertanties.

Separated into: model structure, parameterization and drivers

Change of cpool = input - output

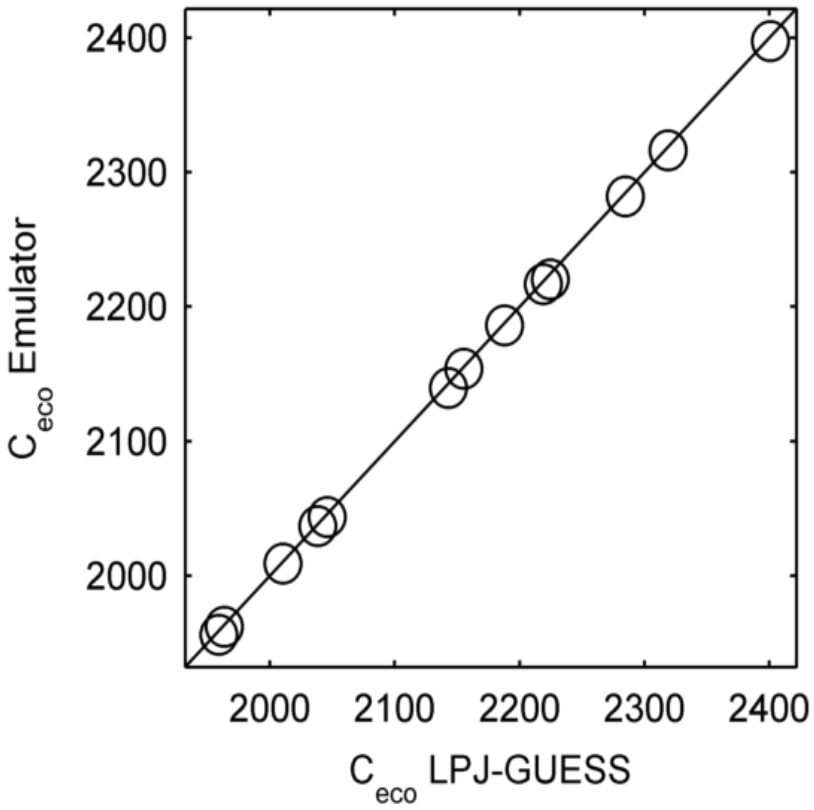
Steady state cpool = input / output rate

$$\frac{dX(t)}{dt} = BNPP(t) - \xi ACX(t) = 0 \quad \Rightarrow \quad X_{ss} = \frac{B_{ss} NPP_{ss}}{\xi_{ss} A_{ss} C_{ss}}$$



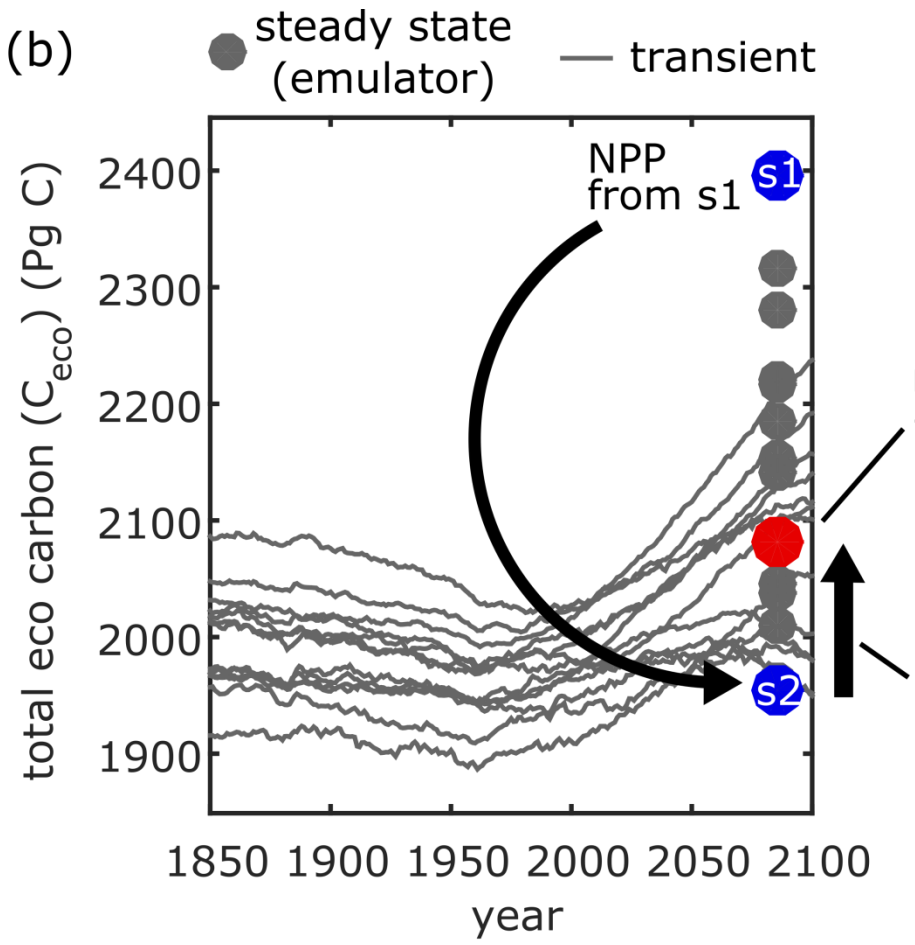
Luo et al. 2003 GBC
Luo and Weng 2011 TREE
Luo et al. 2012
Luo et al. submitted
Xia et al. 2013 GBC

A perfect emulator



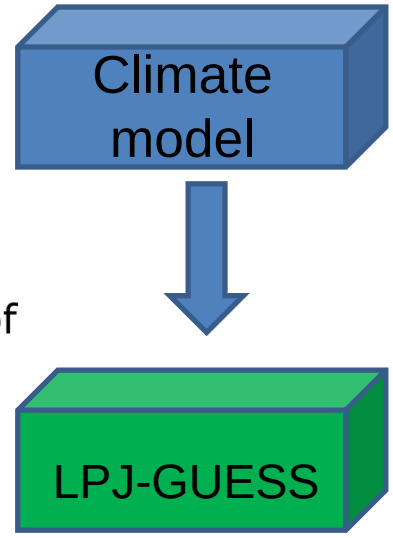
*How much will the difference in total ecosystem carbon between a pair of simulations be reduced if we replace **NPP**, **vegetation turnover** , or **soil respiration rate** between the pair?*

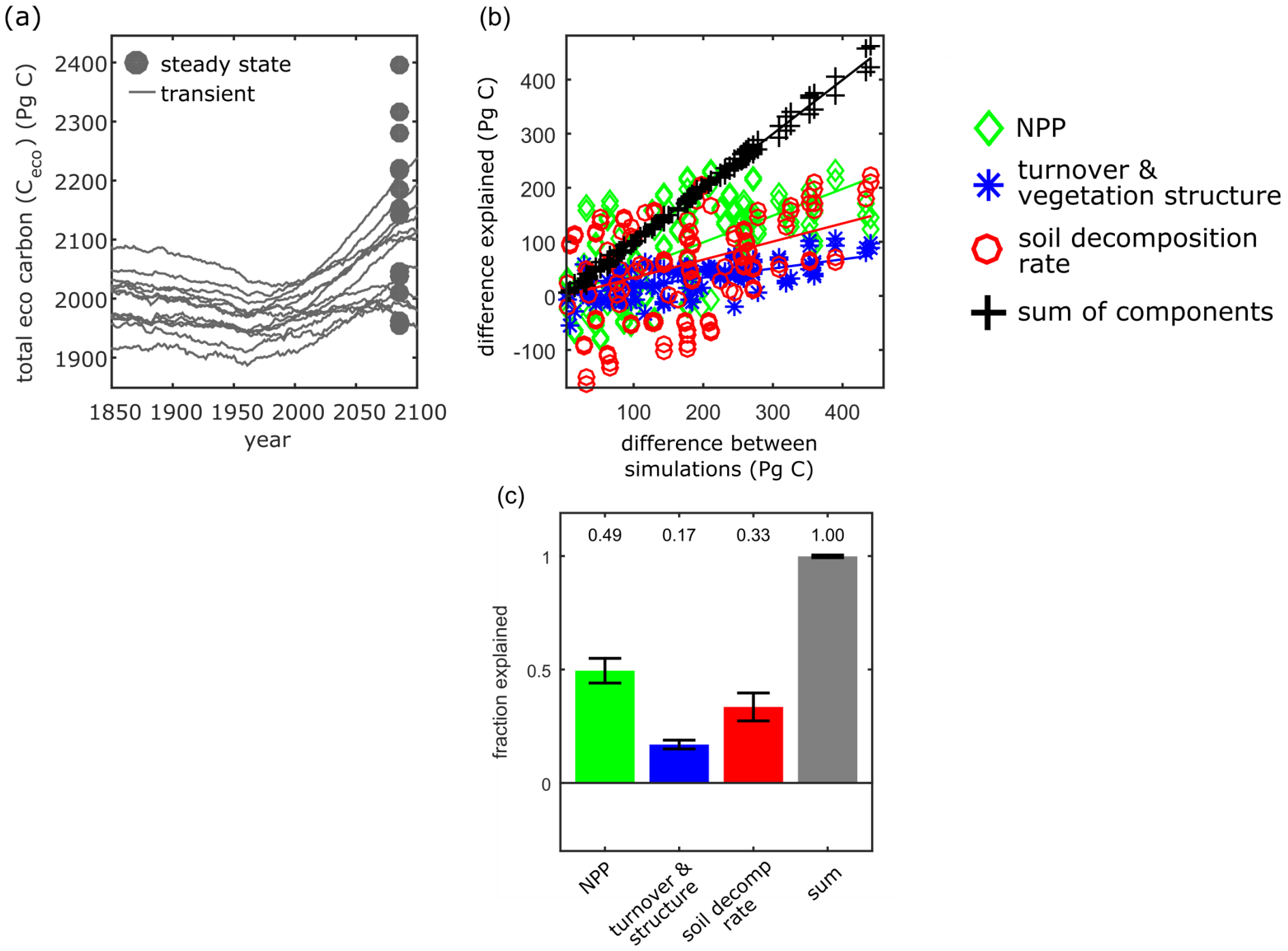
$$X_{ss} = \frac{B_{ss_{s2}} NPP_{ss_{s1}}}{\xi_{ss_{s2}} A_{ss_{s2}} C_{ss_{s2}}}$$

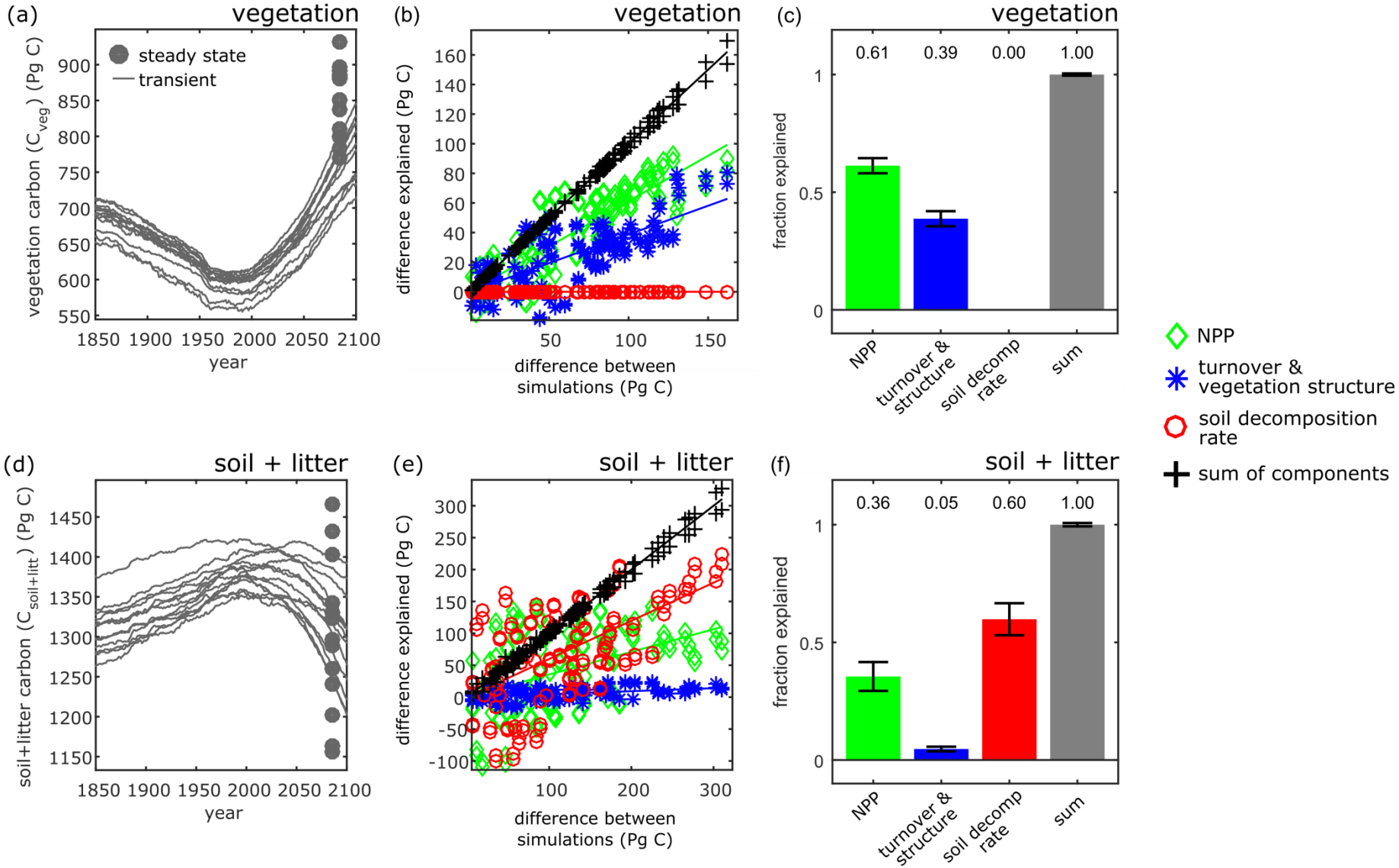


new C_{eco} found by the s2 emulator with NPP from s1

difference between s2 and s1 explained by NPP; 125 Pg C or 28% of the difference between s2 and s1 (442 Pg C)




(a)
steady state
transient
total eco carbon (C_{eco}) (Pg C)
2400
2300
2200
2100
2000
1900
1850 1900 1950 2000 2050 2100
year
(b)
difference explained (Pg C)
400
300
200
100
0
-100
100 200 300 400
difference between simulations (Pg C)
NPP
turnover & vegetation structure
soil decomposition rate
sum of components
(c)
0.49 0.17 0.33 1.00
fraction explained
1
0.5
0
NPP
turnover & structure
soil decomp rate
sum


(a)
vegetation
steady state
transient
vegetation carbon (C_{veg}) (Pg C)
year
(b)
vegetation
difference explained (Pg C)
difference between simulations (Pg C)
(c)
vegetation
0.61
0.39
0.00
1.00
fraction explained
NPP
turnover & structure
soil decomp rate
sum
(d)
soil + litter
soil+litter carbon ($C_{soil+litt}$) (Pg C)
year
(e)
soil + litter
difference explained (Pg C)
difference between simulations (Pg C)
(f)
soil + litter
0.36
0.05
0.60
1.00
fraction explained
NPP
turnover & structure
soil decomp rate
sum
NPP
turnover & vegetation structure
soil decomposition rate
sum of components

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LETTER

Importance of vegetation dynamics for future terrestrial carbon cycling

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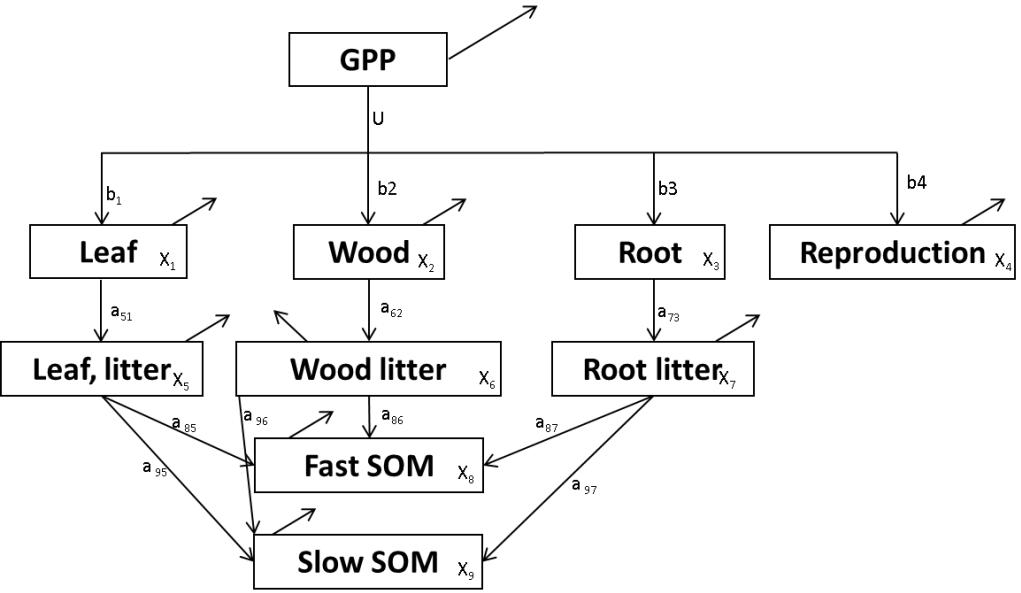
Abstract

Terrestrial ecosystems currently sequester about one third of anthropogenic CO_2 emissions each year, an important ecosystem service that dampens climate change. The future fate of this net uptake of CO_2 by land based ecosystems is highly uncertain. Most ecosystem models used to predict the future terrestrial carbon cycle share a common architecture, whereby carbon that enters the system as net primary production (NPP) is distributed to plant compartments, transferred to litter and soil through vegetation turnover and then re-emitted to the atmosphere in conjunction with soil decomposition. However, while all models represent the processes of NPP and soil decomposition, they vary greatly in their representations of vegetation turnover and the associated processes governing mortality, disturbance and biome shifts. Here we used a detailed second generation dynamic global vegetation model with advanced representation of vegetation growth and mortality, and the associated turnover. We apply an emulator that describes the carbon flows and pools exactly as in simulations with the full model. The emulator simulates ecosystem dynamics in response to 13 different climate or Earth system model simulations from the Coupled Model Intercomparison Project Phase 5 ensemble under RCP8.5 radiative forcing. By exchanging carbon cycle processes between these 13 simulations we quantified the relative roles of three main driving processes of the carbon cycle: (I) NPP, (II)

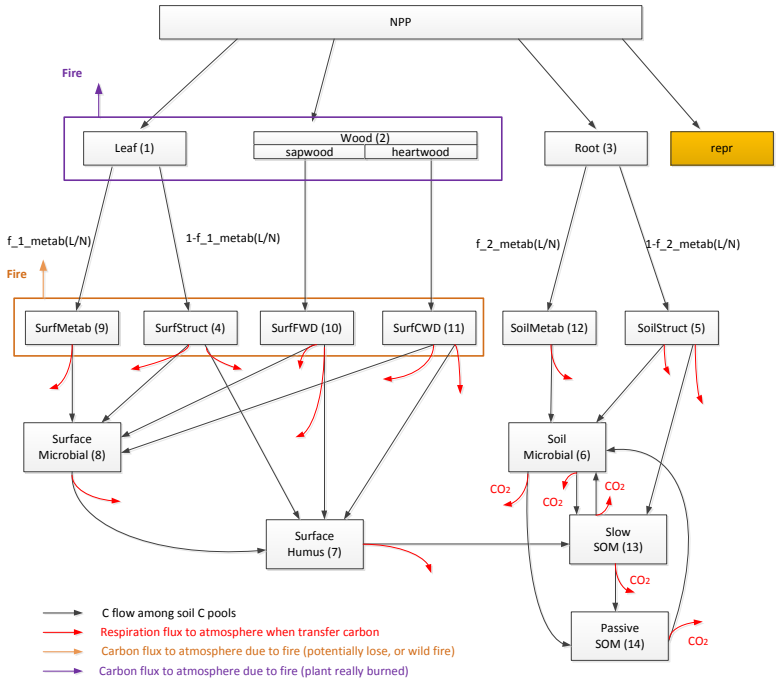
“Observations”

- NPP/GPP
- Respiration rates
- Vegetation turnover
- …

Model 1



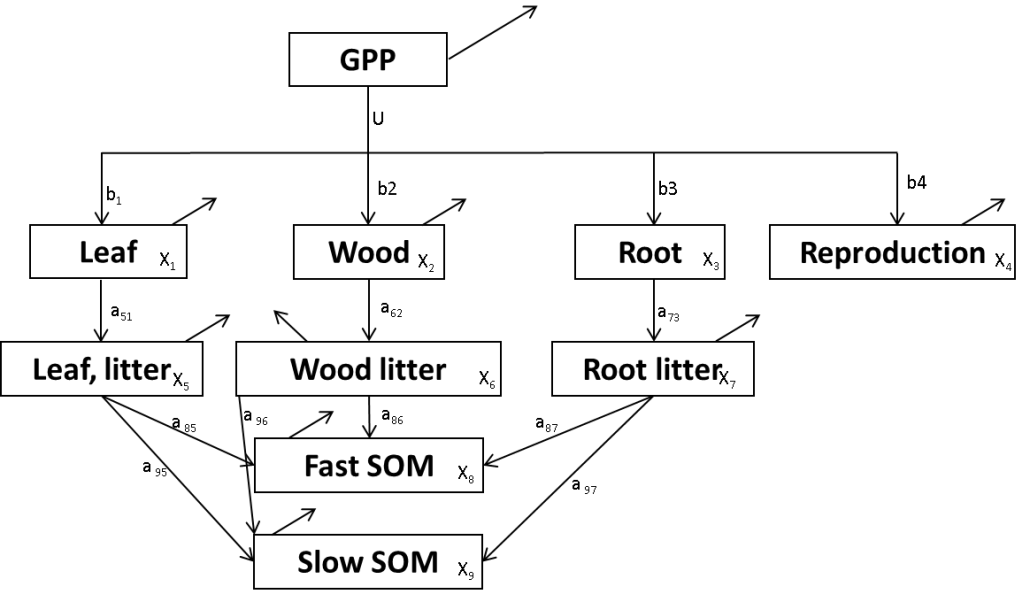
Model 2



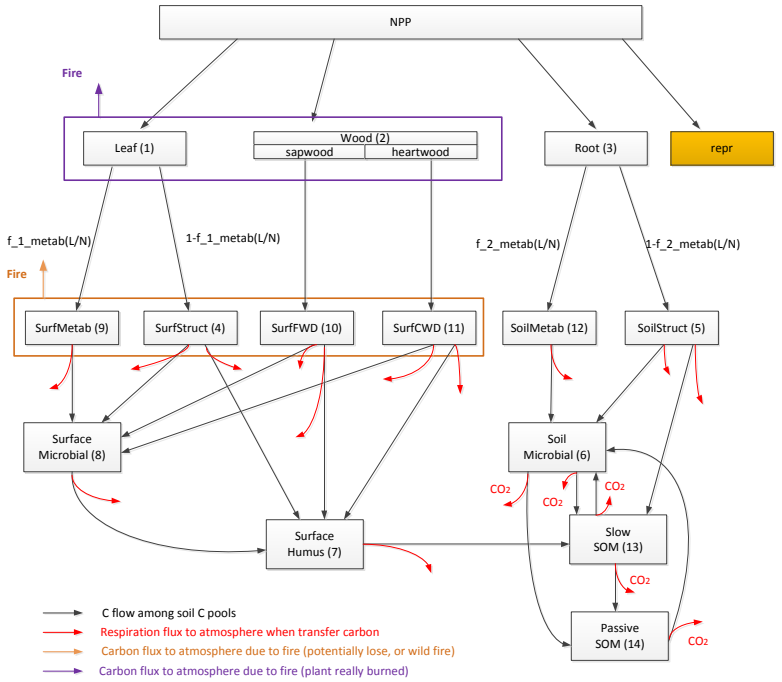
- NPP/GPP
- Environmental scalars
- Vegetation turnover
- Litterfall
- …

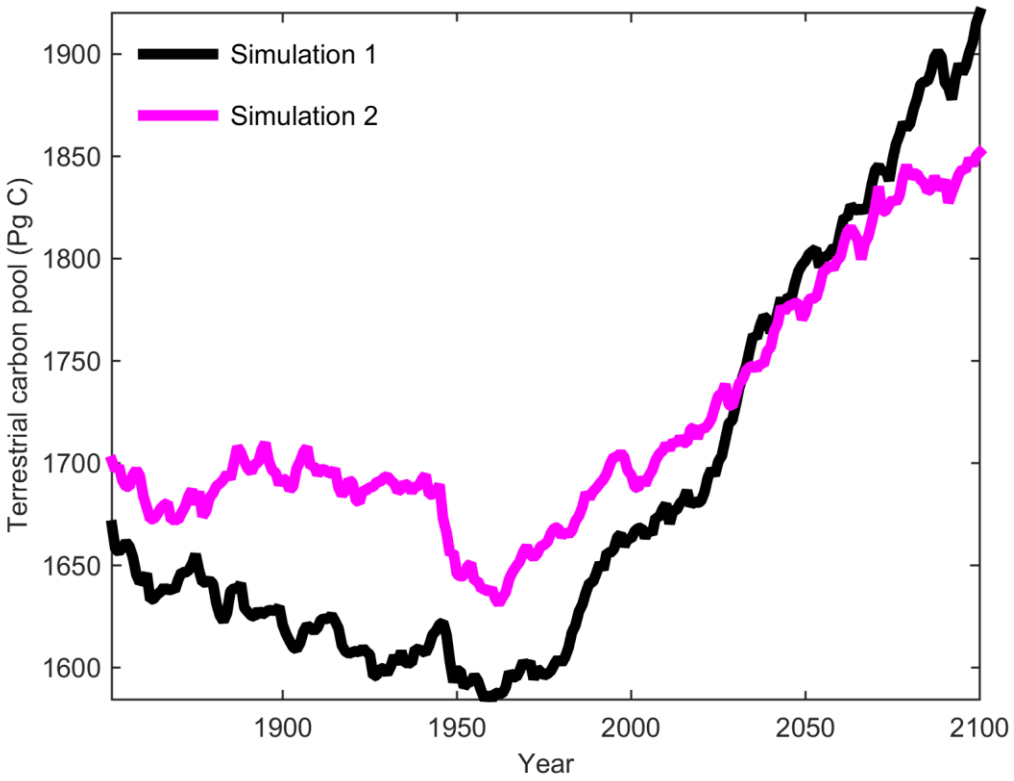
- NPP/GPP
- Environmental scalars
- Vegetation turnover
- Litterfall
- …

Model 1

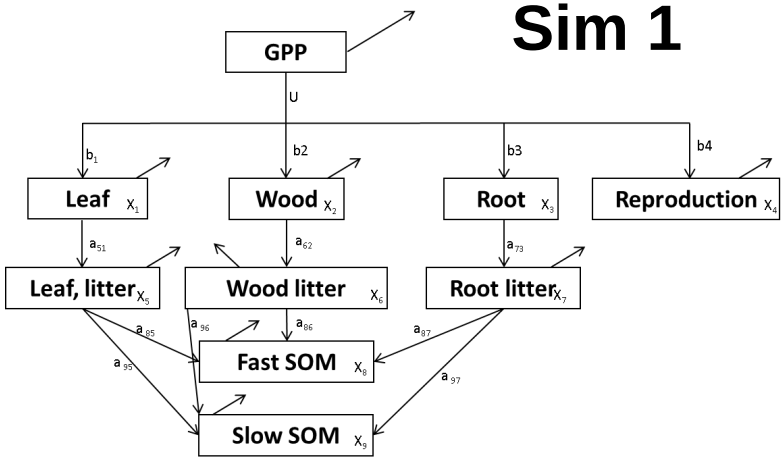


Model 2

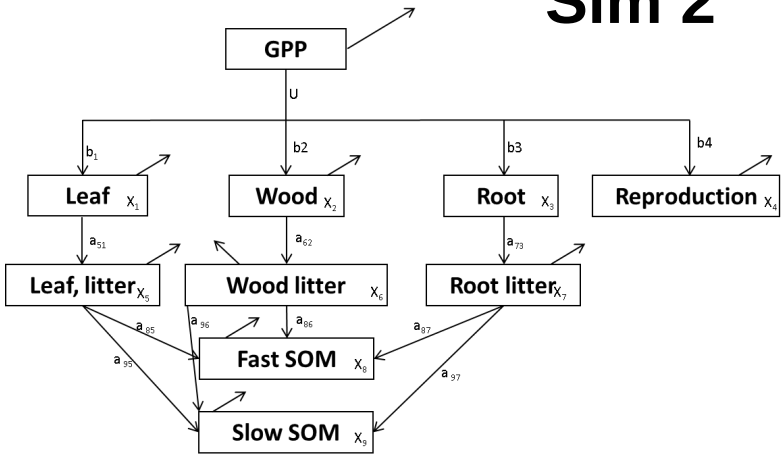


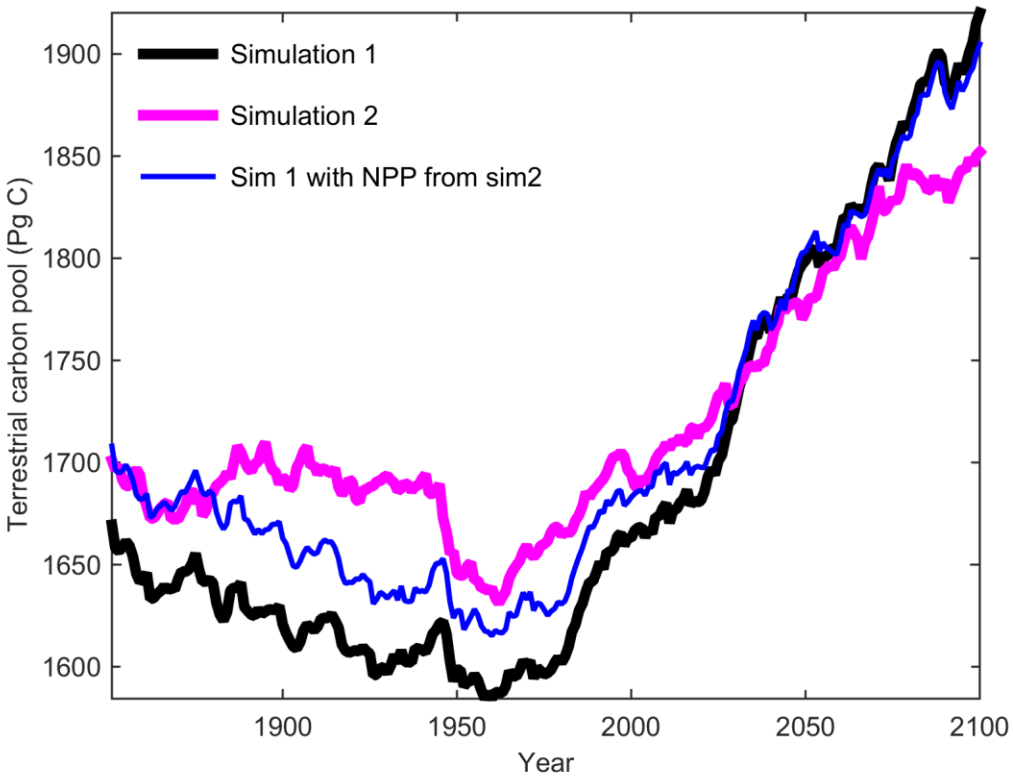

Simulation 1
Simulation 2
Terrestrial carbon pool (Pg C)
1900
1850
1800
1750
1700
1650
1600
1900
1950
2000
2050
2100
Year

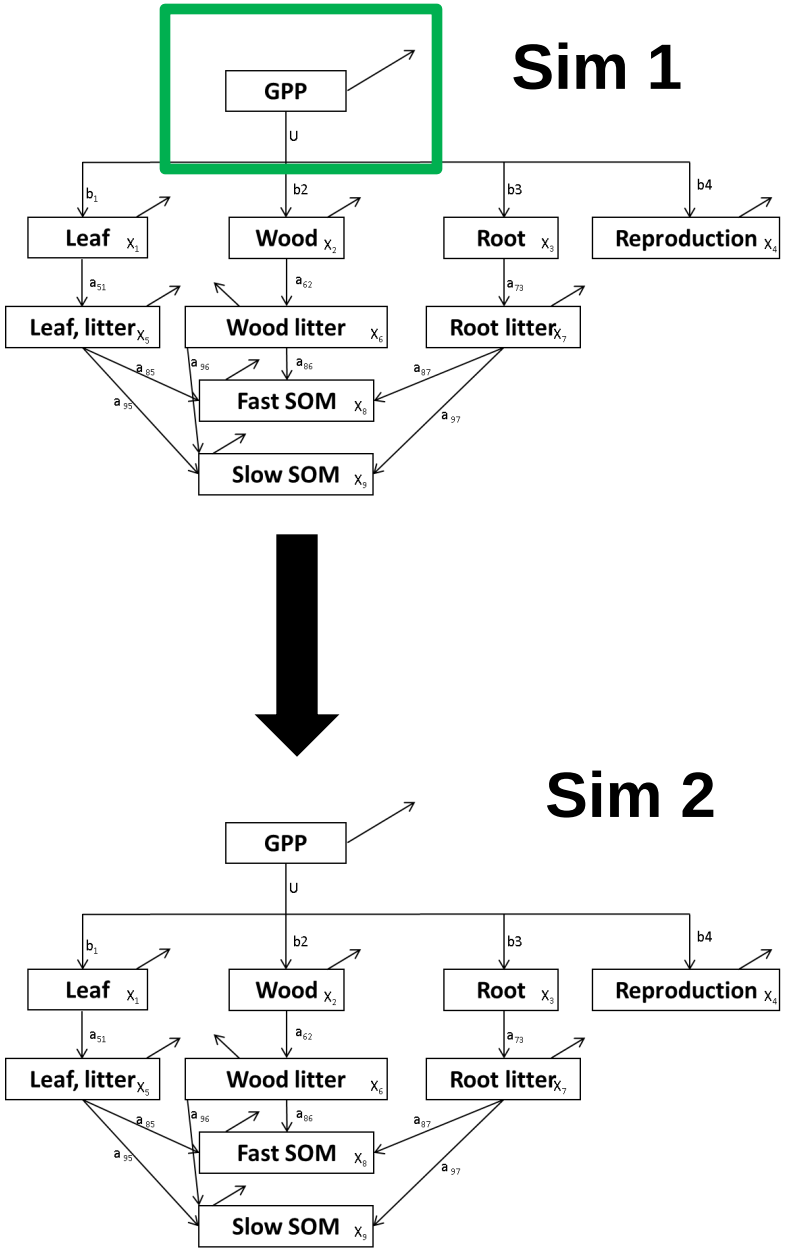
Sim 1

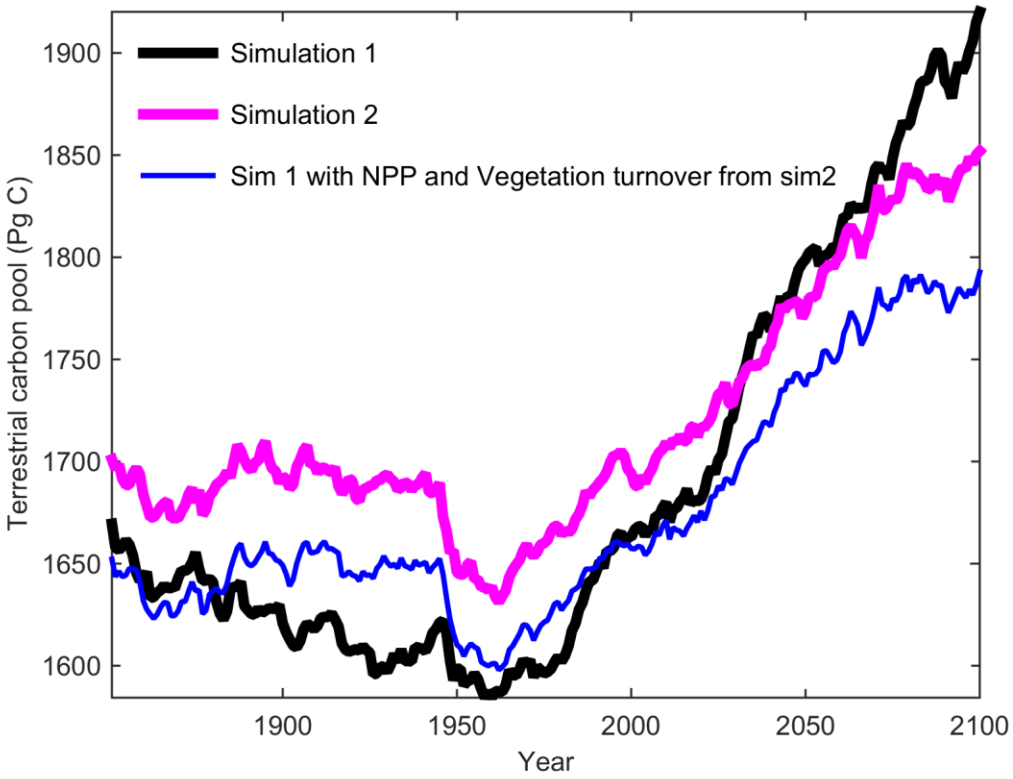

GPP
U
b1
b2
b3
b4
Leaf X1
Wood X2
Root X3
Reproduction X4
a51
a62
a73
Leaf, litter X5
Wood litter X6
Root litter X7
a85
a96
a86
a87
a95
a97
Fast SOM X8
Slow SOM X9

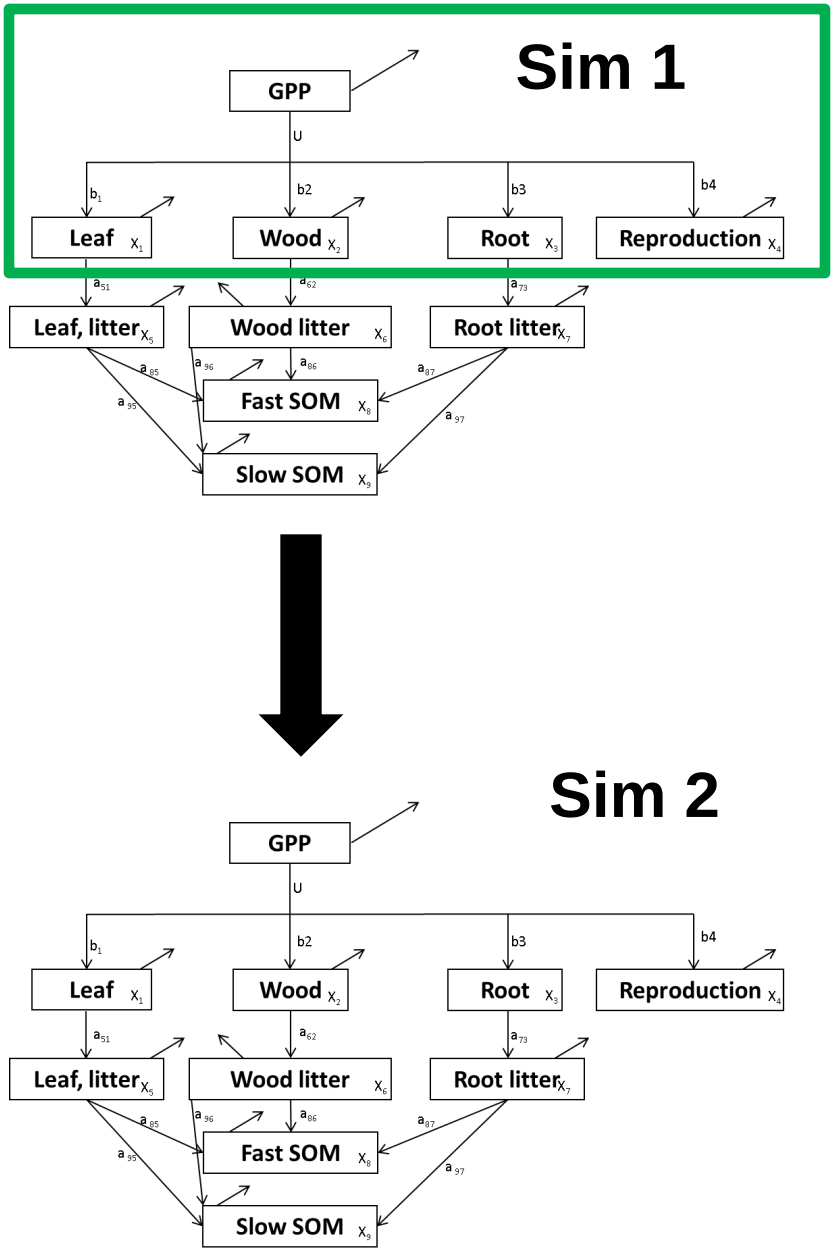
Sim 2

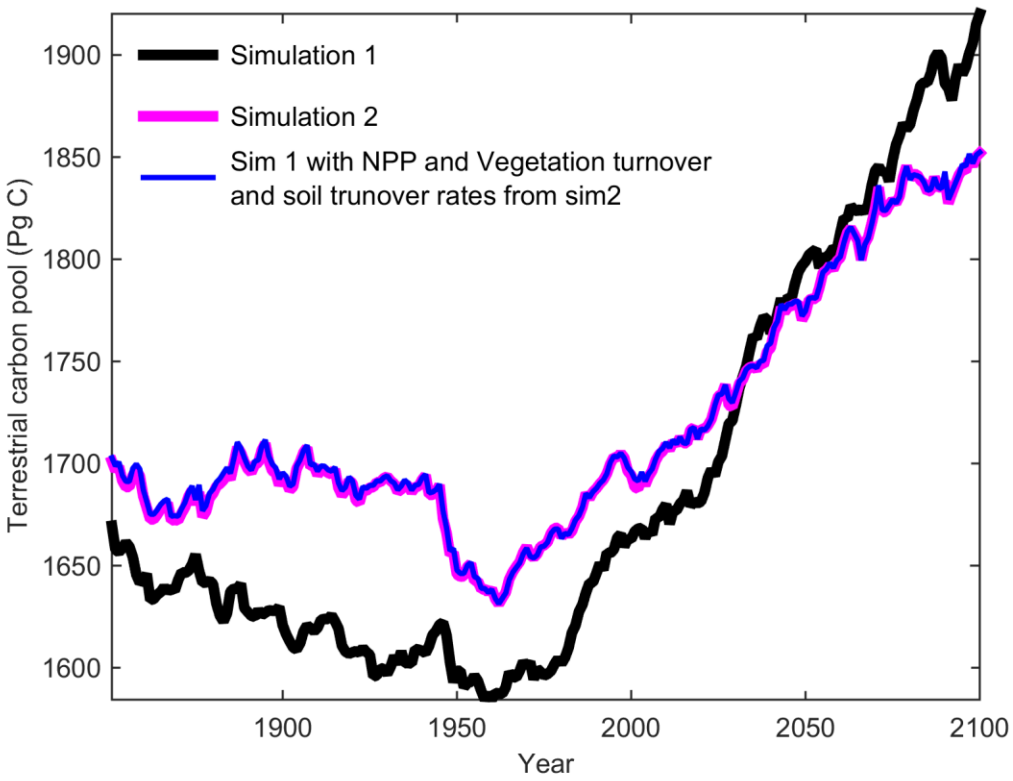

GPP
U
b1
b2
b3
b4
Leaf X1
Wood X2
Root X3
Reproduction X4
a51
a62
a73
Leaf, litter X5
Wood litter X6
Root litter X7
a85
a96
a86
a87
a95
a97
Fast SOM X8
Slow SOM X9

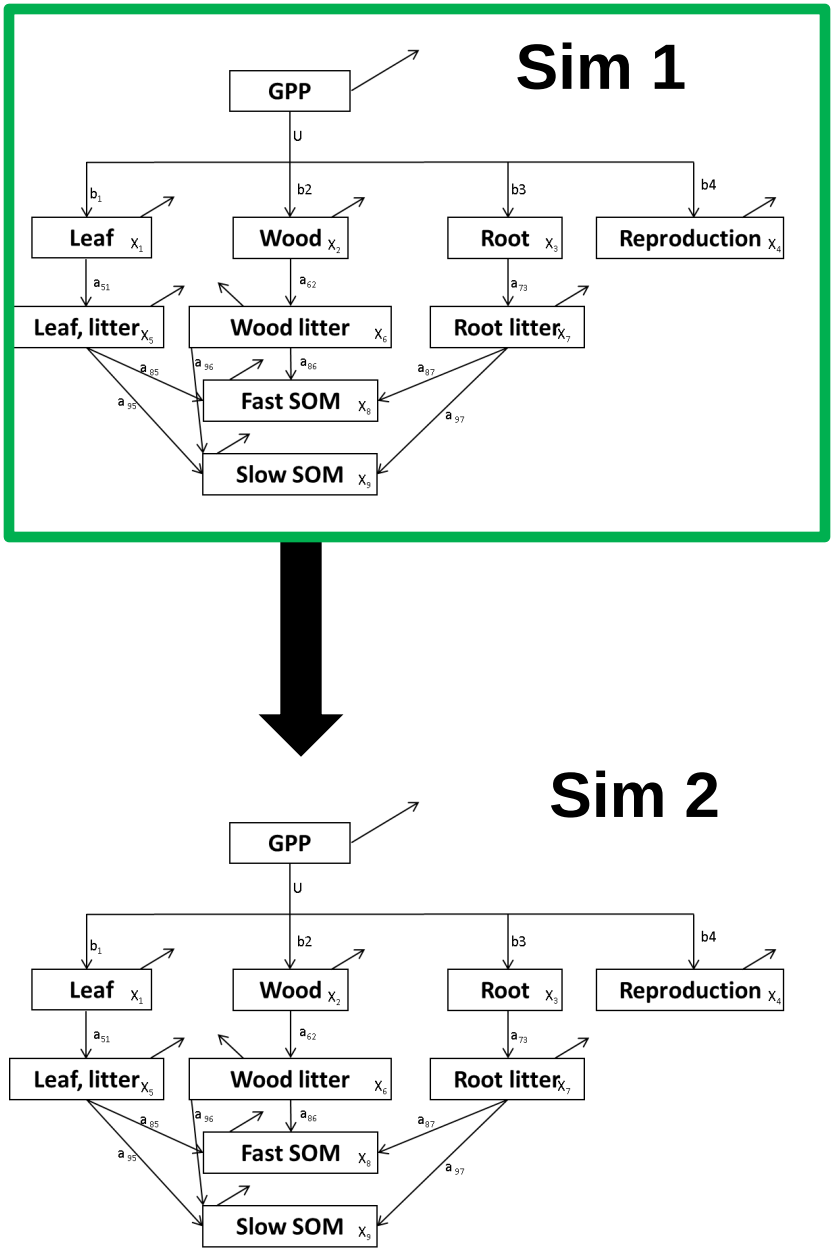

Simulation 1
Simulation 2
Sim 1 with NPP from sim2
Terrestrial carbon pool (Pg C)
1900
1850
1800
1750
1700
1650
1600
1900
1950
2000
2050
2100
Year


Sim 1
GPP
U
b1
b2
b3
b4
Leaf X1
Wood X2
Root X3
Reproduction X4
a51
a62
a73
Leaf, litter X5
Wood litter X6
Root litter X7
a85
a96
a86
a87
a95
a97
Fast SOM X8
Slow SOM X9
Sim 2
GPP
U
b1
b2
b3
b4
Leaf X1
Wood X2
Root X3
Reproduction X4
a51
a62
a73
Leaf, litter X5
Wood litter X6
Root litter X7
a85
a96
a86
a87
a95
a97
Fast SOM X8
Slow SOM X9


Simulation 1
Simulation 2
Sim 1 with NPP and Vegetation turnover from sim2
Terrestrial carbon pool (Pg C)
1900
1850
1800
1750
1700
1650
1600
1900
1950
2000
2050
2100
Year


Sim 1
GPP
U
b1
b2
b3
b4
Leaf X1
Wood X2
Root X3
Reproduction X4
a51
a62
a73
Leaf, litter X5
Wood litter X6
Root litter X7
a85
a96
a86
a87
a95
a97
Fast SOM X8
Slow SOM X9
Sim 2
GPP
U
b1
b2
b3
b4
Leaf X1
Wood X2
Root X3
Reproduction X4
a51
a62
a73
Leaf, litter X5
Wood litter X6
Root litter X7
a85
a96
a86
a87
a95
a97
Fast SOM X8
Slow SOM X9


Simulation 1
Simulation 2
Sim 1 with NPP and Vegetation turnover and soil trunover rates from sim2
Terrestrial carbon pool (Pg C)
1900
1850
1800
1750
1700
1650
1600
1900
1950
2000
2050
2100
Year


Sim 1
GPP
U
b1
b2
b3
b4
Leaf X1
Wood X2
Root X3
Reproduction X4
a51
a62
a73
Leaf, litter X5
Wood litter X6
Root litter X7
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a96
a86
a87
a95
a97
Fast SOM X8
Slow SOM X9
Sim 2
GPP
U
b1
b2
b3
b4
Leaf X1
Wood X2
Root X3
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Leaf, litter X5
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Root litter X7
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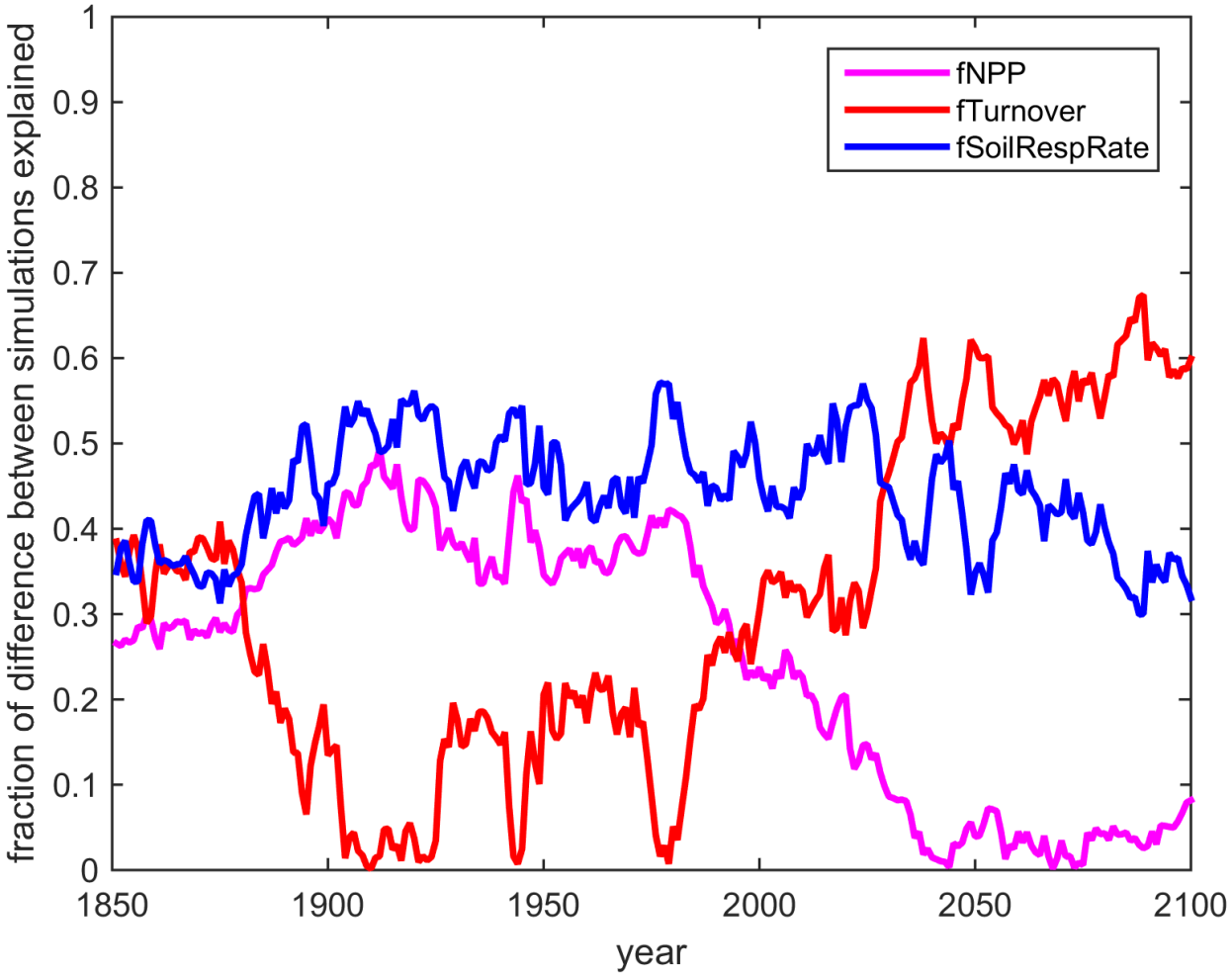
Fast SOM X8
Slow SOM X9


fNPP
fTurnover
fSoilRespRate
fraction of difference between simulations explained
year
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1850
1900
1950
2000
2050
2100

Processes Linked to Uncertainties Modelling Ecosystems (PLUME-MIP)

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Michael Mishurov, LU, Sweden
Yiqi Luo, OU, USA
Jianyang Xia, ECNU, China
ISI-MIP, PIK, Germany