Climate Futures for Ecohydrological Modeling of Emerging Fire Regimes in Central Coast California

Authors

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Client

UC Disaster Resilience Network + UCSB Natural Reserve System collaborative | Project: Building Resilience to Wildfires

Key Personnel

Marion Wittmann, PhD, Executive Director of UCSB Natural Reserve System, marion.wittmann@ucsb.edu (co-lead Building Resilience to Wildfires)

Sarah Anderson, PhD - Professor - | Bren School of Environmental Science and Management, seande@ucsb.edu Director of the UC Disaster Resilience Network (co-lead Building Resilience to Wildfires)
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Naomi Tague, PhD | Professor - | Bren School of Environmental Science and Management | tague@ucsb.edu | 805-893-8579 (lead on RHESSys modeling for Building Resilience to Wildfires)

OBJECTIVES

The overall objective of this MEDS project will be to use meteorologic data to develop a range of potential climate scenarios that could be used by the Tague Team Lab's Regional Hydro-Ecologic Simulation System (RHESSys) to model future fire regimes in the Central Coast Region of California. Specific objectives include:

1. Analyze future climate scenarios using downscaled climate model predictions from Cal-Adapt for the Santa Barbara Central Coast region to provide a statistical summary of the range of likely climate futures.
2. Develop an interactive tool that will allow scientists to quickly extract or construct climate scenarios with specific characteristics that they may want to explore, generate RHESSys inputs for selected scenarios, and visualize possible climate scenarios for communication with other project scientists and stakeholders.
3. Time permitting, apply the climate scenario inputs to RHESSys and analyze model estimates of changing hydrology, vegetation growth and fire regimes for selected test scenarios.

SIGNIFICANCE

The information derived from *Building Resilience to Wildfires* activities will enable characterization of fire behavior and prescribed burn effectiveness in regions like Napa, Santa Barbara, and Orange Counties, and other coastal environments that are currently experiencing catastrophic wildfire events. The MEDS project will make an important contribution to this larger project by analyzing, generating and visualizing potential climate change scenarios that will be used to estimate future fire risk, along with the likely effectiveness of different fuel treatment options.

BACKGROUND

Climate-related environmental change in California is causing increased fire risk with significant impacts to our natural environment and the agricultural, commercial, and municipal uses of our landscapes. Fuel management to reduce the severity of wildfires along with planning to help communities adapt to changing fire regimes is needed. *Building Resilience to Wildfires* is a project funded by the Moore Foundation that brings together scientists from the UC Natural Research System, the UC Disaster Resilience Network, and fire researchers at UCSB. A central component of this project is ecohydrologic modeling of future fire regimes that will help target fuel management and climate adaptation strategies. To develop estimates of future fire, water and vegetation health, *Building Resilience to Wildfire*s will use RHESSys-Fire, a science-based mechanistic model that integrates models of hydrology, vegetation growth, carbon and nutrient cycling with fire spread and fire effects. RHESSys has been widely used to estimate climate impacts on fire regimes in forested watersheds in the California Sierra and Pacific Northwest, as well as impacts on surface water, groundwater recharge and vegetation health (Burke et al., 2021, Kennedy et al., 2021, Hanan et al., 2021). In the *Building Resilience to Wildfire* project, RHESSys-Fire will be applied within the California Coastal region to develop a set of future fire scenarios conditioned on best available estimates of climate trajectories for the next 2 decades and a set of fuel treatment scenarios. A key question – and one that this MEDS project is designed to answer – is what future climate scenarios we should use.

EQUITY
The analysis and summary of climate scenarios for this project will provide information that will be relevant to many communities within the Central Coast region facing a rapidly changing climate. While a primary focus of the capstone is providing scenarios to support the next steps for RHESSys modeling of fire, the climate scenarios themselves will provide information that can be used more generally to inform climate adaptation and to create visual materials that are a central part of *Building Resilience to Wildfires* community outreach. The UC Disaster Resilience Network partner is oriented towards community outreach and can make use of climate visualizations that are accessible to stakeholders of various backgrounds. Communities with more educated residents and higher income residents tend to attract more federal preparedness resources, in part because they are better able to access information and to organize. Given this, it is imperative that we provide climate scenarios (and materials to communicate those scenarios) that are easily accessible to a broad community to reduce those costs and facilitate more equitable climate resilience.

DATA
The primary data for this project will be existing meteorologic data from weather stations in the Santa Barbara region and Cal-Adapt downscaled climate model data (note: Cal-Adapt provides data from multiple climate models). We will also supplement Cal-Adapt scenarios with newly available high resolution climate model output generated by regional climate scientists in the UCSB Geography department as part of the *Building Resilience to Wildfire Initiative.* This data is already available (Zigner et al., 2022) but would need to be simplified (using numerical methods) to be usable for RHESSys simulations. One option is to use patterns found in the high resolution data (e.g changing wind distributions) to refine Cal-Adapt scenarios. Students will consult with climate scientists as part of the *Building Resilience to Wildfire Initiative* to discuss potential strategies.

COMPUTATIONAL TOOLS & NEEDS
This project will require data-storage for climate datasets, and for RHESSys climate inputs generated from student analysis of climate data. We will use a dedicated UCSB Box folder associated with the *Building Resilience to Wildfire Initiative* for this storage.

Computation analysis of the climate data can be done in a variety of different programming languages. Our preference will be to use R, as many of the RHESSys input-output tools have used it. R also provides packages (e.g. Shiny) that can be used to develop interactive tools to visualize climate scenarios and allow scientists to design/select climate scenarios of interest; however, we are open to other data-science tools (e.g. Python).To develop hypothetical climate scenarios that combine features from the high-resolution modeling and from Cal-Adapt scenarios, there are a variety of statistical analyses that can be used; for example, R has a stochastic weather generation package (MetGen). There are also statistical downscaling techniques that can be used (e.g. Tabari et al. 2022).

POSSIBLE APPROACHES
The client will work with students to decide on selection criteria for future climate scenarios. This can be an interactive conversation – students can present their analysis of Cal-Adapt climate model output and historic meteorology (from local station data) to generate discussion with project scientists on particular scenarios that might be important to consider (e.g. rare but high risk scenarios). Students will also meet with project directors to define visualization objectives for community outreach. Tague (and other project scientists) will provide guidance on types of future climate scenarios that may be most useful to drive RHESSys estimates of future fire regimes (and water availability and vegetation health) scenarios.

To develop a library of climate scenarios, the students may use the downscaled climate inputs from specific models from the Cal-Adapt library directly. For other scenarios, however, students will need to sample and generate 'hypotheticals' such as scenarios that replicate the recent drought but with warmer temperatures. We may also want to generate scenarios that include extreme events (such as the high rainfall intensity that caused the Montecito Mudslides). To do this, students can explore statistical downscaling/sampling approaches and stochastic weather generation tools that preserve the main features of the climate time series such as the season distribution of rainfall or temperature and ensure that "hypothetical" scenarios are physical realistic.

DELIVERABLES

1. **Analysis of Cal-Adapt scenarios for study region**, including means, trends, and extremes. The group will compare these scenarios with historic patterns from meteorological station data for the region.
2. **Visualization of possible climate futures**
    a. Interactive visualizations for scientists who will want to be able to easily compare how climate variables that drive vegetation (fuel) growth variables (e.g. precipitation and temperature) and fire spread (e.g. wind speed) are likely to change.
    b. A climate scenario visualization for stakeholders where the focus will be on communicating means, uncertainty and possible extremes in an easy to understand format.
3. **An interactive tool** that allows users to: (1) select predetermined climate scenarios or generate 'hypothetical' scenarios based on specific model criteria (e.g. a scenario that shows an 'moderate' temperature increase or a scenario where a drought is followed by extreme rainfall), (2) generate RHESSys inputs for the selected or generated climate scenarios, and if time permits, (3) allow users to modify some Cal-Adapt scenarios to include information about wind and other find resolution climate patterns from UCSB Geography Departments regional climate models.

    The team should provide user documentation and a developer's guide to the tool that could be utilized to modify the tool to apply to other regions. The team will also conduct usability testing with the TagueTeamLab group where the tool will be used to generate RHESSys inputs. TagueTeamLab staff will then run RHESSys for 2-3 of climate scenarios generated by the capstone project as a test and provide capstone members with sample RHESSys output. Given the potentially broad applicability of the climate scenario generation tool, the TagueTeamLab will include the tool as part of the RHESSys family of pre-and post-processing tools on its RHESSys Git-hub site. We will also include documentation on the RHESSys Wiki.

AUDIENCE

The initial audience for the capstone will be the scientists and other team members who will make use of climate scenarios as part of the *Building Resilience to Wildfires* project. The climate data tool will be particularly relevant to project team members involved in RHESSys-Fire simulation implementation (RHESSys-Fire simulations for the project will be undertaken by a project post-doctoral scholar under supervision by Tague) but will also be used by the broader project team, including project leads (Marion Wittman and Sarah Anderson), who guide overall project goals and will participate in climate scenario selection.

We also anticipate that climate scenario visualization developed by the capstone will be used as part of community outreach materials. Additionally, the broader RHESSys-Fire user community will benefit from interactive tool that can translate Cal-Adapt and other climate model output into RHESSys ready inputs.

Citations

Burke, W. D., Tague, C., Kennedy, M. C., & Moritz, M. A. (2021). Understanding how fuel treatments interact with climate and biophysical setting to affect fire, water, and Forest health: A process-based modeling approach. *Frontiers in Forests and Global Change*, *3*, 591162.

Hanan, Erin J., Jianning Ren, Christina L. Tague, Crystal A. Kolden, John T. Abatzoglou, Ryan R. Bart, Maureen C. Kennedy, Mingliang Liu, and Jennifer C. Adam. "How climate change and fire exclusion drive wildfire regimes at actionable scales." *Environmental Research Letters* 16, no. 2 (2021): 024051.

Kennedy, M. C., Bart, R. R., Tague, C. L., & Choate, J. S. (2021). Does hot and dry equal more wildfire? Contrasting short-and long-term climate effects on fire in the Sierra Nevada, CA. *Ecosphere*, *12*(7), e03657.

Zigner, K., Carvalho, L. M., Jones, C., & Duine, G. J. (2022). Extreme winds and fire weather in coastal Santa Barbara County, CA: An observational analysis. *International Journal of Climatology*, *42*(1), 597-618.

Tabari, H., Paz, S. M., Buekenhout, D., & Willems, P. (2021). Comparison of statistical downscaling methods for climate change impact analysis on precipitation-driven drought. *Hydrology and Earth System Sciences*, *25*(6), 3493-3517.

Budget Justification

All of the data needed for this project is publicly available or will be provided by the clients (e.g high-resolution climate output). Computational software needed for the project is also freely available. Thus we do not anticipate any additional costs. Clients are local so meeting can be done either in person or by zoom.

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October 12, 2022

TO: Bren School Master of Environmental Data Science Capstone Project Committee

FROM: Marion Wittmann, Executive Director, UC Santa Barbara Natural Reserve System

RE: Climate Futures for Ecohydrological Modeling of Emerging Fire Regimes in Central Coast California

To the Bren MEDS Capstone Project Committee,

I am writing to confirm my support for the MEDS capstone project entitled "**Climate Futures for Ecohydrological Modeling of Emerging Fire Regimes in Central Coast California".** The proposed project is a unique opportunity for Bren students to work directly with UCSB faculty, and environmental and management professionals and experts on the development of climate modeling and visualization tools. The outcomes of this project will not only contribute to the body of knowledge concerning wildfire resilience and climate forecasting, as well as the ability for land managers, including those of the UC Santa Barbara Natural Reserve System, to sustainability steward critical habitats, but will also enhance students' skill sets via direct experience working in these areas.

I also commit to regular interaction (2-3 times per quarter) with MEDS capstone to provide input on climate scenario visualization for stakeholders. I strongly support the selection of this important project and look forward to this collaboration.

Sincerely,

Marion Wittmann, PhD
Executive Director
UC Santa Barbara Natural Reserve System

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October 12, 2022

I am writing to confirm my support for the MEDS capstone project entitled "**Climate Futures for Ecohydrological Modeling of Emerging Fire Regimes in Central Coast California".** I am very excited about this project. The climate scenario analysis, generation and visualization will be a valuable contribution to "Building " and more broadly to the use of RHESSys (and other models) to develop insight into possible futures for the Central Coast and elsewhere.

I also commit to regular interaction with MEDS capstone to provide guidance on criteria for climate scenarios, possible strategies for generating hypothetical (but meaningful) scenarios and meeting RHESSys requirements.

Sincerely,

Naomi Tague

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