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University of Washington Program on Climate Change
Summer Institute, 11-13 September 2019 at Friday Harbor Marine Lab

Climate Change Impacts on 21st Century Food and Water Security

Invited Talks

Floods, Fish, and People: Food-Energy-Water Challenges & Opportunities in the Mekong River Basin

Gordon W. Holtgrieve
School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA

One of the greatest challenges facing humanity is maintaining the critical ecosystem goods and services human societies depend on in the face of an expanding human population and increasing global environmental change. More than any other ecosystem, freshwaters are experiencing the full suite of environmental transformations, including habitat alterations, pollution, climate change, and over-exploitation. The Mekong is a paragon for studying global alterations to freshwaters, with looming changes from hydroelectric dams, climate change, and deforestation. I will present a combination of evolving theory on how riverine Food-Energy-Water systems should be viewed in development context, critical unanswered scientific questions for sustainability, and ongoing research by our group to address these questions. Our ultimate goal is to develop a better understanding of how energy policy, watershed hydrology, and ecosystem function interact to maintain the exceptionally high productivity of Mekong, and from this, enable stakeholders to mitigate the effects of future hydrologic and climatic changes on the river's ability to provide food and nutrition for people.

Crop simulation models for assessing climate impacts and adaptation strategies in agriculture

Soo-Hyung Kim
School of Environmental and Forest Sciences, University of Washington, Seattle

Crop simulation models have become critical tools for assessing climate impacts and developing adaptation strategies in agriculture. Numerous process-based crop models exist with

a wide range of purpose, use, and complexity. A brief background and basics of process-based crop simulation models are introduced. Process-based crop models (PBCMs) simulate growth, development, and performance of a crop plant by modeling its underlying physiological processes (e.g., photosynthesis, transpiration, respiration, organ development, and assimilate transport) and their coordinated integration into the whole-plant behavior. Most PBCMs are explanatory models by nature as they integrate sub-models that represent the mechanisms and processes at lower levels of biological organization into the whole-crop and crop systems level responses. PBCMs are useful to investigate the integrative effects of multiple plant processes and their interactions with environmental, management, and genetic factors. Recent research in applying PBCMs for evaluating climate-crop relationships is introduced.

Interactions between Climate Variability and Agricultural Activities in South Asia

Deepti Singh
School of the Environment, Washington State University, Vancouver, WA

South Asia is a region where climate and agriculture are intimately linked. The South Asian summer monsoon is the predominant source of rainfall for the Indian subcontinent, where approximately 60% of the total agricultural area is still rainfed. This dependence on rainfall makes the region's agricultural production particularly sensitive to rainfall variability. In addition to variability in total seasonal rainfall, rainfed agriculture is also sensitive to shorter-term variability in the form of wet and dry spells that occur within the monsoon season. In this talk, I will discuss the observed changes in seasonal and daily rainfall variability characteristics and their implications for agricultural activities in the region.

These changes have been accompanied by a transformation of the atmospheric composition (greenhouse gases and anthropogenic aerosol emissions) and regional land-surface conditions, driven largely by industrialization and agricultural expansion and intensification for food, fuel, and fiber. Across the Indo-Gangetic basin and central India, over 80% of the land-surface has been modified for agriculture and these croplands are heavily irrigated for much of the year. While several studies link the observed changes in rainfall patterns to changes in the atmospheric composition, particularly to increasing anthropogenic aerosols over South and East Asia, I will also discuss emerging research that identifies a potentially substantial role of these land-cover and land-management decisions on observed South Asian rainfall patterns.

By discussing the influence of agriculture-driven land-surface changes on South Asian climate and the influence of these changing climatic conditions on agriculture, I will demonstrate the relevance of considering these climate-agricultural interactions for policy decisions in the region.

Adapting Food Systems to 21st Century Climate: from Systematic to Transformative Change

Brian Smoliak
Two Degrees Adapt, LLC

Humanity achieved enormous material progress and improved most quality of life indicators over the course of the 20th century. But these gains have tended to come at the expense of natural capital, the resources and services that ecosystems provide. Climate change and other environmental crises are symptoms of a fundamental failure to account for the value of healthy ecological, social, and cultural systems. As a subset of the economy, food systems are no exception to these trends. Absent action to curtail greenhouse gas emissions, increasing climatic constraints make adaptation unavoidable. This presentation conceptualizes climate adaptation and features examples drawn from modern food systems, each with its own set of intended economic, environmental, social, and cultural impacts. In the 21st century, humanity will flourish to the extent that we can muster the will and resources to appropriately select, test, and scale adaptive technologies and strategies.

Beyond grains: Considering climate change impacts across food system components

Michelle Tigchelaar
Center for Ocean Solutions, Stanford University

Most of the research on climate change impacts on food production has centered on the yields of staple crops – corn, wheat, rice, soy – because of their dominance in global food production and central role in providing basic access to calories. But while the percentage of undernourished people globally is falling, hidden hunger and obesity are on the rise. Fruits, vegetables, and aquatic foods are all contributors of important micronutrients, yet global production of these food groups falls short of recommended dietary intakes. Climate change threatens the quality and quantity of production of these foods, as well as the livelihoods and health of the people engaged in these labor-intensive sectors. In this talk I will discuss two examples of ongoing work on the climate change impacts on these understudied production systems. Firstly, I will look at the impacts of rising heat extremes on the more than one million workers involved in crop production in the United States. We find that only with radical adaptations in on-farm operations can health risk be reduced. Secondly, I will explore the environmental and market linkages between terrestrial (crop, livestock) and aquatic (fisheries, aquaculture) food production systems, and how climate change may disrupt those. A better understanding of food system connectivity is needed to pro-actively plan for a resilient and equitable future of food.

Adapting agriculture to a changing climate

Nathan D. Mueller
Department of Earth System Science, University of California, Irvine

The dependence of agricultural systems on favorable climate conditions represents one of humanity's greatest vulnerabilities to climate change. Efforts to adapt to shifting conditions via changes in management could mitigate climate-induced harm, or, conversely, take advantage of climate-induced benefits. Here I will describe the concept of adaptation as it applies to agricultural systems and share recent research that seeks to identify adaptation priorities for agricultural systems and detect whether adaptation is already occurring. First, I will present a global-scale assessment of irrigated agriculture's dependence on snowmelt water resources, identifying basins where water management adaptations will be required to sustain production in light of changes to the timing and magnitude of snowmelt runoff. Second, I will demonstrate how rainfed agricultural systems are "migrating" across the globe in an adaptive manner to minimize exposure to hot and undesirable growing conditions. Third, I will show how changes in US maize planting dates and cultivars are significantly more beneficial in recent years, indicating ongoing adaptation to climate change. Together, these studies indicate that farmers and water managers can and must adapt to climate change via a range of management options, including by altering cultivar choice, planting dates, cropping locations, and reservoir management.

Posters

1.Multidecadal Climate Response of Outlet Glaciers in Northwestern and West Central Greenland

Taryn Black[1,2], Ian Joughin[2]
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[2] University of Washington, Polar Science Center, Applied Physics Laboratory; Seattle

Marine-terminating outlet glaciers of the Greenland Ice Sheet are in retreat, and their retreat has accelerated over the last two decades. Previous studies of a small number of glaciers or studies over several months or years have conventionally associated these changes with climate forcing. However, there is no published literature that looks at multi-decadal retreat trends and forcings on a regional scale and at regular time intervals. We have created a record of annual outlet glacier fronts since 1972 for 92 glaciers in northwestern Greenland in order to better assess the timing and magnitude of glacier retreat. These glacier fronts were mapped from a combination of optical and synthetic aperture radar satellite imagery. This record shows that nearly every glacier in the study region has retreated over the last several decades, with only one small glacier that has significantly advanced. Widespread regional retreat in northwest Greenland began in the late 1990s and has persisted to the present. Continuing work with this glacier front record will assess the relationship between the timing of glacier retreat and various forcing mechanisms, such as air temperatures, ocean temperatures, and sea ice characteristics.

2. Foodways at the Intersection of Culture and Climate Change

Isabel Carrera
University of Washington, College of the Environment, Office of Diversity, Equity, and Inclusion; Seattle

Our current industrialized food systems are not sustainable, threatening all manner of life in the planet. Unless we dramatically change what we eat, by 2050, food systems will not be able to sustain human population. Unfortunately, the governance of natural resources and environmental policies attempting to address the impacts of climate change have been historically determined by the interests and behavior of limited groups of people. In fact, environmental policies tend not to reflect the diversity in environmental values shaped by cultural bonds. This approach entails a disconnection between local and global scales, which leads to a decrease in efficiency of environmental responses that can lead to social and environmental injustices. Food represents the first contact many people have to nature, so foodways become a rich lens through which the connection to nature and pro-environmental decision-making at a local scale can be analyzed. The change in values and beliefs resulted in changes of habits as a form of adaptation. The study of these adaptation processes could inform current studies in resilience and provide additional information about impacts of climate change a local scale.

3. Did Eunice Foote Discover the Greenhouse Effect?

Michael Diamond
University of Washington, Department of Atmospheric Sciences; Seattle

Abstract: Since her work was first re-discovered in 2011, Eunice Newton Foote has received considerable attention as a pioneering climate scientist. Controversy has even erupted over whether John Tyndall, currently viewed as the "discoverer" of the physics behind the greenhouse effect, deserves that title given that Foote's experiments occurred several years before his. However, Foote was interested in the interactions between air and sunlight, not terrestrial radiation, and could not establish the absorption of terrestrial radiation given her instrumentation. Although Foote came to the fortuitous conclusion that increasing CO2 in the atmosphere would lead to a warming climate, her experimental results, as viewed with our modern understanding, do not support this statement. Indeed, Foote may have actually discovered the "anti-greenhouse effect" in which absorption of sunlight in the atmosphere shades and cools the surface, as occurs with elevated smoke plumes on Earth and the organic haze layer on Titan. Care will be needed in incorporating Foote's story into introductory climate science courses to avoid confusion regarding the roles of sunlight and terrestrial radiation in the greenhouse effect.

4. Increases in Arsenic Availability and Uptake into Rice under Elevated Temperature

Yasmine Farhat
University of Washington, Department of Civil and Environmental Engineering; Seattle

Rice is the primary staple food to roughly half the world's population. Recent research has highlighted the looming threat of climate change to both the production and nutritional quality of rice. Elevated temperature may impact the bioavailability of arsenic, a toxin commonly occurring in rice paddy environments. Arsenic concentrates in rice tissue and therefore poses a substantial threat to consumers of rice heavy diets. We established four controlled growth chambers within the laboratory, representing a gradient of environmentally relevant increases in temperature and cultivated rice from germination to full maturation. At key plant developmental stages, we monitored arsenic content in soil, porewater, plant tissue. Elevated temperature was associated with higher dissolved arsenic in soil porewater, as well as arsenic content in the vegetative tissue. Data analysis is still on-going to quantify arsenic content in the grain tissue in order to better understand the risks that rice consumers may face in the face of climate change.

5. Taming Bigfoot

Richard Gammon
University of Washington, Atm Sci, Oceanography, Chemistry (Emeritus)

'Taming Bigfoot' is a community-based campaign to reduce our individual/family carbon footprint. These campaigns have expanded from their start in Jefferson County two years ago, to Seattle and Edmonds last year, and South Whidbey this past spring. Bigfoot himself may make an appearance at Friday Harbor Labs for the PCC Summer Institute.

6. Land cover change robustly alters shallow cumulus droplet number in an idealized continental boundary layer modeling framework

Sam Pennypacker[1], Kuan-Ting O[1], Robert Wood[1] and Abigail Swann[1,2]
[1]University of Washington, Department of Atmospheric Sciences; Seattle
[2]University of Washington, Department of Biology; Seattle

Shallow cumulus clouds are an important feature of the lower atmosphere over many land surfaces because of their impact on solar radiation and the motions of the underlying planetary boundary layer. The exchange of heat, moisture and momentum between the surface and the atmosphere in turn helps control the properties of these clouds. Because land use change (e.g. deforestation, irrigation) strongly affects those fluxes, it is a useful framework for investigating the connection between surface processes and continental cumuli. We focus specifically on changes to the number of cloud droplets because it is a key parameter in setting cloud optical properties. We hypothesize that perturbations to the surface energy budget can meaningfully alter the cloud droplet number concentration through impacts on the turbulent motions of the boundary layer that form cumulus updrafts. Our first approach is to examine the strength of our hypothesized mechanism in the context of land use changes simulated by a synthesis of

idealized vegetation, planetary boundary layer and cloud parcel models. Under this framework, perturbations to daytime peak surface energy fluxes induce a 20% increase and a 15% decrease in the number of activated cloud droplets in experiments representative of mid-latitude afforestation and tropical deforestation, respectively. We then repeat these experiments under a range of possible soil moisture contents and atmospheric CO_2 concentrations to document the impact of varying partitioning of surface sensible and latent heating. While idealized, these experiments use land cover change as a framework for demonstrating a robust connection between the land surface energy budget and shallow cloud droplet number. This will guide future work applying both our simple models and observations to better understand the larger role that the land surface and the boundary layer have in controlling the properties of continental cumuli.

7. An emergent sea ice floe size distribution in a global coupled climate model.

Lettie Roach
University of Washington, Department of Atmospheric Sciences; Seattle

Sea ice is a critical component of the polar climate system that is tightly coupled to the ocean and atmosphere. It is highly heterogeneous, composed of discrete floes which range in size across space and time from meters to many kilometres. Floe size variability is not represented in CMIP5 nor CMIP6 models. During my PhD, I used a combination of modelling and observational approaches to investigate how different physical processes determine the distribution of sea ice floe sizes. Our resulting model for the floe size distribution enhances the amount of lateral melt that occurs at the edges of sea ice floes, relative to standard assumptions, and paves the way for representation of wave-ice interactions in large-scale models. Such physics will become increasingly important as the Arctic transitions to seasonal sea ice cover.

8. Minding the Carbon: A Carbon Neutral Summer Institute?

Alex Stote[1, 2] and Miriam Bertram[2]
[1]University of Washington, School of Marine and Environmental Affairs; Seattle
[2]University of Washington, Program on Climate Change; Seattle

As climate scholars we have long understood that anthropogenic greenhouse gas emissions, largely CO2, are causing a cascade of changes to earth's systems. Most changes are negative and some eventually *catastrophic* for life as we know it. We also understand the three main sources of CO2 emissions to the atmosphere: burning of fossil fuels, deforestation/land use changes and carbonate decomposition. Pillars in our daily activities contribute to these emissions: transportation, electricity generation, cement manufacture, and food production and transport. There are myriad ways to cut back emissions in these sectors, yet political unwillingness to act elevated by the campaign of denial backed by the fossil fuel industry have prevented significant emission reductions to be enacted at the scale and pace that is needed.

In this project we will examine and evaluate the carbon footprint of our own Summer Institute at Friday Harbor Labs, consider the benefits and shortcomings of different carbon offset programs, and present a model for a carbon neutral conference. In partnership with Friday Harbor Labs we've made some simple food choices, we've also encouraged travelers to weigh their options in transportation, and more, to reduce emissions. What remains will be referred to a carbon offset program, which is itself a topic of considerable debate lately. We invite you into the conversation about what *our* method of offsetting should be for this conference. Come by the poster or share your ideas with us during our time here. At the end of the institute we will present our carbon footprint and a proposal for offsetting that footprint.

It takes a village.

Speed talks

Olympia Oyster Restoration: Habitat Suitability and Climate Considerations

Charlotte Dohrn
School of Marine and Environmental Affairs, University of Washington, Seattle

Multiple Equilibria in a Tropic World Climate Model

Dennis L. Hartmann and Brittany D. Dygert
Department of Atmospheric Sciences, University of Washington, Seattle

A simple diagnostic tool to predict growing-season temperature variability

Lucas Vargas Zeppetello[1], David S. Battisti[1] and Marcia B. Baker[2]
University of Washington [1] Department of Atmospheric Sciences & [2] Department of Earth and Space Sciences

Ocean Acidification and Carbonate System Geochemistry in the Arabian Gulf

James W Murray[1], Connor Izumi[1], Jassim Al-Thani[2], Oguz Yigiterhan[2]
[1] University of Washington [2] Qatar University

The role of vapor pressure deficit in crop yield under a changing climate

Jennifer Hsiao, University of Washington, Department of Biology, Abigail L.S. Swann, University of Washington, Department of Atmospheric Sciences, Department of Biology & Soo-Hyung Kim, University of Washington, School of Environmental and Forest Sciences

Food security threatened by population growth

Stephen G. Warren
Department of Atmospheric Sciences, University of Washington, Seattle

During the 20th century, the world's population grew by the factor 3.5. What permitted this growth was the agricultural advances of the 20th century; without those advances the population

would not have grown as it did, from 1.7 billion in 1900 to 6 billion in 2000. Now in the 21st century, the ability to secure adequate food and water worldwide is threatened by continued rapid population growth, which has been steady at ~80 million per year for each of the last 50 years. For some countries the growth has instead been nearly exponential, as in the Philippines, whose population grew from 7 million in 1900 to 100 million in 2014, by doubling every 28 years. A population will double in every generation, as it did in the Philippines, if the average couple has 4 children surviving to reproduce. Nigeria, a country twice the size of California, had a population of 33 million in 1950. It is now 200 million, and is projected by the UN to reach 900 million in the year 2100. But even this projection assumes optimistically that Nigeria's total fertility rate will drop rapidly through this century, from 5.5 children per woman now, down to 2.2 in 2100. A failure to feed those 900 million would result in a combination of migration and starvation.

Reference: S.G. Warren, 2015: Can human populations be stabilized? Earth's Future 3, 82-94, doi:10.1002/2014EF000275.
What this paper does:
(1) presents equations relating family size to population growth rate
(2) explains that the UN projections are based on a logical fallacy
(3) offers several simple mathematical exercises to illustrate population dynamics, suitable as homework problems in an undergraduate class