U.S. DEPARTMENT OF ENERGY

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RUBISCO Soil Carbon Dynamics Working Group 2018 Fall Meeting Final Report

RUBISCO

Final Report Revised June 26, 2019

DISCLAIMER

Contents

1.0 Introduction

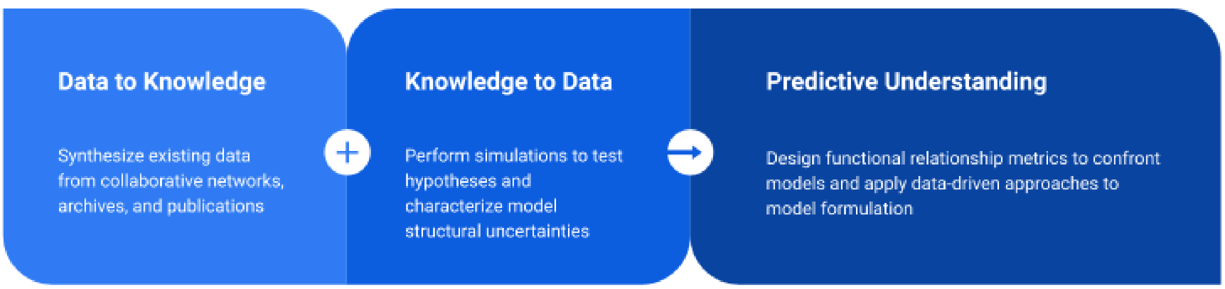
The Reducing Uncertainties in Biogeochemical Interactions through Synthesis and Computation (RUBISCO) Scientific Focus Area (SFA), sponsored by the U.S. Department of Energy (DOE)'s Office of Biological and Environmental Research (BER), has initiated a Soil Carbon Dynamics Working Group to help advance the development of global soil carbon data sets and evaluation metrics for model benchmarking and to characterize soil carbon process model uncertainties. Created in response to community-identified research priorities from the 2016 International Land Model Benchmarking (ILAMB) Workshop Report (Hoffman et al. 2017), the Working Group is composed of scientists, who participate voluntarily, from DOE national laboratories and U.S. and international universities and research institutes. The Working Group holds regular conference calls to collaboratively identify research priorities, share progress toward obtaining research objectives, and develop manuscripts documenting scientific accomplishments. Face-to-face Working Group meetings will be conducted as needed, pending available funding, to foster interdisciplinary collaboration, organize research tasks and schedules, and advance research goals. Membership in the Working Group may change as research priorities shift.

2.0 Initial Working Group Research Agenda

Two conference calls were held to organize the initial Working Group members and to refine research priorities. The first conference call, held on June 26, 2018, addressed the need for developing data sets and metrics for model evaluation that account for various controls on carbon content and turnover. On September 4, 2018, a second conference call identified the need for improved data for initializing, forcing, and evaluating microbially explicit soil carbon models. These calls identified near-term research efforts that would incrementally advance the current state of data sets and begin to explore the structural uncertainty in various soil carbon models in use and under development today. Moreover, long-term research goals that would take a few years of effort were discussed. Emerging from these calls was a clear indication that the initial Working Group members could make significant progress in synthesizing data for assessing soil carbon in global Earth system models, like those to be used in the Sixth Phase of the Coupled Model Intercomparison Project (CMIP6), and in formulating software and data infrastructure for initializing, testing, and evaluating microbially explicit models. These research challenges set the stage for the Working Group Meeting held at Oak Ridge National Laboratory (ORNL) October 3–5, 2018.

2.1 Applying Data and Models to Improve Predictive Understanding

Current Earth system model (ESM) representations of soil organic matter (SOM) distribution and responses to environmental change vary widely and are not consistent with observations. Through a series of research activities organized within the multidisciplinary Working Group, new data sets and models will be developed to address uncertainties associated with SOM dynamics and lead to improved predictive understanding of soil carbon in the global carbon cycle.



Working Group research will have two primary themes, both aimed at delivering data and metrics for confronting ESM predictions and exploring data-driven approaches for model design and testing.

- The Global Data Synthesis Theme will combine field observations from collaborative sampling networks and databases, including the International Soil Carbon Network (ISCN); data archives; and published literature to develop improved data sets. These data will quantify the vertical distribution of SOM and characterize the dynamical responses of SOM to controlling processes, including decomposition, mineralization, aggregation, and stabilization.
- The Model–Data Integration Theme will address challenges of initializing, forcing, and benchmarking the next generation of microbially explicit soil carbon models. These models attempt to capture important fine-scale mechanisms that govern SOM dynamical processes, but the community lacks a consistent set of data for initialization and parameter estimation. Characterization of model structural uncertainty through one or more software frameworks would advance scientific understanding of important mechanisms.

In addition to metrics of spatial and temporal distributions and trends of soil carbon, relationships between soil carbon and controlling variables will be developed to produce functional relationship metrics for use in the International Land Model Benchmarking (ILAMB) package.

2.2 Global Data Synthesis Theme

The Global Data Synthesis Theme will evaluate the research potential of the following research activities.

- Develop quantitative relationships to represent mineralogical controls on soil carbon stabilization

  Despite soil minerals and organic matter interactions being a primary stabilization mechanism, soil mineralogical control over SOM is poorly represented in land models. We will identify soil mineralogical properties known to affect SOM stabilization (e.g., cation exchange capacity, mineral types, structure), and identify observationally derived sources of this information at large scales. Coupling this information with observed SOC stocks and evaluating relative strength of various controllers may provide insights on needed model structures.

  Benchmarks, parameters, and pedotransfer functions needed for modeling and evaluating mineralogical controls on SOM dynamics will be model dependent. For century-type models, which typically do not have an explicit mechanism or representation, soil texture is used to partition carbon pools of different turnover times. For microbially explicit models that also represent adsorption and desorption with Langmuir-like isotherms, estimates of Qmax and affinities are needed. Current work suggests a first cut for global pedotransfer functions for Qmax can be generated from literature, but further work will be required to bring more mineralogical details (e.g., cation and anion exchange capacity, soil pH) into the relationships.

- Synthesize field observations of organic soils (peat/wetlands) to develop environmental controllers of organic soil carbon

  Soil carbon stabilization mechanisms differ in mineral and organic soils. Better spatial representation of organic soils and their environmental controls in global models is needed. For example, environmental controllers of peat SOM is poorly represented in global models. Similarly, organic layer thickness and its role in permafrost dynamics and SOM stabilization is important but not represented in land models. Soil drainage conditions and fire occurrence are important determinants of SOM storage of peat soils. Currently, not much data is available for organic soils, and its stabilization and vulnerability mechanisms. Our working group will separate organic soils from mineral soils and focus on environmental controllers and stabilization mechanisms of SOM of organic soils.

- Develop model benchmarks of temperature and moisture controls on SOM decomposition rates

  Temperature and moisture affect SOM decomposition rates, but model representation of these processes are extremely diverse. We will address several prominent knowledge gaps on these controls, including the temperature dependence and sensitivity of decomposition rates at temperatures >25°C. Models do not agree whether there is a continuous increase, a saturation, or a decline in SOM decomposition rates at the upper end of the temperature range. Models also disagree on dependence and sensitivity of decomposition rates as a function of soil moisture, and on interactive temperature and moisture effects. Another possible angle of inquiry relates to combined temperature and moisture effects on soil structure (e.g., aggregation, turbation) and subsequent effects on SOM dynamics.

  Observations with sufficient metadata are required to accurately parameterize and benchmark the relationships representing interactive impacts of soil moisture and temperature on SOM decomposition in models. Again, field observations, and in particular metadata, required to evaluate models will depend on model structure. Synthesis of literature is needed for temperature and moisture controls of soil organic matter dynamics under field and laboratory conditions. Analyzing differences between field- and laboratory-derived inferences of SOC dynamics could be useful to understand how (or whether) to use incubation data for model benchmarking.

- Develop model benchmarks for microbial control on SOM dynamics

  Microbes use enzymes to degrade plant materials and access SOM protected by soil mineral associations. Microbial community structure impacts SOM dynamics. For example, fungal symbionts with plants have recently been identified as important for SOM dynamics, and in particular, for facilitating plant access to SOM nutrients. Benchmarks, and metadata, required to evaluate models of these processes will be model dependent, but these benchmarks will probably focus on field and laboratory (1) emergent responses to perturbations; (2) microbial dynamics (e.g., growth rates, enzyme production) and related controls (e.g., substrate availability, temperature, moisture); and (3) mineral-surface interactions. Soil structure information, such as aggregate size distributions, are also important for developing these models. Field and laboratory perturbation experiments can provide measurements to develop or falsify modeling assumptions and hypothesis. A categorized synthesis could be informative for model development and benchmarking.

- Develop model representations of lateral and vertical soil transport mechanisms

  Soil erosion is an important physical process that determines SOM spatial structure and its dynamics. However, lateral erosion occurs on spatial scales finer than are, and probably can explicitly be, represented in current generation of Earth system models. Therefore, we envision a several-pronged approach for developing model benchmarks for soil erosion process: (1) synthesize literature on fine-scale (e.g., 10 m) soil erosion observations and its environmental controls and (2) synthesize approaches and observations available for spatial scaling of soil erosion processes e.g., universal soil loss equations.

  Similarly, vertical soil movement processes such as clay migration, cryoturbation, and pedoturbation also play important roles in deeper soil SOC stabilization, decomposition, and release to the atmosphere. However, these processes are either represented in models in very simplistic ways or not at all. Therefore, a synthesis of the magnitude of these effects inferred from observations, their temporal and spatial scales, and existing model formulations could be very helpful for next-generation model development.

- Synthesize soil databases and literature to model impacts of soil structure and aggregation on SOM dynamics

  Soil structure (e.g., soil aggregates, porosity distribution) affects substrate, O_2, and moisture availability. However, most models do not explicitly represent soil structure controls on SOM dynamics. Chemical diffusion observations as a function of soil structure for different types of soils would be valuable for next-generation model development. A synthesis of existing data and model structures would be useful to guide benchmark and model development. Current models do not distinguish the SOM dynamics of newly formed aggregates and older soil aggregates, though it is well known that wet-dry cycles tend to break up newly formed aggregates but stabilize older aggregates. Similarly, soil texture dependence on aggregate formation and dynamics needs to be investigated to be included into models. Soil aggregation information is available in soil profile descriptions of Natural Resource Conservation Services in a semi-quantitative way. Synthesizing this information would be helpful for model development.

- Develop emergent benchmarks for CMIP6 models

  We will also require emergent benchmarks to evaluate CMIP6 predictions. The potential emergent benchmarks include:

  – Observed spatial (and temporal where available) relationships between SOM stocks and hypothesized controllers (e.g., MAT, MAP, topographic indices, soil texture, etc.) for different regions. This analysis will include evaluating differences among the several available global and regional SOM stock data sets.

  – Perturbation experiment results for SOM dynamics, including manipulations of C inputs (e.g., none, double), warming, and moisture. This analysis will require synthesizing and evaluating responses in a manner amenable to large-scale model evaluation.

  – Radiocarbon measurements provide important information regarding the SOM turnover rates. The observed vertical radiocarbon depth profiles can be used to benchmark the modeled SOM turnover rates.

2.3 Model–Data Integration Theme

Operating in parallel with the data synthesis activities described above, the Model–Data Integration Theme will synthesize field observations and experimental data to develop a common set of model initialization and calibration data for use by the modeling community. In addition, next-generation soil carbon model parameterizations will be tested in a standard fashion, and model frameworks for simulation, testing, and evaluation will be developed and tested as a part of related research activities with participants. In particular, the Working Group will evaluate the following activities.

- Create a soil model farm for benchmarking soil processes within a land model

  Several new soil process model formulations are being developed at varying levels of complexity. For example, some soil carbon models represent vertical transport mechanisms, reactive transport mechanisms, and vegetation controls on SOM. Such models can be brought into one platform and can be used for benchmarking specific processes within the context of land models, like ELM or CLM.

- Create a data testbed to quantify uncertainties in model representations and field observations

  Uncertainty exists both in models and soil carbon observations. Two separate efforts can be made to constrain uncertainties in models and field observations. In models, we can develop an ensemble of models representing similar processes. The ensemble of model predictions can be used to quantify uncertainty estimates in specific processes, and characterize their driving factors. Similarly, a separate effort can be made to harmonize field observations (such as soil organic carbon stock observations), characterize their uncertainties, and use them for data model intercomparisons.

  Creating data testbeds may provide insights to develop data-driven models, instead of more process-driven representations. Certain processes can be derived from observations — for example, Michaelis-Menten representations, but the issues around spatial scaling to measurable scales remains daunting. Similarly, using data testbeds' linear and nonlinear functions can be developed using machine learning and other data-driven statistical approaches. We should welcome different ideas and approaches, as data-driven and process-driven approaches each have uncertainties.

3.0 Future Working Group Activities

As a research community, we expect to continue to define new data products, develop improved models, and use the results of this research to help inform the design of future field experiments and observational campaigns. Continued efforts in developing statistical frameworks and conducting hypothesis testing and data-driven approaches for modeling will need sustained effort in a community-driven organization, like this Working Group. As the team progresses, it will consider organizing a long-term activity, similar to the National Science Foundation's Research Coordination Networks, and seek funding to further advance soil carbon research.

Several ideas were discussed and multiple research priorities were identified over the course of the three-day Soil Carbon Dynamics Working Group Meeting. Four research topics were identified under the Global Data Synthesis Theme, and three topics were identified as priority research topics under the Model–Data Integration Theme.

3.1 Global Data Synthesis Theme

The objectives of this theme are to synthesize soil carbon databases for benchmarking and to use these data to improve understanding of factors that influence SOC storage and rates of decomposition. Four specific research activities were identified for this theme.

1. How will soil carbon stocks change over the next several decades?

   Due to its large stock, a small change in soil carbon could have a large influence in atmospheric carbon concentrations. Knowledge gaps exist in our understanding of how soil carbon will change in the near future in response to environmental change and anthropogenic factors (Todd-Brown et al. 2013, 2014). As a result, the current generation of models produce divergent future soil carbon dynamics. A synthesis of existing soil carbon observations and associated controlling environmental factors at large spatial scales could provide insights about (1) the strength of environmental controllers on total SOC stocks, and (2) the carbon decomposability (for example, proportions of mineral-associated carbon or particulate organic carbon in total carbon stocks and their distribution across a range of environmental conditions). This information, in combination with projections of future climatic and land cover data, can be used to predict observationally constrained changes in future soil carbon stocks. The magnitude of uncertainty in the strength of environmental controllers of SOC stocks could provide benchmarks for model representations of environmental controllers.

2. Synthesize litter dynamics data to infer soil C formation in models

   Most (about 90%) of the net primary productivity enters the soil and gradually decays to soluble carbon and nutrients, CO_2, and mineral constituents. However, predicting plant litter decomposition and the fate of decomposed carbon is not easy due to several interacting factors related to the chemical, physical, and biological properties of soil, as well as climate and land management practices. A literature and data synthesis activity focused on plant litter decomposition can inform soil carbon formation in land surface models. For example, relative humidity is a strong regulator of plant litter decomposition. An effort should be made to compare relative humidity representations across CMIP models. This task may also provide insights about differing mechanisms of above- and below-ground litter decomposition processes. Similarly, it can also be investigated whether edaphic and environmental controllers of litter decomposition vary regionally.

3. Precipitation manipulation experiments to study drought impacts

   Drought conditions are expected to increase in many parts of the world with consequences for soil carbon dynamics. The impact of drought on soil organic matter decomposition will primarily depend on drought intensity and the timing of rewetting periods. Recent studies also show that drought can alter the biochemical composition of the plant biomass, thereby altering its decomposition potential. An effort to synthesize precipitation manipulation experiments to study the impact of drought on soil carbon dynamics could provide valuable insights into the impact of drought on altering plant input composition. This task should investigate the impact of water exclusion on soil carbon and surface litter dynamics using the data from experimental plots. The results from this effort could provide emergent controls to benchmark CMIP6 models.

4. Soil carbon age and turnover rates

   Carbon turnover time in an ecosystem is a critical parameter for accurately modeling carbon cycling and assessing the carbon sink potential of ecosystems. However, our current knowledge of how long carbon can be stored in soils and vegetation, and what controls spatial variations in carbon turnover time is very limited. An effort to analyze soil carbon age and its spatial controllers could produce valuable information about terrestrial carbon dynamics (He et al. 2016). Such an effort can be executed in collaboration with the International Soil Radiation Database (ISRaD) project. ISRaD is attempting to produce a global map of ^{14}C data using machine learning techniques. These data will be very useful for benchmarking carbon dynamics in isotope-enabled land surface models. One interesting activity could be to bring both point observations of ^{14}C and the gridded data into the ILAMB framework to enhance model benchmarking efforts.

3.2 Model–Data Integration Theme

The objectives in this theme were to test and improve microbially explicit models of soil carbon dynamics. Three research activities were proposed for this theme.

1. Use reduced-complexity models to evaluate model uncertainties

   Reduced-complexity models, which can be simplified to appropriate levels of complexity in order to reduce computational and parametric overhead and allow for time-efficient simulations, can be used to evaluate the uncertainty of complex model projections. An effort could be made to start with a reduced-complexity model that is then built into a hierarchy of models of increasing complexity, to understand how uncertainty propagates with model complexity. For example, one could start with one or two pools of soil carbon and one or two enzymes, or one could keep at least one microbial pool or retune a CENTURY-style model to study soil carbon dynamics. We can investigate the minimum number of soil carbon pools that are required to capture the carbon dynamics represented by complex microbially enabled carbon models. Simplified models based on stoichiometric relationships may also be generated. We could also develop a mathematical framework to construct a hierarchy and request modeling centers to contribute their soil carbon sub-models into the framework.

2. Evaluate models at various spatial and temporal scales

   The current generation of Earth system models does not accurately represent the spatial and temporal heterogeneity of land-atmosphere interactions of carbon, water, energy, and other greenhouse gases. An effort to evaluate soil carbon models at various spatial and temporal scales can potentially improve these heterogeneity representations in models. For example, wavelet or spectral analysis could be used on a data set to study which models capture certain processes right at various timescales. Potential studies could also evaluate relationships between soil respiration and microbial biomass, and dissolved organic matter export. An analysis framework could be developed such that these mathematical relationships can be eventually incorporated into ILAMB for sustained model benchmarking efforts. Another example could be to evaluate the role of soil erosion on terrestrial carbon dynamics.

3. Develop model parameterizations and evaluation protocols for microbial measurements

   A multitude of soil microbial properties are increasingly being measured with varying degrees of uncertainty. A literature and data synthesis effort could use these measurements to develop model parameters and model evaluation protocols. An effort could identify mechanisms with implicit versus explicit representations. Similarly, microbial soil carbon decomposition processes can be parameterized using these observations.

The agenda and attendee list from the Working Group Meeting are contained in the appendices.

4.0 References

He, Y, SE Trumbore, MS Torn, JW Harden, LJS Vaughn, SD Allison, and JT Randerson. 2016. "Radiocarbon constraints imply reduced carbon uptake by soils during the 21st century." *Science* 353(6306): 1419–1424, https://doi.org/10.1126/science.aad4273

Hoffman, FM, CD Koven, G Keppel-Aleks, DM Lawrence, WJ Riley, JT Randerson, A Ahlström, G Abramowitz, DD Baldocchi, MJ Best, B Bond-Lamberty, MG De Kauwe, AS Denning, AR Desai, V Eyring, JB Fisher, RA Fisher, PJ Gleckler, M Huang, G Hugelius, AK Jain, NY Kiang, H Kim, RD Koster, SV Kumar, H Li, Y Luo, J Mao, NG McDowell, U Mishra, PR Moorcroft, GSH Pau, DM Ricciuto, K Schaefer, CR Schwalm, SP Serbin, E Shevliakova, AG Slater, J Tang, M Williams, J Xia, C Xu, R Joseph, and D Koch. 2017. International Land Model Benchmarking (ILAMB) 2016 Workshop Report. U.S. Department of Energy. DOE/SC-0186, https://doi.org/10.2172/1330803

Todd-Brown, KEO, JT Randerson, WM Post, FM Hoffman, C Tarnocai, EAG Schuur, and SD Allison. 2013. "Causes of variation in soil carbon simulations from CMIP5 Earth system models and comparison with observations." *Biogeosciences* 10(3): 1717–1736, https://doi.org/10.5194/bg-10-1717-2013

Todd-Brown, KEO, JT Randerson, F Hopkins, V Arora, T Hajima, C Jones, E Shevliakova, J Tjiputra, E Volodin, T Wu, Q Zhang, and SD Allison. 2014. "Changes in soil organic carbon storage predicted by Earth system models during the 21st century." *Biogeosciences* 11(8): 2341–2356, https://doi.org/10.5194/bg-11-2341-2014

Appendix A

2018 Fall RUBISCO Soil Carbon Dynamics Working Group Meeting Agenda

RUBISCO Soil Carbon Dynamics Working Group Meeting

Oak Ridge National Laboratory

Clinch River Cabin

1 Bethel Valley Road, Oak Ridge, Tennessee, USA

October 3–5, 2018

Final Agenda (2 October 2018)

Remote access to plenary presentations and discussions will be available through BlueJeans videoconferencing at

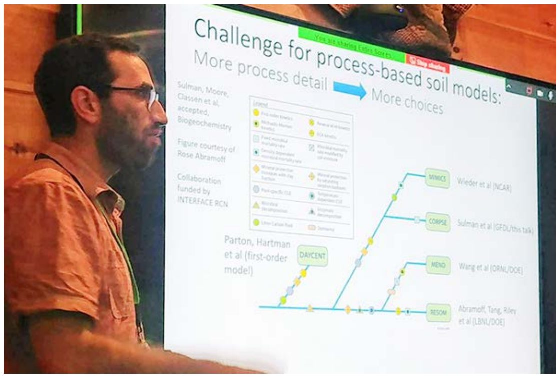
https://bluejeans.com/350542910/0726

Wednesday, October 3, 2018			
8:00	*Continental Breakfast*		Clinch River Cabin
8:30	Welcome and Introductions	Renu Joseph, Forrest Hoffman, Umakant Mishra	Clinch River Cabin
9:00	Presentation and discussion of research paths	Forrest Hoffman	Clinch River Cabin
9:30	Soil carbon measurements and data discussion	Umakant Mishra	Clinch River Cabin
10:00	*Morning break*		Clinch River Cabin
10:30	International Soil Carbon Network (ISCN) data holdings and resources	Avni Malhotra	Clinch River Cabin
11:00	Benchmarking soils in CMIP5 and planning for CMIP6	Kathe Todd-Brown	Clinch River Cabin
11:30	Discussion of data availability and other synthesis activities		Clinch River Cabin

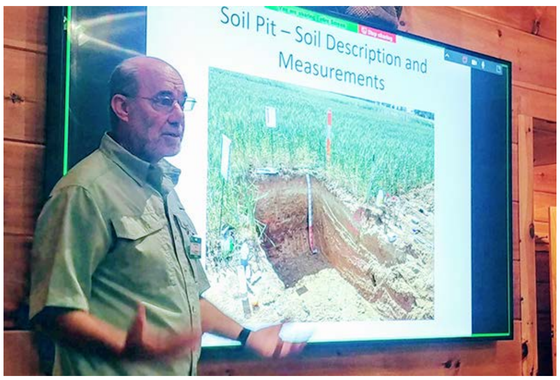
12:30	*Working Lunch*		Clinch River Cabin
	A Guided Introduction to ILAMB - Nathan Collier	Nathan Collier	
14:00	Overview of soil carbon models	Jinyun Tang	Clinch River Cabin
14:30	Key processes and uncertainties in microbe-mineral soil organic matter models	Ben Sulman	Clinch River Cabin
15:20	*Afternoon break*		Clinch River Cabin
15:45	Incorporating omics-informed soil microbial functions into Earth system models	Yang Song	Clinch River Cabin
16:15	Temperature and moisture controls on decomposition	Shijie Shu	Clinch River Cabin
16:45	Soil decomposition processes and mechanisms	Ben Bond-Lamberty	Clinch River Cabin
17:40	Informal discussions		Clinch River Cabin
18:00	*Soil Carbon Dynamics Working Group Working Dinner*		Clinch River Cabin
	Invited Guest Lecture - Dr. W. Mac Post	W. Mac Post	
20:00	Adjourn for the day		

Thursday, October 4, 2018			
8:00	*Continental Breakfast*		Clinch River Cabin
8:30	Updates from previous day		Clinch River Cabin
9:00	Charge for breakout groups		Clinch River Cabin
9:15	Breakout group meetings		Clinch River Cabin
	Global data synthesis		
	Model-data integration		
10:00	*Morning break*		Clinch River Cabin
10:15	Breakout group meetings (continued)		Clinch River Cabin
	Global data synthesis		
	Model-data integration		
11:30	Discussion of controls on SOC stabilization	Xiaofeng Xu	Clinch River Cabin
12:00	*Working Lunch*		Clinch River Cabin
	Getting to Know CORPSE - Ben Sulman	Ben Sulman	
13:00	Kinetic Vegetation, Litter, and Soil Interactions	Mac Post	Area surrounding Clinch River Cabin
14:30	Isotope data synthesis	Bill Riley	Clinch River Cabin

15:00	*Afternoon break*		Clinch River Cabin
15:30	Progress report from breakout groups		Clinch River Cabin
16:00	Open discussion		Clinch River Cabin
17:00	Depart for Group Dinner		Clinch River Cabin
18:00	No Host Group Dinner (Optional)		Calhoun's Oak Ridge, 100 Melton Lake Peninsula, Oak Ridge, TN 37830, (865) 685-0850
20:00	Adjourn for the day		
	Friday, October 5, 2018		
8:00	*Continental Breakfast*		Clinch River Cabin
8:30	Updates from previous days		Clinch River Cabin
9:00	Path forward on global data synthesis		Clinch River Cabin
10:00	*Morning break*		Clinch River Cabin
10:30	Path forward on common model parameterizations and testbeds		Clinch River Cabin
11:30	Writing assignments, student and postdoc activities		Clinch River Cabin
12:30	*Working Lunch*		Clinch River Cabin
	Opportunities for Evaluating CMIP6 Soil Carbon - Kathe Todd-Brown	Kathe Todd-Brown	Clinch River Cabin
13:30	Working Group calendar and activity planning		Clinch River Cabin
14:00	Full Working Group Adjourn for the day		
14:30	3-page summary development	WG Leads and remaining WG participants	Clinch River Cabin
17:00	Depart Cabin		


Challenge for process-based soil models:
More process detail
More choices
Parton, Hartman et al (first-order model!)
DAYCENT


EXIT


Soil Pit – Soil Description and Measurements

Appendix B

2018 Fall RUBISCO Soil Carbon Dynamics Working Group Meeting Attendee List

Name	Institution	
Allison, Steven D.	UC Irvine	Remote Attendee
Berhe, Asmeret A.	UC Merced	Remote Attendee
Bond-Lamberty, Benjamin	PNNL	
Collier, Nathan	ORNL	
Georgiou, Katerina	UC Berkeley	
Hararuk, Oleksandra	UC Irvine	
Hoffman, Forrest M.	ORNL	
Joseph, Renu	DOE	
Malhotra, Avni	ORNL	
Mao, Jiafu	ORNL	
Mishra, Umakant	ANL	
Post, W. Mac	ORNL (Retired)	
Riley, William J.	LBNL	
Shi, Zheng	UC Irvine	Remote Attendee
Shu, Shijie	U. Illinois	
Song, Yang	ORNL	
Sulman, Benjamin	ORNL	
Tang, Jinyun	LBNL	
Todd-Brown, Katherine E.	Wilfred Laurier University	
Xu, Xiaofeng	San Diego State U.	
Yang, Xiaojuan	ORNL	

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