Mini-symposium and short training course on

New Advances in Land Carbon Cycle Modeling

Who should attend?

Modelers who want to gain simplicity in coding, diagnostic capability, and computational efficiency for your carbon cycle models

Students, post-docs and young scientists who want to learn carbon cycle modeling with CLM

What are you going to learn?

New theory on land carbon storage dynamics
Matrix representations of land carbon, nitrogen, and phosphorus cycles
A unified diagnostic system for full understanding of uncertainty sources
Carbon cycle data assimilation system for both flux- and pool-based data
Semi-analytic spin-up for computational efficiency

Who are going to teach?

Anders Ahlström, Stanford University, USA
Yizhao Chen, NFU, China
Philippe Ciais, LSCE, France
Zhenggang Du, Northern Arizona University, USA
Yuanyuan Huang, LSCE, France
Debbie Huntzinger, Northern Arizona University, USA
Lifen Jiang, Northern Arizona University, USA
Charlie Koven, Lawrence Berkeley National Laboratory, USA
David Lawrence, National Center for Atmosphere Research, USA
Hank Leoscher, NEON, USA
Chris Lu, Northern Arizona University, USA
Yiqi Luo, Northern Arizona University, USA
Markus Müller, MPI-BGC, Germany
Kiona Ogle, Northern Arizona University, USA
Jim Randerson, UC Irvine, USA
Zheng Shi, University of Oklahoma, USA
Carlos Sierra, MPI-BGC, Germany
Yingping Wang, CSIRO, Australia
Jianyang Xia, ECNU, China
Sha Zhou, Columbia University, USA

Where and When?

Northern Arizona University, Flagstaff, AZ 86011, USA

May 19-26, 2018. Arriving on May 19 and leaving on May 27. Classes on May 20-26 except May 23 for hiking

What funs may you have?

Hiking in Grand Canyon; Mixing with top scientists in the field; Networking with fellow attendees

What is the cost?

Self-paid traveling and lodging plus registration fee of $100 for the mini-symposium and $750 for both symposium and training course.

Fee will cover coffee, lunch, local transportation, rental of meeting rooms, and others.

How to apply?

Send your application, using form from http://www2.nau.edu/luo-lab/?workshop, to Dr. Lifen Jiang, Lifen.Jiang@nau.edu, by February 1, 2018.
We will select up to 30 applicants by February 15, 2018 to attend the training course.

Tentative schedule
Starting Day 2, participants will use either your own models or demo version of CLM4.5 for training on matrix approach.

Day 1: Mini-symposium
Carbon cycle research
- Philippe Ciais: Progress and challenges in carbon cycle research
- Yiqi Luo: Theoretical foundation of carbon cycle in terrestrial ecosystems

Model development
- Charlie Koven: CLM and ELM development
- Yingping Wang: Coupled carbon-nitrogen-phosphorus models
- Yuanyuan Huang: Matrix solution to carbon cycle in CLM

Model Intercomparison projects (MIPs)
- Jim Randerson: C4MIP
- Deb Huntzinger: MsTMIP
- Carlos Sierra: Time scales and system-level diagnostics of the carbon cycle
- Zhenggang Du: Traceability analysis of coupled carbon and nitrogen models
- Sha Zhou: Post-MIPs analysis to identify sources of uncertainty

Data assimilation and ecological forecasting
- Hank Leoscher: Imperatives and Challenges in ecological forecasting
- Kiona Ogle: Bayesian analysis of data and models
- Zheng Shi: Data assimilation with matrix models to improve forecasting
- Yizhao Chen: Super ensembles of multiple matrix models to improve land carbon cycle predictions

Day 2: Learning basic concepts and structures of carbon models, including carbon flow diagrams and carbon balance equations of your models
Introduction of carbon cycle models
- Dave Lawrence: Recent development of CLM5.0
- Participants make presentation to induce their own models

Examples of carbon flow diagrams and balance equations
- Yuanyuan Huang: Carbon balance equation of ORCHIDEE
- Charlie Koven: Carbon and nitrogen balance equations in CLM4.5
- Yingping Wang: Carbon, nitrogen, and phosphorus balance equations in CABLE
- Anders Ahlström: Carbon cycle equations in LPJ-GUESS

Carbon balance equations in participants' models (by working groups, each having 5 trainees plus one instructor, up to 6 groups):
- A table is distributed to trainees for developing carbon transfer pathways
- Participants extract the carbon balance equations of their own models

Participant presentation
- Carbon balance equations in participant's models

Day 3: Re-organization of the carbon balance equations into one matrix equation and coding the matrix equations
Re-organizing the carbon balance equations into a matrix equation
- Yuanyuan Huang: Example from ORCHIDEE
- Zhenggang Du: Example from CLM carbon-nitrogen coupling

Participants: To create a matrix equation each for their models
Carlos Sierra: Compartmental systems and general properties of matrix equations
Participants: Present their matrix equations

Programming of matrix equations (by working groups)

1. A standard coding procedure is distributed to attendees
2. General instruction of coding matrix equation

Day 3 Evening: Markus Müller: demo of biogeochemistry model database (BGC-MD), and the CompartmentalModels python packages

Day 4: Hiking

Day 5: Review on matrix representation of carbon cycle models and introduction of a diagnostic system

Review

Participants: present their carbon balance equations, matrix equations, and coding
General discussion

The unified diagnostic system (more technical)

Yiqi Luo: The 1-3-5 scheme for uncertainty analysis
Jianyang Xia: Traceability analysis
Sha Zhou: Three techniques for post-MIPs uncertainty analysis
Yuanyuan Huang: Uncertainty analysis with matrix equations of CLM, ORCHIDEE, and LM3V

Day 6: Uncertainty analysis

Development of diagnostic capability (by working groups)

Participants: adding diagnostic variables in their models
Participants: adding a module for semi-analytic spin-up in their models
Participants: running the models at the same single site

Uncertainty analysis

Participants: generating models output of diagnostic variables for uncertainty analysis with the 1-3-5 scheme

Brainstorm on possible products

Comparison of spin-up among models?
Traceability analysis?
Other ideas?

Day 7: Discussing the new modeling activities with the matrix approach

Workshop products

Participant: Presenting implementation of matrix approach to attendees' models
Technical challenges in implementing the matrix approach
General discussion

Other applications

Yuanyuan Huang: Parameter sensitivity analysis with ORCHIDEE
Lifen Jiang: Traceability analysis of carbon cycle at Duke and Harvard forests
Zheng Shi, Carbon cycle data assimilation system
Anders Ahlström: Attribution analysis with matrix model

Publications

Lead authors, topics, and timelines.

Adjourn

Readings

New theory

Luo YQ, Keenan TF, Smith M. (2015) Predictability of the terrestrial carbon cycle. Global Change Biology, **21**, 1737-1751.

Luo YQ, Shi Z, Lu X *et al.* (2017) Transient dynamics of terrestrial carbon storage: mathematical foundation and its applications. Biogeosciences*,* **14**, 145-161.

Luo YQ, Weng ES.(2011) Dynamic disequilibrium of the terrestrial carbon cycle under global change. Trends in Ecology & Evolution*,* **26**, 96-104.

Metzler H, Sierra CA. (2017). Linear autonomous compartmental models as continuous-time Markov chains: transit-time and age distributions. Mathematical Geosciences, in press. doi:10.1007/s11004-017-9690-1.

Sierra CA, Muller M. (2015) A general mathematical framework for representing soil organic matter dynamics. Ecological Monographs*,* **85**, 505-524.

Matrix representation of carbon and nitrogen cycle models

Huang YY, Lu XJ, Shi Z, Lawrence D, Koven C, Xia JY, Du ZG, Kluzek E, Luo YQ. (2017) Matrix approach to land carbon cycle modeling: A case study with Community Land Model. Global Change Biology, doi: 10.1111/gcb.13948.

Shi Z, Yang Y, Luo Y, Zhou X, Weng E, Finzi A. (2016) Inverse analysis of coupled carbon-nitrogen cycles against multiple datasets at ambient and elevated CO_2. Journal of Plant Ecology, **9**, 285-295.

Traceability analysis

Ahlström A, Xia JY, Arneth A, Luo YQ, Smith B. (2015) Importance of vegetation dynamics for future terrestrial carbon cycling. Environmental Research Letters*,* **10**, 054019.

Jiang LF, Shi Z, Xia JY, Liang JY, Lu XJ, Wang Y, Luo YQ. (2017) Transient traceability analysis of land carbon storage dynamics: procedures and its application to two forest ecosystems. Journal of Advances in Modeling Earth Systems, doi: 10.1002/2017MS001004.

Xia JY, Luo YQ, Wang YP, Hararuk O. (2013) Traceable components of terrestrial carbon storage capacity in biogeochemical models. Global Change Biology*,* **19**, 2104-2116.

Zhou S, JY Liang, XJ Lu, QY Li, LF Jiang, Y Zhang, CR Schwalm, JB Fisher, J Tjiputra, S Sitch, A Ahlström, DN Huntzinger, YF Huang, GQ Wang, YQ Luo. 2018. Sources of uncertainty in modeled land carbon storage within and across three MIPs: Diagnosis with three new techniques. *Journal of Climate,* In press

Spin-up

Xia JY, Luo YQ, Wang YP, Weng ES, Hararuk O. (2012) A semi-analytical solution to accelerate spin-up of a coupled carbon and nitrogen land model to steady state. Geoscientific Model Development*,* **5**, 1259-1271.

Data assimilation

Du Z, Zhou X, Shao J, Yu G, Wang H, Zhai D, Xia J, Luo Y. (2017) Quantifying uncertainties from additional nitrogen data and processes in a terrestrial ecosystem model with Bayesian probabilistic inversion. Journal of Advances in Modeling Earth Systems, **9**, 548-565.

Hararuk O, Xia JY, Luo YQ. (2014) Evaluation and improvement of a global land model against soil carbon data using a Bayesian MCMC method. Journal of Geophysical Research-Biogeosciences, **119**, 403-417.