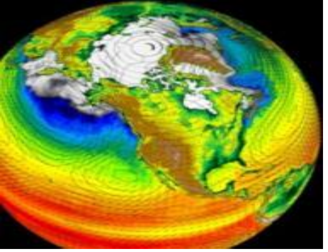
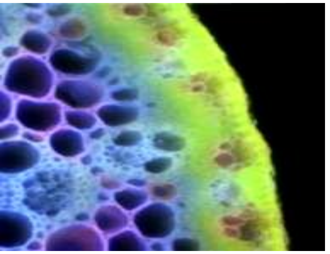
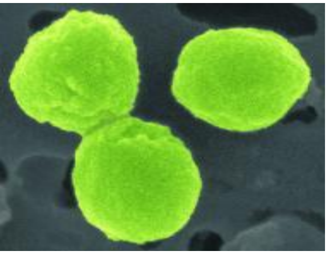


Earth and Environmental Systems Sciences Division

BERAC update

October 21, 2021

G. Geernaert

BER/EESSD

What's happened since the last BERAC on Oct 23, 2021

More extreme weather
- Hurricane Ida
- Texas grid collapse
- Tennessee floods
- California wildfires
- Extreme Arctic warming
- NZ warmest winter
- Extreme flood-Europe, China, India
- Record low Arctic sea ice
- New Canada heat record

ICAMS established January 2021
A new framework to advance weather and climate services
- Research and innovation
- Observational systems
- Cyberinfrastructure / facilities
- services

A new era of prediction science
- AI4ESP – hybrid science
- Exascale readiness
- EJ40 initiatives: IFL; NVCL,…

New Administration Executive Orders on climate
EO13985: racial equity, underserved communities
EO13990: health, environment, climate – reversing last 4 yrs
EO14008: climate crisis – home and abroad, security
EO14017: America's supply chains
EO14027: Climate change support office established
EO14030: Climate related financial risk

EXECUTIVE OFFICE OF THE PRESIDENT
WASHINGTON, D.C. 20503

M-21-32

MEMORANDUM FOR THE HEADS OF EXECUTIVE DEPARTMENTS AND AGENCIES

FROM: SHALANDA D. YOUNG
ACTING DIRECTOR
OFFICE OF MANAGEMENT AND BUDGET

DR. ERIC S. LANDER
DIRECTOR
OFFICE OF SCIENCE AND TECHNOLOGY POLICY

SUBJECT: Multi-Agency Research and Development Priorities for the FY 2023 Budget

This moment in American history, as we face unprecedented challenges but also unprecedented opportunities, is a moment for the Federal Government to take action to refresh and reinvigorate our Nation's science and technology enterprise with the aim of harnessing the full power of science and technology on behalf of the American people. Scientific discovery, technological breakthroughs, and innovation are the engines for expanding the frontiers of human knowledge and are vital for responding to the challenges and opportunities of the 21st century.

Federal funding for research and development (R&D) is essential to maximize the benefits of science and technology to tackle the climate crisis and advance health, prosperity, security, environmental quality, equity, and justice for all Americans. Simply supporting R&D is not sufficient; however, Federal agencies should ensure that the R&D results are made widely available to other scientists, to the public to facilitate understanding and decisions, and to innovators and entrepreneurs who can translate them into the businesses and products that will improve all of our lives. And, as we seek to make our supply chains more resilient, R&D investments should create more than just cutting-edge technology; they should also create products that are made in the United States by U.S. workers.

This memorandum outlines the Administration's multi-agency R&D priorities for formulating fiscal year (FY) 2023 Budget submissions to the Office of Management and Budget (OMB). The priorities covered in this memo require continued investments in R&D; science, technology, engineering, and mathematics (STEM) education and engagement; STEM workforce development; technology transfer and commercialization; and research infrastructure, with emphasis on Historically Black Colleges and Universities, other Minority Serving Institutions, and disadvantaged communities who have been historically underserved, marginalized, and adversely affected by persistent poverty and inequality. These priorities should be addressed within the FY 2023 Budget guidance levels provided by OMB.

President's S&T memo: climate, AI, computing, pandemic S&T

Executing our Strategic Plan 2018-2023

Vision: Improve a systems level understanding and predictability of the earth system in support of DOE's mission, through integrative theory, modeling, and experiment, over a variety of spatial and temporal scales.

High level Grand Challenges

- Integrated water cycle
- Biogeochemistry
- High latitudes
- Drivers and responses
- Data-model integration

Execution involving emphasis on boundaries, interfaces, extremes

- Collaborative opportunities: NOAA; USGS; NGA; NSF; NASA; others
- Topics: disturbance, initialization, data analytics (e.g., machine learning), software, advanced technologies, Terrestrial-Aquatic Interfaces, Coastal, etc.

Workshops set the stage for future EESSD priorities

Date	Topic	Venue
Oct 13-14, 2020	ARM-ASR Machine Learning	virtual
Nov 2-3, 2020	Coastal Integrated Hydro-terrestrial Modeling (USGCRP)	virtual
Nov 30 – Dec 2, 2020	DOE-NOAA precipitation prediction workshop	virtual
May 18, 2021	Cyberinfrastructure workshop	virtual
June 28-30, 2021	Workshop on predictability limits (Cloud-aerosol interactions) with four days: w/NASA, NOAA, and NSF	Virtual as 4 webinars
July 1, 2021	7th climate modeling summit – predictability of climate system	virtual
July 13, 2021	Global Change Applications Model (GCAM) annual workshop	virtual
July 22-23, 2021	MSD Urban Resilience workshop	virtual
Sept 2, 7, 2021	AI4ESP planning workshop for session chairs	virtual
Oct 25 – Dec 2, 2021	AI4ESP workshop – 17 sessions plus panels	virtual
Nov 15-16	Mountainous hydrology workshop	virtual

Management Update: solicitations

Funds	Program lead	Issued	Proposals	Panel	Selections
FY21	Early Career (ASR)	Oct 20, 2020	28	March 25, 2021	2+2
FY21	ESS	Nov 19, 2020	108	May 4-7, 2021	17
FY21	ASR	Oct 21, 2020	91	April 5-8, 2021	27
FY21	Modeling	Dec 17, 2019	70*	May 28-29, 2020	11
FY22	Early Career (ESS)	Sept 9, 2021			
FY22	ASR	Sep 28, 2021			
FY22	ESS	Oct 18, 2021			
FY22	Modeling	Nov 2021*			
FY22	SciDAC	Nov 2021*			
FY22	Urban IFL	Pending approps.			
FY22	RENEW	Pending approps.			

Management updates - PI meetings: 2020-2022

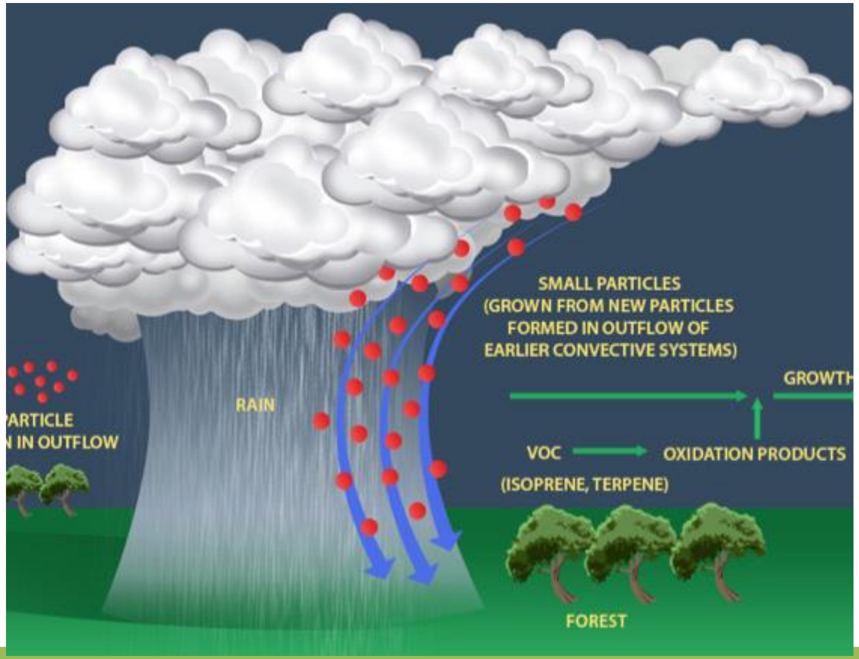
PI meeting	Dates	Location
Modeling ESMD	October 25-29, 2020	Virtual
NGEE Arctic all hands	January 28-30, 2021	virtual
SPRUCE all-hands	May 11-13, 2021	Virtual
ARM-ASR PI meeting	June 21-23, 2021	virtual
ESS PI meeting	August 16-19, 2021	virtual
ARM-ASR PI meeting	May-June 2022	Virtual/hybrid?
ESS PI meeting	Summer 2022	Virtual/hybrid?
Modeling PI meeting	Summer 2022	Virtual/hybrid?

Management updates: Major reviews in 2020-2021

Lab	Program	Type	Review date	Decision	Date
LLNL	Data	ESGF	Sep 22-23, 2020	recompete	Nov 5, 2020
PNNL	Division	COMPASS	Sep 28-30, 2020	Accept*	April 30, 2021
PNNL and other labs	ARM	Facility	Nov 4-6, 2020	Accept**	Dec 15, 2021
LLNL/all	E3SM	SFA (mid course)	Nov 9-10, 2020	positive	Dec 22, 2021
BNL-ANL	ASR	SFA	Nov 17-19, 2020	Accept	Feb 11, 2021
Penn State	Model	Coop agreement	March 23, 2021	Accept/Revision	April 15, 2021
CATALYST	Model	Coop agreement	May 3-4, 2021	Accept	June 15, 2021
ORNL-ANL-LLNL	Data	ESGF	Aug 30-31, 2021	Accept	Sept 23, 2021
PNNL	EMSL	EMSL triennial	Nov 3-4, 2021		
PNNL	ASR	ICLASS SFA	Nov 17-19, 2021		

ARM Update

- **ARM Triennial Review – held virtually Nov 2020; new Decadal Vision Document published**
- **SAIL campaign in Colorado began Sep 1 – strong media coverage, including Science article**
- **TRACER campaign in Houston delayed due to COVID, new start date Oct 1; intensive observing period summer 2022**
- **New campaign, EPCAPE (Eastern Pacific Cloud Aerosol Precipitation Experiment) selected for Feb 2023 start**
  - AMF at Scripps Pier; additional instruments on Mt Soledad
  - PI – Lynn Russell, UCSD/Scripps
- **ARM identifying potential sites for extended deployment of 3rd Mobile Facility to southeastern US**
  - Looking at promising sites in northern Alabama
  - Science goals focusing on deep convection, aerosol processes and land-atmosphere interactions
  - Five-year deployment beginning 2023



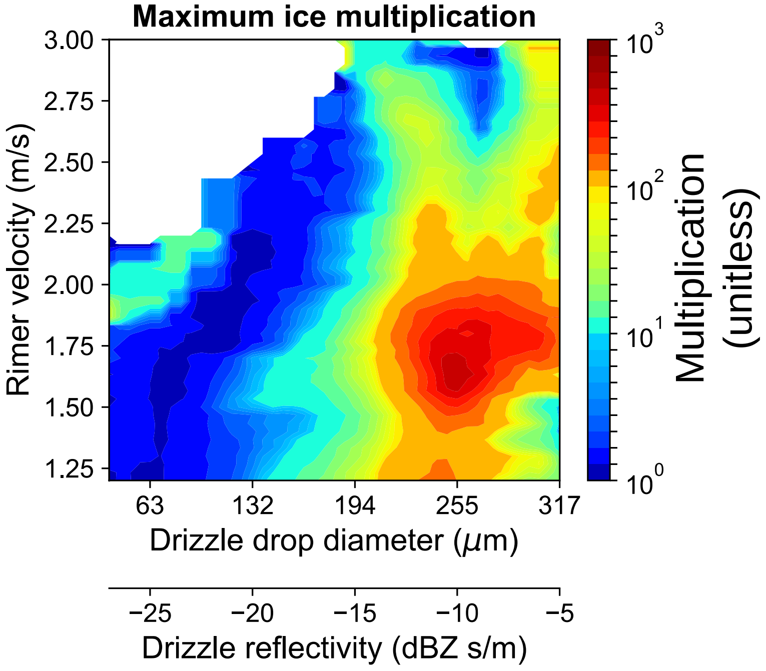
ARM Radars Bring New Insights Into Ice Multiplication Processes

Scientific Challenge

- Number and size of ice crystals in clouds is important for cloud lifetime, precipitation formation, and the energy budget
- Ice formation in supercooled and mixed phas clouds are complex processes that need to b represented in models

Approach and Results

- Used multiple years of dual-polarization rada spectral data from ARM Alaska site
- Examined conditions of “secondary ice” formation, in which ice particles are created i clouds from already existing cloud particles
- Found that secondary ice production events are more likely to occur in the presence of drizzle droplets – likely from freezing and shattering of the drizzle droplets
- When secondary ice events occur, they can increase local ice number concentration by a factor of 1000



Maximum ice multiplication (color) as a joint function of rimer velocity and drizzle drop diameter. Drizzle drop diameter is associated with drizzle spectral reflectivity (second x axis).

Significance and Impact

- Results show that drizzle freezing/shattering is more important to secondary ice formation in Arctic clouds than the better-known Hallet-Mossop rime-splintering process
- Quantify conditions, frequency of occurrence, and ice number concentration during secondary ice formation events
- Provides critical insights for model parameterizations

Luke, E.P., F. Yang, P. Kollias, A.M. Vogelmannn, and M. Maahn, 2021: New insights into ice multiplication using remote-sensing observations of slightly supercooled mixed-phase clouds in the Arctic, *PNAS*, 118(13), e2021387118, DOI: 10.1073/pnas.2021387118

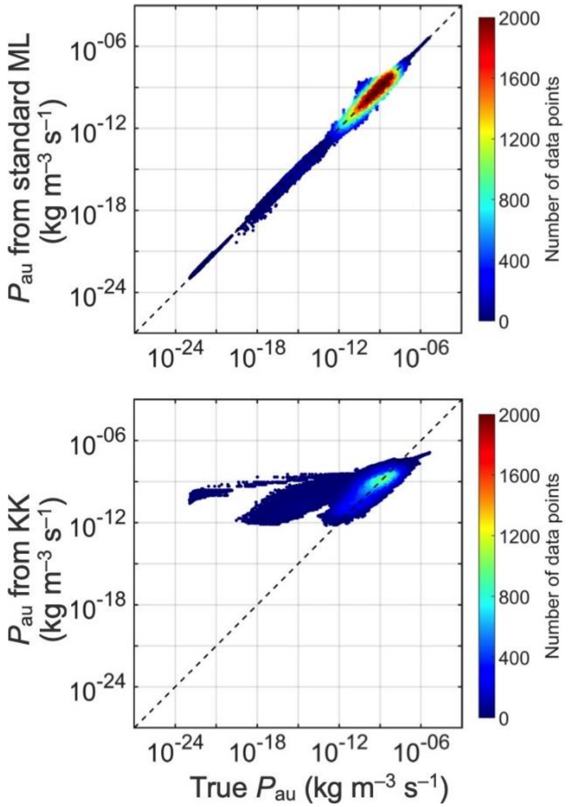
Machine Learning Provides Surprising Information on Warm Rain Processes

Scientific Challenge

- Many global climate models produce rain too frequently in marine boundary layer clouds, which may be due to their parameterizations of warm rain processes
- Two important warm-rain processes that are parameterized in large-scale models are collision-coalescence and accretion

Approach and Results

- In situ cloud measurements from the ARM G-1 aircraft during the ACE-ENA campaign in the Azores are combined with a machine learning neural network model to examine warm rain processes
- The machine-learning model predicts autoconversion rates from cloud to rain due to the collision-coalescence process and accretion rates, with uncertainties of 15% and 5%, respectively
- The machine-learning model outperforms standard climate model parameterizations



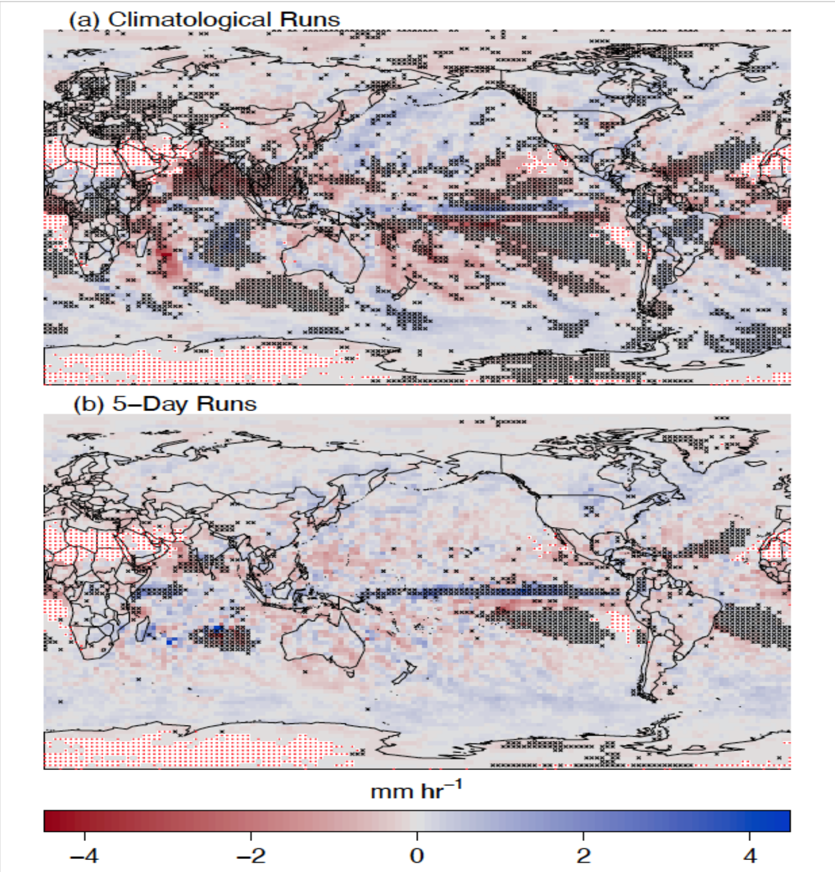
Predicted versus true autoconversion rates from the machine learning model (upper panel) and the Khairoutdinov & Kogan (2000) parameterization (lower panel).

Significance and Impact

- Analysis of the results indicates that the rate of drizzle formation due to collision-coalescence can be related to the number of drizzle droplets
- This somewhat surprising relationship occurs because the number of drizzle droplets provides information about the evolution of the width of the cloud droplet size distribution
- Including drizzle number concentration in parameterizations of collision-coalescence can improve model representation of warm rain processes

Chiu J, C et al. 2020. "Observational constraints on warm cloud microphysical processes using machine learning and optimization techniques." *Geophysical Research Letters*, 48(2), e2020GL091236, 10.1029/2020GL091236.

Global microphysical sensitivity of superparameterized precipitation extremes



2-moment microphysics 2-year return value minus that from 1-moment microphysics for (a) climatological (5-year) and (b) short (5-day) runs. Black stippling denotes grid cells with statistically significant differences. Red stippling denotes grid cells where fitting of extreme value distributions failed.

Scientific Achievement

The choice of cloud microphysics in a superparameterized climate model can lead to statistically significant differences in precipitation extremes, driven by changes in the strength of vertical air motions.

Significance and Impact

This is the first study to examine the effect of cloud microphysics on precipitation extremes globally in a superparameterized climate model. The model's precipitation extremes are generally bracketed by two observational datasets (in terms of magnitude).

Research Details

– A superparameterized climate model was run, using four representations of microphysics, for long times (years) and short times (days).

– Extreme value theory is used to determine statistically significant differences in the distributions of extreme precipitation.

Charn, A., W. Collins, H. Parishani, and M. Risser, (2021), Global microphysical sensitivity of superparameterized precipitation extremes. Earth and Space Science, 8. DOI:10.1029/2020EA001308.

U.S. DEPARTMENT OF ENERGY | Office of Science

EARTH & ENVIRONMENTAL SCIENCES | BERKELEY LAB

The Simple Cloud-Resolving E3SM Atmosphere Model (SCREAM)

Scientific Challenge

- Treatment of sub-grid scale convection in general circulation models (GCMs) is a major source of climate-change uncertainty
- Climate impacts are felt on scales too small to resolve in conventional global models
- Upcoming exascale computers won't perform individual calculations faster, they will do more in parallel. This requires more parallel work… which higher resolution provides…

⇒ Now is the time for a convection-resolving global model!

Approach and Results

- E3SM is creating a new global atmosphere model (SCREAM) which is:
  - targeted for 3 km grid spacing but able to run at any resolution
  - written in C++ for fast performance on GPUs
- Prototype (F90) runs contributed to the "DYAMOND2" intercomparison look very promising (see movie)

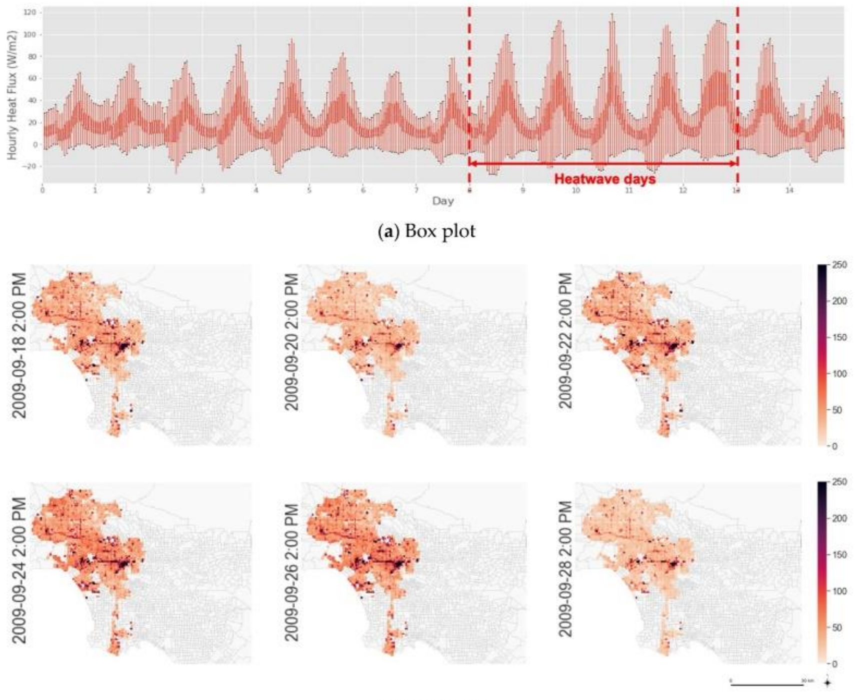
Impact

- This effort provides E3SM with a GPU-enabled atmosphere model
- Explicitly resolving convective events appears to solve many long-standing biases in GCMs (e.g., diurnal cycle of tropical precipitation, the frequency and structure of important weather events like hurricanes, atmosphere rivers, cold air outbreaks)
- Because it resolves finer scales, SCREAM will be more useful for climate impacts studies

Movie: Precipitation (colors) and integrated water vapor (gray) for an atmospheric river from E3SM's DYAMOND2 simulation along the US West Coast during 11-Feb-2020 and 12-Feb-2020. By Paul Ullrich/UC Davis

Citation: Caldwell, Terai, and 28 coauthors, *Convection-Permitting Simulations with the E3SM Global Atmosphere Model*, Submitted to J. Adv. Model. Earth Syst. (2021)

City-Scale Building Anthropogenic Heating during Heat Waves



(a) Box plot

(b) Heatmap

Spatial and temporal variation in anthropogenic waste heat from buildings during a heat wave in Los Angeles.

Objective

We developed a bottom-up building heat emission model to investigate the temporal and spatial variations of waste heat fluxes at the city scale during extreme heat events.

Approach

- We developed a coupled-simulation approach to quantify these effects, mapping urban environmental data generated by the mesoscale Weather Research and Forecasting (WRF) coupled to Urban Canopy Model (UCM) to urban building energy models (UBEM).
- We generated grid-level building heat emission profiles and aggregated them using prototype building energy models informed by spatially disaggregated urban land use and urban building density data.
- We analyzed the surge in city-scale building heat emission and energy use during the extreme heat event.

Impact

The method provides a high-resolution representation of the magnitude and distributions of buildings' anthropogenic heating profiles under extreme heat, as a fundamental step toward a continued investigation of the feedback between building heat fluxes and urban microclimates.

- **Citation:** Luo, X.; Vahmani, P.; Hong, T.; Jones, A. City-Scale Building Anthropogenic Heating during Heat Waves. Atmosphere 2020, 11, 1206. doi:10.3390/atmos11111206.

U.S. DEPARTMENT OF ENERGY | Office of Science

EARTH & ENVIRONMENTAL SCIENCES | BERKELEY LAB

Impacts of the Morphology of New Neighborhoods on Microclimates

Objective

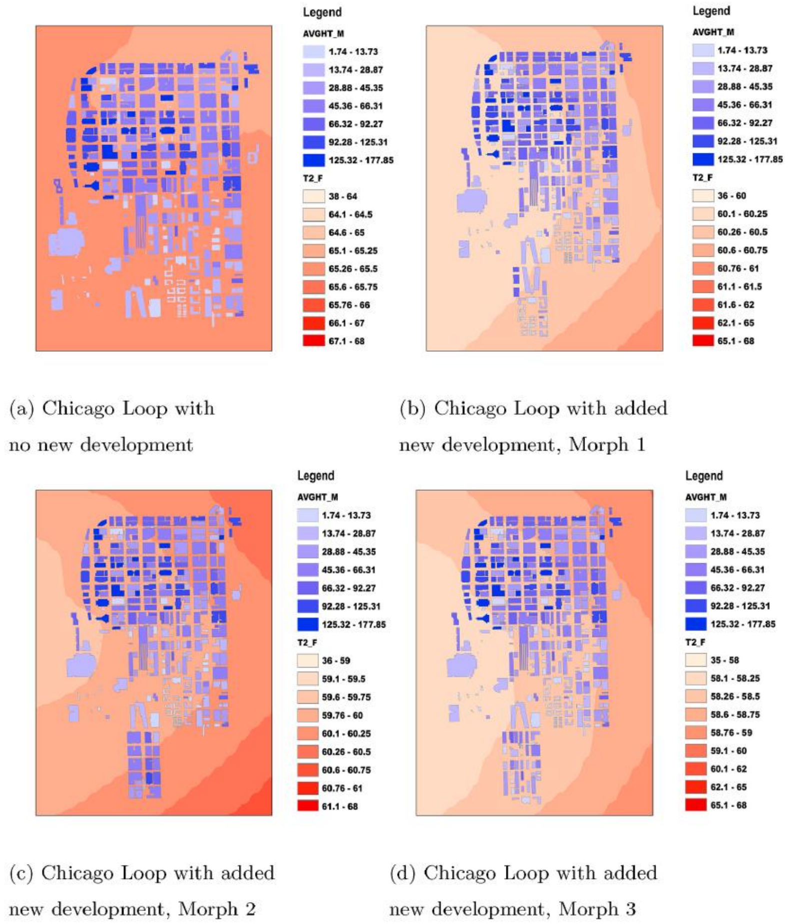
Demonstrate how new neighborhood morphologies affect local meteorology within a two-way-coupled mesoscale weather model.

Approach

- Five 1-year, simulations for 2015 were run using the Weather Research and Forecasting (WRF) model for two locations..
- Urban terrain inputs were generated using ORNL-produced shapefiles from LiDAR imagery and laser measurement and included in the simulations.
- Future morphologies were generated using the concept of Urban Tissues, in which physical elements and relationships of the existing neighborhood are identified, subsetted, recombined for the new neighborhood.
- Building-specific meteorological profiles were defined at 90m resolution and used to initialize each building in massively parallel building energy simulations.

Impact

This work quantifies relationships among climatic conditions, urban morphology, land cover, and energy use, with up to 4C change expected. Useful for planning climate-friendly urban communities and incorporation into climate and Earth system models.



Comparison of July average 2m temperature in the Chicago Loop with four different morphological configurations shows the influence of the addition of each morphology on the microclimate, which affects the amount of building heating and cooling used in response.

Allen-Dumas, MR, Rose, AN, New, JR, Omitaomu, OA, Yuan, J, Branstetter, ML, Sylvester, LM, Seals, MB, Carvalhaes, TM, Adams, MB, Bhandari, MS, Shrestha, SS, Sanyal, J, Berres, AS, Kolosnaa, CP, Fu, KS, Kahl, AC (2020). *Renewable and Sustainable Energy Reviews*, 133 (2020) 110030.

Wild Grass Releases a Variety of Particles into the Air Over its Life Cycle

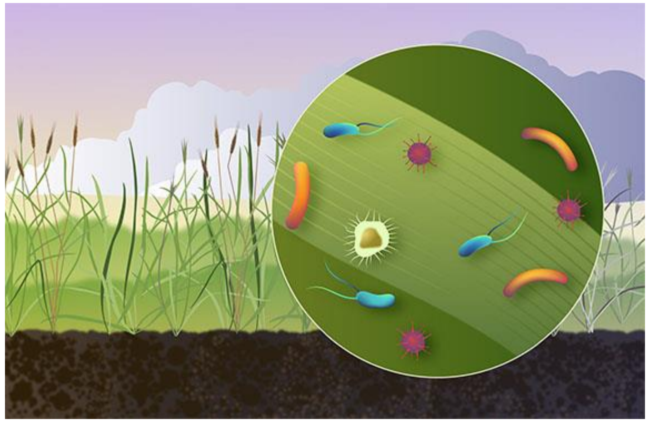
EMSL

Challenge

- Characterize biological particles produced by the above-ground parts of a model grass, *Brachypodium distachyon*, over its life cycle

Approach and Results

- Collected particles during eight developmental stages, ranging from leaf development to senescence.
- Measured particle shape and composition using various forms of microspectroscopy.
- Fungal spores were most abundant particle during heading stage, while bacteria most abundant during flowering and fruit development stages.



The aboveground parts of plants, mainly stems and leaves, are among the most prevalent microbial habitats on Earth. Pollen, bacteria, viruses, algae, and cell debris released from plants can seed cloud and ice crystal formation in the atmosphere.

Significance and Impact

- Understanding differences in the composition and morphology of biological particles during the plant life cycle provides more accurate and reliable insights on structural, functional, and biochemical properties of plant systems, as well as their interactions with microbial communities.
- This study also provides insights into Earth geoscience system models that represent primary biological particle emissions from the biosphere.

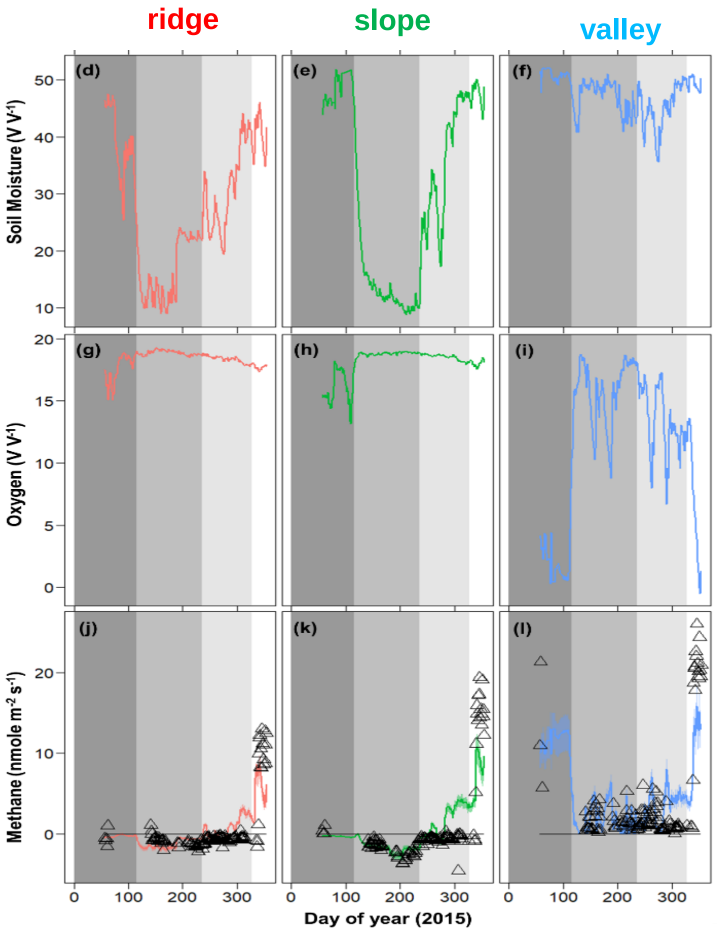
S. China, *et al.*, "Microanalysis of Primary Biological Particles from Model Grass over Its Life Cycle," *ACS Earth and Space Chemistry* in press (2020). [DOI: 10.1021/acsearthspacechem.0c00144] OSTI ID 1677514

Predicting Methane Dynamics during Drought Recovery

Microbial geochemical model predicts methane emissions during drought and recovery along a hillslope catena

Scientific Challenge	• Why do ridge and slope soils in a tropical rainforest only emit methane following a strong drought, while valley soils emit methane year-round?
Approach and Results	• A microbial functional model considered acetoclastic and hydrogenotrophic methanogenesis and methanotrophy, and diffusion of gas and liquid into soil microsites. • High oxygen diffusion and methanotrophy normally inhibit production and release of methane in the ridge and slope positions. • After drought, oxygen transfer and methanotrophy are inhibited due to increased moisture, causing enhanced methane release from the entire hillslope.
Significance	• Soil microsites contribute to hotspots and hot moments of microbial greenhouse gas emissions, particularly during climate events.

Sihi et al. (2021) Representing methane emissions from wet tropical forest soils using microbial functional groups constrained by soil diffusivity. Biogeosciences 18, 1769–1786, https://doi.org/10.5194/bg-18-1769-2021



Soil moisture, oxygen, and methane emissions. Dark gray, medium gray, light gray, and white shading represent pre-drought, drought, drought recovery, and post drought events.

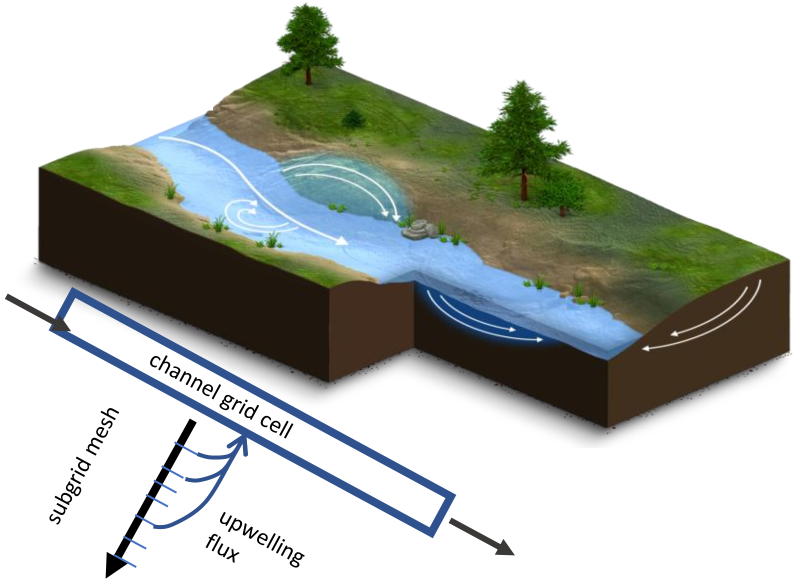
Capturing Biogeochemical Details in River Corridor Models

Challenge

- To represent the effects of small, biogeochemically-active hyporheic zones in watershed-scale models.

Approach and Results

- A new representation of reactive transport in the stream corridor associates a one-dimensional subgrid model for hyporheic-zone transport and reactions with each channel grid cell in a stream network flow model.
- Each subgrid model is written in travel-time form, with hyporheic age serving as the independent spatial variable to represent a diversity of hyporheic zone flowpaths, consistent with tracer tests.



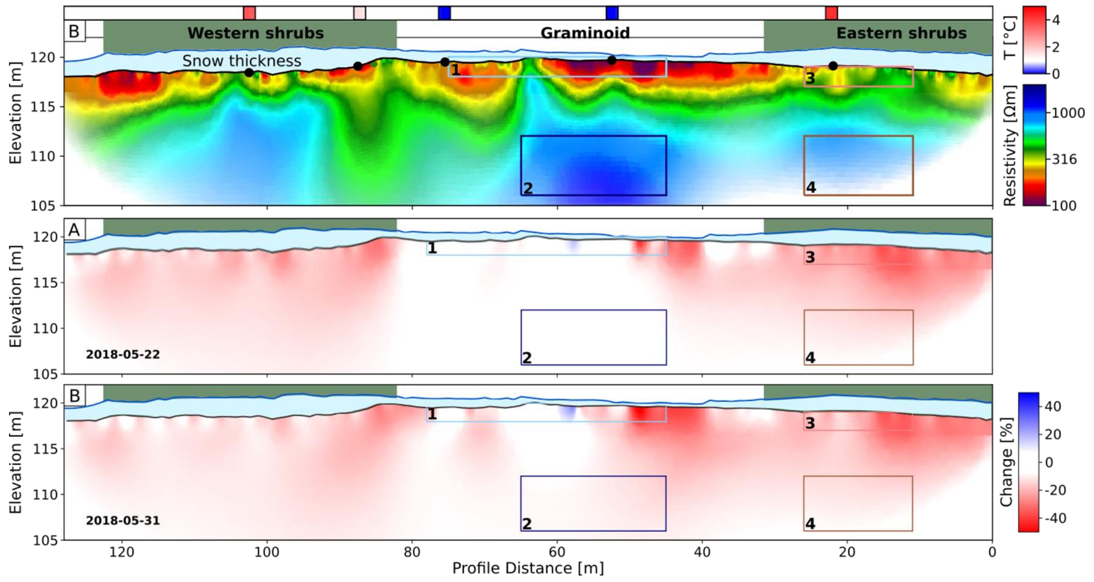
Schematics showing water exchange between a stream and surrounding groundwater in a stream corridor and how those exchanges are represented in a multiscale river-corridor model.

Significance

- This work provides insight into how hyporheic exchange flux controls reactive transport.
- It also provides a framework for a new generation of reactive transport models that are tractable at scale without sacrificing important details of biogeochemical processes.

Painter. S. L. "On the representation of hyporheic exchange flows in models for reactive transport in streams and rivers," *Frontiers in Water* **2**, 69. (2021). [DOI: 10.3389/frwa.2020.595538]

Investigating Dynamics That Reshape Permafrost Environments



Snowmelt is causing rapid change in electrical resistivity, particularly underneath tall shrubs, where thick snowpack is insulating the ground, enabling rapid infiltration of snowmelt. It also highlights that initial vertical flow is followed by lateral flow.

Citation: Uhlemann, S., B. Dafflon, J. Peterson, C. Ulrich, et al. (2021). Geophysical monitoring shows that spatial heterogeneity in thermohydrological dynamics reshapes a transitional permafrost system. Geophysical Research Letters, 48, e2020GL091149. [DOI: 10.1029/2020GL091149]

Scientific Challenges

When permafrost thaws, water can flow quicker through the ground, creating a complex subsurface flow system. However, the data needed to unravel complex subsurface processes are scarce. Using geophysical and in situ sensing, researcher at Lawrence Berkeley National Lab closed an observational gap to show spatial heterogeneity in thermohydrological dynamics reshape transitional discontinuous permafrost systems.

Approach and Results

Continuous monitoring of subsurface electrical resistivity, temperature and soil moisture shows that vegetation and snowpack distribution control the subsurface temperatures and hydraulic flow. Where snow accumulates, temperatures stay warmer and water and energy from snowmelt and rain can flow through the ground quickly. Where the snowpack is thin, ground temperatures are colder, preventing flow.

Significance

Snow pack and vegetation distribution play major role in spatially variable permafrost thermohydrological responses. Inter-annual measurements show that deep (~10 m) permafrost temperatures increased by about 0.2°C over 2 years.

The data highlight that permafrost at the research team's study site could disappear within the next decade. This process could be accelerated by changes in snowpack distribution and rainfall patterns.

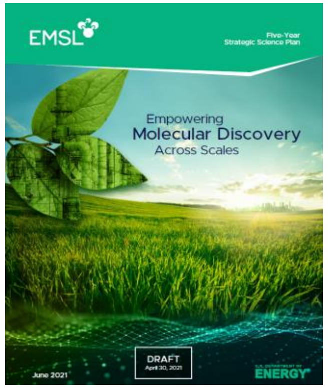
U.S. DEPARTMENT OF ENERGY | Office of Science — NGEE-Arctic Next-Generation Ecosystem Experiments — EARTH & ENVIRONMENTAL SCIENCES — BERKELEY LAB

Environmental Molecular Sciences Laboratory

Accelerating scientific discovery and pioneering new capabilities to understand biological and environmental processes across temporal and spatial scales

Strategic Planning

- New EMSL Strategic Plan (https://content-qa.emsl.pnl.gov/sites/default/files/2021-07/EMSLStrategicPlanFY2021_0.pdf)
- Three Science Areas and associated Strategic Science Objectives
- CD-0 Approved for the Microbial Molecular Phenotyping Capability (M2PC) Project ($80-$120M)



User Proposals

- Large-Scale Research – 84 Proposals (vs. 89 last year), 34 projects selected.
- EMSL-JGI FICUS – 53 Proposals, 12 projects selected.
- EMSL-ARM FICUS – 4 Proposals, 2 projects selected.

Outreach and User Activities

- Summer School – “Multi-omics Models of Biochemical Pathways,” July 12-15, 2021
- Annual Integration Meeting – “Environmental Sensors,” October 4-7, 2021

Virtual Triennial Review (past 4 years)

- November 2-4, 2021, recruiting reviewers

THANK YOU!