Matrix tool to facilitate land carbon modeling: case studies from CLM4.5

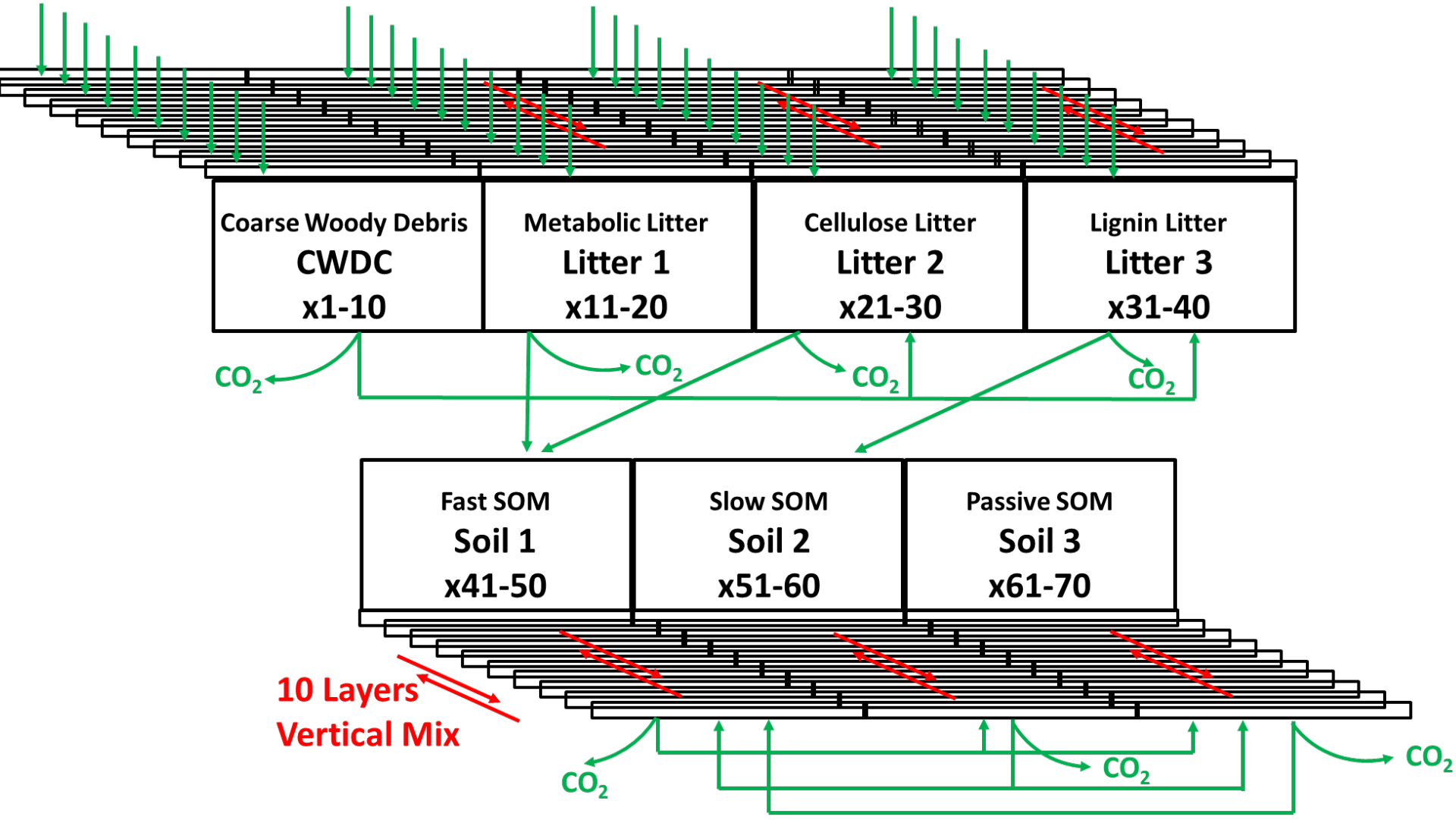
Yuanyuan Huang, Xingjie Lu,
Zheng Shi, Yiqi Luo

David Lawrence(NCAR)
Charles Koven (LBNL)

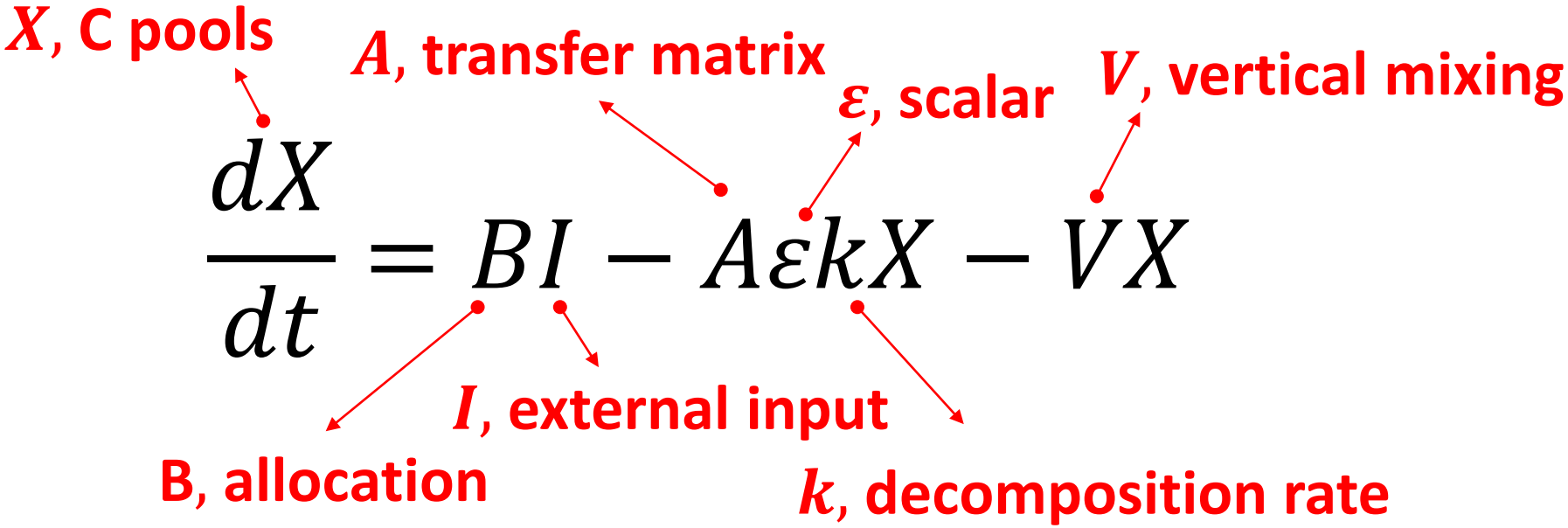
2017 CESM Working Group Meeting

ECOLAB
OF DR. YIQI LUO

CLM4.5 dead C pool structure

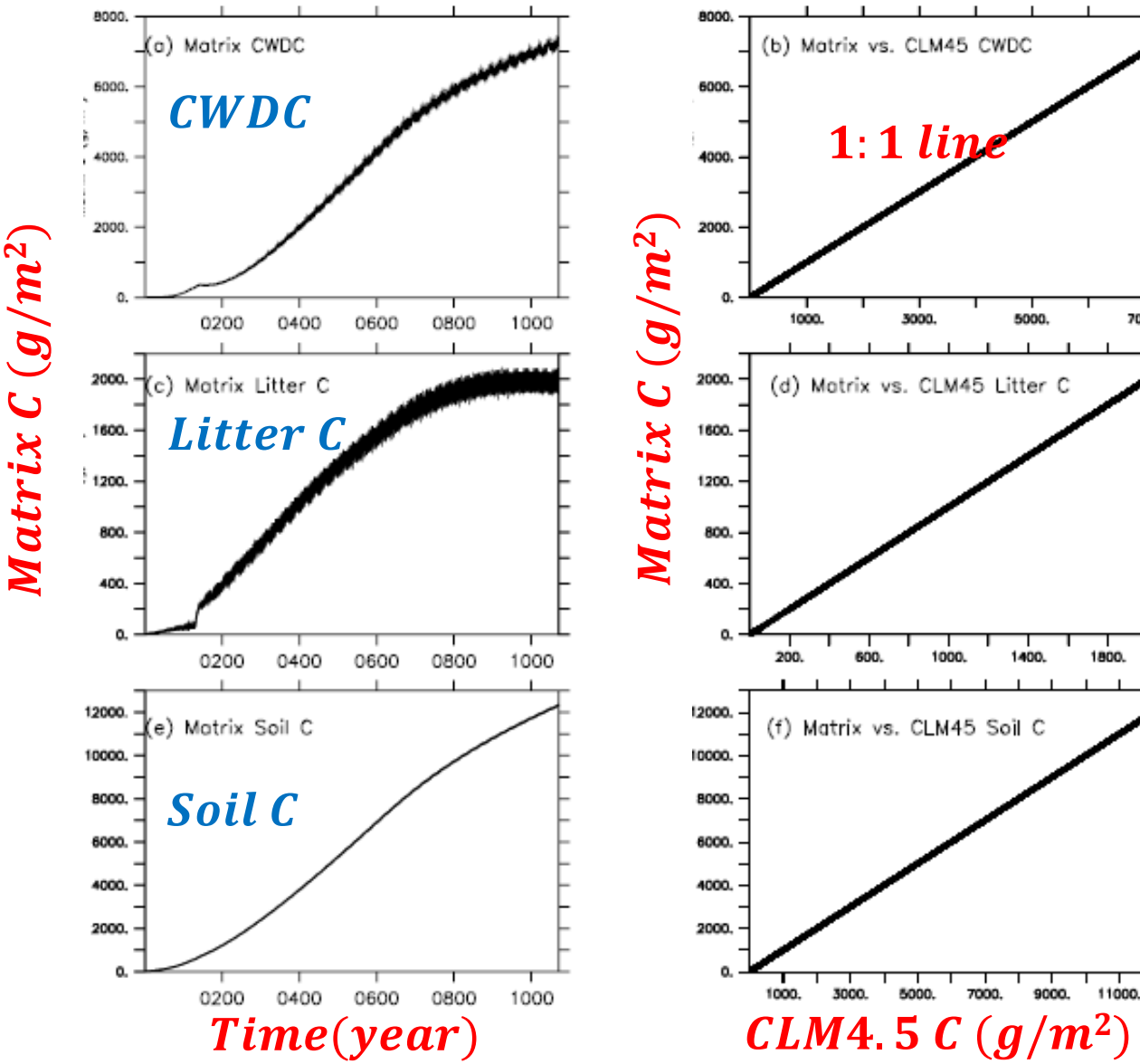


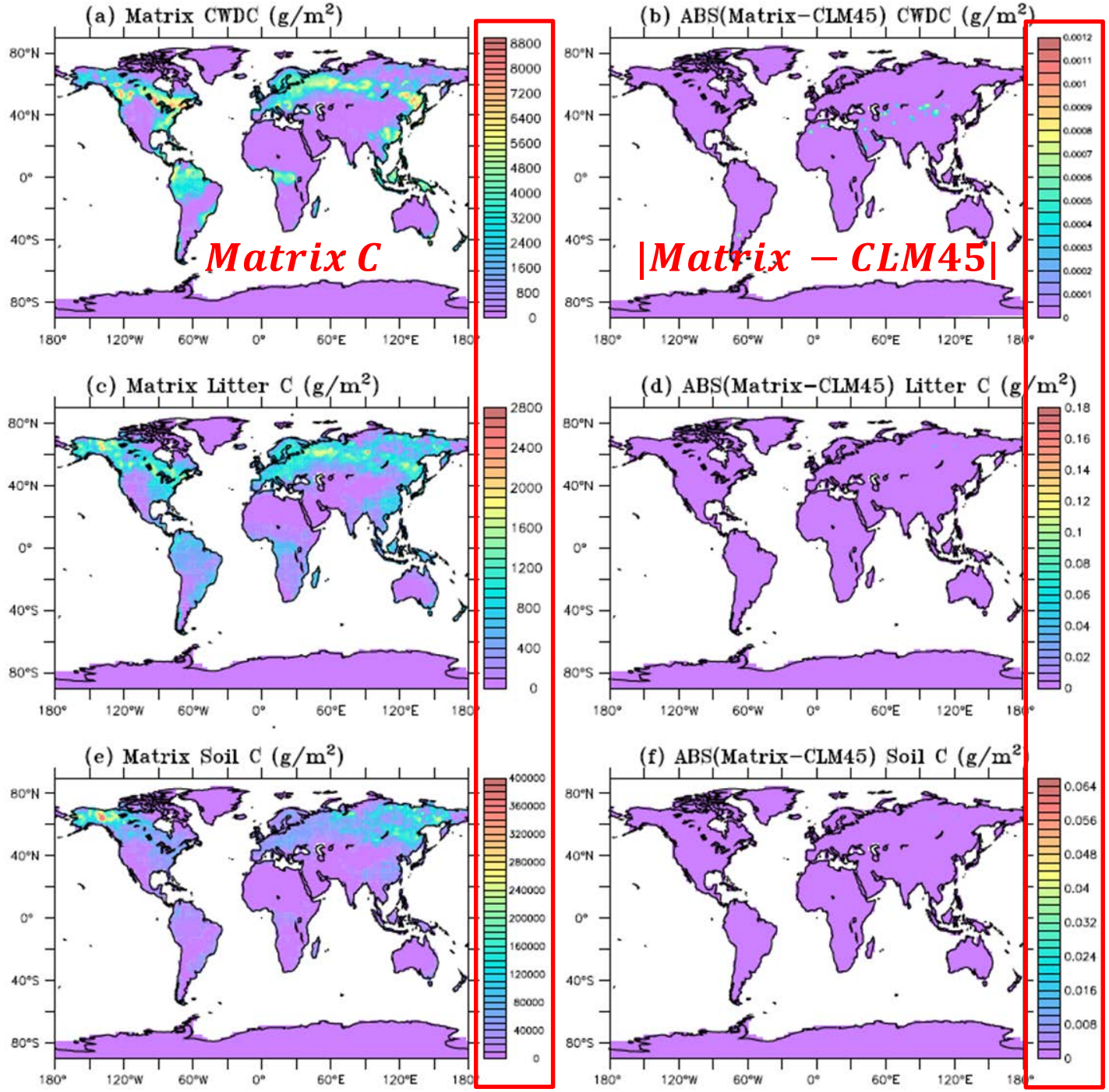
Matrix representation



$\boldsymbol{X}$	: 70x1	7 C types by 10 layers
$\boldsymbol{I}$	: 1x1	C inputs to cwd and litter
$\boldsymbol{B}$	: 70x1	allocation of C inputs
$\boldsymbol{A}$	: 70x70	transfer of C among 7 C types
$\boldsymbol{\varepsilon}$	: 70x70	moisture, temperature, oxygen, N and depth scalars
$\boldsymbol{k}$	: 70x70	decomposition rate
$\boldsymbol{V}$	: 70x70	vertical mixing of C

Matrix vs. original CLM4.5bgc



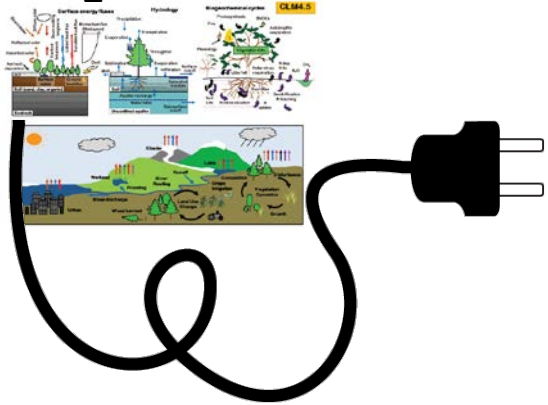


Matrix representation 100% reproduces CLM45bgc dead C dynamics

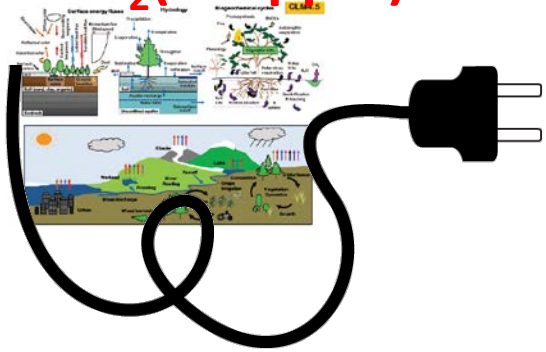
Matrix Application 1

Attribute dead C response to global changes

CLM Run 1
CO_2(280ppm)

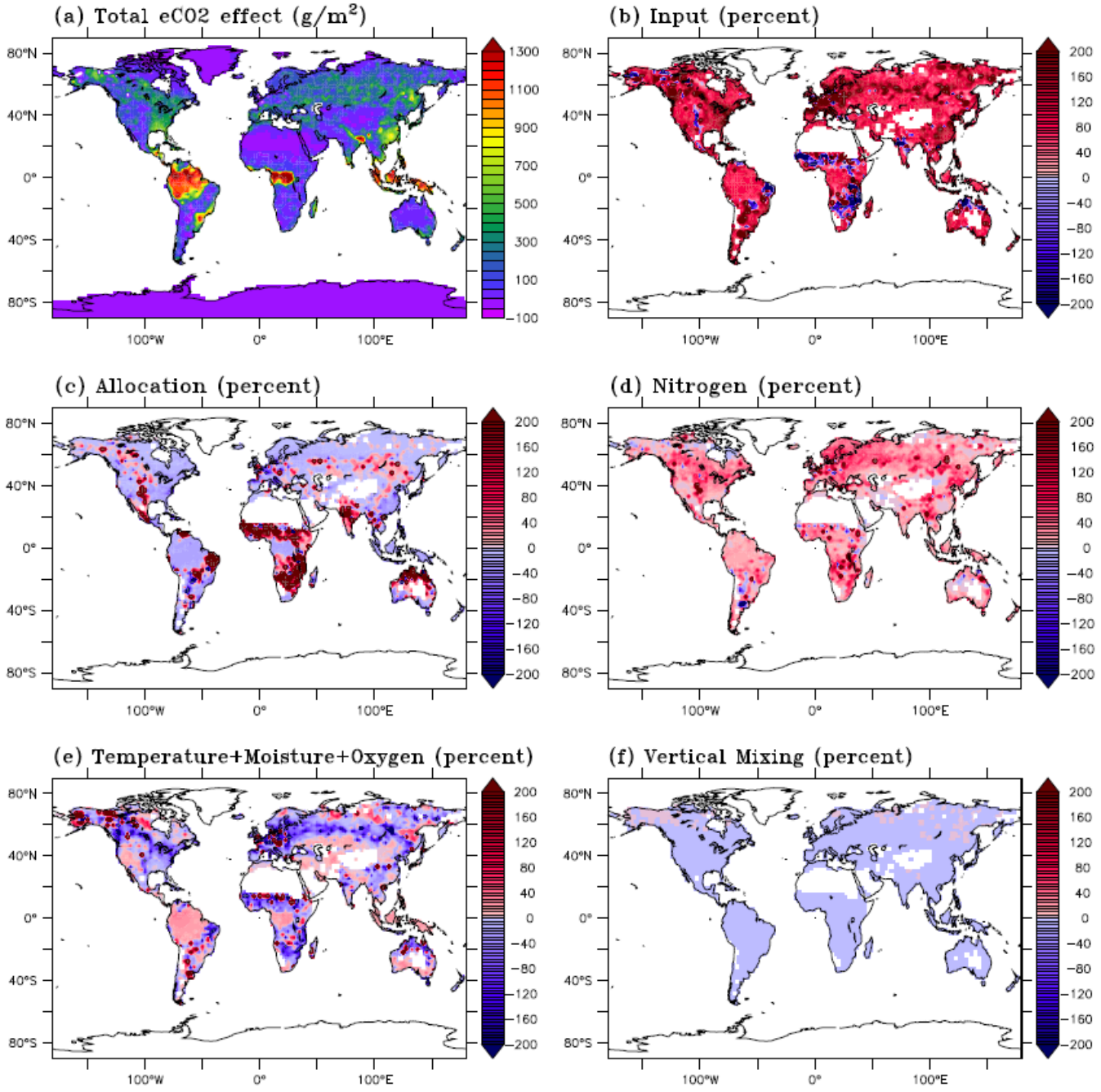


CLM Run 2
eCO_2(560ppm)



Matrix Simulations (matlab)

	S0	S1	S2	S3	S4	S5
I	I0	Ie	Ie	Ie	Ie	Ie
B	B0	B0	Be	Be	Be	Be
N	N0	N0	N0	Ne	Ne	Ne
ε	ε0	ε0	ε0	ε0	εe	εe
V	V0	V0	V0	V0	V0	Ve


(a) Total eCO2 effect (g/m^2)
(b) Input (percent)
(c) Allocation (percent)
(d) Nitrogen (percent)
(e) Temperature+Moisture+Oxygen (percent)
(f) Vertical Mixing (percent)
80°N
40°N
0°
40°S
80°S
100°W
0°
100°E
1300
1100
900
700
500
300
100
−100
200
160
120
80
40
0
−40
−80
−120
−160
−200

Matrix Application 2

Diagnose CLM simulations

- $X(t) = \left(A\xi(t)K - V(t)\right)^{-1} B(t)I(t) - \left(A\xi(t)K - V(t)\right)^{-1} \frac{dX(t)}{dt}$

C storage (X)

C storage Capacity (X_c)

C storage Potential (X_p)

At steady state:

C storage potential approaches 0 ($X_p = 0$)

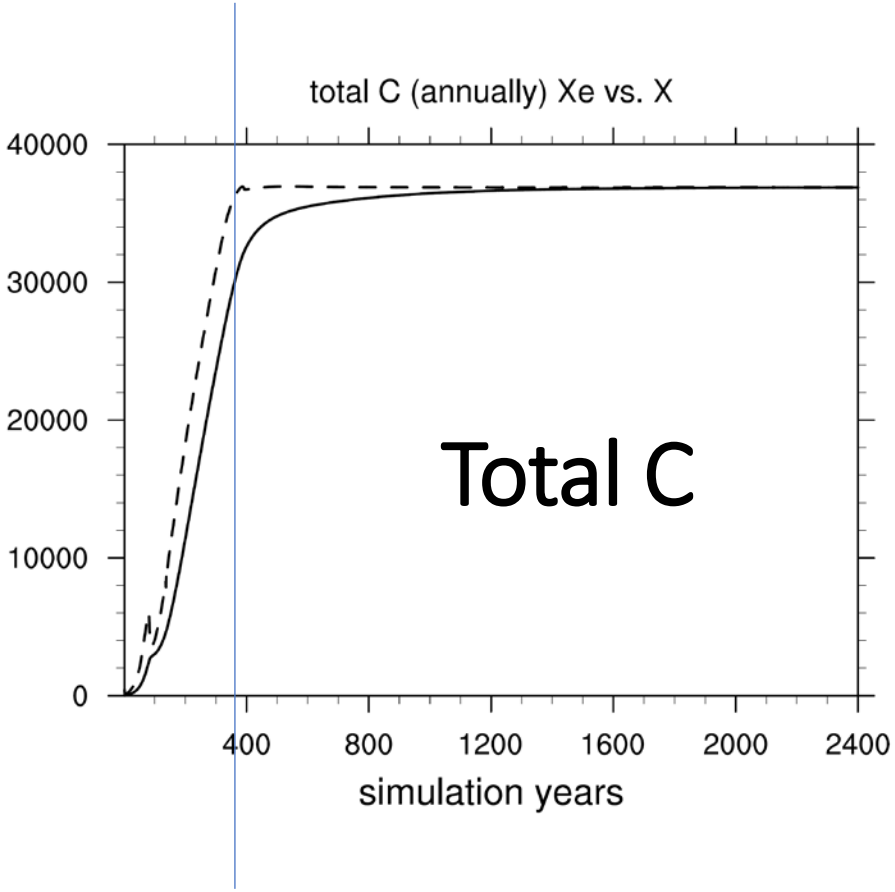
C storage equals C storage capacity ($X = X_c$)

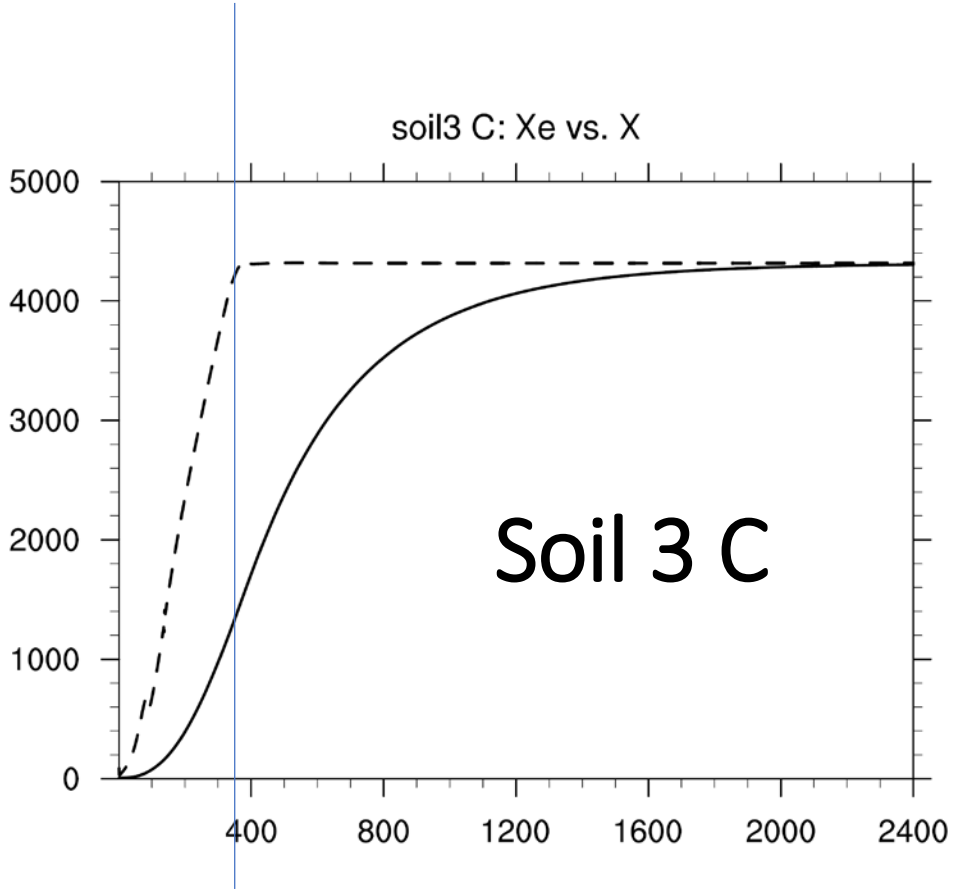
Luo et al., Biogeoscience (2017)

Spin-up

C Storage

C Storage Capacity

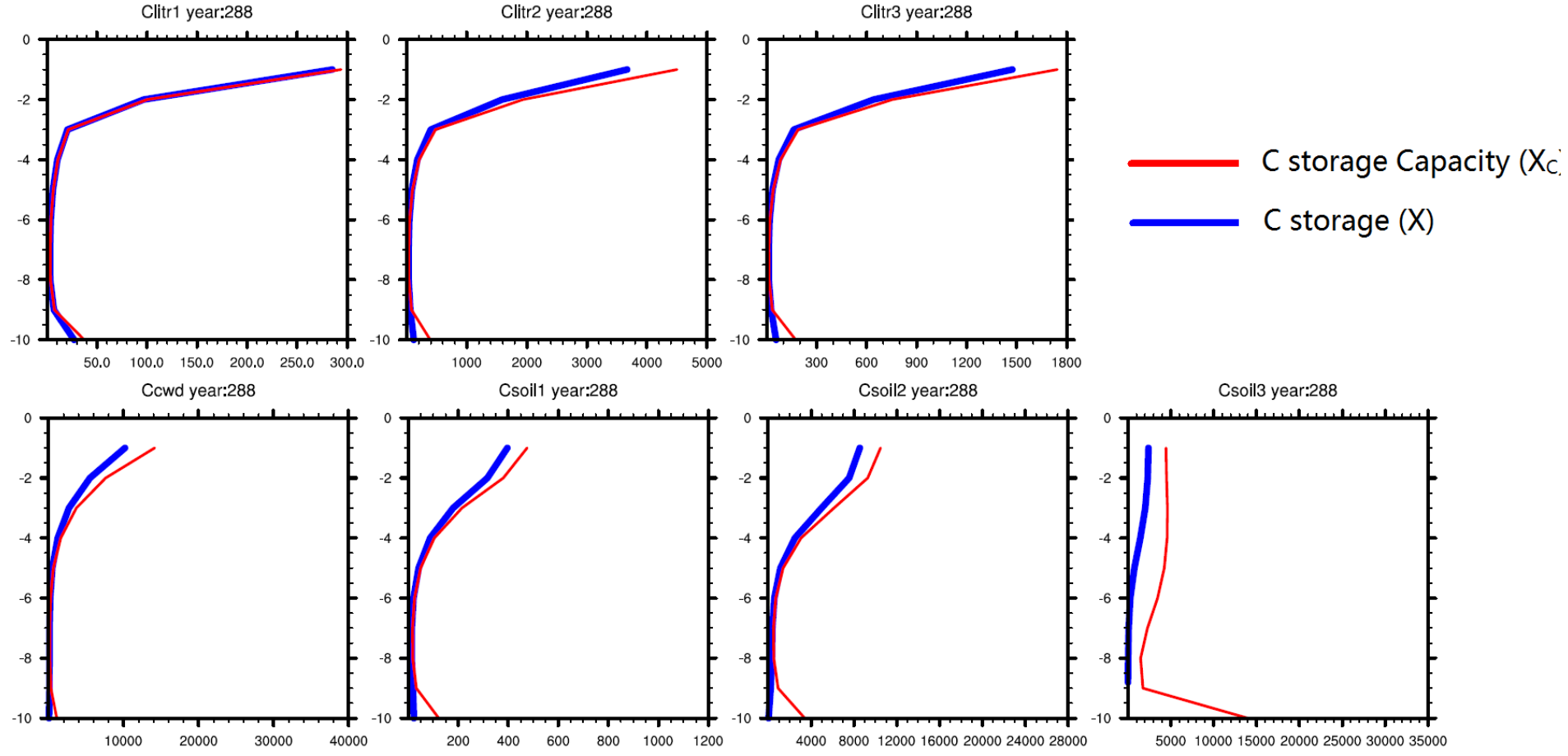




Z_tau = 10

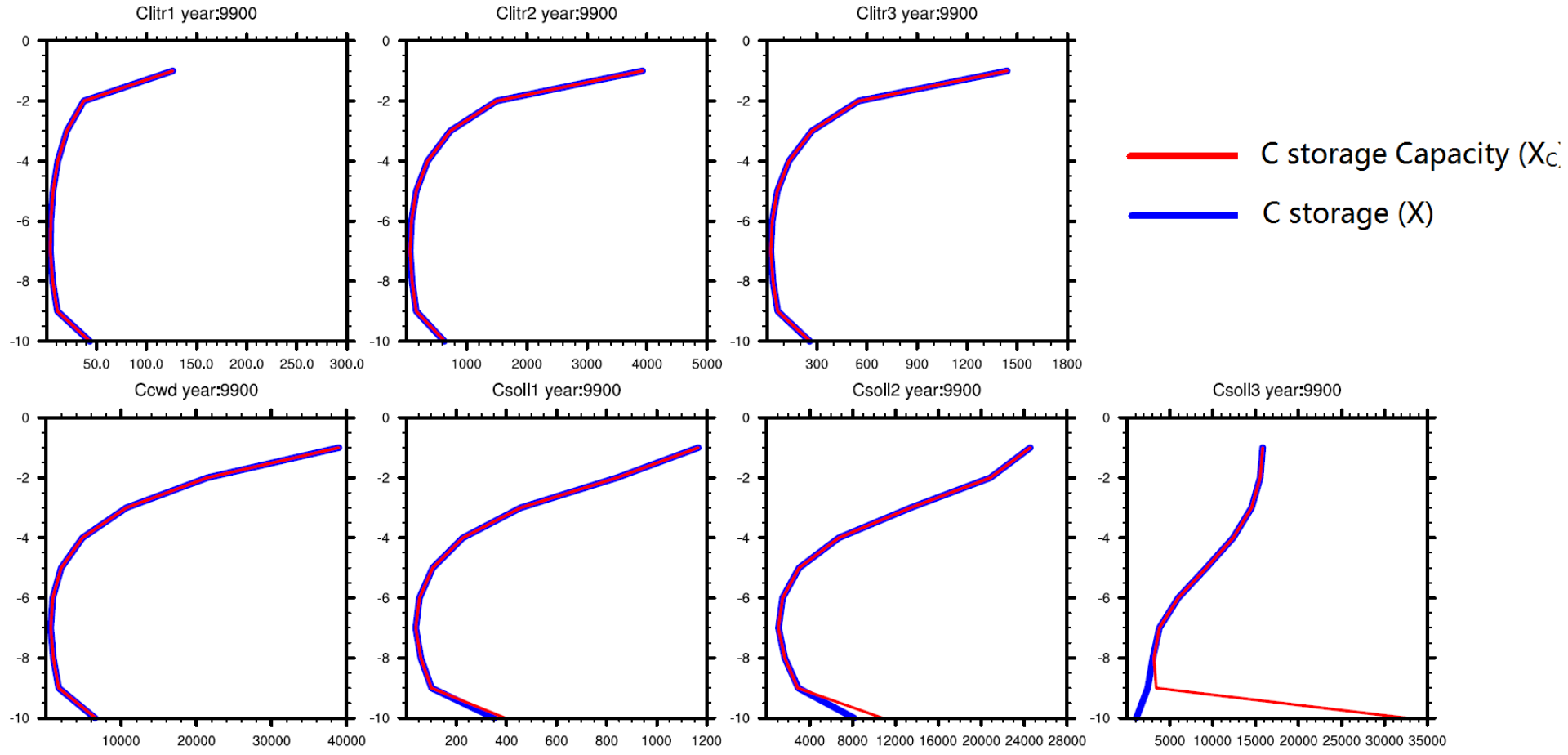
Vertical profile of C storage capacity (X_c) vs. C storage (X) (z_tau=0.5)

- Spin up for ~300 years



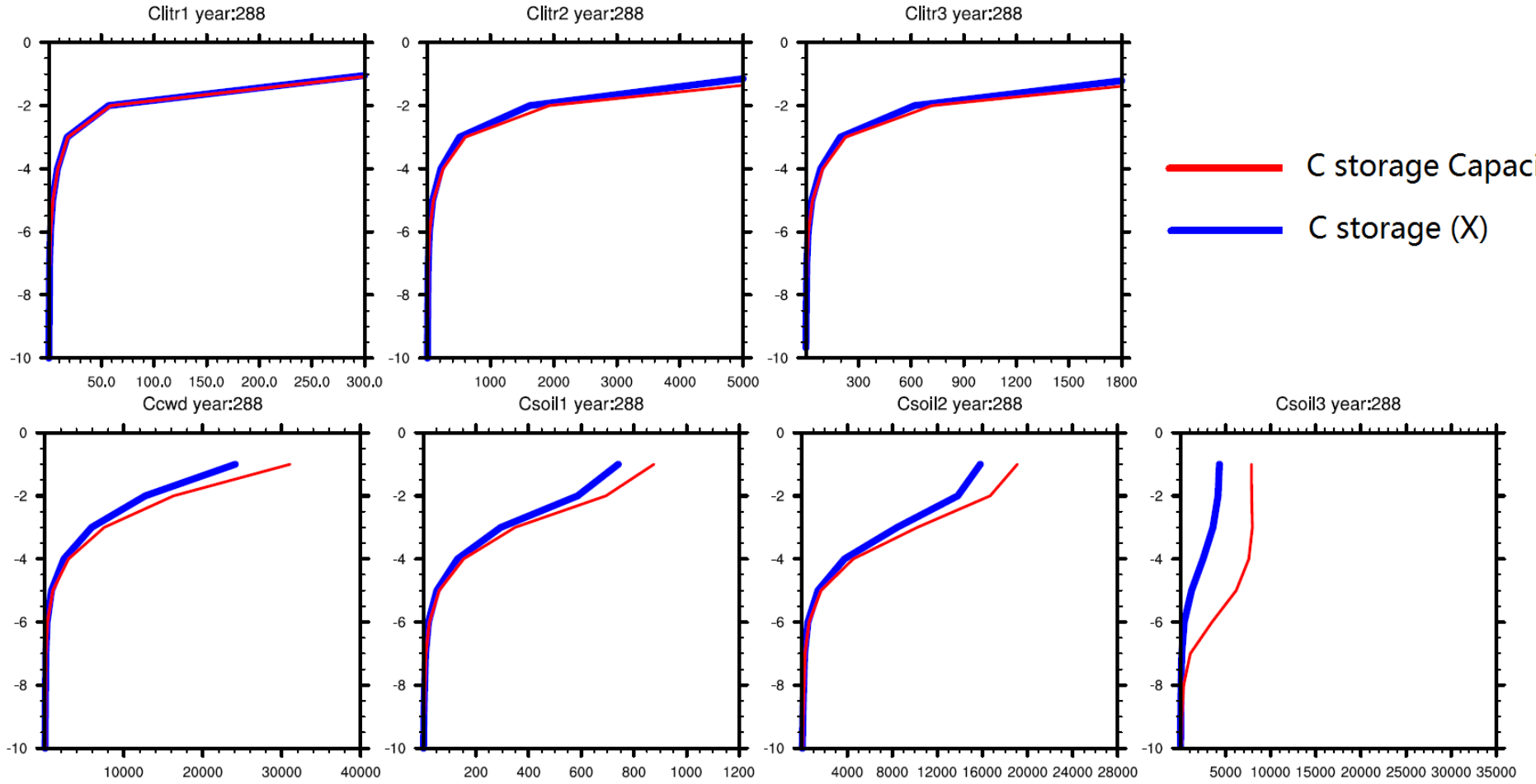
Vertical profile of C storage capacity (X_c) vs. C storage (X) (z_tau=0.5)

- Spin up for >5000 years



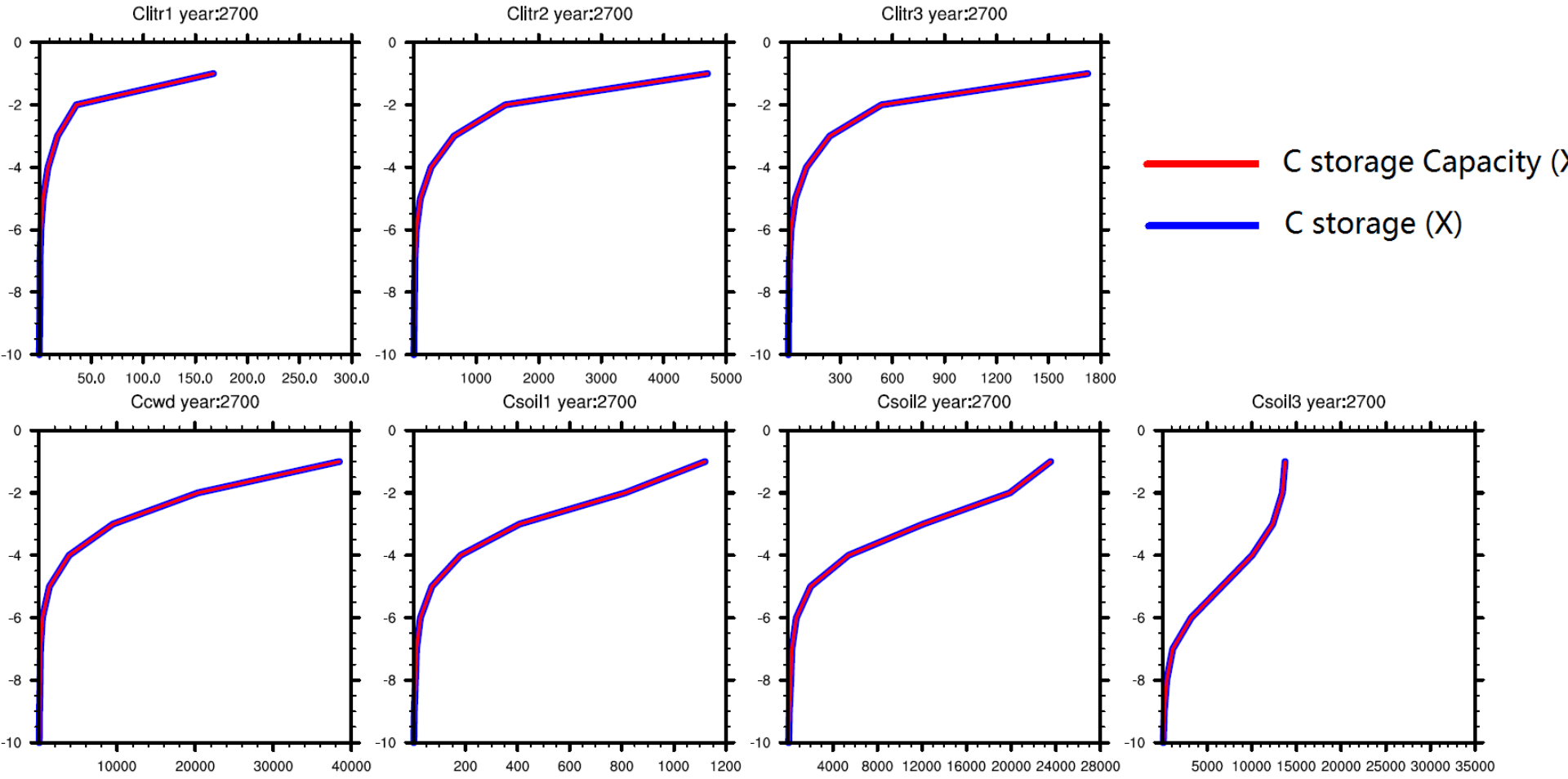
Vertical profile of C storage capacity (X_c) vs. C storage (X)
(z_tau=10)

- Spin up for ~300 years



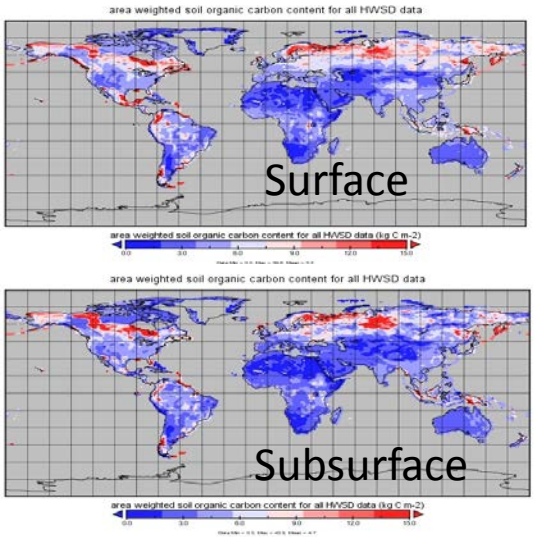
Vertical profile of C storage capacity (X_c) vs. C storage (X) (z_tau=10)

- Spin up for 2700 years



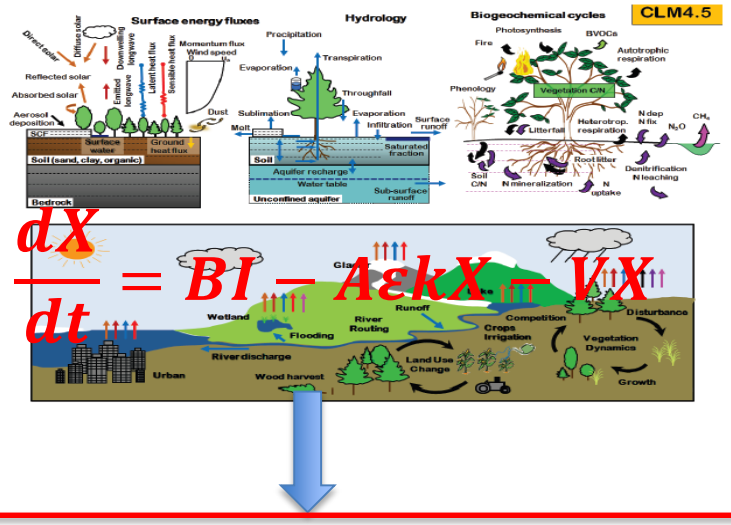
Matrix Application 3

Realize data assimilation to constrain global SOM

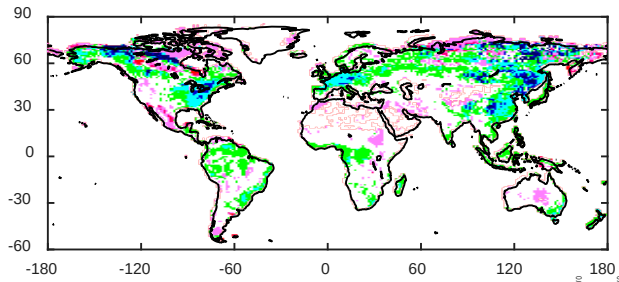


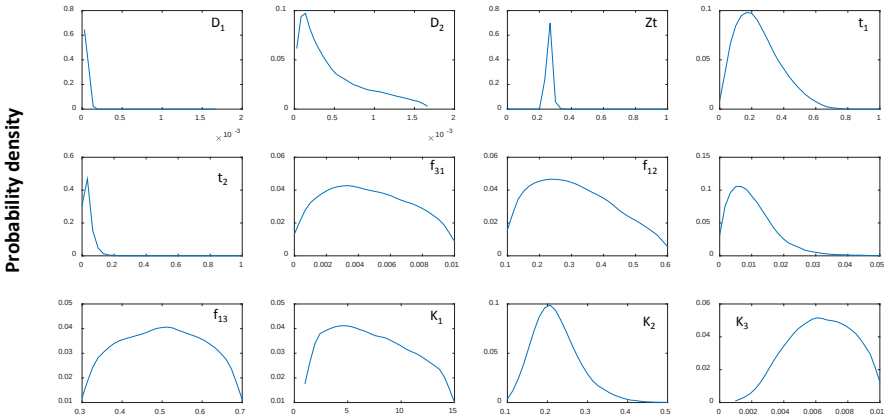
Harmonized soil C content by Wieder et al., (2015)

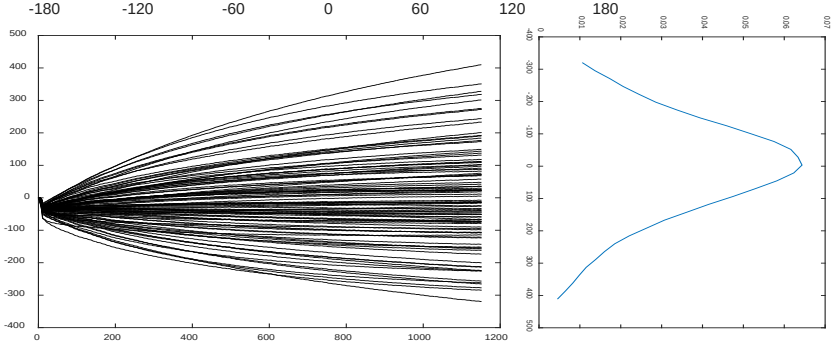
MCMC



$$\frac{dX}{dt} = BI - A\varepsilon kX - VX$$







Summary

- One matrix equation to reproduce dead C dynamics
- Easy manipulation and exploration of different components
- Diagnose CLM simulations
- Promote data assimilation in SOM researches
- ……

Thank you!