UCI University of California, Irvine

"UCI-National Labs Connections"

A Forum connecting UCI faculty and students to research at the National Labs

Climate and Environmental Systems Science @UCI

UCI Samueli School of Engineering

Los Alamos NATIONAL LABORATORY EST. 1943

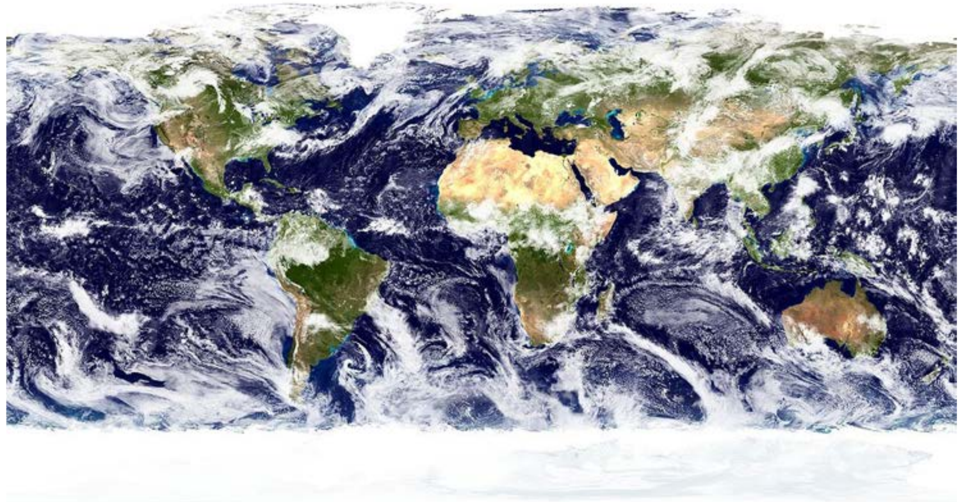
Climate and Environmental Systems Science @ UCI

Oceans

Arctic systems

Wildland fires and terrestrial ecosystems

Data driven climate science



Theme: Oceans
Lead: Kristen Davis

- How is climate change modifying local-to-global scale ocean circulation patterns, biogeochemistry, and ecosystem processes?
- How will sea level rise influence coastal erosion, flooding, and infrastructure?
- What are the key processes regulating nearshore wave and transport dynamics?
- How do we improve the representation of ocean biogeochemistry in E3SM and other earth system models?

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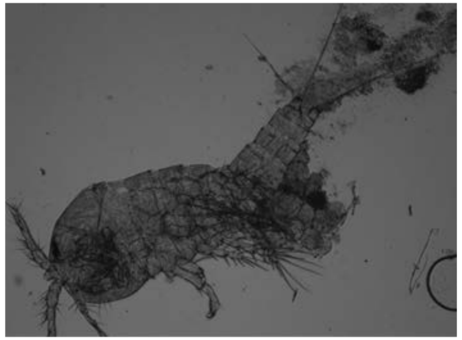
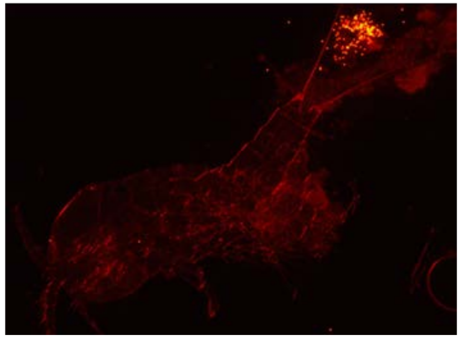
Oceans (Katherine Mackey)
Overall Objectives

- How do phytoplankton sense, acclimate, & adapt to environmental stimuli and global change?
- What interplay does adaptation cause within natural populations and with their environment?
- How does the environment drive phytoplankton diversity and biogeochemical activity?

Ongoing studies





How do plastics enter marine food webs?

Microbial ecology of the Salton Sea: A dwindling oasis

Effect of emissions from the global shipping industry on marine biogeochemistry and phytoplankton ecology

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Oceans (Francois Primeau)

Overall Objectives

- The ocean’s overturning circulation has timescales of hundreds to thousands of years, making it computationally prohibitive to spin-up tracers in global ocean models. Inadequate spin-up makes it difficult to calibrate model parameters using observations. It also leads to spurious climate drifts in Earth System Model.

- **We are developing algorithms to accelerate the spin up of ocean tracers in global ocean models.**

Ongoing studies

- DOE-ESMD project in collaboration with Mark Petersen (LANL) to develop algorithms to accelerate the spin-up of marine biogeochemical tracers such as carbon and nutrients in the *E3SM* Earth System Model.

- The approach uses a preconditioned Newton-Krylov algorithm with the preconditioning matrix constructed using impulse response functions in the *MPAS-O* ocean model.

MPAS-O impulse locations

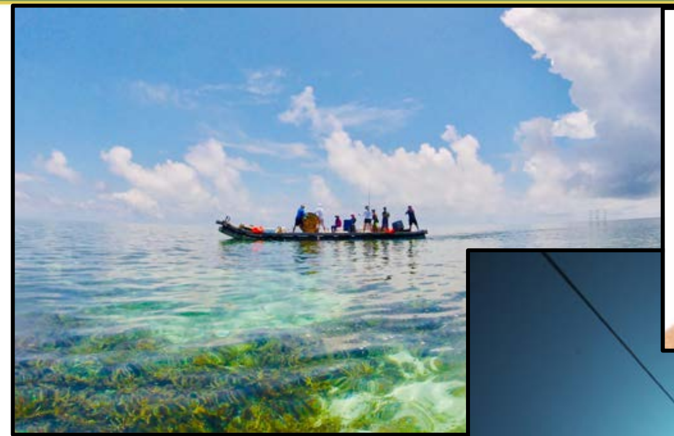
Oceans (J. Keith Moore)
Overall Objectives

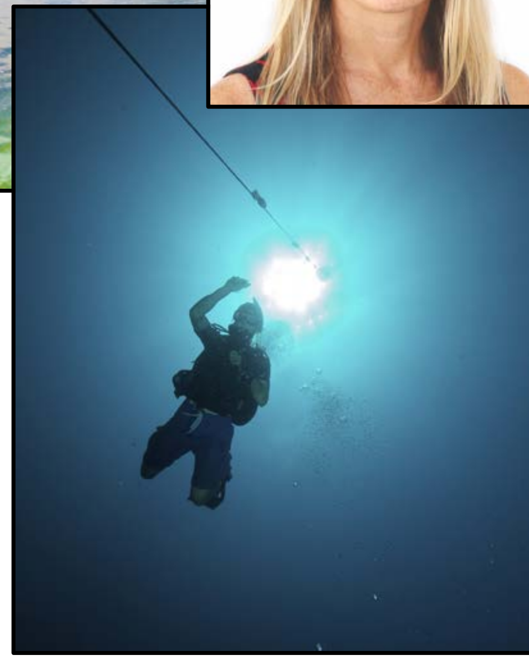
Develop and apply ESM ocean component models to study climate-biogeochemistry feedbacks and the impacts of climate change on marine ecosystems. Research group members learning to run simulations and write code for the E3SM.

Ongoing studies

- PI on DOE project, **Development of the E3SM Marine Biogeochemistry for Studying Biogeochemistry-Climate Feedbacks**, funds development of plankton variable stoichiometry, work on marine methane and nitrous oxide sources, and examines ice sheet impacts on marine biogeochemistry. **Mat Maltrud (LANL)** is a collaborator, plan additional DOE collaborators for ice sheet work.
- Co-PI on the **DOE RGMA funded RUBISCO SFA**, focused on potential Climate- Biogeochemistry feedbacks, multiple DOE scientists, **Forrest Hoffman (PI, Oak Ridge)**.
- Co-PI on **ESMD grant** to Primeau seeking to build model spin up capabilities for the E3SM, several DOE scientists are collaborators including **Mark Peterson (LANL).**

Oceans (Kristen Davis)





Overall Objectives

- In the Coastal Dynamics Laboratory we use field observations and numerical models to understand how **physical processes govern circulation in the coastal ocean**, its natural variability, and influence on coastal ecosystems.
- Further, we are interested in natural **ocean-based strategies for mitigating climate change**.

Ongoing studies

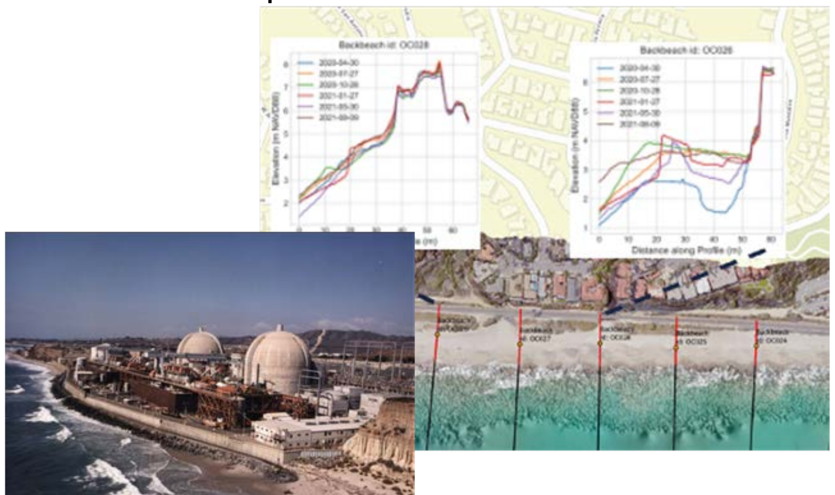
- Dynamics of oceanic **internal waves** on the inner shelf - shoaling, breaking, reflection, refraction, turbulent mixing, and dissipation of energy (NSF/ONR).
- Physical drivers of **hypoxia** (low oxygen) in shallow coastal embayments (NSF).
- Seaweed farming: Evaluating the potential for offshore **cultivation of macroalgae for biofuels and carbon sequestration** (DOE/ARPA-E)

Oceans (Brett Sanders)
Overall Objectives

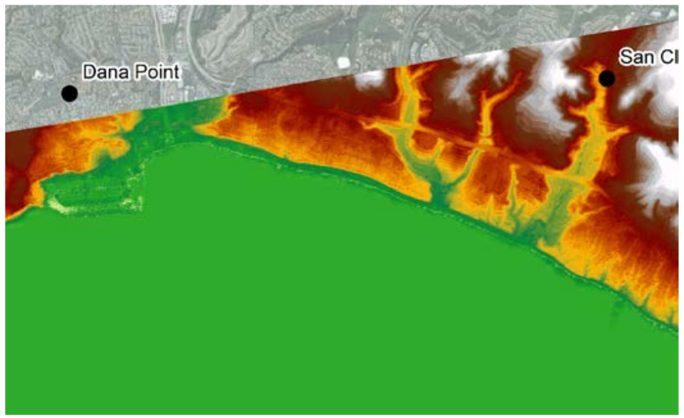
- Characterize urban shoreline and beach dynamics over seasonal to multi-decadal time scales.
- Develop remote sensing methods for improved spatial and temporal resolution of shoreline and beach dynamics
- Simulate coastal flood risk

Ongoing Studies

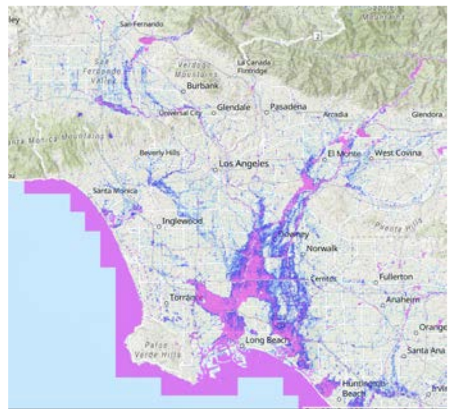
Monthly Drone Surveys of Beach Topography Capture Seasonal Dynamics and Infrastructure Impacts

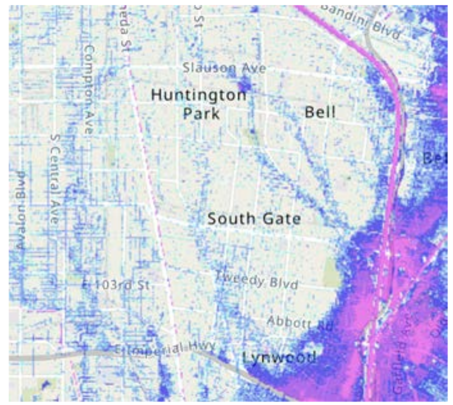


Satellite-based InSAR Monitoring of Beach Topography to Infer Coastal Risks and Sediment Budgets



Metropolitan Scale Modeling of Coastal Flood Risks at Fine Resolutions (1-3 m)





Oceans

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Brett Sanders
floodlab.eng.uci.edu/

Katherine Mackey
www.katemackey.com/

Adam Martiny
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Francois Primeau
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Keith Moore
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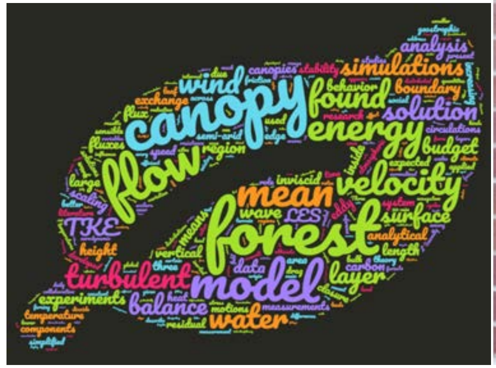
Theme : Wildland fires and terrestrial ecosystems
Lead: Tirtha Banerjee

- How can we improve our measurement and modeling capability for wildfire dynamics to improve prediction?
- What are the key physical processes regulating fire-atmosphere interactions?
- How do we design more effective fire and ecosystem management strategies?
- How are terrestrial ecosystems changing and what are the mechanisms responsible for observed trends?
- How do we improve the representation of biogeochemical processes and hydrology in Earth System models?

Wildland fires and terrestrial ecosystems (Tirtha Banerjee)

Overall Objectives

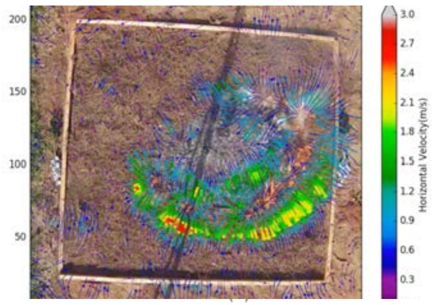
- Fluid dynamics of ecosystem-atmosphere interaction.
- Physics of wildland fire behavior.
- Engineering ecosystem management approaches to combat devastating wildfires.

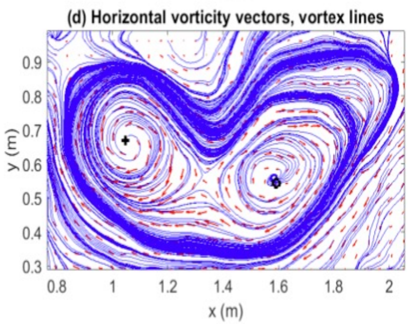



Banerjee Lab
Boundary Layers and Turbulence (BLT) Research Group, CEE@UCI

Ongoing studies:

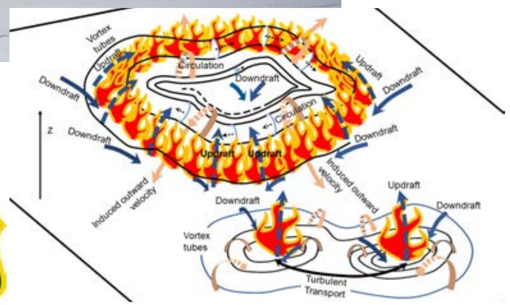
Scales

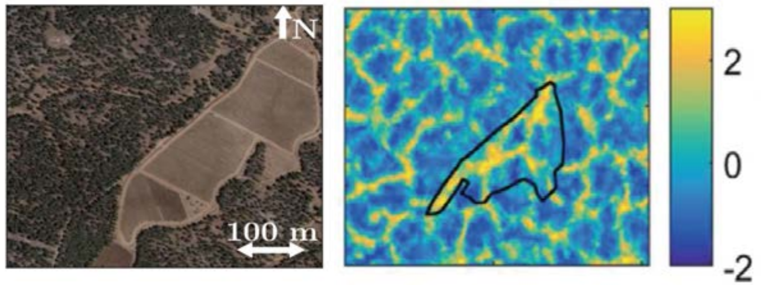




Small scale experiments

Funding:

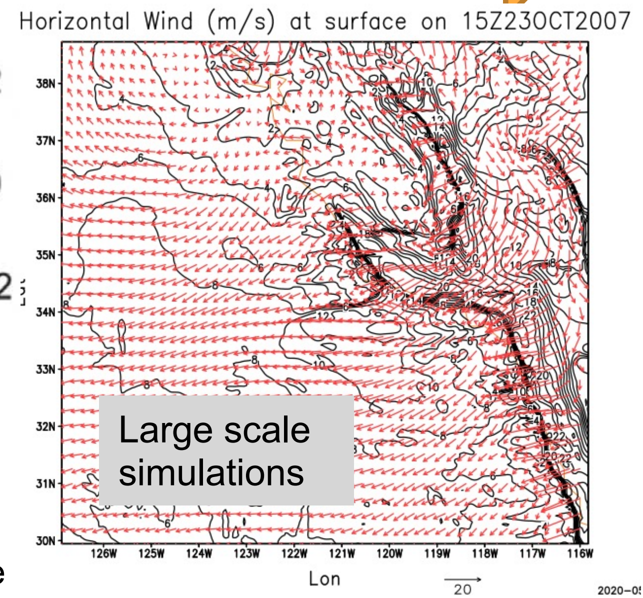




Top: CFD simulations of forest-atmosphere exchange

Left: lab and field scale burn experiments

Right: WRF simulations of specific fire events



Large scale simulations

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Research projects

SPARx

Smart **P**ractices and **A**rchitectures for **Rx** Fires

UC Lab Fees Project: Transforming Prescribed Fire Practices for California

UNIVERSITY of CALIFORNIA

Office of the President

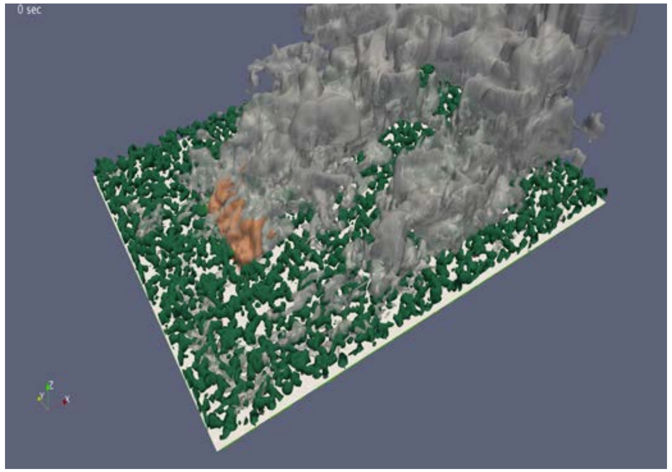
USD 3.6 Million, 2020-2023

FIRETEC access provided by LANL

Collaboration:
Rod Linn
Alex Josephson

Los Alamos NATIONAL LABORATORY EST.1943

UC ANR



NSF

iFireNet

An International Network of Networks for the Prediction and Management of Wildland Fires

(1) Synergy among complementary experiments in different geographical settings
(2) A standardized protocol to collect, interpret and share data from these experiments,
(3) The basis of model intercomparisons in the context of multi-fidelity fire modeling,
(4) A protocol for benchmarking wildfire simulations across multiple scales, and
(5) A unified training module that adapts the best practices of local knowledge yet can be translated in the international setting.

Other LANL Collaborations: Alex Jonko (WRF modeling), Dubey (UAV, air quality and fires), Satish Karra, Navamita Ray (Quantum computing for CFD)

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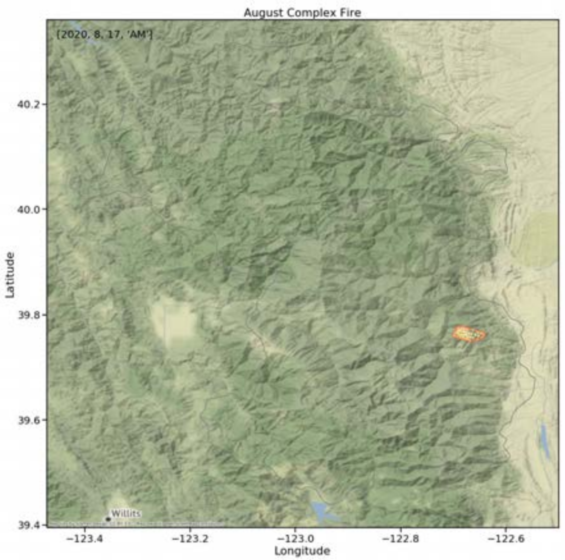
Wildland fires and terrestrial ecosystems (Jim Randerson)

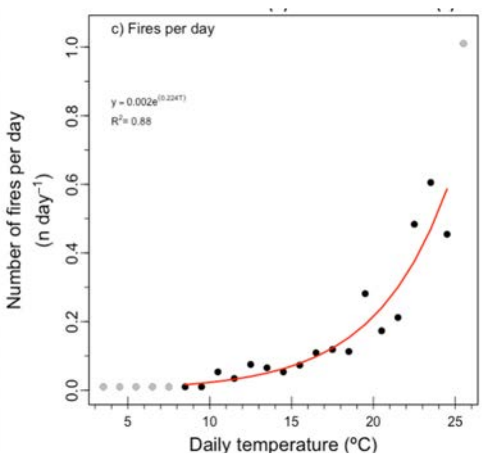
Overall objectives:

Our lab seeks to improve our understanding of interactions between humans, ecosystems, and climate change that influence the long-term sustainability of the Earth System. To this end, we use satellite data, atmospheric trace gas observations, and earth system models in new ways to study the global biosphere.

Ongoing studies:

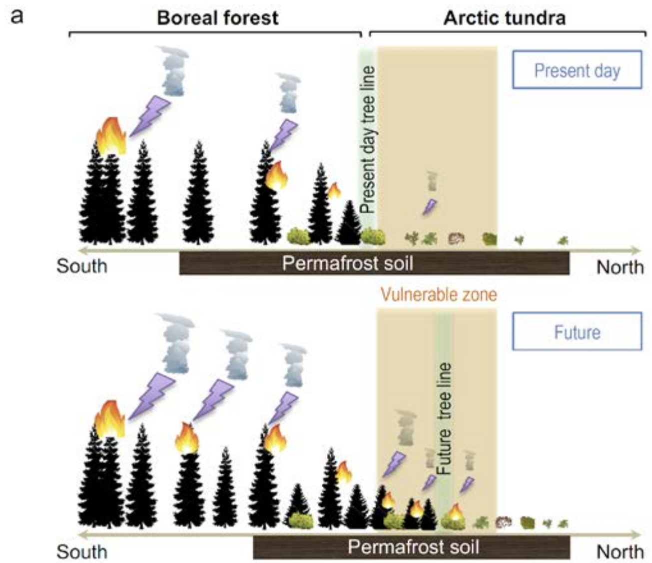
California wildfires and climate change





UC Lab Fees "California Futures" with Chonggang Xu from LANL

Biosphere-climate-carbon feedbacks



DOE BER RUBISCO Science Focus Area

C-FIRES satellite concept

UC Irvine and NASA GSFC

Wildland fires and terrestrial ecosystems (Mike Goulden)

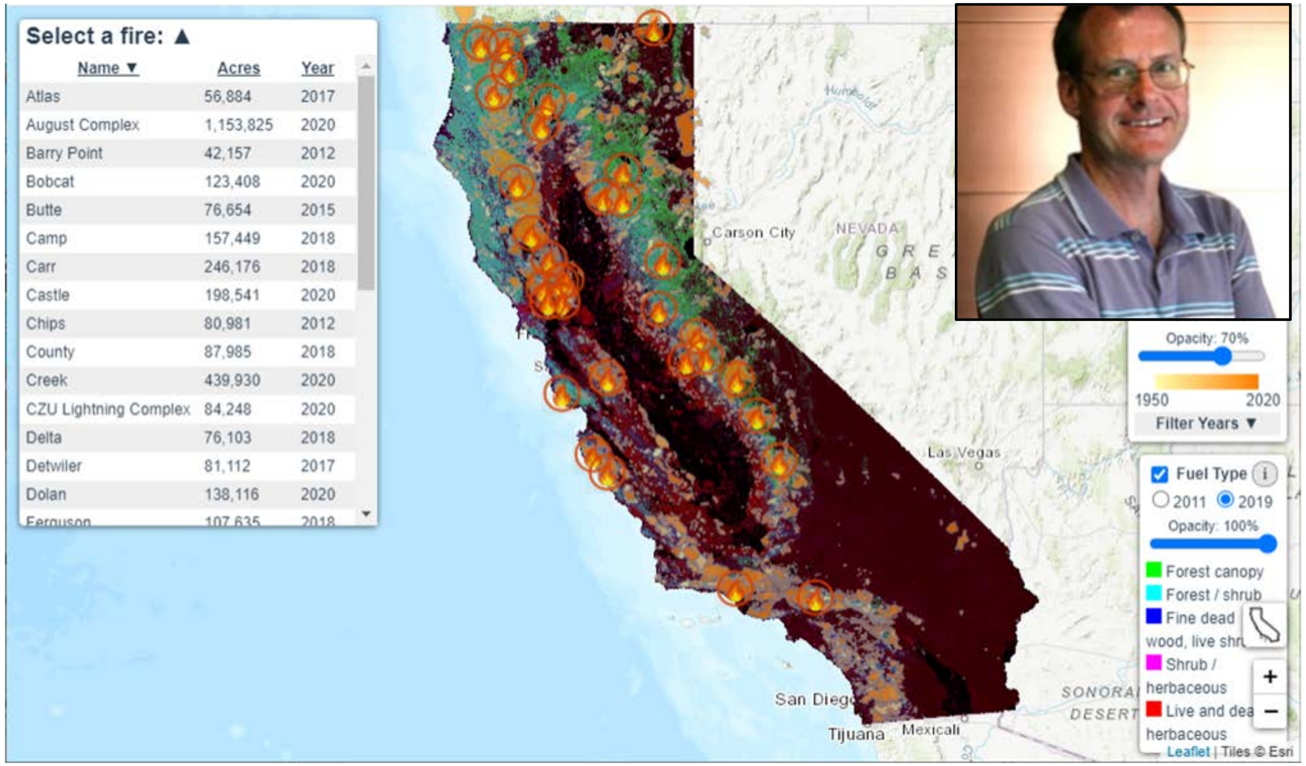
Center for Ecosystem Climate Solutions

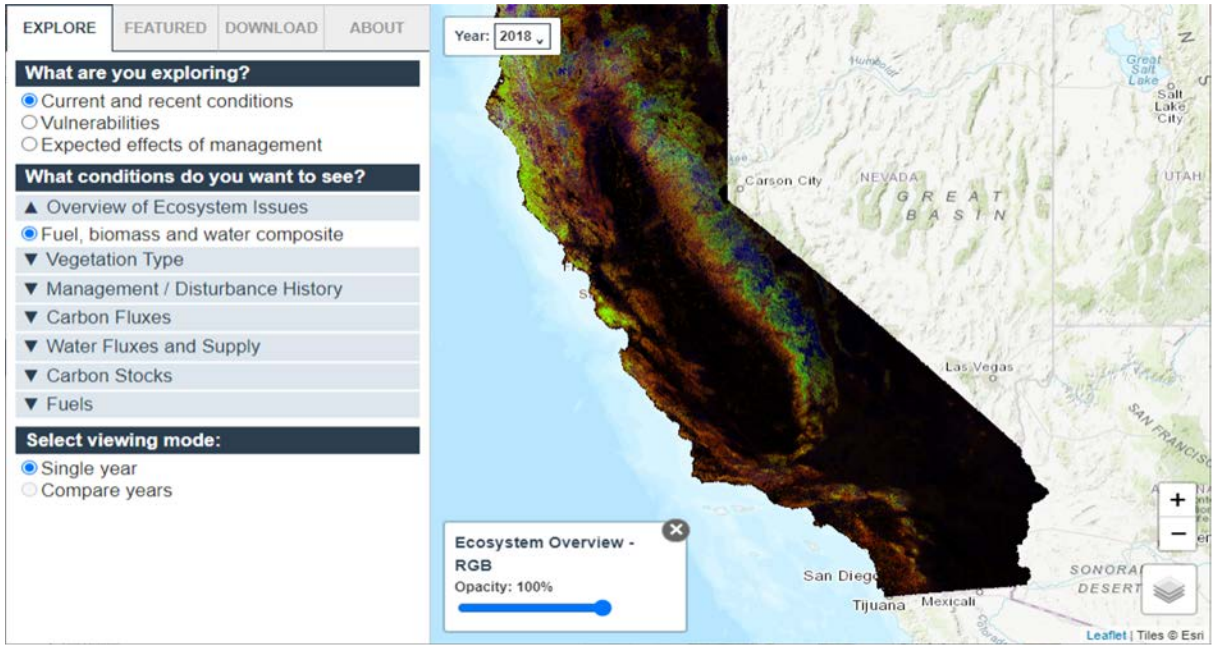
Overall Objectives

Understand/address climate/fire/water/carbon/die-off problem

Ongoing:

- $4.6M Center grant from state
- Based at UCI; appx. 8 institutions, 40 PhDs
- Agency ties (CNRA, CARB, CALFIRE, DWR, etc.)
- Regional collaboratives (NCRP, TCSI, etc)





UCIrvine · University of California UC Merced · UC Davis · Berkeley University of California · University of California Agriculture and Natural Resources · Stanford University · San Diego State University · Forest Service U.S. Department of Agriculture · California Strategic Growth Council · California Climate Investments (Cap and Trade Dollars at Work)

Center for Ecosystem Climate Solutions

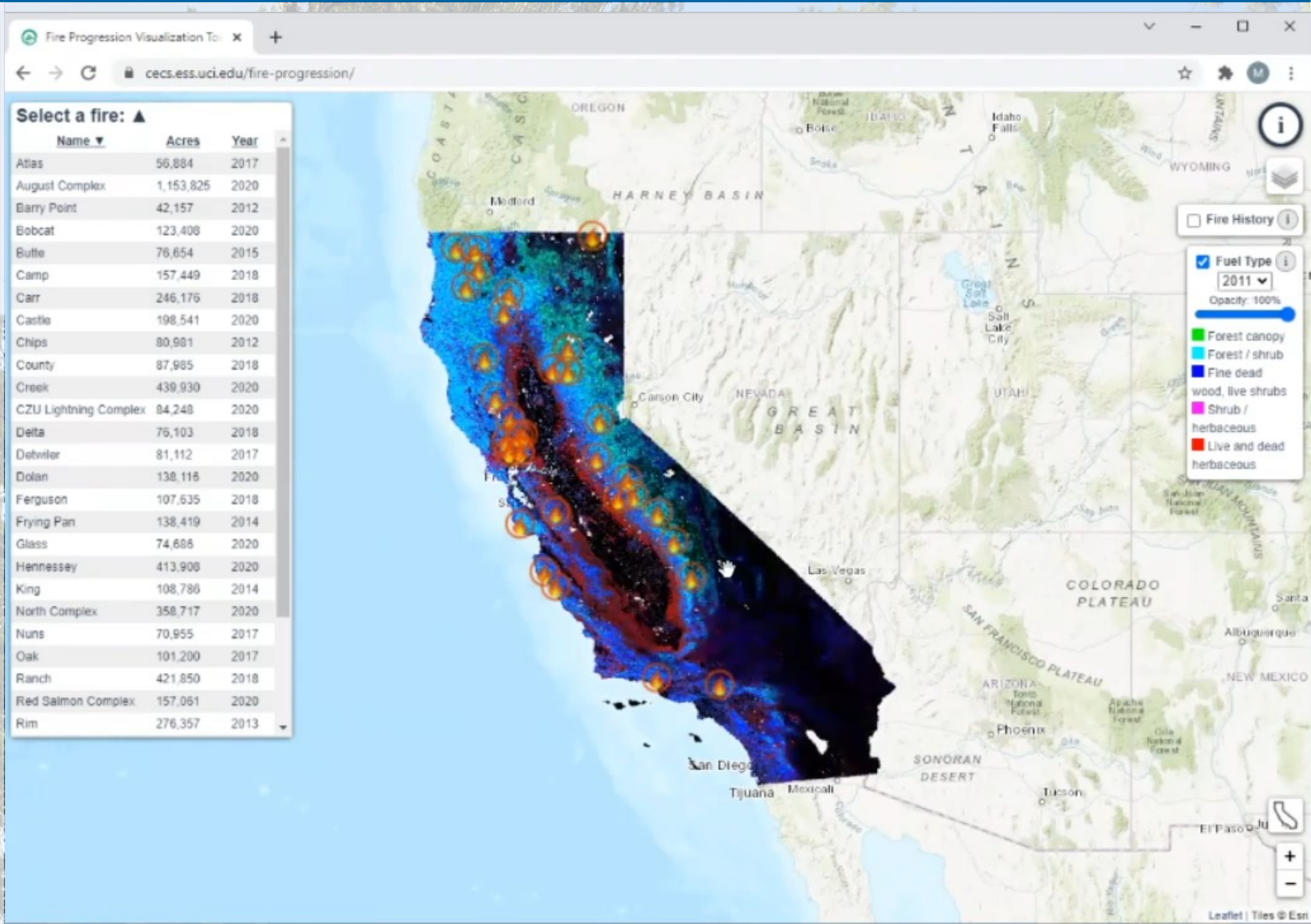
- Actionable geospatial datasets and tools
- Satellite observed fire spread with surface fuels
- Rapid spread along canyon shrub belts (blue areas)

https://cecs.ess.uci.edu/data-atlas/

https://cecs.ess.uci.edu/fire-progression/

https://cecs.ess.uci.edu/carbon-vulnerability/

https://california-ecosystem-climate.solutions/



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Wildland fires and terrestrial ecosystems (Paulo Brando)

Overall Objectives

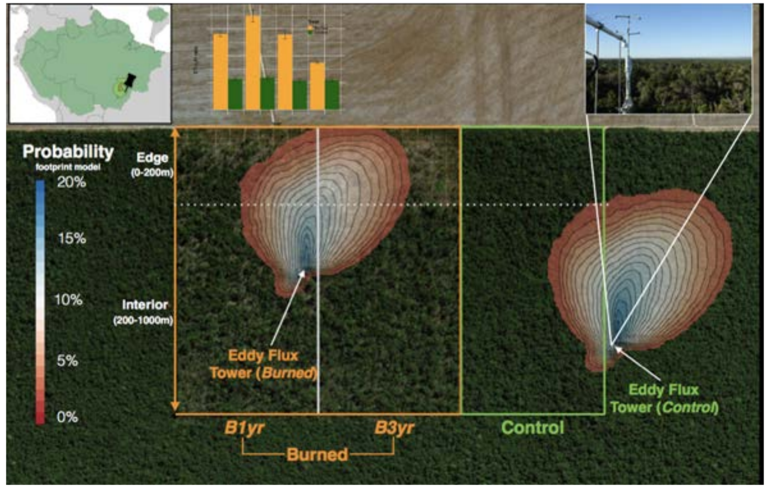
- Identify climatic thresholds beyond which wildfires and other disturbances cause major transformations in tropical forest structure, dynamics, and functions.
- Quantify roles of land use and land cover change in degrading natural ecosystems by altering disturbance regimes, forest resilience

SCIENCE ADVANCES | RESEARCH ARTICLE

ENVIRONMENTAL STUDIES

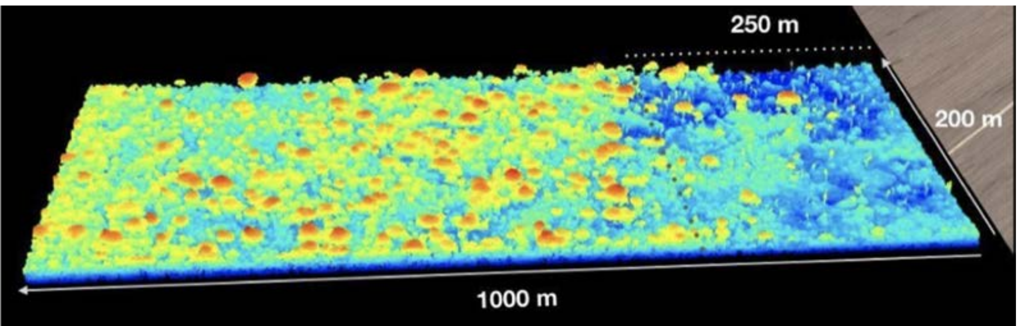
The gathering firestorm in southern Amazonia

P. M. Brando[1,2,3]*, B. Soares-Filho[4], L. Rodrigues[4], A. Assunção[4], D. Morton[5], D. Tuchschneider[6], E. C. M. Fernandes[6], M. N. Macedo[2,3], U. Oliveira[4], M. T. Coe[2,3]



Ongoing studies

- Legacy effects of compounding disturbances in the Amazon: implications for ecosystem carbon and water cycling (NSF: PI).
- Interactions, feedbacks, carbon consequences of Amazon forest fragmentation incorporating ecosystem structure and thermal dynamics (NASA: PI)
- Incorporating fire and drought dynamics into Earth System Models (CNPq: PI)



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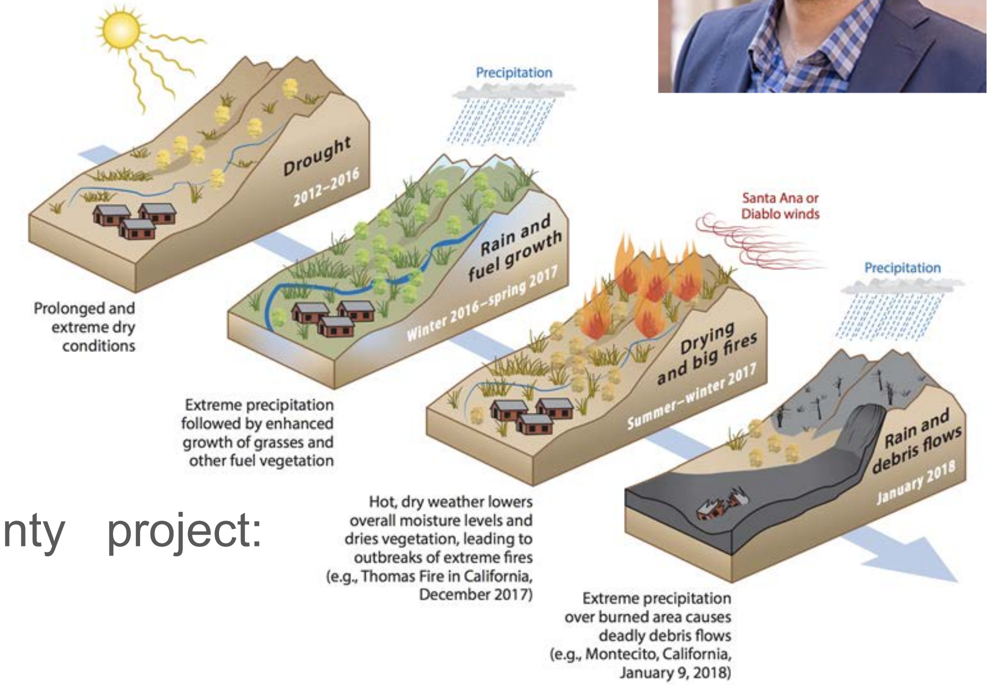
Wildland fires and terrestrial ecosystems (Amir Aghakouchak)

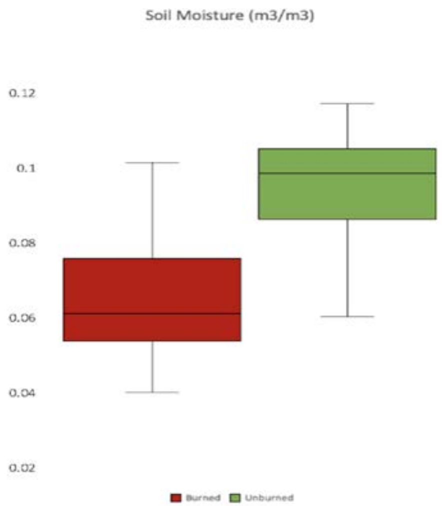
Overall Objectives

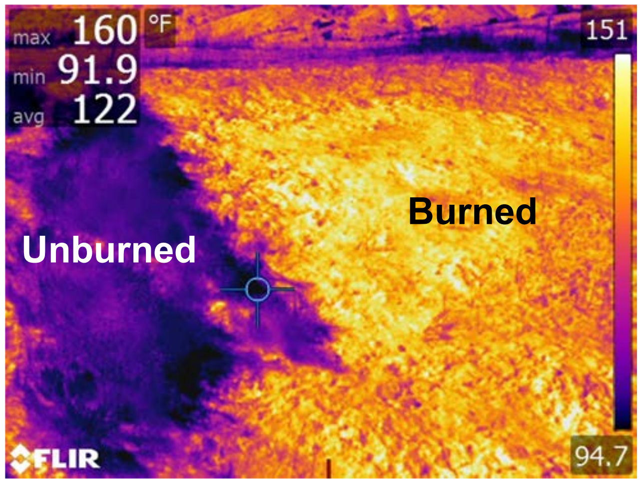
- Reducing vulnerability of disadvantaged communities to impacts of wildfire-related cascading hazards (NSF SCC: A.A, Banerjee and Cohen)
- Developing multi-hazard approach to investigate (extreme) climate vulnerability of SoCal's natural gas energy infrastructure
- Collecting perishable post-fire data focusing on soil changes in burned areas (NSF Rapid: A.A & Banerjee)

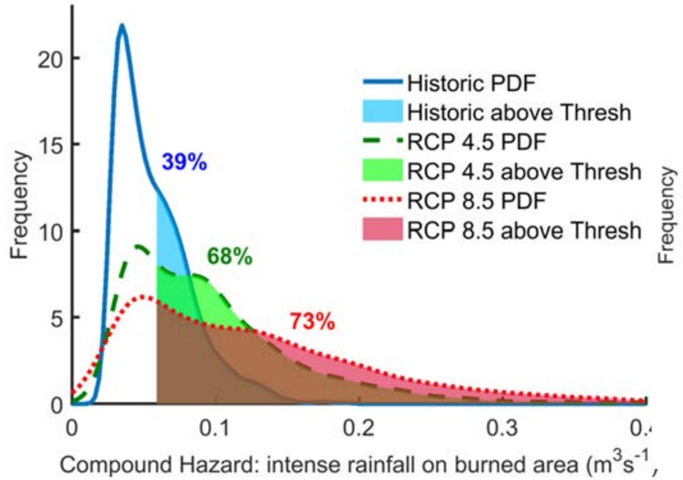


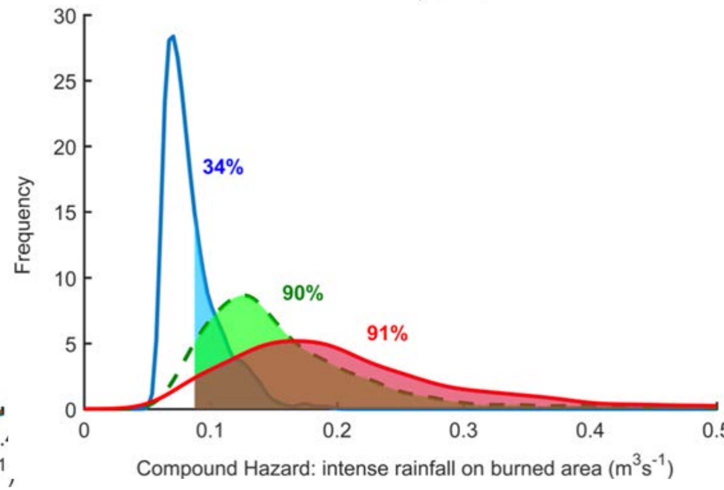
Ongoing:

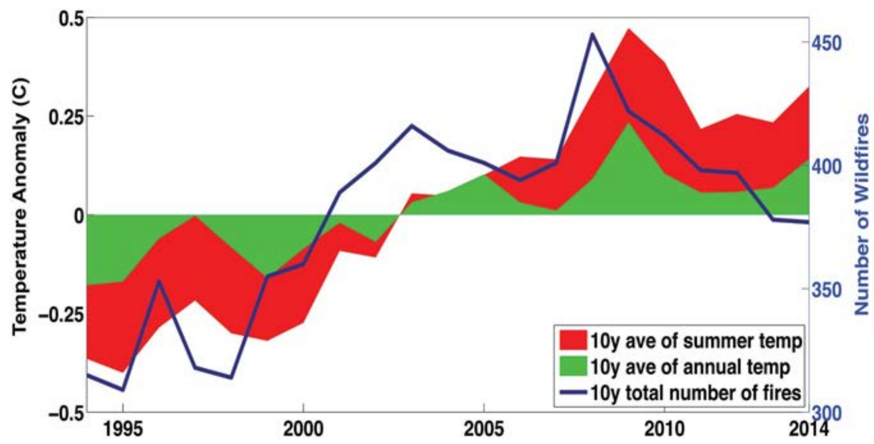
- Collaborating with emergency planning authorities (Lake County project: significant population of economically disadvantaged residents)

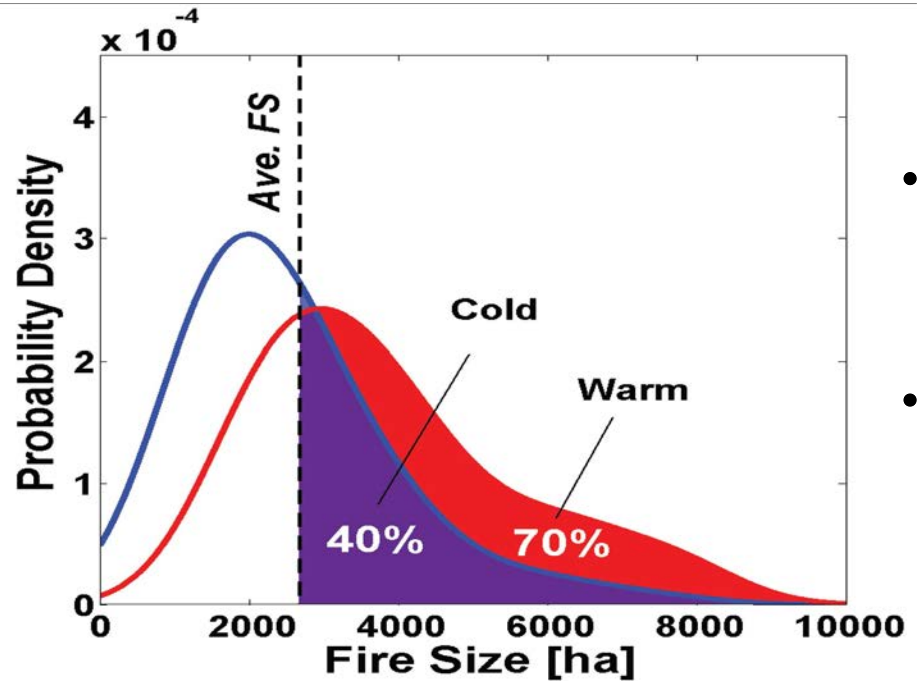












Wildfire response to climatic drivers

- Conditional probability distribution: annual average fire-size in cool and warm summers.
- Temperature anomalies:
  Cool summer: -0.5˚C
  Warm summer: +0.5˚C
- Shaded: probability of exceeding avg. Californian fire-size.
- Increases by **30%** when summer temperature anomaly increases by **1 °C.** (Madadgar et al., 2020.)

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Wildland fires and terrestrial ecosystems (Efi Foufoula-Georgiou)

Overall Objectives

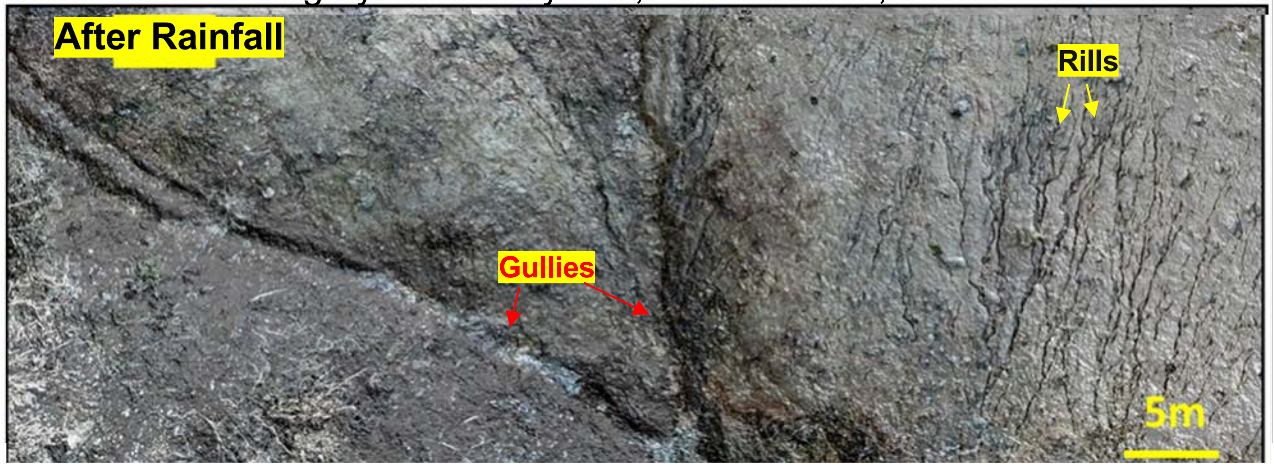
- Stochastic modeling of surface hydrologic and geomorphologic processes.
- Modeling and estimation of space-time rainfall from spaceborne sensors, seasonal precipitation forecasting using observations and climate models
- Stochastic theories of transport on the Earth's surface, river network dynamics and hydrologic response.

Ongoing studies

- Post-fire disturbance of landscapes -- flood and debris flow hazards
- Dependence on previous post-fire disturbance: Integrate into dynamically-updating hazard prediction framework that accounts for postfire **storm cycle dynamics** and **longer-term antecedent conditions**
- How will increasing wildfire frequency affect upland sediment supply?

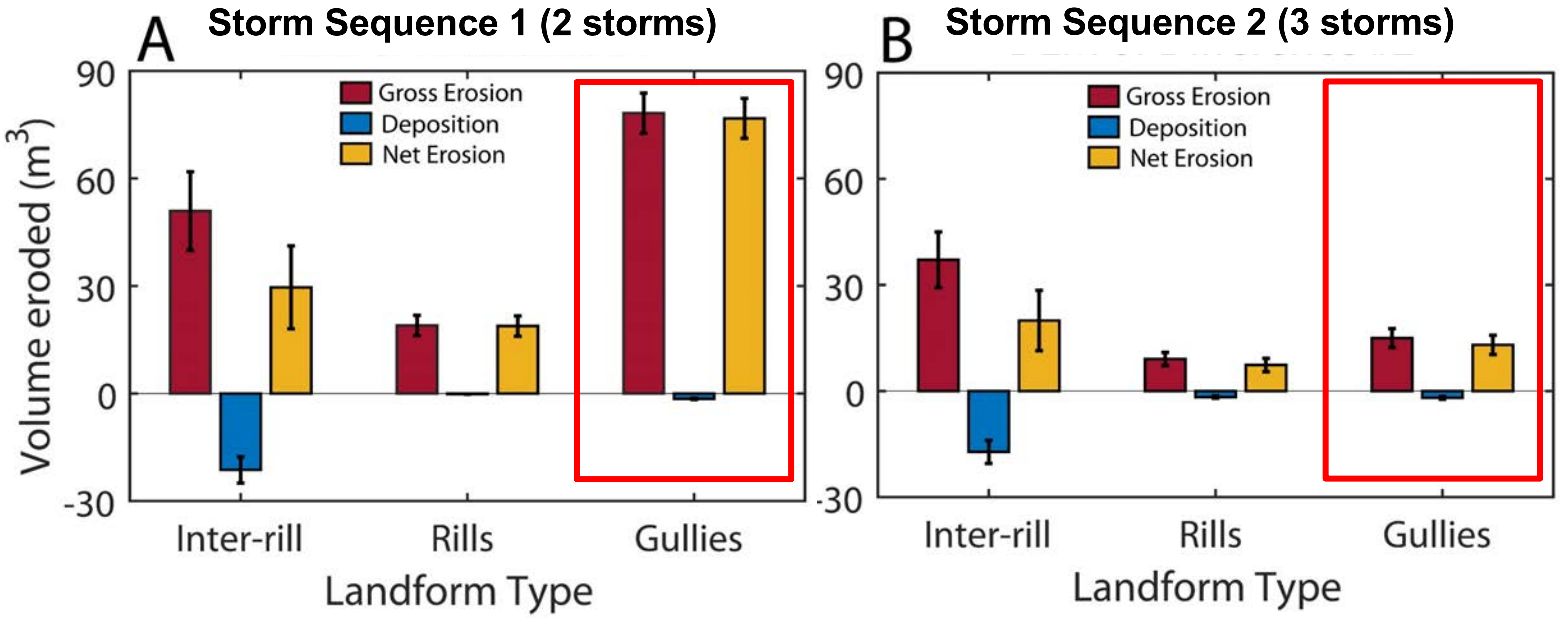
Post-fire disturbance of landscapes -- flood and debris flow hazards

UAV-SfM Imagery: 2018 Holy Fire, Lake Elsinore, CA



How do post-fire upland sediment dynamics change on a storm-to-storm basis during the initial window of disturbance?

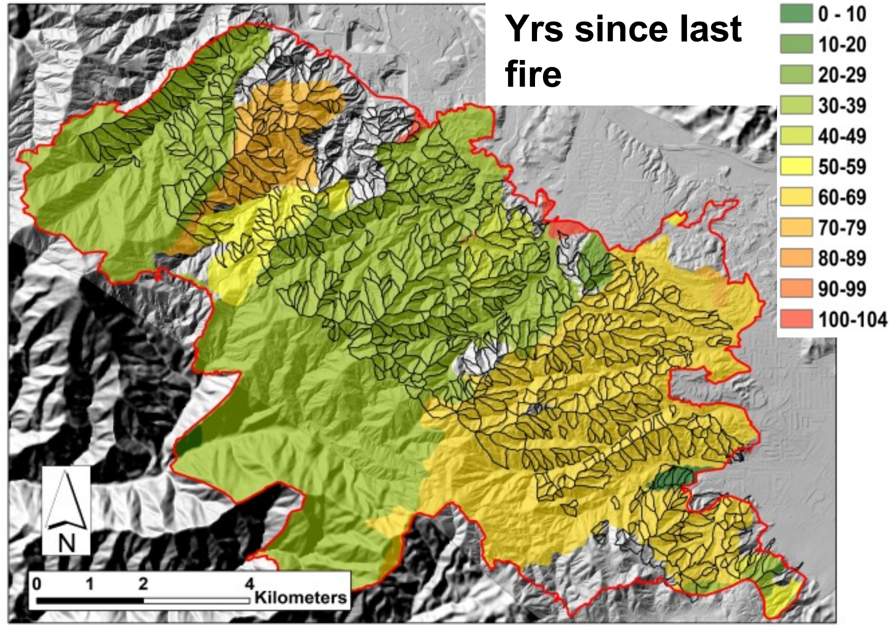
- TLS/SfM field monitoring shows **supply limitations in channelized (gully) domains**, despite only slightly wetter than avg conditions
- Supported by observations **of downcutting through long-term fill to bedrock** by floods + debris flows



Guilinger et al. JGR-Earth Surface, 2020

Dependence on previous postfire disturbance

Does previous wildfire disturbance modulate postfire channel sediment supply?

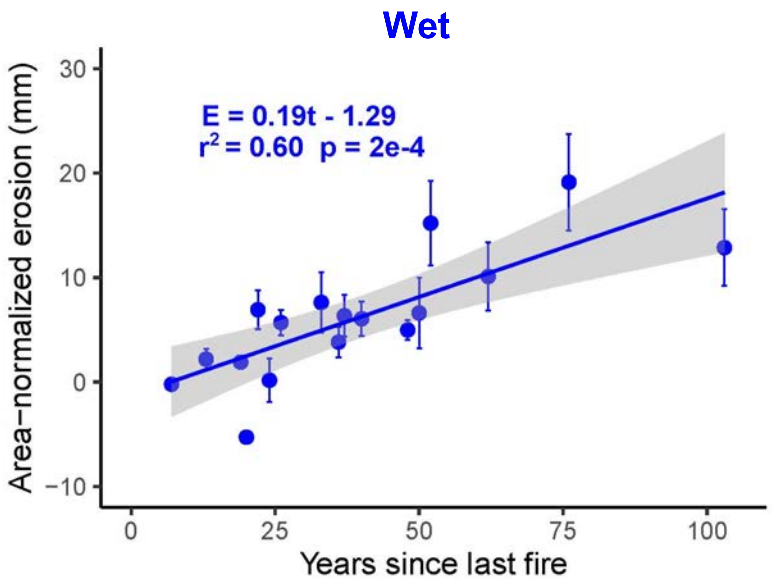


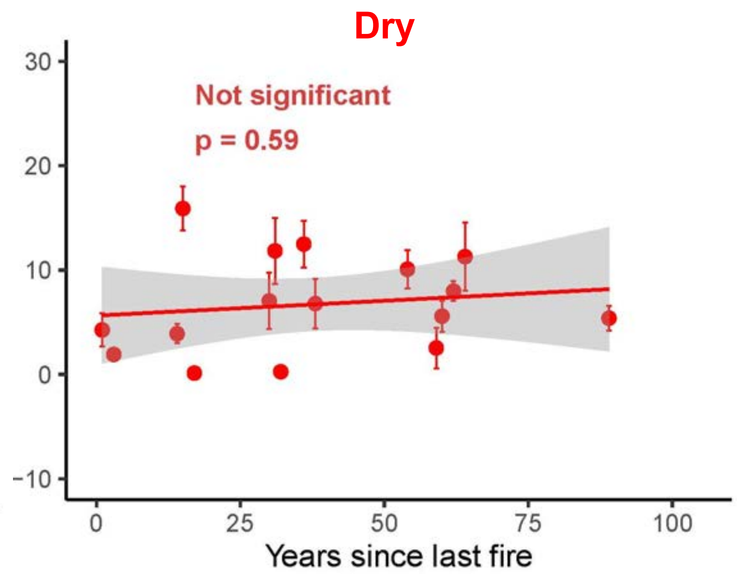
- Use airborne lidar differencing across source headwater catchments (~1-10ha) in 5 burn scars and aggregate erosional responses across fire history (CALFRAP) and associated postfire precipitation indices (PRISM/DRI)

- **There is a significant relationship between channel erosion magnitude and time since previous fire in wetter postfire periods (above median) vs drier (below median)**

Ongoing work:

Integrate into dynamically-updating hazard prediction framework that accounts for postfire **storm cycle dynamics** and **longer-term antecedent conditions**

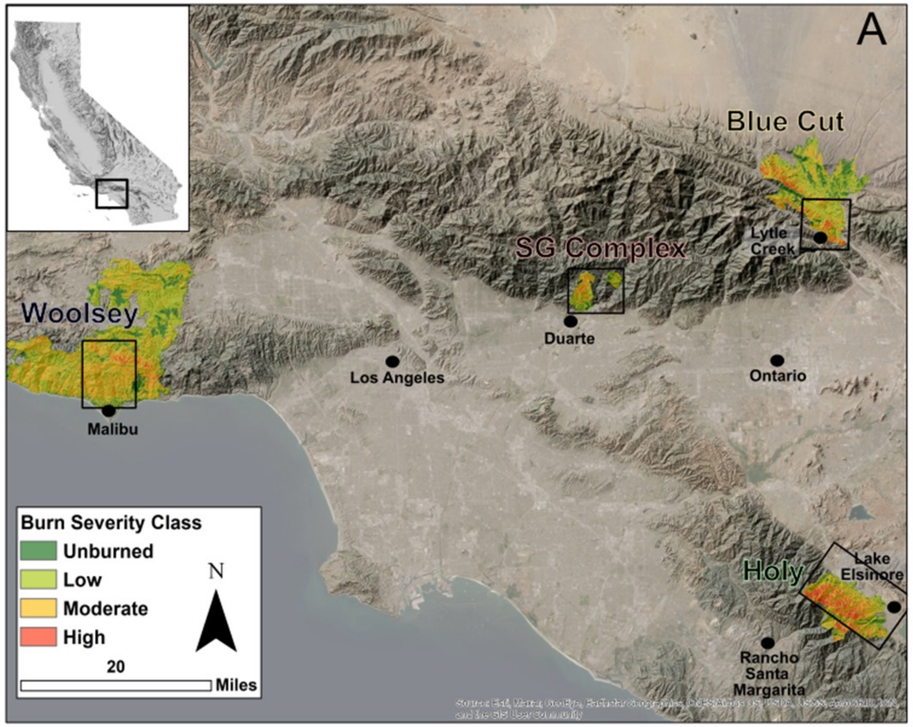


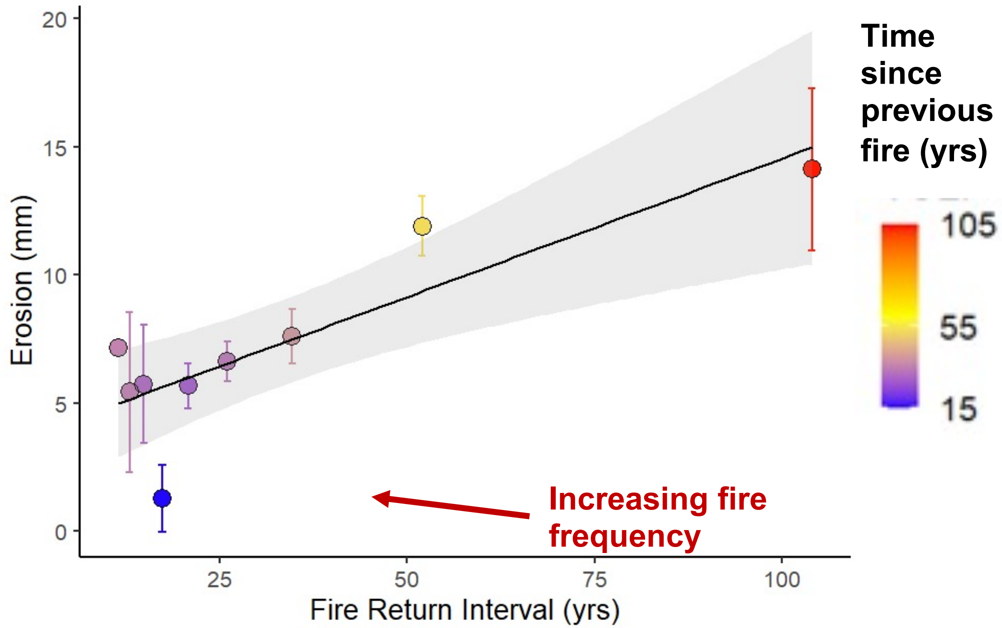


Wildfire frequency impacts on sediment supply

How will increasing wildfire frequency affect upland sediment supply?

- Observations of debris flows fully evacuating channel networks to bedrock
- Used a combination of airborne lidar differencing and historical fire perimeters across four fires that experienced significant erosion to determine dependence of contemporary erosion on **previous fire history**



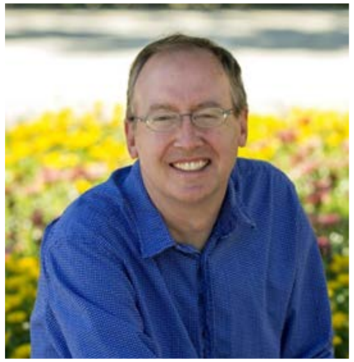


Future **increases in fire frequency** will likely **decrease sediment supply**

Guilinger et al. 2020; in prep

Wildland fires and terrestrial ecosystems

Tirtha Banerjee
faculty.sites.uci.edu/banerjeelab/



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Claudia Czimczik
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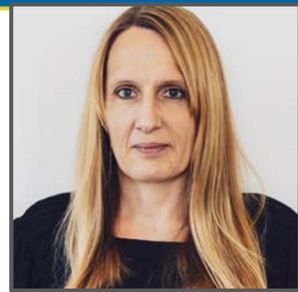
Theme: Arctic Systems
Lead: Claudia Czimczik

- What is the vulnerability of permafrost carbon to climate warming?
- How is climate change impacting the hydrology of the Arctic?
- How are global ice sheets changing and what are the physical processes regulating these dynamics?
- How are vegetation dynamics changing near northern treeline?
- How can we use ice core measurements to study the past composition of the atmosphere and Earth system processes?

Arctic Systems (Claudia Czimczik)

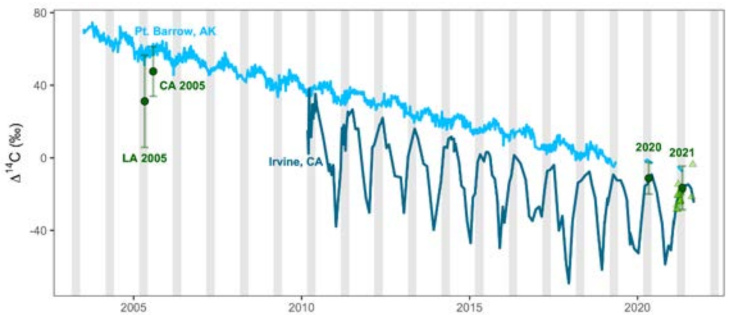


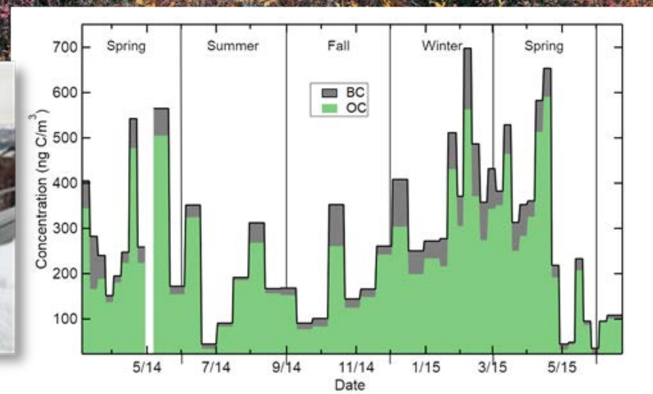
Overall Objectives

The Czimczik Group combines field observation with geochemical analyses to understand how climate change and anthropogenic activities impact C cycling and storage in (Arctic) land ecosystems, air pollution, and the global carbon cycle. Part of KCCAMS.

Ongoing studies

- Sources of winter CO_2 emissions from Arctic tundra (NSF/NASA)
- Impacts of shrub expansion on permafrost thaw (NASA)
- Sources of CO_2/CH_4 emissions from Arctic lakes (NSF/NASA)
- Organic/black C aerosol sources in the Alaskan Arctic (NSF)
- Long-term monitoring of atmospheric $^{14}CO_2$ (NOAA CRN)

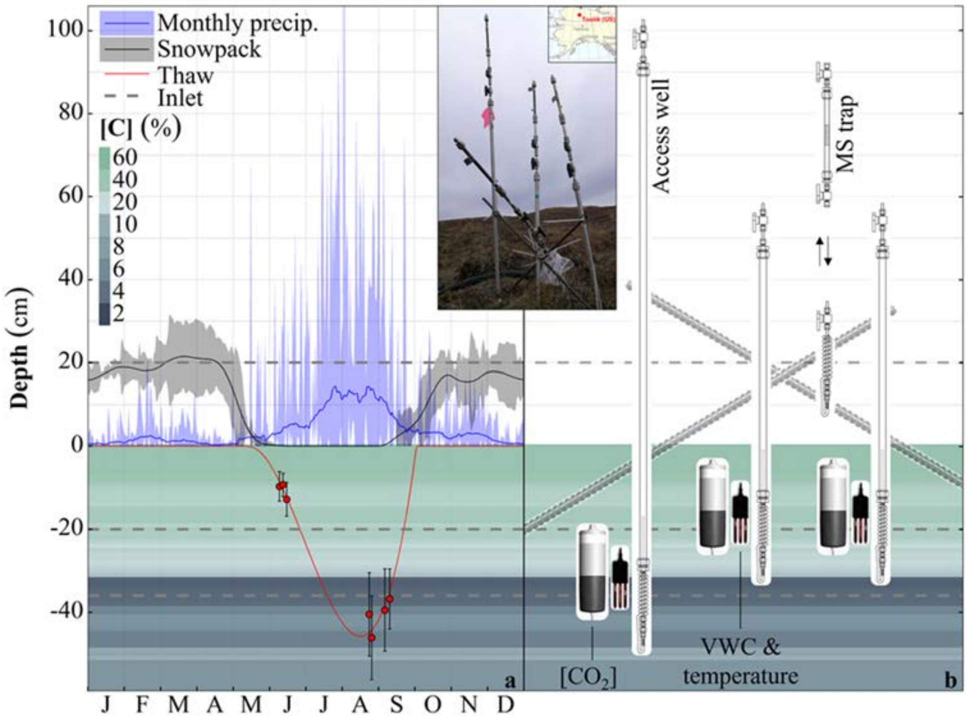


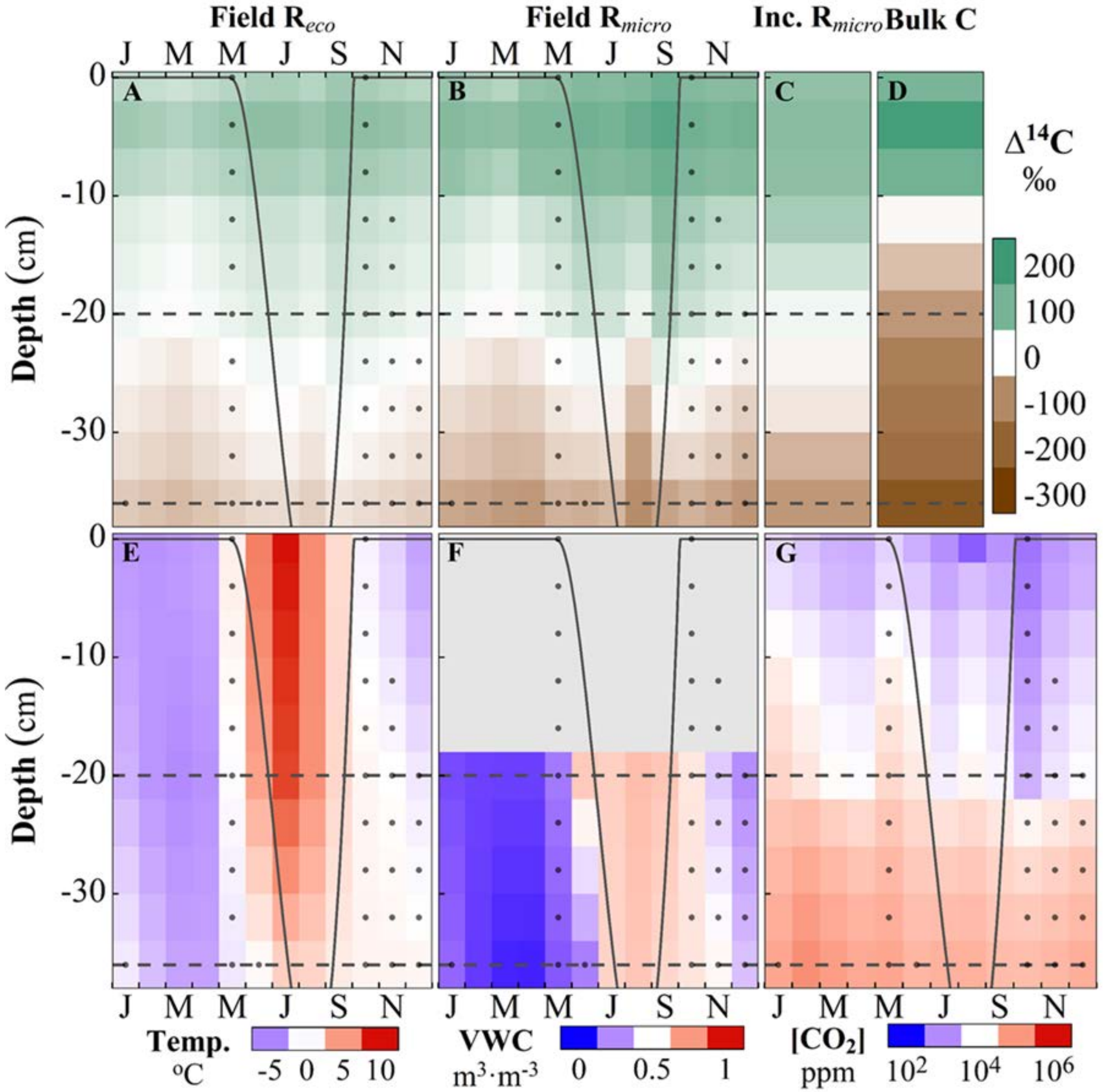


Sources of winter CO_2 emissions from Arctic tundra

First annual time-series of soil $^{14}CO_2$ reveals:

- Seasonal shift in microbial C sources from fresh plant C during the growing season to older, local soil organic matter through fall, winter, and spring; not captured in standard incubation experiments
- Fall/winter warming is not just accelerating the seasonal break-down of current plant litter, but depleting active layer and permafrost C stocks
- 1st step toward direct monitoring of permafrost C loss



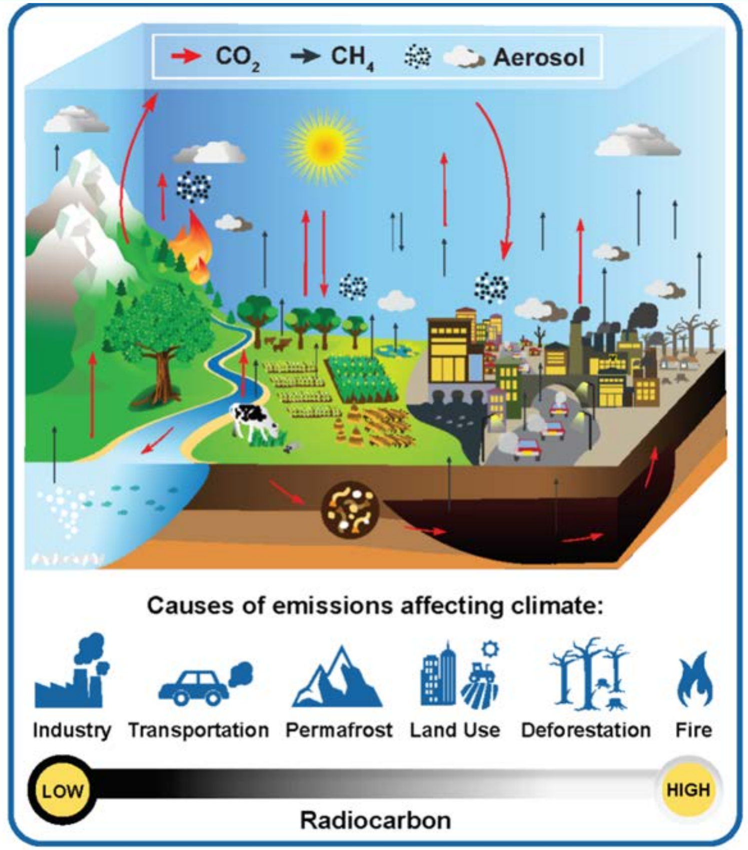


Pedron et al. 2021, Pedron et al. (In Review)

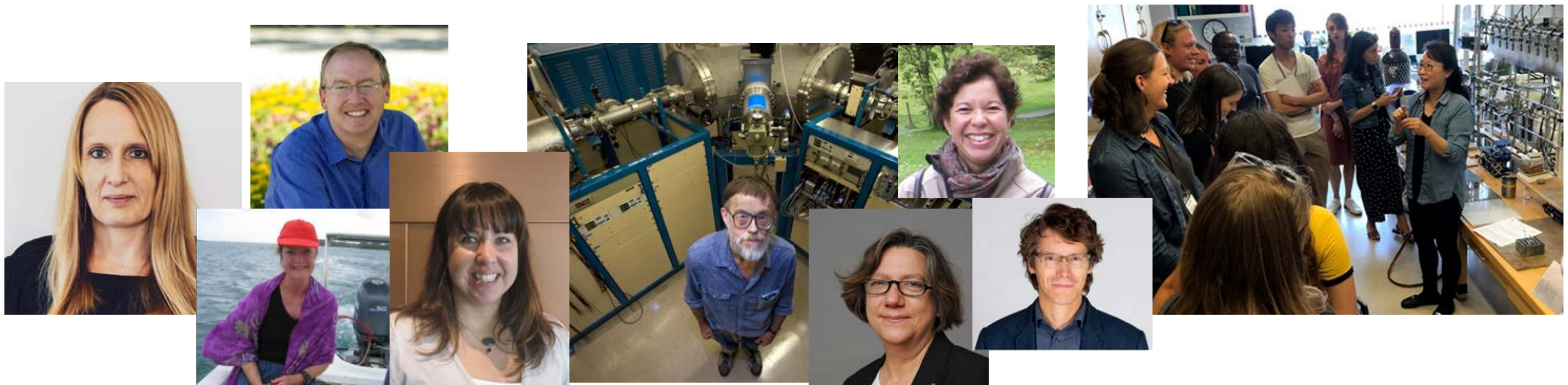
W. M. Keck Carbon Cycle Accelerator Mass Spectrometer Facility (KCCAMS)

Overall Objectives

- Radiocarbon (^{14}C) measurement facility dedicated to supporting carbon cycle research.
- Soon to be upgraded with Mini Carbon Dating System (MICADAS) to support climate change & air quality research



Affiliated Faculty & Staff

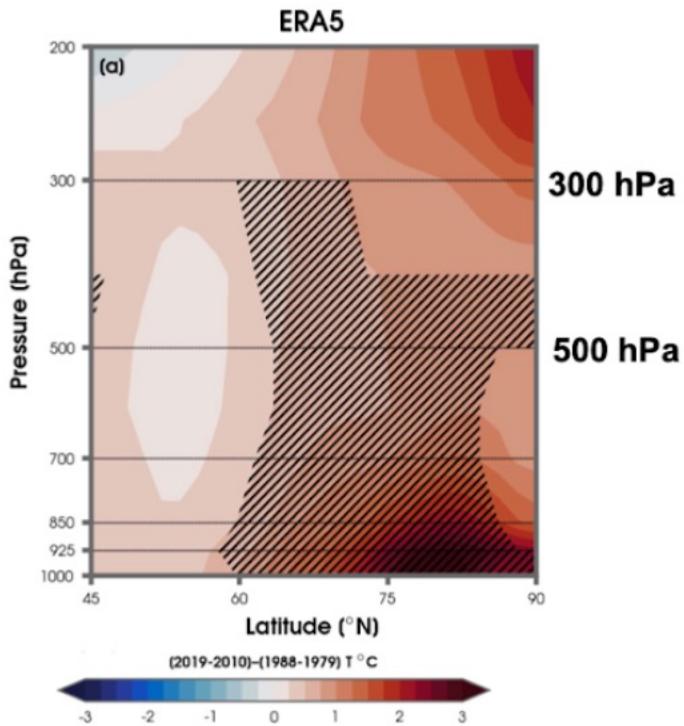


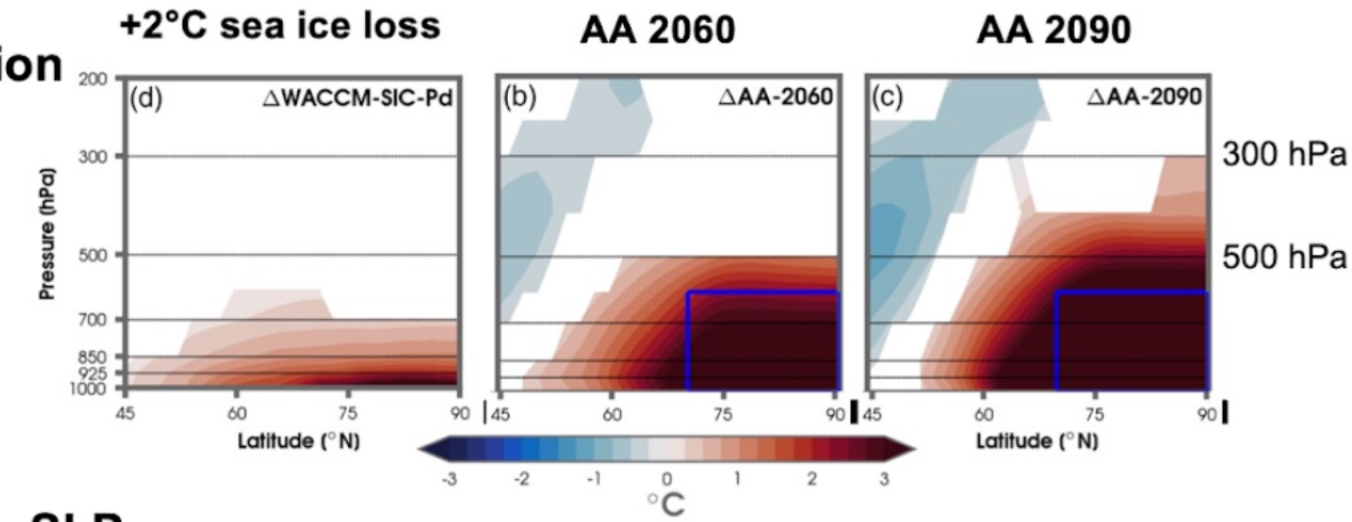
Reducing uncertainty of polar to midlatitude linkages using DOE's E3SM in a coordinated model-experiment setting. PI: Gudrun Magnusdottir (RGMA project, CMIP6 contrib)

Impact of sea ice loss vs full Arctic Amplification in DJF

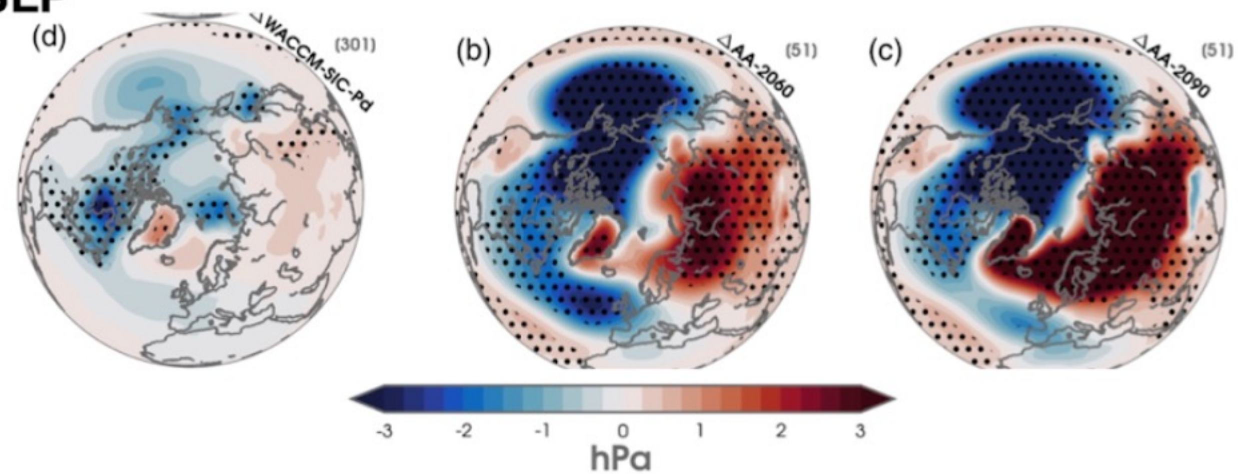
[T] cross section 45N to pole

Zonal mean T trend in obs

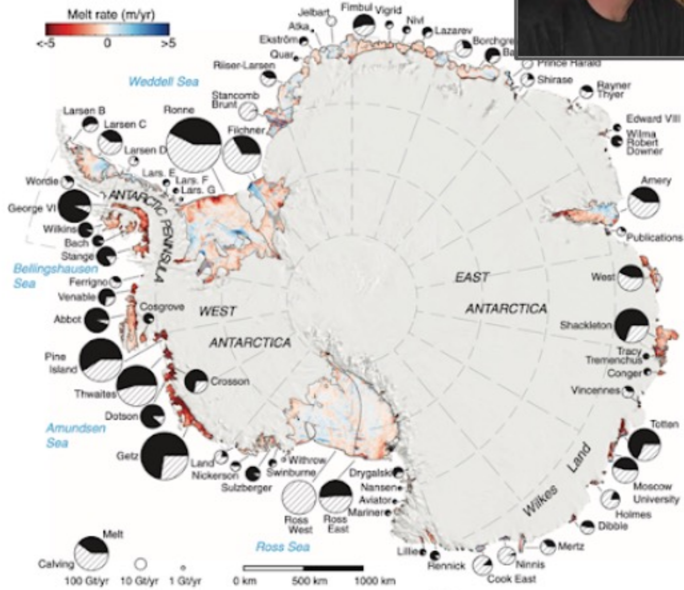




SLP

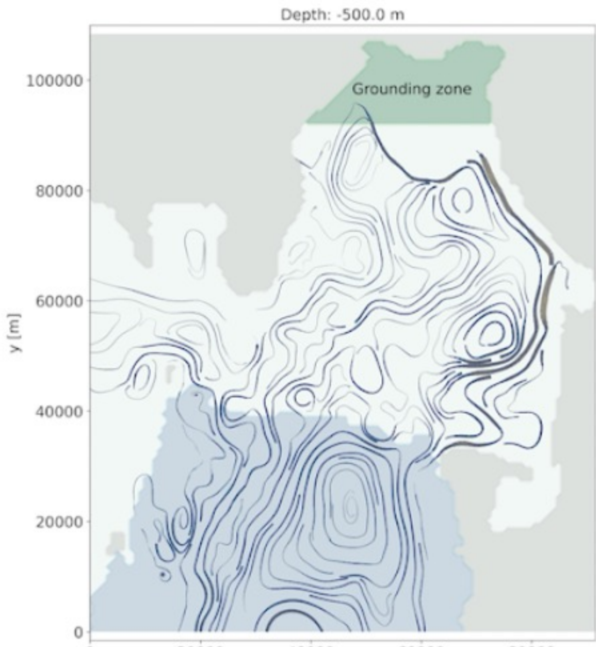


Antarctic and Arctic systems (Eric Rignot)

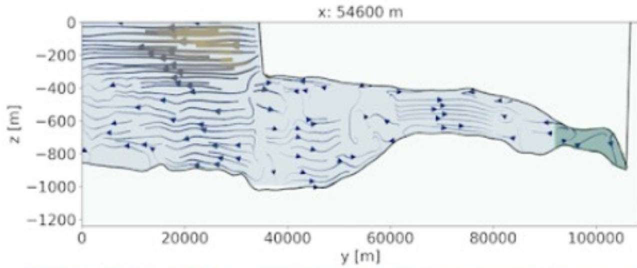


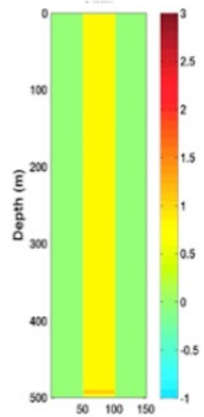
Research Objectives

Large uncertainties in projection of rapid sea level from Antarctica are caused by a lack of understanding/modeling of ice ocean interaction along ice sheet margins. We use couple ice-ocean numerical modeling, remote sensing and in situ observations of ice melt and grounding zone dynamics to study how a warmer ocean is rapidly eroding the Antarctic Ice Sheet away.



Simulation of ocean circulation in cavities





Simulation of ocean circulation at 1 m resolution

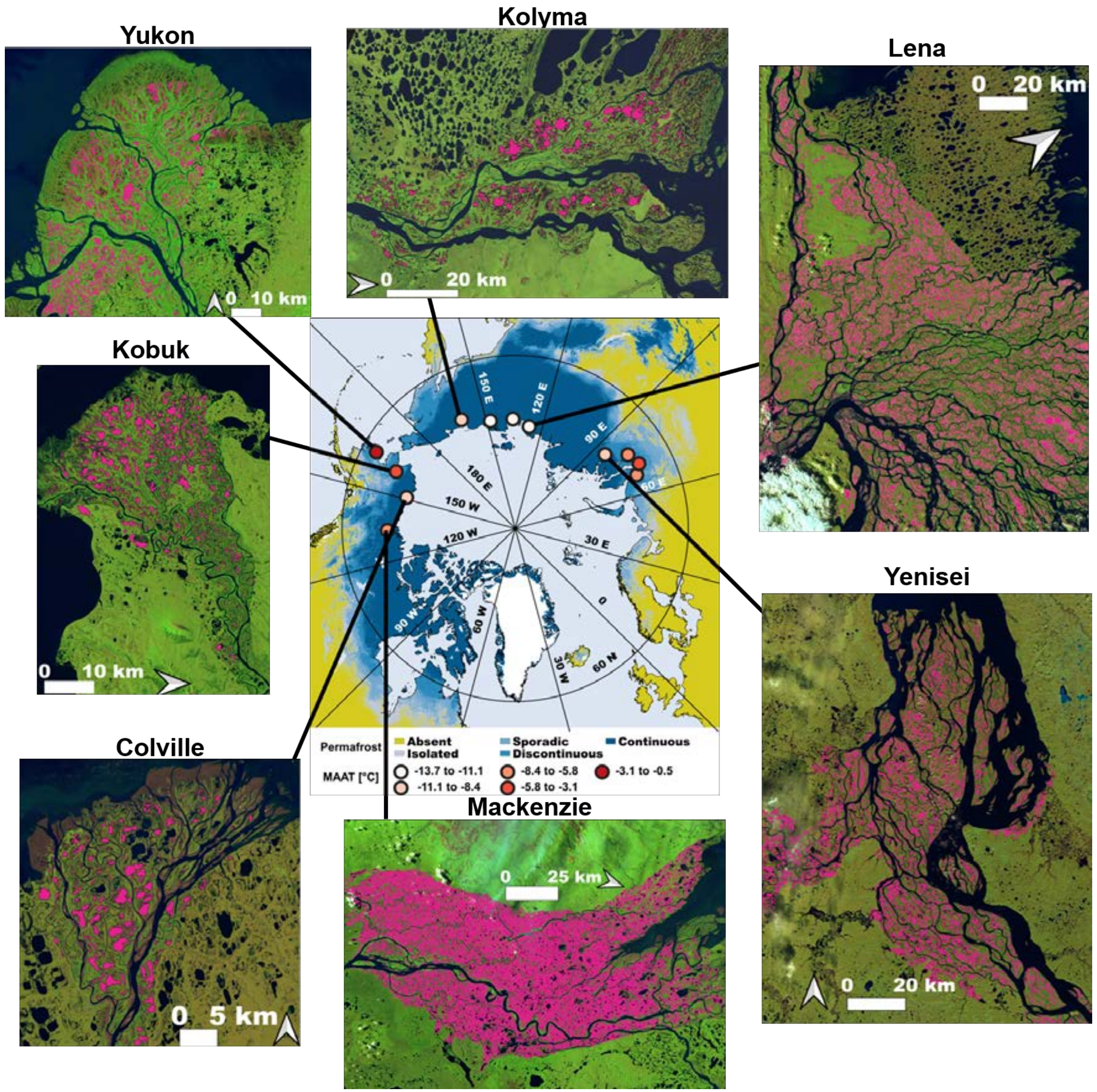
Arctic Systems (Efi Foufoula-Georgiou,)
Overall Objectives

- Stochastic modeling of surface hydrologic and geomorphologic processes.
- Modeling and estimation of space-time rainfall from spaceborne sensors, seasonal precipitation forecasting using observations and climate models
- Stochastic theories of transport on the Earth's surface, river network dynamics and hydrologic response.

Ongoing studies

- Investigate how thaw lake coverage on arctic deltas respond to climate change

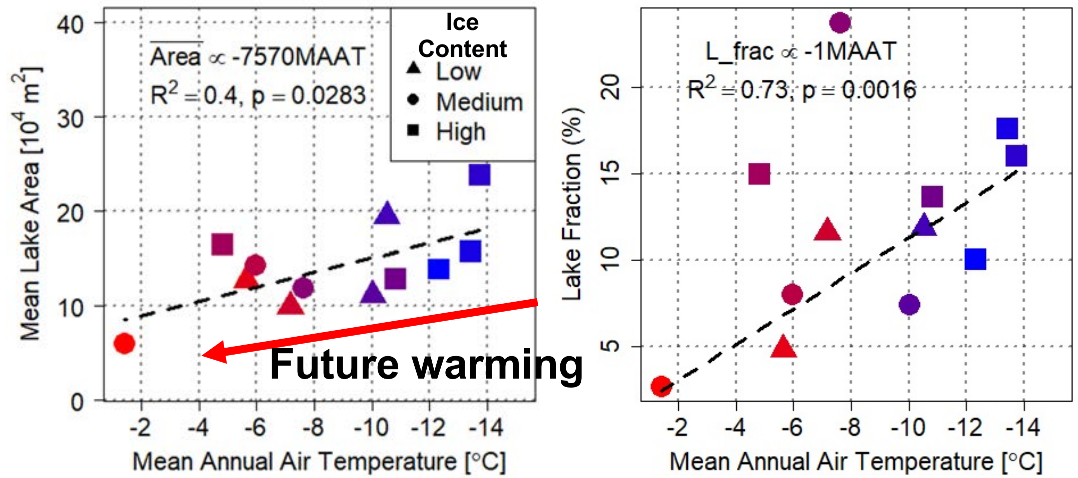
How will thaw lake coverage on arctic deltas respond to climate change?



Ice rich permafrost on arctic deltas leads to the formation of thaw lakes.

Thaw lakes modulate nutrient (C, N, etc.) and sediment delivery to the Arctic Ocean.

Projected SLR, changing hydrology, and permafrost thaw are expected to lead to complex lake cover changes.



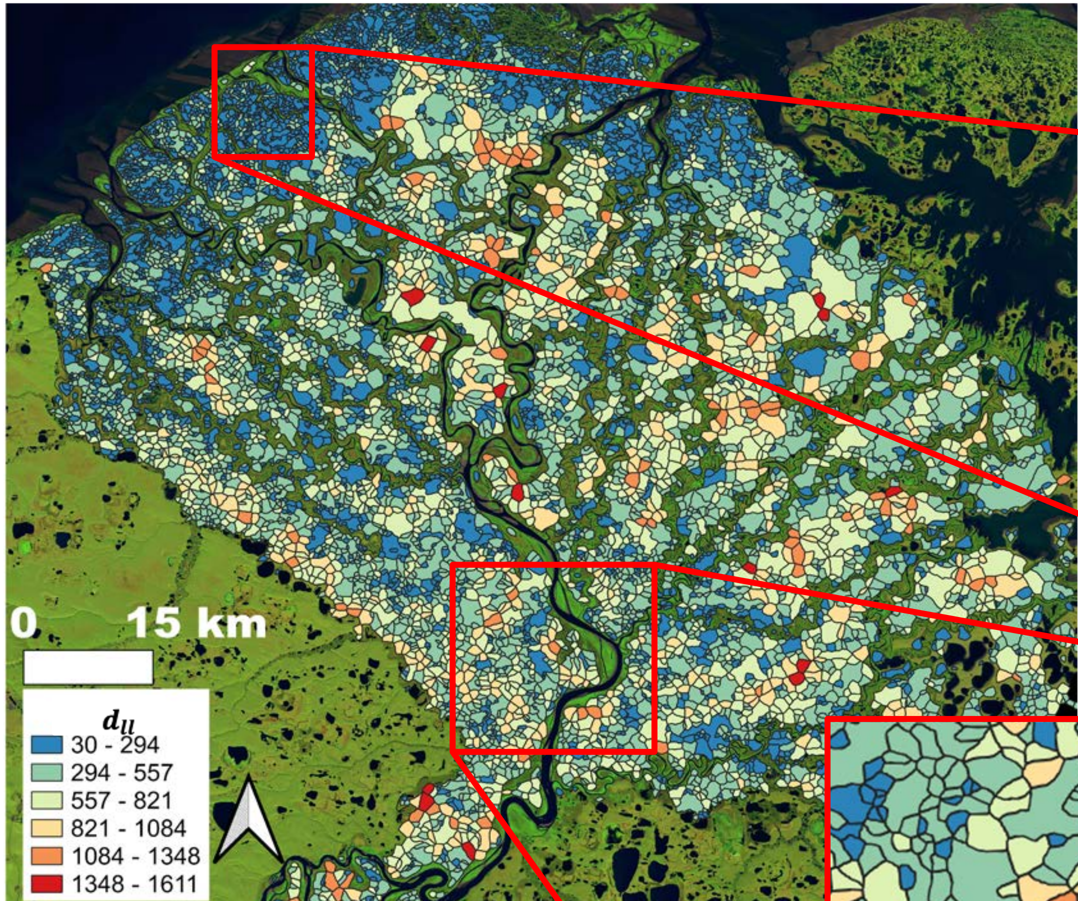
Relevant to DOE's: InteRFACE

Interdisciplinary Research for Arctic Coastal Environments

UCI PI: Foufoula-Georgiou, LANL: Rowland

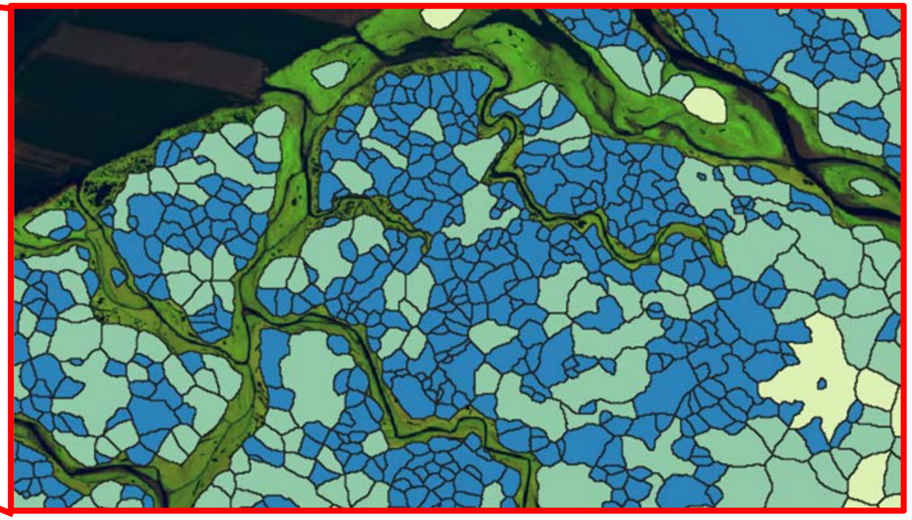
Funding: UC Lab Fees In-Residence Graduate Fellowship @ LANL

How will thaw lake coverage on arctic deltas respond to climate change?

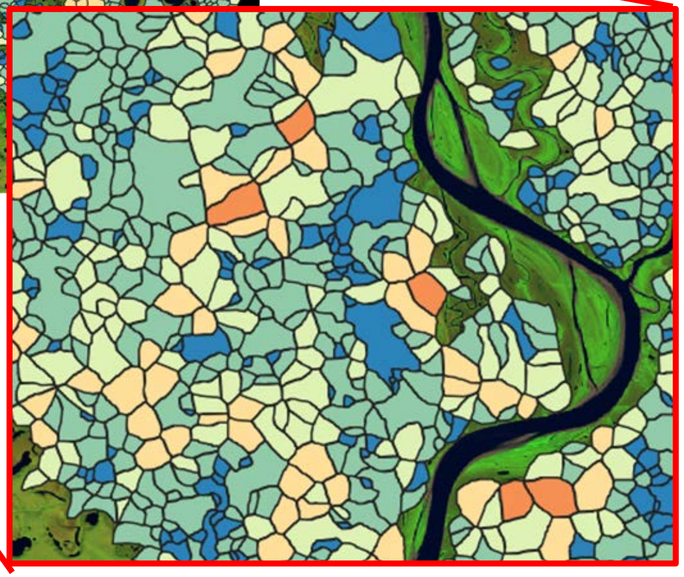


Yana River Delta, Russia
Mean Annual Air Temperature: -13.4°C
Mean Winter Air Temperature: -36.3°C

Lake sizes and spacing are spatially heterogeneous: quantify patterns for process understanding/prediction



Highly packed coastal areas more vulnerable to sea level rise than permafrost thaw



Coarsely packed upper delta is at low risk of permafrost thaw, lake development, and carbon release

Vulis et al., GRL, 2021; Vulis et al., in prep

Arctic Systems

Claudia Czimczik
faculty.sites.uci.edu/czimczik/

Efi Foufoula-Georgiou
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Eric Rignot
faculty.sites.uci.edu/erignot/

Gudrun Magnusdottir
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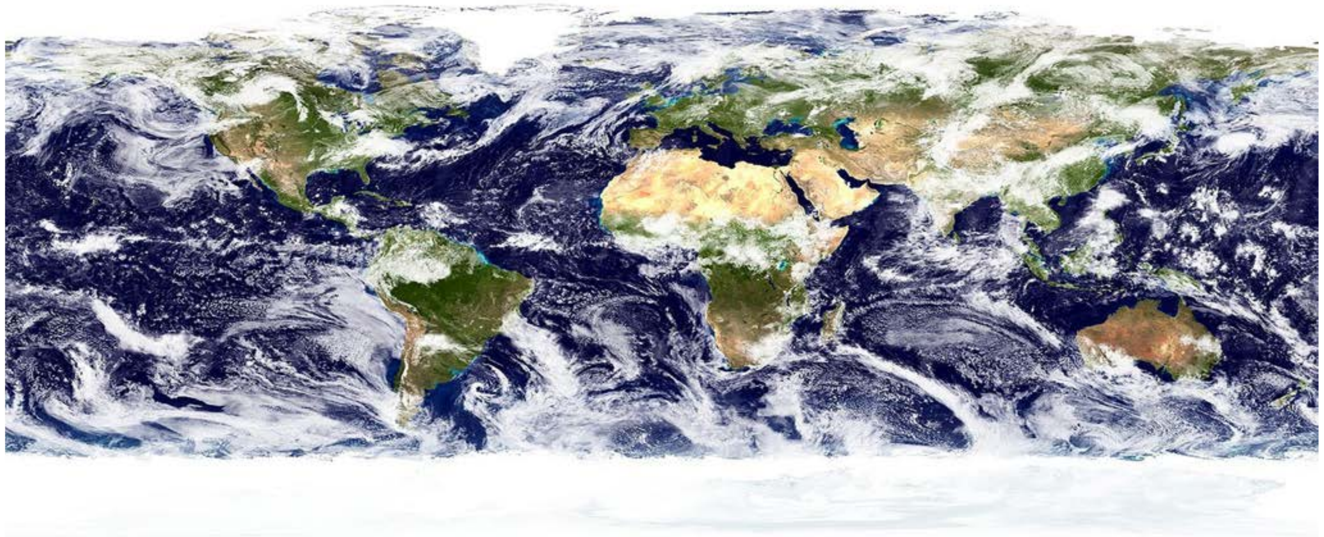
Isabella Velicogna
www.ess.uci.edu/~velicogna/pi.html

Eric Saltzman
sites.uci.edu/saltzman/eric-saltzman/

UCI

Theme: Data-driven climate science
Lead: Jim Randerson



- How do we improve the representation of clouds and other physical and biogeochemical processes in earth system models using machine learning?
- How can we use new machine learning approaches and climate observations together to improve the predictability of the Earth system?
- What are the most effective ways to decarbonize our energy systems?

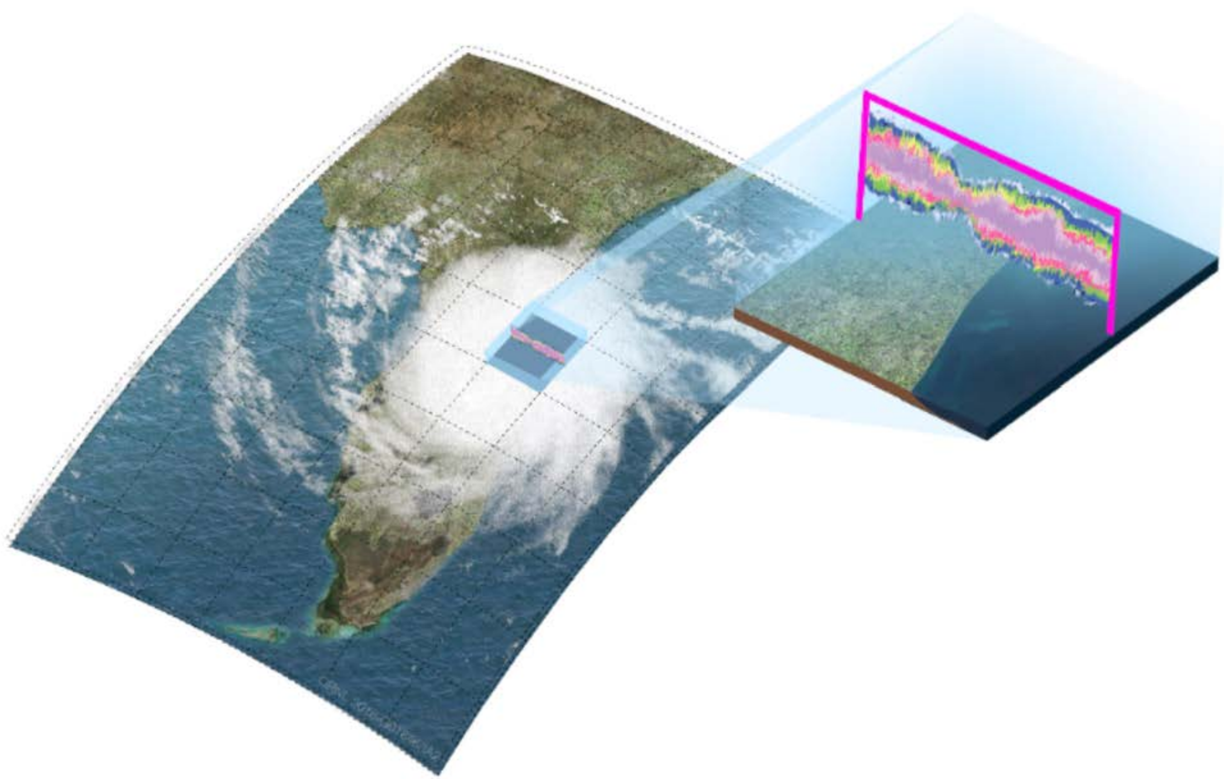
Data-Driven Climate Science (Mike Pritchard)
Overall Objectives:

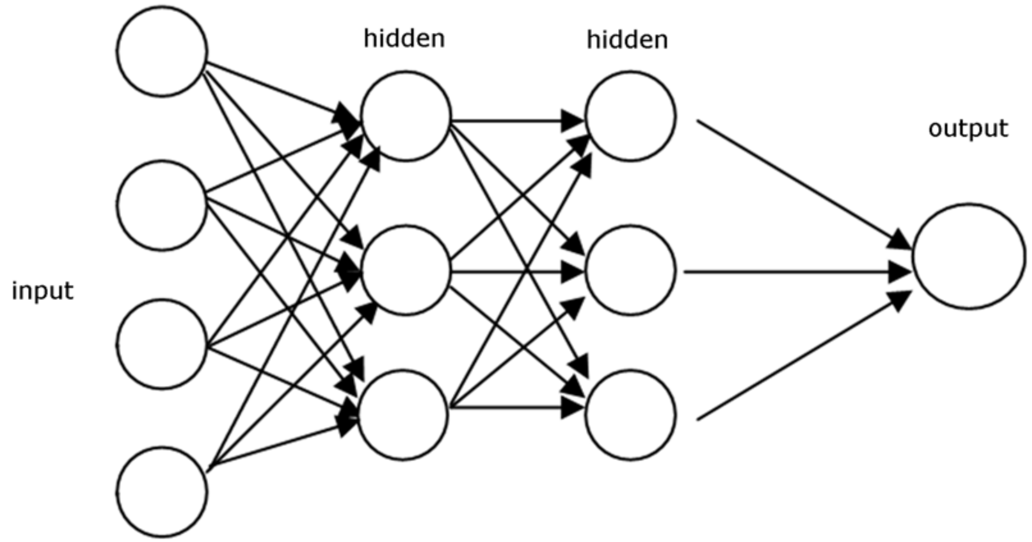
- Add explicit low cloud and boundary layer turbulence feedbacks to global models.
- Outsource hi-res physics to neural network (NN) emulators, bypass Moore's law.
- Enforce physical constraints, develop algorithms for reliable NN emulators
- Make software to bridge the Fortran-python (ML) divide to test NNs inside GCMs.

Ongoing studies:

- Explore unsupervised ML compression methods to summarize stable clusters of coherent turbulent structures in overwhelming hi-res global model output.
- Thus reveal the "latent space of turbulence + microphysics + radiation"
- Bayesian Hierarchical Variational Autoencoders for generative parameterization.

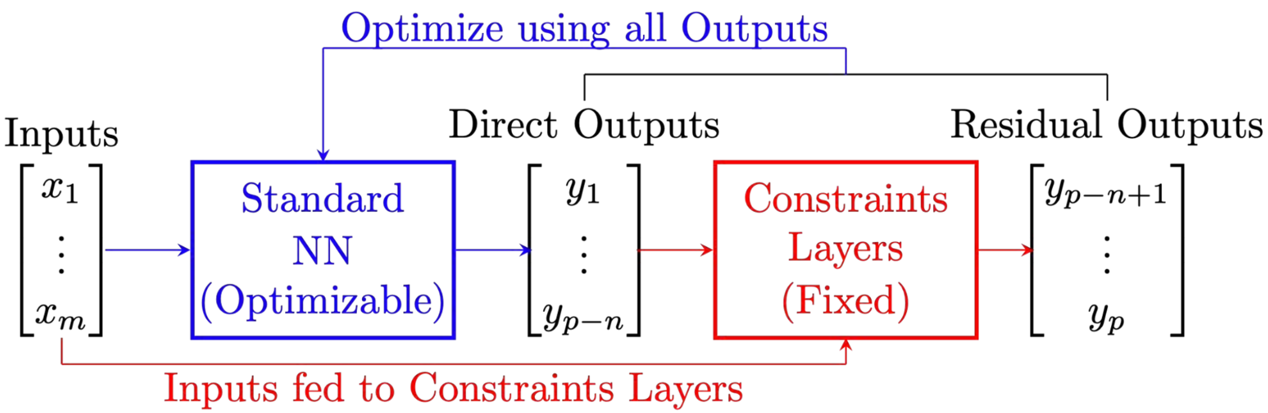
Deep learning to represent sub-grid processes in climate models.

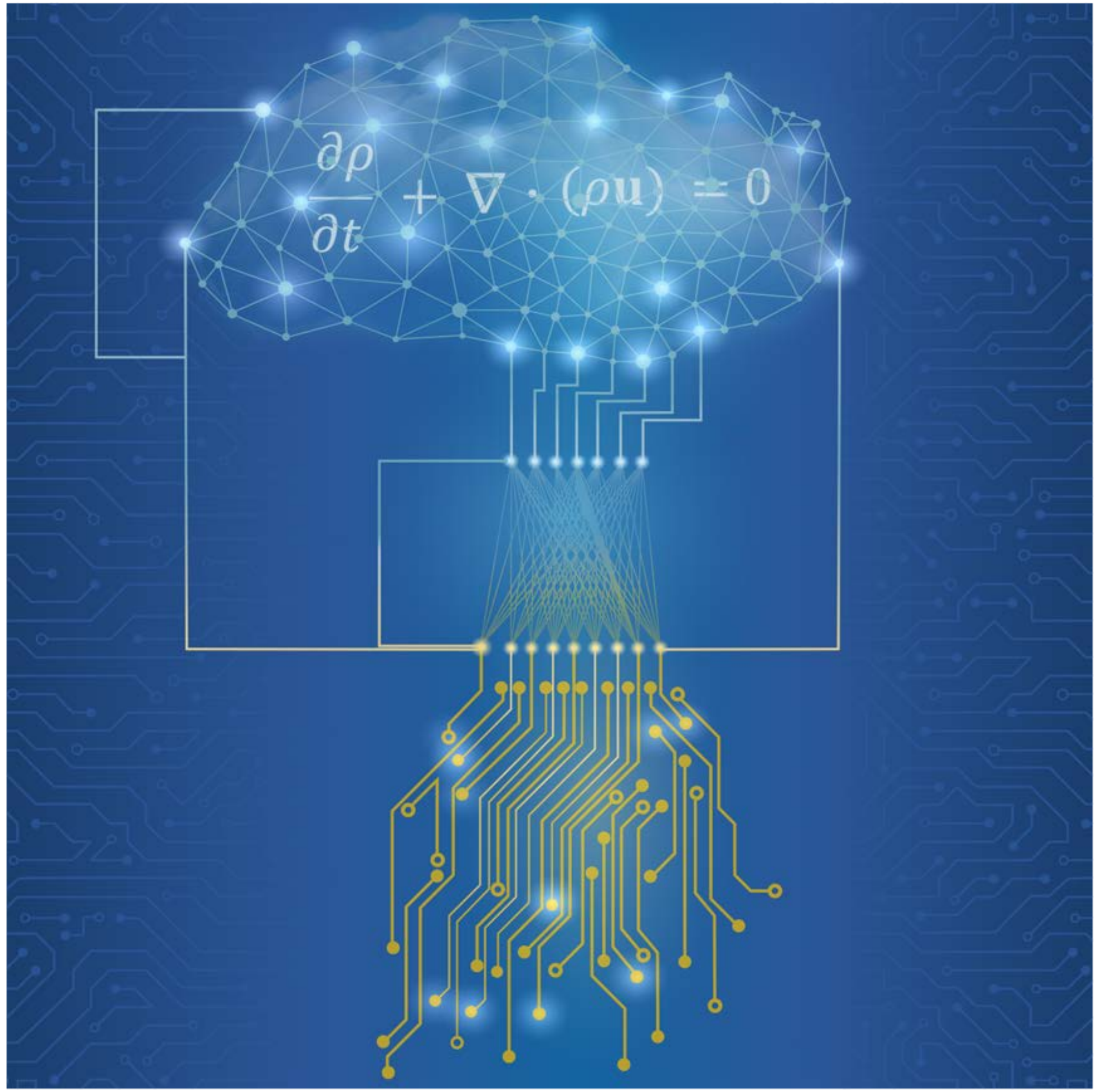




Rasp, Pritchard and Gentine, *PNAS*, 2018 (> 300 citations)

Enforcing analytic constraints in neural network emulators of physical systems.





Beucler, Pritchard et al., *Physical Review Letters* 2021 (APS Editor's spotlight).
> 50 citations.

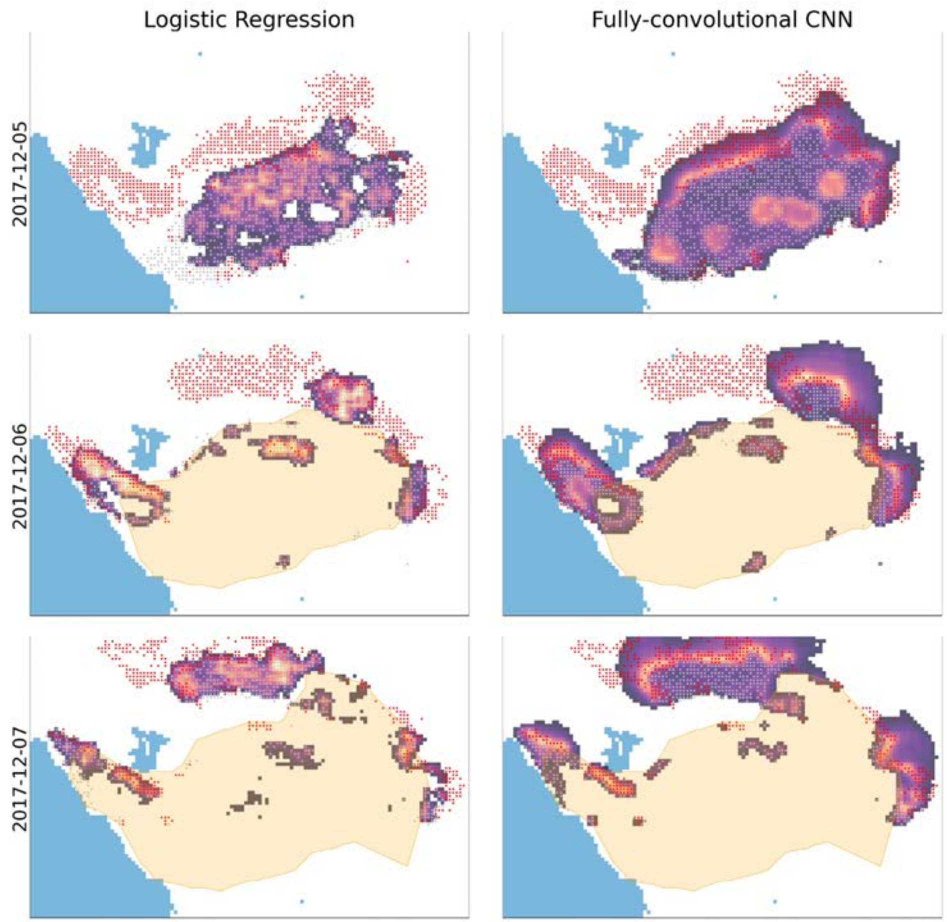
Data-Driven Climate Science (Padhraic Smyth)

Overall objectives:

- Develop and apply new machine learning approaches for climate science

Ongoing and recent studies:

- Forecasting daily wildfire spread with convolutional neural networks
- Forecasting daily wildfire activity using Poisson regression
- Machine learning to predict final fire size at the time of ignition



Data-driven climate science

Mike Pritchard
sites.ps.uci.edu/pritchard/

Padhraic Smyth
www.ics.uci.edu/~smyth/index.html

Steve Davis
www.ess.uci.edu/~sjdavis/

Amir Aghakouchak
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Jin-Yi Yu
https://www.ess.uci.edu/~yu/

Jasper Vrugt
https://faculty.sites.uci.edu/jasper/

Backup Slides

Emerging ML emulation lessons

DO:

- Explore industrial-scale hyper parameter tuning (Ott, Pritchard et al., 2020)
- Use physics to normalize inputs/outputs & perform credibility tests (Brenowitz, Pritchard et al. 2020; Beucler, Pritchard et al., in prep)
- Enforce column constraints
- Separately emulate physical processes

DON'T:

- Coarse-grain in time
- Expect constraints to buy generalization

LLNL / ORNL / Sandia / Pritchard Collab:

Sole University Partner in DOE Exascale Computing Project (PIs: Taylor, Bader)

Overall Objectives

- Port high-fidelity cloud-resolving calculations to GPU in order to:
  Run unprecedented simulations of multi-scale global climate on Summit/Aurora.
- Augment physics of embedded convection with major algorithmic refinements.

Ongoing studies

- Exploit these data for ever more ambitious NN emulators of sub-grid climate physics.
- Use VAE-haloing techniques to hedge against out of sample extrapolation (new BNL collab)

UCI

PNNL / Pritchard Collab:

Overall Objectives

- Refine a new parcel model - trained neural network emulator of aerosol activation.
- Cut cost of high-fidelity kinetics-based benchmarks of aerosol-cloud interaction (ACI)
- Exploit UCI “Fortran-Keras Bridge” software to test within E3SM climate model.
- What is the effect of adding these missing physics on overall global ACI?

Ongoing studies

- Test limits of semi-automated brute-force hyperparameter tuning to optimize fit.
- Industrial-scale architecture searches for improved NN fits.

ENABLING AEROSOL-CLOUD INTERACTIONS AT GLOBAL CONVECTION-PERMITTING SCALES (EAGLES)

New ASCR SCM award spanning UCSD / UCI / Columbia
Re: ML for scientific discovery

Lead PI: Rose Yu (UCSD)

UCI partners: Mandt (ICS)

and Pritchard (ESS)