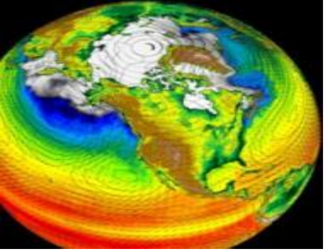
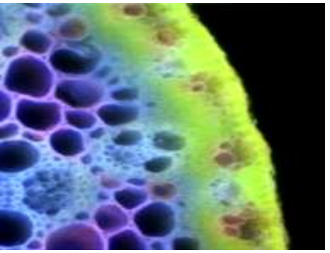
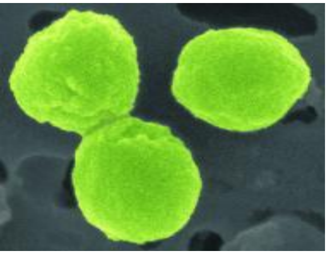


# Earth and Environmental Systems Sciences Division

## *BERAC update*

***April 21, 2022***


**G. Geernaert**

**BER/EESSD**

# 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.

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

More extreme weather

- December tornadoes
- New Years Eve Boulder wildfire
- March
  - Conger Ice shelf collapse
  - south pole 50 to 90 above normal
  - north pole 50 above normal

OSTP and beyond

- USGCRP Strat Plan
- IPCC WG II and WG III
- ICAMS wildfire workshop
- Climate Intervention task force
- GHG monitoring task force
- National nature assessment

A new era of prediction science

- AI4ESP – hybrid science
- Water cycle – mtn hydrology
- EJ40 initiatives: IFL; NVCL, RDPP, RENEW, Centers

<u>New Administration Executive Orders on climate</u>

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

# Workshops set the stage for future EESSD priorities

| Date | Topic | Venue |
|---|---|---|
| Oct 25 – Dec 2, 2021 | AI4ESP workshop – 17 sessions plus panels | virtual |
| Nov 15-16, Dec 6, 2021 | Mountainous hydrology workshop | virtual |
| March 7, 13, 2022 | Puget Sound Scoping workshops | virtual |
| April 1, May 5 | ICAMS Wildfire workshops | virtual |
| April 10 | Marine Cloud Brightening workshop | virtual |
| April 25-26 | Large Eddy Simulation workshop | virtual |
| May 15-17 | Climate Communications Workshop | virtual |
| May 23 | Cyberinfrastructure working group workshop | virtual |
| | | |
| | | |

# Management Update: solicitations

| Funds | Program lead | Issued | Proposals | Panel (2022) | Selections |
|---|---|---|---|---|---|
| FY22 | Early Career (ESS) | Sept 9, 2021 | 11 | Mar 14 | 3 |
| FY22 | ASR | Sep 27, 2021 | 92 | Mar 14-25 | |
| FY22 | ESS | Oct 18, 2021 | 50 | May 2-6 | |
| FY22 | Modeling | Nov 1, 2021 | 89 | May 9-14 | |
| FY22 | SciDAC | Nov 22, 2021 | | Jun 6-10 | |
| FY22 | RDPP | Feb 23, 2022 | | (internal) | |
| FY22 | Urban IFL | Mar 23, 2022 | | Jul 19-20 | |
| FY22 | RENEW | May 2022 | | September | |

# Management updates - PI meetings:  2020-2022

| PI meeting | Dates | Location |
|---|---|---|
| ESS PI meeting | May 24-26, 2022 | Virtual |
| ARM-ASR PI meeting | October 24-28, 2022 | Rockville / hybrid |
| Modeling PI meeting | Oct 31 – Nov 4, 2022 | virtual |
| | | |

# Management updates: Major reviews in FY2022

| Lab | Program | Type | Review date | Decision | Date |
|---|---|---|---|---|---|
| PNNL | EMSL | EMSL triennial | Nov 3-4, 2021 | Accept | April 14, 2022 |
| PNNL | ASR | ICLASS SFA | Nov 17-19, 2021 | Accept | Feb 4, 2022 |
| ORNL-led | ESS | NGEE Arctic Phase 3 | March 9, 2022 | Accept | Mar 21, 2022 |
| PNNL | ESS | COMPASS mid-term review | March 10, 2022 | Accept | April 11, 2022 |
| | Modeling | HYPERFACETS | April 20, 2022 | | |
| ORNL | Model | RUBISCO SFA triennial | July 12-13, 2022 | | |
| LANL | ESS | IDEAS triennial | July 28, 2022 | | |
| ORNL | ESS | ORNL BGC SFA review | Aug 3-4, 2022 | | |
| LLNL | ASR | THREAD SFA initial | Aug 15-19, 2022 | | |
| LBNL | ESS | Belowground BGS SFA | Aug 24-25, 2022 | | |
| | Modeling | MIT Coop Agreement | Aug 29-31, 2022 | | |
| LANL | Model | HILAT SFA triennial | Sept 27-28, 2022 | | |
| LLNL-led | Model | E3SM triennial | Oct 17-20, 2022 | | |
| | | | | | |

# The DOE E3SM v1.2 Cryosphere Configuration Overview

## Objective

- Many Earth System Models crudely represent the way in which freshwater from the Antarctic Ice Sheet (AIS) enters the rest of the climate system.
- Here, this is improved upon by more accurately representing the two main processes involved; ice-shelf basal melting and melting of calved icebergs.
- These improvements will allow for more realistic projections of the AIS's impact on regional and global climate in the future, most notably via sea-level rise.

## Approach

- In E3SM v1.2, the ocean domain has been extended below Antarctic ice-shelf cavities, allowing the model to calculate ice-shelf basal melt rates based on the surrounding ocean properties.
- Realistic iceberg fluxes are accounted for through the addition of an observationally-based iceberg melt climatology.
- Biases in the ocean were found to lead to very high melt-rates (relative to present-day observations) beneath certain ice-shelves. Changes to the ocean's mesoscale eddy parameterization reduced ocean Southern Ocean biases, leading to greatly reduced biases in simulated ice-shelf basal melt rates.

## Impact

- Here we demonstrate the ability of E3SM v1.2 at standard resolution to simulate Antarctic ice-shelf basal melting in line with present day observations. This is an important step towards reducing uncertainties in projections of the Antarctic response to climate change and Antarctica's contribution to global sea-level rise.

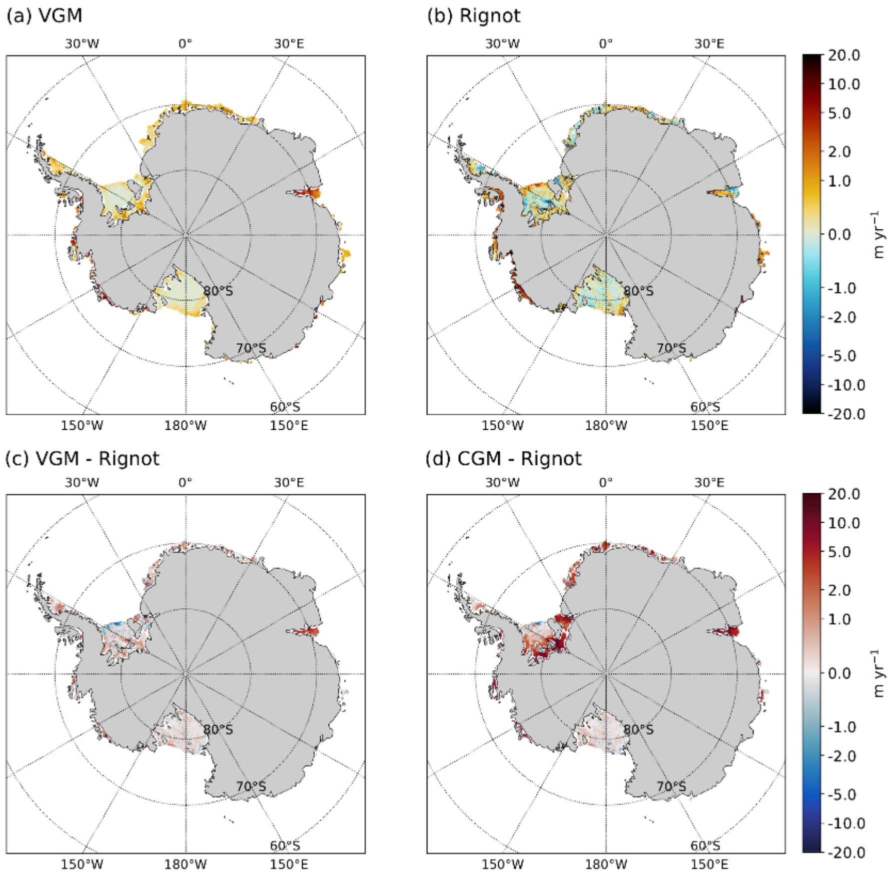



**Figure**: Simulated ice-shelf basal melt rates around Antarctica (a) compared to observations (b). Changes in the ocean model led to a drastic reduction in biases (c) vs. (d).

**Citation:** Comeau, Asay-Davis, and 12 coauthors, *The DOE E3SM v1.2 Cryosphere Configuration: Description and Simulated Antarctic Ice-Shelf Basal Melting*, Accepted at J. Adv. Model. Earth Syst. (2022)

# Environmental Molecular Sciences Laboratory

EMSL

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

## EMSL Strategic Planning


- New EMSL Strategic Plan
  - Initiated “1,000 Soils” pilot as first step toward MONet (Molec Obs Network)
- Microbial Molecular Phenotyping Capability (M2PC) Project ($80-$120M)
  - Analysis of Alternatives (AoA) identified EMSL as the preferred alternative
  - Independent review committee verified AoA (Mar 22)

## User Proposals for October 1, 2022

**Large-Scale Research** | 105 LOIs, 21 new to EMSL

| | | | | | |
|---|---|---|---|---|---|
| Functional And Systems Biology | **37** | Environmental Transformations and Interactions | **56** | Computation, Analytics, and Modeling | **12** |

**EMSL-JGI FICUS** | 47 LOIs, 10 new to EMSL

**EMSL-ARM FICUS** | 7 LOIs, 2 new to EMSL

**New FICUS Call this summer** an EMSL-APS pilot

## Outreach and User Activities

- EMSL Summer School | “Soils Exposed” | July 12-16, 2022
- EMSL LEARN Webinar Series | Monthly
- EMSL Integration | AI and Machine Learning | Oct. 2022

- Breakout Sessions at the ESS PI Meeting
  - EMSL-ARM land-atmosphere FICUS opportunities for SE U.S. deployment
  - MONet

# ARM Update

- **ARM Mobile Facility Deployments:**
  - Recent overview papers on MOSAIC, COMBLE, and TRACER published
  - SAIL and TRACER campaigns ongoing
  - EPCAPE (Eastern Pacific Cloud Aerosol Precipitation Experiment) – Scripps Pier, La Jolla, CA - Feb 2023 start
  - ARM submitted special use application to USFS for 3rd Mobile Facility (AMF3) deployment in Bankhead National Forest
  - Pre-applications for ARM Mobile Facility proposals were due Apr 5
- **Fixed sites:**
  - All sites open to visitors; COVID requirements vary by location; mentor visits to ENA planned this spring/summer
  - Multiple small field campaigns planned this spring/summer
    - AWAKEN – wind energy campaign at SGP
    - Aerosol growth in the Eastern North Atlantic – ENA – June
    - Arctic Shark UAS test flights at SGP
- **ARM High Performance Computing:**
  - New “Cumulus” cluster up and running for ARM operations and PI projects
  - Started CACTI deep convection simulations w/ LASSO

# Large eddy simulations at SGP provide guidance for convective parameterizations

## Scientific Challenge

- Updrafts (vertically moving air) that form convective clouds occur at scales finer than can be resolved in earth system models.
- “Mass flux” approaches are often used to represent these updrafts but make assumptions about updraft characteristics.

## Approach and Results

- Detailed large eddy simulations (LES) are used to study properties of updrafts to inform mass flux parameterizations.
- LES simulations are based upon 26 cases from the ARM LASSO modeling project.
- A new segmentation algorithm is used to identify and track over 1 million simulated convective objects.
- Analysis examines assumptions used in mass flux parameterization approaches to provide insight for global earth system modelers.

## Significance and Impact

- There is a strong positive relationship between the vertical extent and width of the convective objects; this well-defined width-height relationship strongly supports the basis of spectral plume mass flux parameterizations.
- The horizontal area of objects changes substantially with height; caution should be used with parameterizations that assume constant plume area.
- Neglecting horizontal variability in larger updraft plumes underestimates vertical moisture transport by up to 15% - application of a plume-width dependent correction term in models could reduce this underestimation.

3D rendering of simulated clouds over the Atmospheric Radiation Measurement Southern Great Plains site during the 11 June 2016 LASSO case..

Griewank P, T Heus, and R Neggers. 2022. "Size-Dependent Characteristics of Surface-Rooted Three-Dimensional Convective Objects in Continental Shallow Cumulus Simulations." *Journal of Advances in Modeling Earth Systems*, 14(3), e2021MS002612, 10.1029/2021MS002612.

# Machine Learning Helps Identify Meteorological Regimes for TRACER

ASR Atmospheric System Research

**Objective**

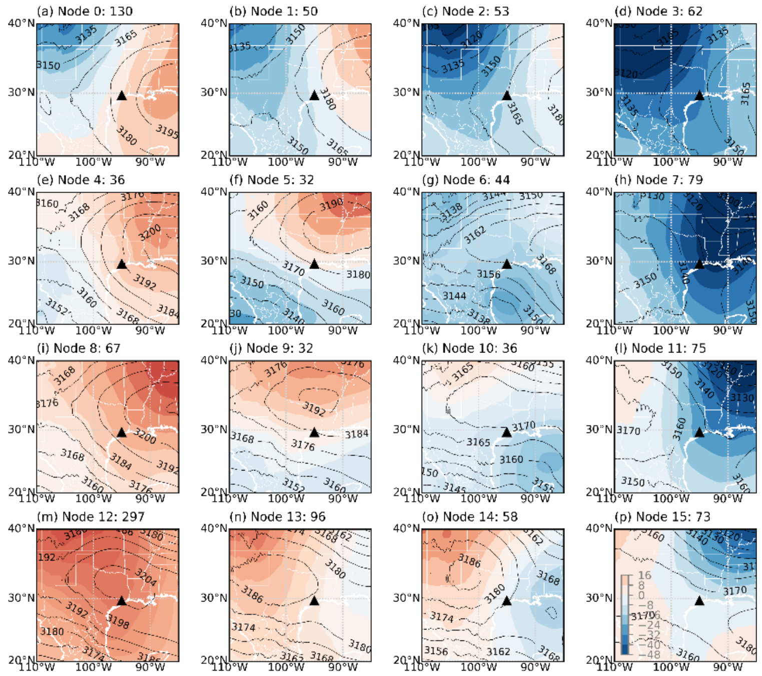
- Use self-organizing maps (SOMs), an unsupervised machine learning approach, to characterize weather and circulation in southeastern Texas to help plan for the TRACER field campaign by providing context for the study of aerosol-cloud interactions.

**Approach**

- Classified the synoptic regimes during June-September in southeastern Texas using SOMs. Analyzed 10 years of 700-hPa geopotential height anomalies from reanalysis data to distinguish three dominant synoptic regimes, with a continuum of transitional states between them.

**Impact**

- Identified three primary regimes: a pre-trough regime associated with a synoptic trough to the northwest of the region, a post-trough regime with upper-level northerly flow, and an anticyclonic regime within the westward extent of the Bermuda High. Identified the impacts of those three circumstances on local weather conditions critical to better planning, execution, and understanding of field campaign data.




**Composite of geopotential heights [m] (contours) and anomalies (colors) at 700 hPa for each SOM node. The number of days within each node is specified in the title of each subplot.**


Wang D, M Jensen, D Taylor, G Kowalski, M Hogan, B Wittemann, A Rakotoarivony, S Giangrande, and J Park. 2022. "Linking synoptic patterns to cloud properties and local circulations over southeastern Texas." *Journal of Geophysical Research: Atmospheres*, 127(5), e2021JD035920, 10.1029/2021JD035920.

# Jet Stream Shift Causes Future Changes in Midwest Hydroclimate

## Objective

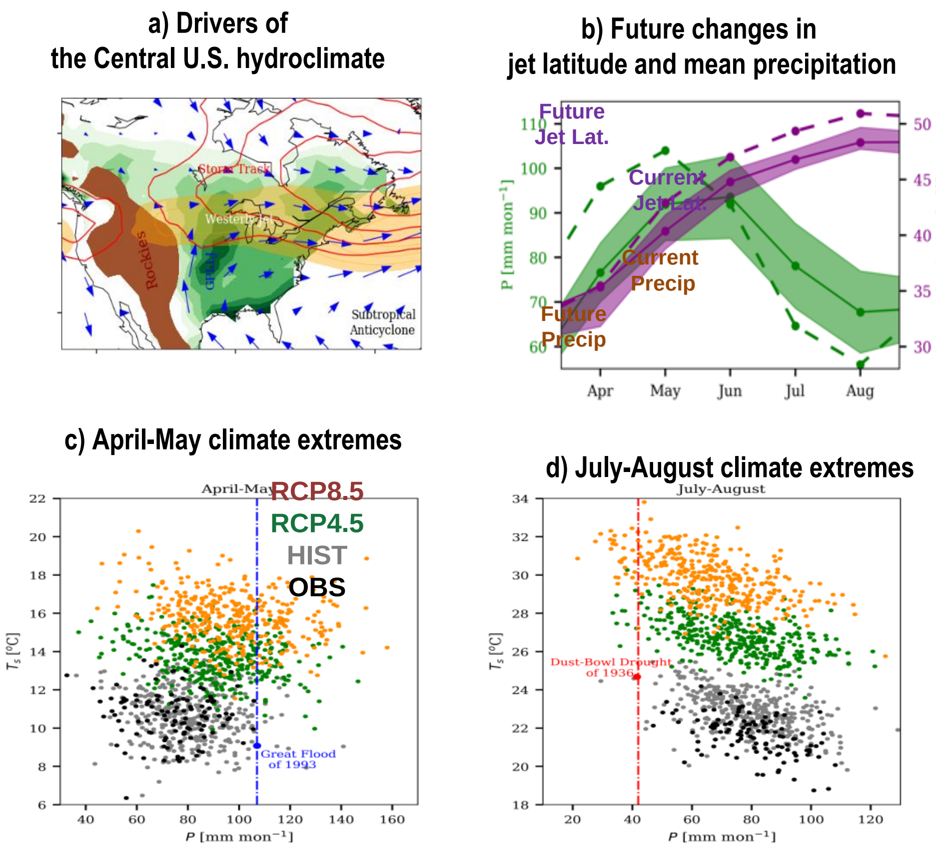
- Investigate monthly changes in the Midwest's future hydroclimate.
- Elucidate the dynamic mechanisms that underpin the seasonally dependent hydroclimate changes.

## Approach

- Analyze future changes in the U.S. Midwest circulation, precipitation, and climate extremes under global warming using ensemble projections of the Coupled Model Intercomparison Project Phase 6 and the Multi-model Initial-condition Large-ensemble Simulations.
- Illustrate the seasonally dependent impacts of the poleward jet shift on the Midwest hydroclimate.

## Impact

- The warm-season North-American westerly jet is projected to shift northward under global warming, making it closer to (farther away from) the Midwest before (after) June, leading to more (less) mean precipitation.
- The seasonally-dependent mean precipitation changes correspond to 10-fold (5-fold) increases in the frequency of late-spring deluges and late-summer droughts under a high (intermediate) emission scenario.




**a) The warm-season central U.S. hydroclimate is regulated by two major systems—the midlatitude storm track (red contours) and the subtropical southerly winds (blue arrows). Both are coupled to the westerly jet (yellow shading). b) Midwest rainfall peaks in June upon the arrival of the westerly jet. Under global warming, the westerly jet is projected to shift northward, making it closer to (further from) the Midwest before (after) June, leading to more (less) precipitation; c,d) Scatterplots of Midwest temperature and precipitation for individual years under current and future warmer climates for April-May and July-August.**

W. Zhou, L. R. Leung, and J. Lu. "Seasonally dependent future changes in the US Midwest hydroclimate and extremes" *Journal of Climate,* **35**, 17-27 (2021). [DOI: 10.1175/JCLI-D-21-0012.1].

# Deforestation Triggering Tipping Point in Amazon Hydrological Cycle

## Scientific Challenges

- Large-scale effects of deforestation on atmospheric moisture and thereby on surface water budgets are uncertain
- We studied how Amazonian deforestation is slowing the hydrological cycle, and leading to an unsustainable forest

## Approach and Results

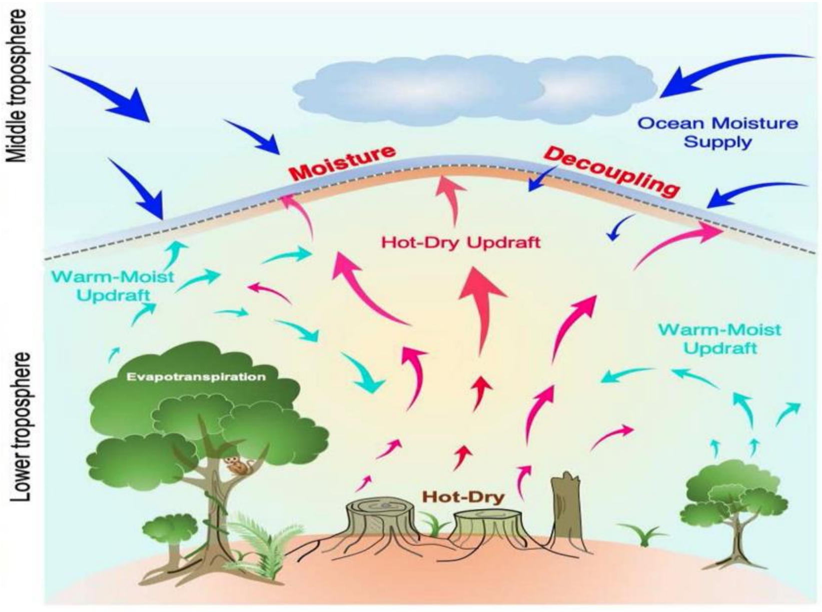
- We used observations of forest change, surface and vertical climate, and evapotranspiration between 1980 and 2016
- We analyzed the atmospheric structure of vapor pressure, updrafts, and precipitation in the context of land cover changes


- **Citation: Xu, X., X. Zhang, W. J. Riley, Y. Xue, C. A. Nobre, T. E. Lovejoy, and G. Jia (2022), Deforestation triggering irreversible transition in Amazon hydrological cycle, *Environmental Research Letters*, *17*, https://doi.org/10.1088/1748-9326/ac4c1d.**

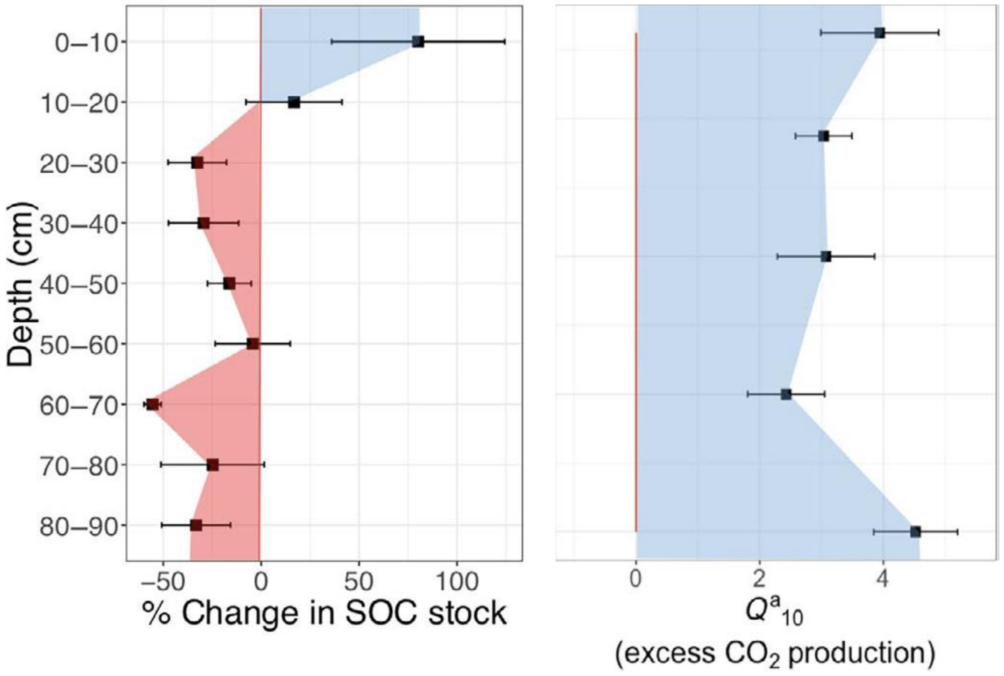

## Significance

- The Amazon is likely to reach an irreversible 'tipping point' when deforestation slows the hydrological cycle sufficiently so that tropical ecosystems are not sustained
- Reduction in evapotranspiration from deforestation dries the atmosphere and causes moisture decoupling
- The severe atmospheric desiccation cannot be compensated by enhanced water supplies from the Atlantic Ocean

**Figure.** Deforestation induced hot and dry atmosphere enhances updrafts to the middle troposphere, decreases downwind moisture transport from tropical oceans and adjoining forests, and decouples moisture exchanges.



# Deep Forest Soils Lose Carbon under Experimental Warming




After five years of experimental warming, soil organic carbon stocks were lower in the subsoil (left panel shows % difference between warmed and control plots) and the high temperature sensitivity of $CO_2$ production through the profile (right panel shows the apparent Q10, or excess CO2 production, due to warming).

Soong et al. "Five years of whole-soil warming led to loss of subsoil carbon stocks and increased $CO_2$ efflux," *Science*, 7(21), eabd1343, DOI: 10.1126/sciadv.abd1343 (2021)

## Scientific Challenges

- A warming climate is predicted to stimulate microbial decomposition of soil organic carbon, but quantifying the effect on soil carbon stocks is difficult. Moreover, most previous warming have only warmed the surface of the soil rather than the whole profile.

## Approach and Results

- Experimental warming of the whole soil profile led to a 30-35% increase in soil CO2 emissions for 5 years, and 33% lower carbon stocks below 20 cm compared to controls. The site is a ponderosa pine forest in the Sierra Nevada of California.

## Significance

– Soils were heated by 4oC to more than a meter deep,

– Soils contain twice as much carbon as the atmosphere does, and subsoils (below 20 centimeters) account for roughly half of the soil carbon.

– Because deeper soil carbon is old, it has been assumed to be stable, but this study shows that deep, older carbon can be disturbed by warming.

– This study provides physical evidence of the net transfer of carbon from the soil, where it was sequestered as organic carbon, to the atmosphere. If it continues, this transfer would generate positive feedback to climate change.

University of Zurich[UZH] EARTH & ENVIRONMENTAL SCIENCES BERKELEY LAB

# Whole Ecosystem Warming Stimulates Methane Production from Plant Metabolites in Peatlands

## Challenge

- Northern peatlands store approximately one-third of Earth's terrestrial soil organic carbon, but under warming conditions this carbon could become available for microbial degradation and be released to the atmosphere.

## Approach and Results

- Collected samples of soil and porewater from multiple locations at the SPRUCE experimental site that had been warmed to 2 meters deep.
- Analyzed molecules in the samples using NMR spectrometry and several complementary forms of mass spectrometry available at EMSL.
- Found that warming enhanced the degradation of soil organic matter, specifically by releasing compounds microbes could easily degrade.
- The increase in plant-derived metabolites was also accompanied by increased greenhouse gas production, particularly methane relative to carbon dioxide.

## Significance and Impact

- Results demonstrate that the vast deep carbon stores in peatlands are vulnerable to microbial decomposition, which would fuel methane production in response to warming.

R.M. Wilson, et al. 2021. Soil metabolome response to whole ecosystem warming at the SPRUCE and Peatland Responses Under Changing Environments experiment. *Proceedings of the National Academy of Sciences*, 118 No. 25 e2004192118, https://doi.org/10.1073/pnas.2004192118

Aerial view of the SPRUCE experimental site in northern Minnesota shows walkways connecting experimental sites in the undrained peatlands during October 2020.

**Participants:**
Florida State University
University of Arizona
EMSL and Pacific Northwest National Laboratory
Georgia Institute of Technology
Oak Ridge National Laboratory
Chapman University
US Department of Agriculture Forest Service
University of Oregon

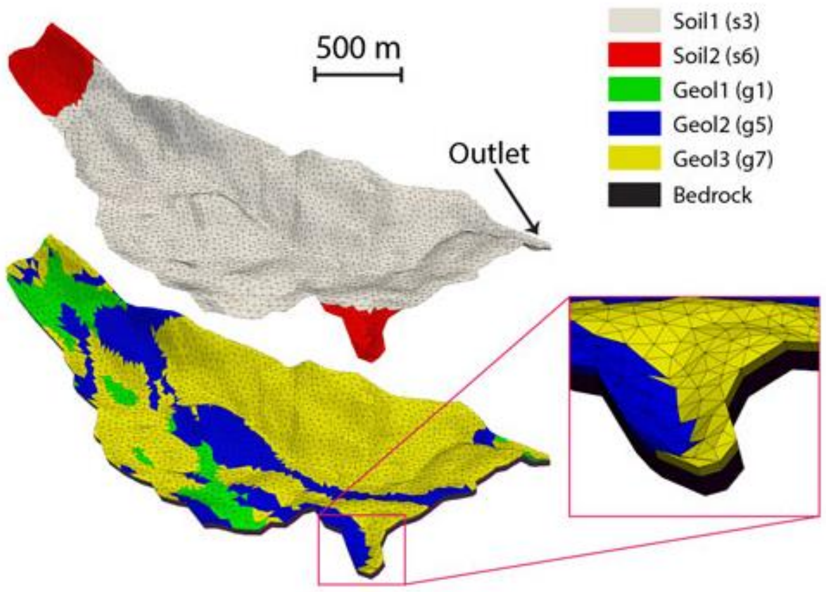
# Deep Learning Method Used to Estimate Watershed Subsurface Permeability

## Objective

- Develop a deep neural network (DNN)-based inverse modeling method to estimate the subsurface permeability of a watershed from stream discharge data.

## Approach

- Run ensembles of watershed simulations using the Advanced Terrestrial Simulator (ATS) to train the DNNs.
- Use trained DNNs to accurately estimate the subsurface permeability of the watershed from observed stream discharge data.
- Employ realistic permeability estimates of the watershed to improve predicted stream discharge.




Maps of soil and geologic layers used in the simulations

## Impact

- Deep Learning methods can improve parameter estimation in watershed modeling.
- Enables opportunities to improve the subsurface characterization of large-scale watersheds.


E. Cromwell, et. al.. “Estimating Watershed Subsurface Permeability From Stream Discharge Data Using Deep Neural Networks.” *Front. Earth Sci.*, 9:613011. (2021) [DOI:10.3389/feart.2021.613011]

# Three Techniques, Three Species, Different Ways to Fight Drought

EMSL

## Objective

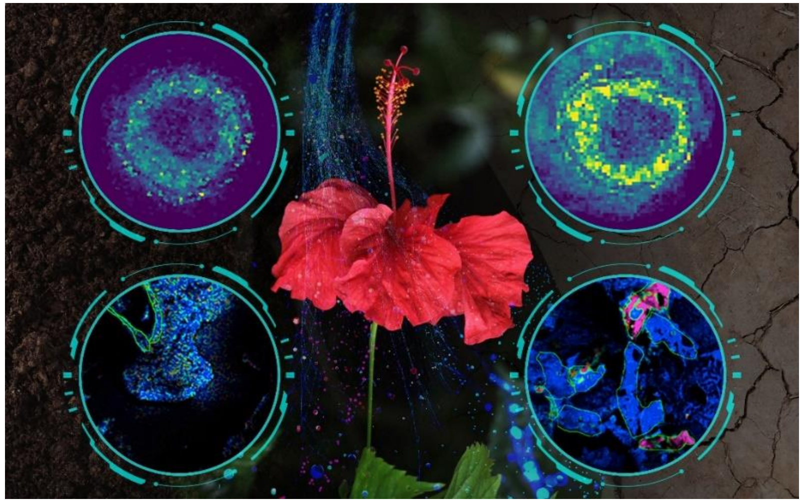
- Better predict how different species of tropical plants would react to stress conditions of rising temperatures and drought.

## Approach

- Studied chemical processes inside roots from three different tropical rainforest plants using metabolomic and imaging technologies (NMR, MALDI-MS, and Nano-SIMS) available at EMSL.
- Identified chemical responses and changes in root structure that provided each plant species with different defense mechanisms against drought and rising temperatures.

## Impact

- Each of the plant roots studied responded in different ways (e.g., building thicker roots or mounting a biochemical defense), proving that more than one strategy will be needed to help fight drought.
- Results also provided information on how carbon is being stored or released by different plants.



Spatial profiling and nanoscale isotopic analysis of the roots of *Hibiscus rosa-sinensis* and several other tropical plant species in response to drought.

**Participants:**
University of Arizona
University of Freiburg
EMSL and Pacific Northwest National Laboratory
Georg August University of Göttingen
Northwest A&F University

FICUS Facilities Integrating Collaborations for User Science

Honeker, L; *et al*., "Elucidating drought-tolerance mechanisms in plant roots through $^{1}$H NMR metabolomics in parallel with MALDI-MS, and NanoSIMS imaging techniques." *Environmental Science & Technology* (2022). [DOI: 10.1021/acs.est.1c06772]

# Reviewing Urban Impact on Regional Climate and Extreme Weather

**Objective**

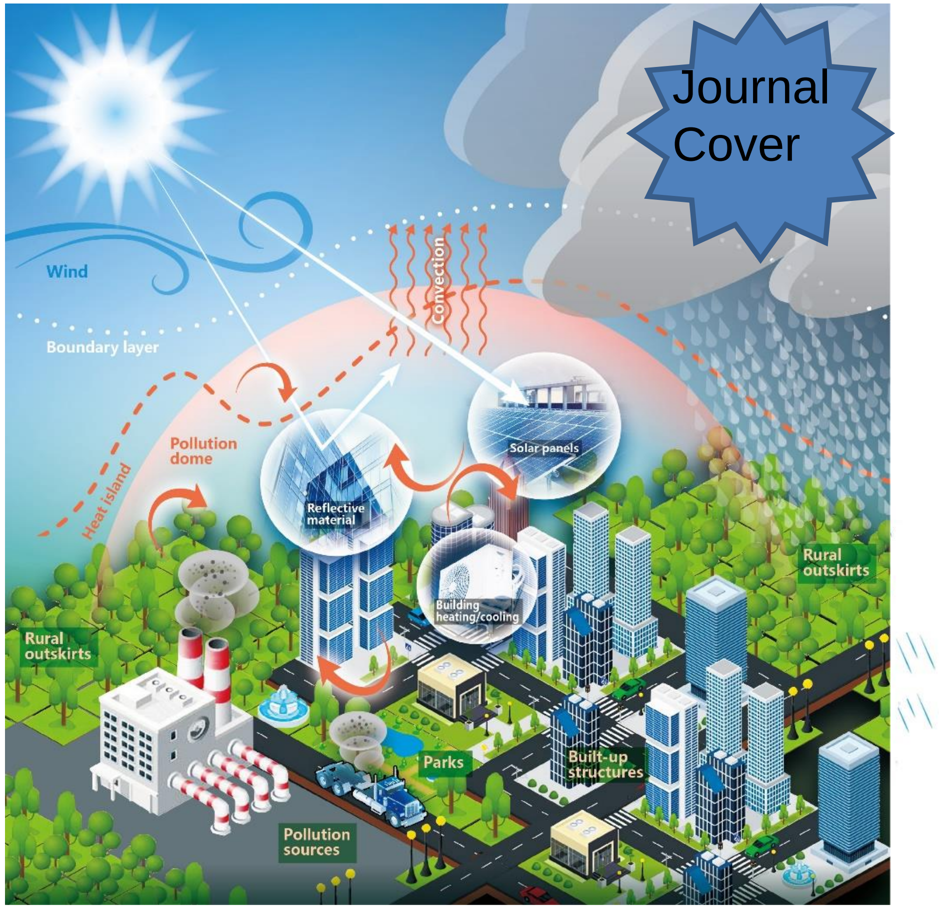
- Summarize the scientific literature on the impact of urbanization on extreme weather and regional climate.

**Approach**

- Examine over 500 published studies focused on urbanization and its impacts on weather and climate. This includes urban heat islands and heat waves, atmospheric moisture, wind, boundary-layer, air pollution, clouds, precipitation, and storms.
- Provide overviews of the main methods and datasets used to study urban areas from both observational and modeling perspectives.
- Describe the limitations and uncertainties of different methods based on the scientific literature, identifying major research gaps.

**Impact**

- Synthesized current scientific understanding of the many local and regional effects of urbanization.
- Identified research gaps and provided recommendations on potential research topics and priorities for advancing the science around urbanization's impact on weather and climate.




**A schematic summarizing the impacts of urbanization on various components of natural and human systems. Urban environments have unique biophysical, morphological, and thermodynamic characteristics due to the continued infrastructure development that generally replaces natural landscapes with built-up structures.**

Qian, Y., T. Chakraborty, J. Li, D. Li, C. He, C. Sarangi, F. Chen, X. Yang, L. R. Leung 2022, Urbanization Impact on Regional Climate and Extreme Weather: Current Understanding, Uncertainties, and Future Research Directions. *Adv. Atmos. Sci.* (2022).[DOI: 10.1007/s00376-021-1371-9]

# THANK YOU!