Cooperative Institute for
CLIMATE, OCEAN &
ECOSYSTEM STUDIES

CICOES Symposium 2023

June 13-14
University of Washington
Seattle

2023 CICOES Symposium

June 13 – 14 | Foege Genome Science Building | 3720 15th Ave NE, Seattle, WA

TUESDAY, JUNE 13, 2023

Ecosystem Features

- Jennifer Fehrenbacher (OSU) – Monitoring the effects of climate change on planktic foraminifera in the Northern California Current
- Evan Howard (UW) and Curtis Deutsch (UW) – Otoliths record hypoxia tolerance

Ecosystem Rapid Talks

- Maria Kavanaugh (OSU) – Dynamic Seascape Metrics as Essential Biodiversity Variables: effects of ocean change on habitat extent and diversity for the NE Pacific
- John Horne (UW) – Operationalizing Alternate Sampling Platforms to Support Ecosystem Research and Management
- Rebecca Cates (UAF), Henry Fleener (NOAA/OSU) and Jordan Hollarsmith (NOAA AFSC) – Developing shellfish research hatchery capacity and technology development at the NOAA AFSC Ted Stevens Marine Research Institute in Juneau, AK
- Douglas Causey (UAF) and Veronica Padula (Seattle Aquarium) – Complex Shifts in Population Dynamics of Beringian Ecosystems are Linked to Long- and Short-term Climate Modes
- Lorenzo Ciannelli (OSU) – Species distribution and ontogenetic habitat constraints
- Franz Mueter (UAF) – Snow crab in a warming Bering Sea: Effects of climate, predation and fishing on their collapse and recovery
- Megan McPhee (UAF), Patrick Barry (USFS) and Wes Larson (NOAA AFSC) – Genetic analysis of salmon bycatch in the Bering Sea and Gulf of Alaska
- Taylor Chapple (OSU), Alexandra McInturf (OSU), Jessica Schulte (OSU) and Josh Bowman (OSU) – Studying sharks in the Northeast Pacific
- Elizabeth McHuron (UW), Elliott Hazen (NOAA SWFSC), Noel Pelland (UW), Rolf Ream (NOAA AFSC), Al Hermann (UW), Kelley Kearney (UW), Wei Chang (UW) and Jeremy Sterling (NOAA AFSC) – Habitat suitability of northern fur seals in the eastern Bering Sea: age-specific variation, overlap with walleye pollock, and predictions under climate projections
- Burlyn Birkemeier (UW), Katie Sweeney (AFSC MML) and Tom Gelatt (AFSC MML) – Leveraging Artificial Intelligence to Automate Image Processing and Detection and Classification of Steller sea lions (*Eumetopias jubatus*) in Aerial Imagery
- Molly McCormley (UW), Alexey Altukhov (North Pacific Wildlife Consulting), Vladimir Burkanov (North Pacific Wildlife Consulting) and Tom Gelatt (NOAA AFSC) – Utilizing Machine Learning Techniques to streamline image processing of Steller sea lion photo data

Grad Students & Postdocs

- Hauke Schulz (UW) – Lagrangian Mesonet Field Experiment on the Atlantic Ocean
- Shuting Zhai (UW) – Implications of Snowpack Reactive Bromine Production for Arctic Ice Core Bromine Preservation
- Yang Xiang (UW), Paul Quay (UW), Rolf Sonnerup (UW) and Andrea Fassbender (NOAA PMEL) – Subtropical gyre nutrient cycling in the upper ocean: Insights from a nutrient-ratio budget method
- Andrew Scherer (OSU), Melanie Fewings (OSU) and Thomas Connolly (SJSU MLML) – Nearshore Nitrate Response to Wind Forcing on the Newport Hydrographic Line

- Megan Feddern (UAF), Eric Ward (NOAA NWFSC), William Satterthwaite (NOAA SWFSC) and Curry Cunningham (UAF) – Non-stationary relationships between climate and fisheries in the California Current and Gulf of Alaska
- Hannah Joy-Warren (UW) – The role of phytoplankton community composition in Southern Ocean carbon fluxes
- Genoa Sullaway (UAF), Curry Cunningham (UAF), David Kimmel (NOAA AFSC), Darren Pilcher (UW) and James Thorson (NOAA AFSC) – Validating the ROMS-NPZ Bering 10 k model with empirical zooplankton data
- Veronica Farrugia Drakard (UAF), Jordan Hollarsmith (NOAA AFSC) and Mike Stekoll (UAF) – High-latitude kelps and future oceans: where do we go from here?
- Emily Bishop (UW) – Scale-driven patterns of nearshore fish response to shoreline armoring
- Alexandra McInturf (OSU) – Salmon shark movement dynamics and overlap with salmon stocks in the Northeast Pacific
- Samuel May (UAF) – Quantifying impacts of hatchery-origin salmon strays to wild population recruitment and resilience using quantitative genetic models
- Mary Fisher (UW), Laura Dee (UC Boulder), Tessa Francis (UW), Steven Gray (MSU), Chris Harvey (NOAA NWFSC), Phil Levin (UW), Kristin Marshall (NOAA NWFSC), Steve Miller (UC Boulder), Laura Nelson (UW), Jameal Samhouri (NOAA NWFSC), Michele Barnes (James Cook University), Josh Cinner (James Cook University), Andre Punt (UW), Corey Ridings (UW) and Franz Simon (Cornell) – Feedbacks associated with climate adaptation, and implications for fishing community resilience

NOAA Leadership

- Dr. Michael Morgan, Assistant Secretary of Commerce for Environmental Observation and Prediction

NOAA Partner Perspectives

- Dr. Michelle McClure, Director, PMEL
- Hélène Scalliet, Planning Officer, NWFSC
- Dr. Laura Hoberecht, Planning Officer, AFSC

Climate Features

- Sarah Doherty (UW) – Research on the feasibility and climate impacts of Marine Cloud Brightening
- Nathan Kettle (UAF) – Improving communication of seasonal to subseasonal sea ice information to rural Alaska communities

Climate Rapid Talks

- Tim Bates (UW), Trish Quinn (NOAA PMEL), Derek Coffman (NOAA PMEL), Jim Johnson (UW) and Lucia Upchurch (UW) – Use of an Uncrewed Aerial System to Investigate Aerosol – Cloud Interactions in the Marine Atmosphere
- Uma Bhatt (UAF) – Sea Ice Prediction Network and the Sea Ice Outlook
- Muyin Wang (UW) – Arctic Present and Future Seen from CMIP6 Models
- Peter Bieniek (UAF) – Improving seasonal outlooks of Alaska river ice breakup and associated flooding risk
- Dongxiao Zhang (UW), Andy Chiodi (UW), Chidong Zhang (NOAA PMEL), Gregory Foltz (NOAA AOML), Meghan Cronin (NOAA PMEL), Calvin Mordy (UW), Jessica Cross (NOAA PMEL), Edward Cokelet (NOAA PMEL), Jun Zhang (CIMAS), Chris Meinig (NOAA PMEL), Noah Lawrence-Slavas (NOAA PMEL), Phyllis Stabeno (NOAA PMEL) and Richard Jenkins (Saildrone, Inc.) – Observing Extreme Ocean and Weather Events using Innovative Saildrone Uncrewed Surface Vehicles
- Nick Bond (UW) and Karin Bumbaco (UW) – Extreme Weather Events in WA State: Variations and Trends

- Aaron Levine (UW) – Common Initial Conditions for False Alarm El Niño Forecasts

- Andy Chiodi (UW), Sim Larkin (USDA PNRS), Joel Dubowy (UW) and Brian Potter (USDA PNRS) – Prescribed Fire and Smoke Planner: Development of a planning and decision support system for prescribed burning

- Albert Hermann (UW) – Hybrid dynamical-statistical methods for climate downscaling: A comparison of methods with examples from the Northeast Pacific

- Kevin O'Brien (UW) – Open Access to GTS: A GOOS and WMO Pilot Project to Modernize Data Exchange for the 21st Century

WEDNESDAY, JUNE 14, 2023

Ocean Features

- Laramie Jensen (UW), Randie Bundy (UW), Rebecca Woodgate (UW APL) – Temporal and spatial variability of trace metal supply to the Chukchi Sea

- Carl Dierking (UAF) and Jennifer Delamere (UAF) – High Latitude Ocean Monitoring from Space

Ocean Rapid Talks

- Yolande Serra (UW) – Upper Ocean Vertical Velocity from Saildrone ADCP

- Nan-Hsun Chi (NOAA PMEL), Dongxiao Zhang (UW) and Chidong Zhang (NOAA PMEL) – Saildrone observed inertial wave generation in seasonal ice-free Chukchi Sea

- Brodie Pearson (OSU) – The Fate of Sea-ice Across Scales: From Leads to Arctic Communities

- Melanie Fewings (OSU), Craig Risien (OSU) and Brandy Cervantes (OSU) – Seasonal cycles of subsurface ocean conditions and salinity control of density stratification along the Newport Hydrographic Line

- Natalie Monacci (UAF), Jessica Cross (NOAA PMEL), Linquan Mu (UW), Darren Pilcher (UW) and Adrienne Sutton (NOAA PMEL) – Ocean Acidification Research Center: Observing the marine carbonate system in Alaska

- Caitlin Guerin (UW) – NOAA Potential Location Assessment of Current and Estuarine Surveys (PLACES)

- Wei Cheng (UW), Albert Hermann (UW), Anne Hollowed (AFSC), Kirstin Holsman (AFSC), Kelly Kearney (UW), Darren Pilcher (UW), Charles Stock (NOAA) and Kerim Aydin (AFSC) – Eastern Bering Sea dynamical downscaling from CMIP6: Results and caveats

- Natalia Sannikova (CIMAR) – Coastal ocean SCHISM model evaluation

- Yong Wei (UW) – Capacity-building in short- and long-term tsunami forecasting for coastal resilience

ABSTRACTS
2023 CICOES Symposium

Ecosystem Features

Jennifer Fehrenbacher (OSU)
Monitoring the effects of climate change on planktic foraminifera in the Northern California Current

Planktic foraminifera are globally ubiquitous marine calcifiers that have well defined ecological niches, based primarily on ocean temperature. Where they thrive in the modern ocean will change as the ocean warms and habitats shift poleward. In addition to their shifting habitats, increasing atmospheric carbon dioxide (CO_2) emissions may impact their ability to build their shells due to ocean acidification. Precisely how foraminifera will fare in a warmer, high CO_2 world is not certain. Our research off the Oregon coast, which includes seasonal research cruises and sediment trap collections, is monitoring planktic foraminifera assemblages and their calcification response to regional climate change. We are also exploiting the Newport Hydrographic Line plankton tow archive to assess assemblage changes over the last decade. Here, I will share results describing foraminifera community changes in the Northern California Current in response to two recent transient marine heat waves (Lane, Fehrenbacher, et al., 2023). I will also describe our planned efforts for assessing the impact of ocean acidification on shell calcification. (jennifer.fehrenbacher@oregonstate.edu)

Evan Howard (UW) and Curtis Deutsch (UW)
Otoliths record hypoxia tolerance

A new mechanistic model demonstrates that otolith carbon isotopes in marine fish species record their temperature-dependent hypoxia tolerance, and its variability from individual to global scales. This model provides a foundation for the use of otolith chemistry to reconstruct modern spatial patterns and paleoceanographic changes in key traits that shape the aerobic habitat of aquatic species and their responses to climate change. (ehoward2@uw.edu)

Ecosystem Rapid Talks

Maria Kavanaugh (OSU)
Dynamic Seascape Metrics as Essential Biodiversity Variables: effects of ocean change on habitat extent and diversity for the NE Pacific

Pelagic seascape ecology requires a dynamic geographic framework to track changes in ecosystem extent and location; quantify mechanistic relationships between habitat community structure, and ecosystem functioning; and ultimately determine the vulnerability or resilience of pelagic organisms or systems to climate change. Dynamic and synoptic seascapes are classified from satellite- and model-based fields that characterize phytoplankton responses to multi-scale physicochemical changes in surface water masses, and validated and extended in time and depth with bio-optics, long term ecological studies, and marine ecosystem models. As an Essential Biodiversity Variable, we document interannual variability of seascape identity, extent, and habitat diversity. We also discuss potential effects of habitat extent and diversity on occupancy and abundances for benthic and planktonic organisms in temperate and polar ecosystems. Seascape maps are produced in near real-time and served to the community via NOAA CoastWATCH and regional IOOS (Integrated Ocean Observing System) nodes, providing: 1) a biogeographical framework for biodiversity assessments; 2) an objective means to conduct ecosystem comparisons; 3) a means to track movement and habitat usages of marine fisheries; and 4) a means to quantify interannual variability in the quality and availability of critical habitats. (maria.kavanaugh@oregonstate.edu)

John Horne (UW)
Operationalizing Alternate Sampling Platforms to Support Ecosystem Research and Management

Vessels staffed with people are expensive sampling platforms. The proliferation of new remote sensing technologies combined with development of autonomous stationary or mobile platforms continually increases the number of ways to collect data in support of environmental research and resource management. Universal objectives in this quest are to acquire temporally or spatially indexed data and produce accessible data products in near-real-time. Two examples illustrate challenges associated with meeting these objectives: fish migration monitoring in the Tonle Sap River, Cambodia; ecosystem monitoring in the Gulf of Alaska. Both examples integrate commercially available components that are adapted to power, space, and communication requirements of each platform. The resulting raw data volumes and quality match those that would be obtained with traditional human-led, sampling efforts. Economics, coupled with expanding technological toolboxes, incentivize data acquisition innovations in support of research and management. (jhorne@uw.edu)

Rebecca Cates (UAF), Henry Fleener (NOAA/OSU) and Jordan Hollarsmith (NOAA AFSC)
Developing shellfish research hatchery capacity and technology development at the NOAA AFSC Ted Stevens Marine Research Institute in Juneau, AK

The oyster industry is well poised for rapid expansion in Alaska; however, the lack of oyster hatchery capacity to produce oyster seed in Alaska and oyster strains optimized for growth in the region presents significant hurdles for farm operations. To date, oysters have not been spawned consistently, and cost-effectively in Alaska, creating a reliance on larvae supplied from outside the state and an extreme insecurity and shortage of seed supply. Likewise, oyster strains cultivated in Oregon, Washington, California, and Hawaii hatcheries have been bred for optimized growth in the Pacific Northwest where the range, seasonality and variability of temperature, pH, tidal amplitude, and salinity regimes in the nearshore differ from those found in Alaska. The goal of this project is to resolve the scientific barriers to oyster research in Alaska by providing a research hatchery to identify cost efficiency rearing strategies to produce seed for the industry, as well as breeding oyster strains optimized for growth in Alaska. Housing, conditioning, and spawning of the broodstock oysters and subsequent generations will occur at NOAA AFSC facilities in Juneau, as well as assessment of production metrics (growth rates, mortality, and tissue composition), and physiological metrics (shell composition, genetic diversity, and metabolic rate). (rebecca.cates@noaa.gov)

Douglas Causey (UAF) and Veronica Padula (Seattle Aquarium)
Complex Shifts in Population Dynamics of Beringian Ecosystems are Linked to Long- and Short-term Climate Modes

Marine ecosystems and their populations are affected by complex long-term and short-term climatic modes climatic modes ranging from interannual and decadal variabilities. Because interactions between abiotic and biotic components of ecosystems, and oceanographic system change are subtle and complex, integrated analysis of these factors is essential to understanding the nature of interactions among them. We utilize a wavelet transform analysis simultaneously to multiple datasets centered on the Beringian marine environment and on the population dynamics and breeding success of selected breeding seabirds (eg., Puffins *Fratercula* spp, Auklets *Aethia* spp, Cormorants *Phalacrocorax* spp, Murres *Uria* spp. We show that over the last five decades, population and demographic parameters of these species fluctuate with a periodicity of 3-5 years similar to that detected in standard oceanographic parameters. Although the major periodicity of these interannual fluctuations is not common to different species and environmental variables, their cyclic characteristics not only show significant change, but diverse patterns of change. (dcausey@alaska.edu)

Lorenzo Ciannelli (OSU)
Species distribution and ontogenetic habitat constraints

As marine fish experience climate-driven changes in the ocean, one mode of adaptation is for fish to spatially and/or temporally shift the occupancy of their habitats. Spawning location (geography) and timing (phenology) are key traits that can affect not only survival, but also assessment and management of commercially harvested species. There are, however, limits to these changes, imposed by the presence of essential habitats and by the timing of life cycle events. I will discuss these boundary responses and the analytical approaches that can characterize potential bottlenecks affecting spatial distribution and timing of life cycle events. Knowledge about these boundary responses is key for predicting the impact of future environmental change, such as ocean warming. Through these analyses we build the capacity to study species adaptability to climate change and to project species in future scenarios. In this talk I will summarize work conducted with collaborators to: 1. quantify the degree to which fish geography and phenology are constrained in space and/or sensitive to changes in environmental conditions, particularity during early life stages; 2. assess possible trade-offs between changes in phenology and changes in geography; 3. develop size-specific distribution models; and 4. project species distribution over multiple life history stages. (lorenzo.ciannelli@oregonstate.edu)

Franz Mueter (UAF)
Snow crab in a warming Bering Sea: Effects of climate, predation and fishing on their collapse and recovery

The unexpected collapse of the snow crab (*Chionoecetes opilio*) stock in the Eastern Bering Sea between 2018 and 2021 and the subsequent fishery closure raises concerns about the future of this important fishery. A new CICOES project, leveraging other ongoing research at NOAA's Alaska Fisheries Science Center, the Alaska Department of Fish and Game, and the University of Alaska Fairbanks, aims to better understand the causes of the collapse and the interactions between fishing gear, predators and crab stocks in the Bering Sea that may inhibit their recovery. Ultimately, the project aims to identify hot spots for crab-gear interactions and crab-predator interactions, as well as the role of bottom temperatures in modifying these interactions. Results are expected to inform a more dynamic management approach for Bering Sea snow crab, including a spatially explicit stock assessment model. (fmueter@alaska.edu)

Megan McPhee (UAF), Patrick Barry (USFS) and Wes Larson (NOAA AFSC)
Genetic analysis of salmon bycatch in the Bering Sea and Gulf of Alaska

Incidental catch of chum and Chinook salmon in the Bering Sea and Gulf of Alaska groundfish fisheries is gaining more attention in light of recent, severe declines in Yukon River salmon returns. Since 2005, NOAA has monitored the genetic stock composition of salmon bycatch samples but these estimates have typically been published up to three years after the fishing seasons ended. In this project, we are capitalizing on recent advances in genotyping, stock composition estimation, and spatiotemporal modeling to: 1) reduce the time it takes to publish genetic stock composition estimates; and 2) combine environmental and fleet data to better understand bycatch dynamics. This information can be used to improve bycatch avoidance strategies and to better communicate stock composition data with those most impacted by salmon declines. (mvmcphee@alaska.edu)

Taylor Chapple (OSU), Alexandra McInturf (OSU), Jessica Schulte (OSU) and Josh Bowman (OSU)
Studying sharks in the Northeast Pacific
The Northeast Pacific, and more specifically the waters off the Pacific Northwest (PNW), supports at least 15 species of sharks. Yet, relatively little work has been focused understanding the biology and ecology of sharks in this region. The Big Fish Lab (BFL) at Oregon State University is working on a number of projects to understand the role these predators play in marine ecosystems of the PNW. I will cover some of the cool and collaborative work the BFL is doing to increase our appreciation and understanding of sharks off our coasts. (chapplet@oregonstate.edu)

Elizabeth McHuron (UW), Elliott Hazen (NOAA SWFSC), Noel Pelland (UW), Rolf Ream (NOAA AFSC), Al Hermann (UW), Kelley Kearney (UW), Wei Chang (UW) and Jeremy Sterling (NOAA AFSC)
Habitat suitability of northern fur seals in the eastern Bering Sea: age-specific variation, overlap with walleye pollock, and predictions under climate projections

Identifying the environmental factors that drive species distributions are crucial for protected species and climate-informed ecosystem-based fisheries management. We developed age-specific Species Distribution Models for northern fur seals (*Callorhinus ursinus*), which play a central ecological role as one of the key walleye pollock (*Gadus chalcogrammus*) predators in the eastern Bering Sea, the target species of one of the world's largest commercial fisheries. They provide food stability and are central to the cultural identity of Aleut communities on the Pribilof

Islands, where an unexplained population decline has occurred since the mid-1990s. We used long-term satellite telemetry datasets from lactating adult females and juvenile fur seals in conjunction with the Bering Sea ROMS model to identify associations with environmental variables and predict current and future habitat suitability under two shared socioeconomic pathways. Age- and habitat-specific (basin vs. shelf) models varied in their predictive ability, likely resulting from differences in ROMS model skill and life history constraints on behavior. We identified areas where high pollock biomass overlapped with suitable fur seal habitat and interannual variations in overlap extent. Predicted changes in habitat suitability have implications for the already declining Pribilof fur seal population as well as consumptive effects on walleye pollock. (emchuron@uw.edu)

Burlyn Birkemeier (UW), Katie Sweeney (AFSC MML) and Tom Gelatt (AFSC MML)
Leveraging Artificial Intelligence to Automate Image Processing and Detection and Classification of Steller sea lions (*Eumetopias jubatus*) in Aerial Imagery

The Marine Mammal Laboratory (MML) conducts annual aerial surveys as part of their charge to monitor and manage the endangered western distinct population segment of Steller sea lion. The traditional method of processing and analyzing aerial survey images to produce population abundance estimates can take two full-time biologists up to four months, and should be completed in a timely manner as the results are critical for resource management and industry partners. In 2019, MML collaborated with the experts at Kitware to create an automated count program that could reduce the traditional workflow's processing time by up to 75%. Initially, 6,524 images with traditional count and classification marks were sent to Kitware and converted to box annotations, of which MML personnel edited 151,490 for model training, validation, and image registration. An early detection model was evaluated by MML at 81% accuracy, missing 12% of pups and 7% of non-pups in the images. Preliminary data from our assessment of subsequent models indicate improvements in the proportion of missed detections and accuracy up to 87%. Although assessment is still in progress, the models show great promise in producing highly accurate counts in significantly less time than traditional methods. (bbirkeme@uw.edu)

Molly McCormley (UW), Alexey Altukhov (North Pacific Wildlife Consulting), Vladimir Burkanov (North Pacific Wildlife Consulting) and Tom Gelatt (NOAA AFSC)
Utilizing Machine Learning Techniques to streamline image processing of Steller sea lion photo data

The endangered western Steller sea lion (*Eumetopias jubatus*) population has significantly declined in the western Aleutian Islands since 2002. In 2011, the Marine Mammal Laboratory began permanently marking (i.e., branding) sea lion pups in that region to estimate rates of survival, natality, and movement, and installed remote cameras to monitor sites for branded individuals year-round. Over 3.1 million images have been collected thus far, requiring high processing effort by image reviewers. To help reduce processing time, machine learning models were applied in 2019, utilizing U-net and object identification frameworks. These models were already in use and highly effective on Russian sea lion sites, but model validation results have varied for the western Aleutian Islands. Of the five sites that have been evaluated for accuracy, model success rates of detecting a branded sea lion in images range between 54% and 81%, with false positive rates ranging from 6% to 35%. Human reviewers, on average, detected 28% more instances of branded Steller sea lions than the models. While machine learning models have been effective at reducing processing time, further work is needed to enhance the accuracy and therefore efficiency of these models for use on western Aleutian Islands sites. (mccorm5@uw.edu)

Grad Students/Postdocs

Hauke Schulz (UW)
Lagrangian Mesonet Field Experiment on the Atlantic Ocean

Research is more than ever driven by data. However, on the oceans we still lack a lot of valuable insights. As a consequence, the uncertainties of our future climate projections can be largely attributed to our marine environment, in particular to the shallow clouds of the sub-tropical and tropical oceans. These clouds are very ubiquitous and reflective, but are too small to be resolved by current climate simulations and their effect are current estimated. With recent field campaigns and ever evolving model simulations a lot of new insights could be gained. However, a lot of processes influencing the clouds happen on different scales. To measure processes on the order of

10-100 km we need a dense network of measurement platforms. Here we present the on-going effort to equip more than 100 sailboats with meteorological instruments to capture the mesoscale variability within the entire Atlantic trades from the Cape Verde islands to the Caribbean. The dataset will help evaluate satellite retrievals and quantify processes responsible for the organization of clouds at the air-sea interface and provide a reference for model evaluations like EUREC4A-MIP and CP-MIP. (haschulz@uw.edu)

Shuting Zhai (UW)
Implications of Snowpack Reactive Bromine Production for Arctic Ice Core Bromine Preservation

Snowpack emissions are recognized as an important source of gas-phase reactive bromine in the Arctic and are necessary to explain ozone depletion events in spring caused by the catalytic destruction of ozone by halogen radical. Quantifying bromine emissions from snowpack is essential for interpretation of ice-core bromine. We present ice-core bromine records since the pre-industrial (1750 CE) from six Arctic locations and examine potential post-depositional loss of snowpack bromine using a global chemical transport model. Trend analysis of the ice-core records shows that only the high-latitude coastal Akademii Nauk ice core from the Russian Arctic preserves significant trends since pre-industrial times. Model simulations suggest that recycling of reactive bromine on the snow skin layer results in 9–17% loss of deposited bromine across all six ice-core locations. Reactive bromine production from below the snow skin layer and within the snow photic zone is potentially more important, but the magnitude of this source is uncertain. Model simulations suggest that the Akademii Nauk core is most likely to preserve an atmospheric signal compared to five Greenland ice cores. Understanding the sources and amount of photochemically reactive snow bromide in the snow photic zone in the high Arctic is essential for interpreting ice-core bromine. (stzhai@uw.edu)

Yang Xiang (UW), Paul Quay (UW), Rolf Sonnerup (UW) and Andrea Fassbender (NOAA PMEL)
Subtropical gyre nutrient cycling in the upper ocean: Insights from a nutrient-ratio budget method

We use a nutrient-ratio budget method to investigate the relative importance of different nutrient source and sink terms at time-series Station ALOHA and BATS in the North Pacific and North Atlantic subtropical gyres, respectively. At mean state conditions over annual and multi-year time scales, vertical phosphate (PO_4 3-) supply from the subsurface accounts for approximately 60% of the total phosphorus supply at both sites. Dissolved organic matter transport and zooplankton excretion are more important phosphorous export pathways than sinking particles at Station ALOHA and BATS. The nutrient-ratio budget approach provides quantitative, observation-based constraints on nutrient sources and sinks in the surface ocean, which helps improve our understanding of the biological carbon pump in oligotrophic oceans. (yaxiang@uw.edu)

Andrew Scherer (OSU), Melanie Fewings (OSU) and Thomas Connolly (SJSU MLML)
Nearshore Nitrate Response to Wind Forcing on the Newport Hydrographic Line

The northern California Current System is a highly productive eastern boundary upwelling system (EBUS) that relies on wind-driven upwelling to transport nitrate-rich water to the surface, driving primary productivity. Using eight years of moored observations from the National Science Foundation's Ocean Observatories Initiative Endurance Array as well as two decades of data from the Newport Hydrographic Line surveys, we find a strong empirical relationship between nearshore nitrate concentrations and an exponentially decaying time average of the recent along-shelf wind stress. We use this average to account for the delayed response of upwelling to wind stress and find that the nitrate response is best fit with a wind averaging timescale of three to seven days. We then construct a model for nitrate as a function of depth based on an exponential fit for the depth of the nitracline as a function of cross-shelf location. The observed nitrate-wind relationship can be reproduced by this model. Using this model, wind stress may be used as a proxy for nearshore nitrate concentrations when in-situ data is sparse. This framework also provides the groundwork for future research into the physical controls on nearshore nitrate and, by extension, biological productivity in EBUS. (scherand@oregonstate.edu)

Megan Feddern (UAF), Eric Ward (NOAA NWFSC), William Satterthwaite (NOAA SWFSC) and Curry Cunningham (UAF)

Non-stationary relationships between climate and fisheries in the California Current and Gulf of Alaska

An emerging challenge in ecosystem based management is that many relationships that are taken as gospel are changing over space and time. Recent examples include shifting spatial distributions of fish populations, changing meanings of environmental indices (e.g., Pacific Decadal Oscillation) and changing relationships between environmental drivers (e.g., sea surface temperature and sea level pressure). Working with a diversity of assembled oceanographic and biological datasets, we investigate and synthesize non-stationary relationships that are relevant to management in the California Current and Gulf of Alaska marine ecosystems using Bayesian linear modeling, dynamic linear modeling, and self-organizing maps. First, we will examine changing relationships between atmospheric forcing (wind stress, sea level pressure), climate conditions (SST, upwelling) and environmental indices (PDO, NPGO) from 1967 - 2022. Next, we will identify if these changing relationships are reflected in low trophic level species of zooplankton (CalCOFI, Newport Line, Seward Line) and protected and commercially important species (Pacific salmon, groundfish). Finally we will identify whether these changing relationships are useful in improving short-term (1-2 years) forecasts. (mfeddern@alaska.edu)

Hannah Joy-Warren (UW)
The role of phytoplankton community composition in Southern Ocean carbon fluxes

The Southern Ocean has historically been considered a strong carbon dioxide (CO_2) sink—responsible for ~40% (~1 PgC) of anthropogenic CO_2 that enters the ocean—but its efficacy as a CO_2 sink has recently had a weaker period and may be more variable than previously thought. The Southern Ocean is also responsible for ~30% (~3.3 PgC) of the annual global organic carbon export, thereby exerting substantial influence on global climate. Prior research has identified connections between the ocean CO_2 sink strength and natural oscillations in ocean circulation, but less work has been done to evaluate the contribution of biological factors. Phytoplankton are a key driver in global carbon cycling through photosynthesis and potential export of organic carbon to the deep ocean but, different taxa contribute differently to carbon drawdown and export. This has implications for the amount of POC produced and exported to the deep ocean, as well as the overall impact of phytoplankton on air-sea CO_2 flux. Using a machine learning approach, we modeled phytoplankton taxa distributions along BGC-Argo float paths. We estimated air-sea CO_2 flux along the same float paths and connected variability in air-sea CO_2 flux to the taxa distributions. (hjoyw@uw.edu)

Genoa Sullaway (UAF), Curry Cunningham (UAF), David Kimmel (NOAA AFSC), Darren Pilcher (UW) and James Thorson (NOAA AFSC)
Validating the ROMS-NPZ Bering 10 k model with empirical zooplankton data

Regional Ocean Modeling-Nutrient Phytoplankton Zooplankton (ROMS-NPZ) models seek to simulate and forecast biological dynamics in the ocean, including zooplankton, whose production dynamics are tightly linked to oceanographic conditions and are a direct link to higher trophic levels. The Bering Sea 10 k ROMS-NPZ model has zooplankton biomass hindcasts beginning in 1970 for five zooplankton species groups, however, hindcasts have not been validated in depth with empirical data. We used a survey replication method to compare the ROMS-NPZ model hindcasts to empirical zooplankton data. We found differences in absolute biomass values, in addition to relative variation in estimated phenology, annual and spatial variation across species group. Next, we constructed a hybrid spatial distribution model (H-SDM), which uses the ROMS-NPZ and environmental information as covariates to quantify zooplankton biomass in the Eastern Bering Sea. We used cross validation to compare prediction skill between the H-SDM, the ROMS-NPZ and empirical model. The H-SDM model, with ROMS-NPZ as a covariate, had the greatest spatial prediction skill, while the ROMS-NPZ had the best skill in forecasting short-term relative zooplankton biomass trends. This research highlights areas where ROMS-NPZ can be implemented in short-term adaptive management and areas where it can be improved to better reflect ecological processes. (gsullaway@alaska.edu)

Veronica Farrugia Drakard (UAF), Jordan Hollarsmith (NOAA AFSC) and Mike Stekoll (UAF)
High-latitude kelps and future oceans: where do we go from here?

Kelp forests worldwide are threatened by both climate change and localized anthropogenic impacts. High-latitude species are projected to experience range contractions over the coming decades, exacerbated by climatic events such as marine heatwaves and increased freshwater and sediment input from contracting glaciers. Gaps in our understanding of how cold-temperate kelp species respond to climate stressors have limited our ability to forecast the status of kelp forests in future oceans. In this presentation, I will synthesize the impacts of climate-related stressors on kelp forests in the northeast Pacific, assess existing knowledge gaps, and outline our research priorities. A review of the literature revealed biases towards studies investigating the impacts of temperature or temperature in combination with light. Other stressors have received much less focus despite rapidly changing conditions in high-latitude regions. Furthermore, multiple stressor studies appear to focus on kelp sporophytes, and it is necessary that we improve our understanding of how microstages will be affected by stressor combinations. Building on this, we aim to identify how kelp microstages respond to variation in temperature, salinity, and sedimentation, how kelp microstages respond to combined climate stressors, and whether stress events early in the kelp life cycle confer resilience at later stages. (vhfarrugiadrakard@alaska.edu)

Emily Bishop (UW)
Scale-driven patterns of nearshore fish response to shoreline armoring

Coastal nearshore marine habitats play an important role for many culturally and economically significant fish species. Within these areas, shallow water and submerged aquatic vegetation offer opportunities to fishes for feeding and avoiding predation. Yet not all nearshore habitats are equal and fish distribution on a fine scale is influenced by a mosaic of biophysical factors like depth and presence of vegetation. On a broad scale, however, fish distribution may be influenced by the cumulative effect of other shoreline features. Evidence suggests that shoreline armoring modifies adjacent beaches to negatively influence some fish species, by reducing shallow water habitat and altering prey communities. This project aims to explore whether there is a threshold of armoring at which there is a detectable change in fish abundance. To accomplish this, we collected fish abundance data at sites throughout the southern Salish Sea over four years, evaluated a series of Generalized Linear Mixed Models that relate abundance to armor extent, and examined how patterns evolve across a series of hierarchically nested spatial scales. This work serves to advance our understanding of the circumstances which cause armoring to have an impact on nearshore fish populations and to inform habitat restoration strategies in urban estuaries. (ebish@uw.edu)

Alexandra McInturf (OSU)
Salmon shark movement dynamics and overlap with salmon stocks in the Northeast Pacific

In the Northeast Pacific Ocean (NEP), many overfished stocks have responded positively to management. However, others, including Chinook salmon (*Oncorhynchus tshawytscha*), are still declining despite active conservation strategies. Recent evidence suggests that top-down forcing (e.g., predation) is likely contributing significantly to these declines and confounding recovery efforts. In this study, we examine a marine predator that likely impacts salmon recovery efforts but has not been explicitly considered in modeling efforts of this system: the Salmon shark (*Lamna ditropis*). Salmon sharks are endothermic apex predators that range throughout the NEP. Given their endothermy and elevated metabolic rates, Salmon sharks are probably a substantial source of mortality for maturing Chinook salmon at sea. To examine their potential impact, we used a combination of stomach content and stable isotope analysis to determine the diet composition of Salmon sharks. We then modeled the spatial distribution of Salmon sharks with that of Chinook salmon to determine degree of overlap and conditions under which it is likely to occur. Our preliminary results suggest that Salmon sharks are generalist predators that may consume salmon opportunistically, and that overlap is likely to be seasonal and influenced by factors such as sea surface temperature and primary productivity. (mcintura@oregonstate.edu)

Samuel May (UAF)
Quantifying impacts of hatchery-origin salmon strays to wild population recruitment and resilience using quantitative genetic models

Aquaculture is an integral component of global food security; however, aquaculture operations must not diminish the productivity and resilience of currently sustainable wild capture fisheries. The USA is a global leader in the production of captive-bred (i.e., hatchery) Pacific salmon that are released into the ocean to grow to maturity before being harvested as adults. However, empirical evidence from multiple species suggests that captive-bred salmon have a reduced reproductive performance when they stray into wild habitats, compared to natural-origin individuals. The biological mechanisms producing these reproductive differences remain unclear. The present study used a recently published quantitative genetic model to examine possible mechanisms that could be driving differences in reproductive success between hatchery- and natural-origin fish, and the ultimate consequences of hatchery straying for wild population recruitment and resilience. We found that differences in reproductive timing between hatchery and natural-origin fish may play a significant role in driving differences in reproductive success. Despite these reproductive differences, more hatchery strays resulted in greater recruitment in wild populations but also increased synchrony and therefore decreased portfolio effects and resilience of wild populations. We discuss how this tradeoff between recruitment and resilience should be a primary consideration for the management of production hatcheries. (samay3@alaska.edu)

Mary Fisher (UW), Laura Dee (UC Boulder), Tessa Francis (UW), Steven Gray (MSU), Chris Harvey (NOAA NWFSC), Phil Levin (UW), Kristin Marshall (NOAA NWFSC), Steve Miller (UC Boulder), Laura Nelson (UW), Jameal Samhouri (NOAA NWFSC), Michele Barnes (James Cook University), Josh Cinner (James Cook University), Andre Punt (UW), Corey Ridings (UW) and Franz Simon (Cornell)
Feedbacks associated with climate adaptation, and implications for fishing community resilience

As marine social-ecological systems experience extreme events of increasing frequency and intensity under climate change, efforts to mitigate short-term impacts could unintentionally amplify negative environmental or societal effects. Our research explores how coping, adaptive, and transformative responses to extreme events may amplify or dampen impacts to human well-being and adaptive capacity in U.S. West Coast fisheries. We first present a "status quo" qualitative network model (QNM) that captures key social-ecological dynamics for representative West Coast fishing communities, centered around the commercial Dungeness crab fishery. We then describe a set of existing and potential response strategies, drawing on output from regionally-focused climate change scenario planning workshops, peer-reviewed literature, and expert knowledge. We use qualitative network modeling to simulate extreme events, including harmful algal blooms and marine heatwaves, with and without the addition of various response strategies. Our results: (1) highlight influential system relationships that may affect the impacts of response strategies across different events and communities; and (2) identify important sources of risk to well-being and adaptive capacity in the form of amplifying socio-economic feedbacks. (mfisher5@uw.edu)

NOAA Leadership

Dr. Michael Morgan, Assistant Secretary of Commerce for Environmental Observation and Prediction

NOAA Partner Perspectives

Dr. Michelle McClure, Director, PMEL

Hélène Scalliet, Planning Officer, NWFSC

Dr. Laura Hoberecht, Planning Officer, AFSC

Climate Features

Sarah Doherty (UW)
Research on the feasibility and climate impacts of Marine Cloud Brightening

With the growing realization that dangerous levels of climate warming are increasingly becoming inevitable, discussions are also growing about the potential for intentionally increasing the reflection of sunlight (i.e. using "solar radiation modification" or "climate intervention") to reduce climate warming. One climate intervention approach would involve adding sea salt particles to low clouds in specific ocean regions to make them brighter. This presentation will give an overview of the research being done under the University of Washington Marine Cloud Brightening (MCB) Program to study whether MCB could be used to predictably and reliably reduce climate warming, and how different implementations of MCB would affect climate impacts. (sarahd@atmos.washington.edu)

Nathan Kettle (UAF)
Improving communication of seasonal to subseasonal sea ice information to rural Alaska communities

Seasonal to subseasonal (S2S) forecasts offer significant potential to support risk-management decisions for subsistence, search and rescue, and transportation in Alaska coastal communities. In partnership with the Alaska Region National Weather Service (NWS), Arctic Testbed and Proving Ground, Alaska Environmental Science and Services Integration Center, this project seeks to improve NWS communication of S2S information on sea ice for coastal communities in Alaska. The project consists of two phases. First, we conduct a document analysis to assess previous engagement activities and S2S sea ice information needs. Second, conduct a series of community meetings in three regional hub communities (Nome, Kotzebue, Utqiaġvik) to develop a deeper understanding of decision contexts, preferences, and priorities as well as NWS capacities. This includes: (1) identifying important ice freezing, thaw, and intra-seasonal evolution that impact activities; (2) understanding locally-relevant environmental factors and time frames related to ice evolution; (3) identifying accessible means of communicating S2S information; (4) assessing understanding and use of S2S information; and (5) tolerances for uncertainty in S2S predictions. This assessment will lead to a report to the NWS that outlines guidance for better communicating information in Alaska regional hub communities related to sea ice. Preliminary findings will be reported. (nkettle@alaska.edu)

Climate Rapid Talks

Tim Bates (UW), Trish Quinn (NOAA PMEL), Derek Coffman (NOAA PMEL), Jim Johnson (UW) and Lucia Upchurch (UW)
Use of an Uncrewed Aerial System to Investigate Aerosol – Cloud Interactions in the Marine Atmosphere

University of Washington Cooperative Institute for Climate, Ocean, and Ecosystem Studies (CICOES) the NOAA Pacific Marine Environmental Laboratory (PMEL) scientists are developing an Uncrewed Aerial System (UAS) to investigate aerosol-cloud interactions in the marine atmosphere. The system uses the L3Harris Fixed Wing Vertical Takeoff and Landing Rotator (FVR-55/FVR-90) UAS to measure aerosol and cloud vertical profiles with the NOAA Clear Sky and Cloudy Sky scientific payloads. The sensors in the payloads measure aerosol properties relevant to aerosol direct radiative forcing and aerosol – cloud interactions. The mission is supported, in part, by NOAA's Earth Radiation Budget (ERB) program that was initiated to investigate natural and human activities that might alter the reflectivity of marine boundary layer clouds. The UAS measurements will provide critical information on the processes that lead to the brightening of marine clouds with a potential cooling of the Earth's surface. (batest@uw.edu)

Uma Bhatt (UAF)
Sea Ice Prediction Network and the Sea Ice Outlook

The Sea Ice Prediction Network emerged from a meeting of Arctic researchers in autumn 2007, shortly after the first extreme September low in the satellite sea ice extent record. The goal was to galvanize the community to investigate seasonal predictions of Arctic sea ice. Seasonal sea ice prediction is advanced through transdisciplinary thinking across research areas including observations, coupled earth system modeling, climate variability, data assimilation, prediction and data-driven techniques. SIPN is the collaborative community that brings together sea ice prediction interests in a forum that fosters teamwork and collaboration to help advance the science of sea ice predictability. The SIPN Sea Ice Outlook (SIO) solicits predictions of September mean Arctic sea ice in the summer months of June–August. The number of yearly contributions has quadrupled over the past 14-years. A SIO signature product displays rank ordered predictions initialized in early July 2021 compared to the observed September mean of 4.92 million km2. The SIO attracts contributions spanning diverse methods and models and has advanced our understanding of the errors in seasonal sea ice predictions. While pan-Arctic September mean sea ice extent serves as a useful climate indicator, regional and local sea ice predictions are more relevant for stakeholders. (usbhatt@alaska.edu)

Muyin Wang (UW)
Arctic Present and Future Seen from CMIP6 Models

The Arctic is at the forefront of climate change. Rapidly changing temperatures, sea ice, and ocean conditions will continue as global warming continues. Projections of future atmosphere, ocean, and ice conditions in Arctic are important not only for the climate change studies, but also for stake holders and decision makers. In this study we investigate how the most up-to-date climate models (CMIP6) simulate the present-day Arctic climate and what are their future projections under different emission scenarios. Overall speaking the CMIP6-era models show considerable improvement from its precursors, CMIP3 and CMIP5 in the sea ice simulations. Compared with the observational records, CMIP6 models are able to capture the general features of the present-day climatology, spatial variability, and historical linear trends in surface air temperature, sea-ice concentration, sea-ice extent, Northern Hemisphere spring-snow extent, and ocean sea-surface salinity in the Arctic. As global warming is projected to continue, so will the amplified Arctic warming and the strongest Arctic warming is projected to occur in winter. The CanESM2 large ensemble simulations show that the probability of an ice-free Arctic summer is an order of magnitude smaller under 1.5C global warming, a scenario consistent with the Paris Agreement, compared to 2.0C global warming. (muyin@uw.edu)

Peter Bieniek (UAF)
Improving seasonal outlooks of Alaska river ice breakup and associated flooding risk

Ice jam flooding is one of the most frequently declared disasters in Alaska. Because of these hazards there is a need to advance S2S guidance of Alaska river ice breakup. By applying data science principles to observational data sets this project is working with the NOAA Arctic Testbed and Proving Ground (ATPG) and the Alaska-Pacific River Forecast Center to: a) develop a statistical model(s) to estimate the occurrence of river ice breakup date and the severity (i.e. thermal vs. dynamic breakup); b) test the methodology at various locations; and c) deliver the final code(s) to ATPG. Preliminary analysis is underway to identify predictors of breakup based on Thawing Degree Days (the running sum of daily temperatures above 0°C) at weather stations throughout Alaska and teleconnection indices. These new spring outlooks will provide guidance that may be complemented with localized information for underserved communities that are off the road system and in observational-data sparse areas. (pbieniek@alaska.edu)

Dongxiao Zhang (UW), Andy Chiodi (UW), Chidong Zhang (NOAA PMEL), Gregory Foltz (NOAA AOML), Meghan Cronin (NOAA PMEL), Calvin Mordy (UW), Jessica Cross (NOAA PMEL), Edward Cokelet (NOAA PMEL), Jun Zhang (CIMAS), Chris Meinig (NOAA PMEL), Noah Lawrence-Slavas (NOAA PMEL), Phyllis Stabeno (NOAA PMEL) and Richard Jenkins (Saildrone, Inc.)
Observing Extreme Ocean and Weather Events using Innovative Saildrone Uncrewed Surface Vehicles

Extreme ocean events and severe weather systems have large environmental impacts but are under-observed due to their harsh conditions and associated challenges with deployments of in-situ observing platforms. Through a Public-Private-Partnership, the Saildrone Uncrewed Surface Vehicle (USV) has been developed into a viable air-sea interaction observing platform that can be utilized by the broader ocean research community. We have demonstrated the potential of USVs for observing the Arctic Marginal Ice Zone during the seasonal Arctic ice retreat and for observing the extreme ocean and weather conditions inside major hurricanes. USVs can be an essential part of the Global Ocean Observing System, providing real-time data to improve prediction of rapid climate change and extreme ocean and weather events, and to reduce their harmful impacts. (dzhang@uw.edu)

Nick Bond (UW) and Karin Bumbaco (UW)
Extreme Weather Events in WA State: Variations and Trends

The mean climate of Washington state has featured interannual and multi-year fluctuations, and for temperatures, systematic trends, over the historical record. This type of variability has been reasonably well-documented, in part because it is relatively straightforward to obtain and analyze temperature and precipitation data on monthly and longer time scales. Less is known about how the frequency and intensity of short-term (on time scales of hours to a few days) weather events such as wind storms have varied over the record. That issue is addressed in the present study. (nab3met@uw.edu)

Aaron Levine (UW)
Common Initial Conditions for False Alarm El Niño Forecasts

El Niño is the largest driver of year to year climate variability and plays a large role in winter time temperatures and precipitation across North America. A major challenge of El Niño forecasts is the spring predictability barrier, where forecast quality is significantly diminished for predictions initialized in the spring time for the upcoming winter. However, dynamical forecast models frequently produce forecasts initialized in spring that are significantly over-confident that an El Niño event will develop in the subsequent winter. We explore the origins of these False Alarm forecasts using the North American Multi-Model Ensemble (NMME) coordinated hindcasts. In false alarm forecasts, initial warm sea surface temperatures in the eastern equatorial Pacific encourage anomalous enhanced precipitation near and to the east of the dateline in the equatorial Pacific which does not occur. The enhanced precipitation reduces the trade winds near the equator, leading to further erroneous surface warming. This cycle triggers the Bjerknes feedback and allows the initial warm sea surface temperature anomalies to consistently grow into an El Niño event. We find that with warm eastern Pacific temperatures in spring initializations, forecasters should be skeptical of limited model forecast spread for El Niño in the upcoming winter. (aflevine@uw.edu)

Andy Chiodi (UW), Sim Larkin (USDA PNRS), Joel Dubowy (UW) and Brian Potter (USDA PNRS)
Prescribed Fire and Smoke Planner: Development of a planning and decision support system for prescribed burning

Prescribed burning is critical for managing threats of extreme wildfire and restoring fire-ecosystem balance. Prescribed fire and smoke management objectives require burning when weather and fuel conditions are within specific bounds. Determining safe and effective bounds that have the maximum likelihood of occurring and understanding when the resulting burn windows will occur will be critical to increasing prescribed burning at the scale needed to successfully address the growing threats of extreme wildfire. We present progress on a system that allows historical weather records to be mined to provide this understanding in a way that is tailorable to an individual manager's needs. Present development status offers climatological burn window evaluations based on specification of bounds for any number of presently supported fire-behavior (e.g., near surface wind speed, relative humidity, temperature, and equilibrium moisture content) and smoke management (e.g., transport wind speed and direction, mixing height, ventilation index) variables, which have been extracted from 30 years of hourly, 25 km-horizontal resolution data from the ERA5 reanalysis over the conterminous US, and an 11 year archive of hourly, 4 km-horizontal resolution, operational Weather Research and Forecasting (WRF) output covering the northwestern US. The intent of this planning tool is to help facilitate prescribed burning nationwide. (chiodi@uw.edu)

Albert Hermann (UW)
Hybrid dynamical-statistical methods for climate downscaling: A comparison of methods with examples from the Northeast Pacific

The process of dynamical downscaling entails the use of high-resolution regional models driven by lower resolution global re-analyses and projections. Such regional models, given their higher spatial resolution and sometimes higher biogeochemical detail relative to the global models which drive them, are typically computationally expensive. This expense limits the ultimate size of any downscaled regional ensemble (including parameter sensitivities), which in turn constrains both the skill and uncertainty estimates of the regional forecasts, needed for their effective use in fisheries management. Statistical downscaling based on presently observed correlations between large-scale forcing and small-scale response is an alternate approach but lacks the ability to capture future emergent behaviors of complex, nonlinear regional biogeochemical systems. Here we describe several alternative techniques for the statistical expansion of dynamically downscaled ensembles. These "hybrid" methods offer a compromise between the spatial, temporal and trophic detail of dynamical methods vs. the numerical efficiency of purely statistical methods. We illustrate several methods, including the use of Machine Learning, with examples from ongoing Management Strategy Evaluation research in the Bering Sea and the Gulf of Alaska. (hermann@uw.edu)

Kevin O'Brien (UW)
Open Access to GTS: A GOOS and WMO Pilot Project to Modernize Data Exchange for the 21st Century
The majority of in situ near real time marine meteorological and oceanographic data used in operational forecasts and forecasting centers is distributed and accessed via the World Meteorological Organization's (WMO) Global Telecommunications Systems (GTS), a component of the WMO Information System (WIS). Due to the operational and restricted nature of the WIS/GTS, including tightly governed data formats, the process of distributing data via the WIS/GTS has remained opaque to the marine community. This has resulted in significant amounts of marine data being collected but not exchanged on the WIS/GTS. For the last five years, the Open Access to GTS project (Open-GTS) has forged a path to make it easier for data producers to exchange their data on the GTS. In doing so, the project has helped illustrate the difficulties of data access through the existing infrastructure. To improve data exchange and modernize data access, the WMO has launched the WIS 2.0 effort, which is an evolution of the WMO Information Service (WIS). This presentation will discuss how the Open-GTS fits into the WIS 2.0 evolution, and the work being done, in collaboration with the WMO and Global Ocean Observing System (GOOS), to radically improve near-real time operational data exchange. (kob@uw.edu)

Ocean Features

Laramie Jensen (UW), Randie Bundy (UW), Rebecca Woodgate (UW APL)
Temporal and spatial variability of trace metal supply to the Chukchi Sea

Trace metals (e.g., iron (Fe), copper (Cu), nickel (Ni), zinc (Zn), cadmium (Cd), and manganese (Mn)) are essential micronutrients for phytoplankton in the ocean. In the Arctic Ocean, oceanic inflows, continental shelves, and rivers play a dominant role in trace metal supply, while biological cycling of trace metals is relatively small in the oligotrophic, ice-covered basin. The supply of trace metals to the western Arctic is thought to be dominated by nutrient-rich Pacific waters, which enter though the Bering Strait and eventually ventilate the Canadian Basin upper halocline. High resolution trace metal measurements (~6 km) made in July 2021 show that trace metal concentrations are elevated in the Alaskan Coastal Water (ACW), which has not been previously observed. In contrast, the nitrate and phosphate-rich Anadyr Water was low in trace metals. Thus, the ACW contributes up to 42% of the trace metal supply despite accounting for 10% of the total volume. Given the seasonal presence of the Alaskan Coastal Current that supplies the ACW repeat measurements of trace metals in the strait are vital to determining the seasonality in supply of trace metals to the southern Chukchi Sea. (jensenla@uw.edu)

Carl Dierking (UAF) and Jennifer Delamere (UAF)
High Latitude Ocean Monitoring from Space

Alaska is huge, but its adjacent oceans have an equally important impact on the lives of residents. With limited roads, commerce is primarily by air or sea, with the vast majority of freight shipped by boat. Fish from Alaskan waters are a vital food source for the nation as well as local residents. For ocean vessels in the high latitudes, winds, seas, temperature and sea ice can have a significant impact but surface observations are sparse. Polar satellite data helps to identify hazardous conditions and the Geographic Information Network of Alaska (GINA) provides this information to users in near real-time through Direct Broadcast antenna reception. For example, GINA supplies satellite imagery to the R/V *Sikuliaq* for navigating ice floes and the Alaska Sea Ice Program (ASIP) for charting the Arctic ice edge. GINA's primary research objective is to improve satellite product effectiveness and reduce latency, however GINA also partners with researchers to develop new satellite products. An example presented here is the SeaSpray RGB. GINA Satellite Liaison, Carl Dierking, assisted Lead Developer, Bill Line, of the Cooperative Institute for Research in the Atmosphere (CIRA) to refine and implement this product that identifies spray from strong winds over water. (cfdierking@alaska.edu)

Ocean Rapid Talks

Yolande Serra (UW)

Upper Ocean Vertical Velocity from Saildrone ADCP

As part of the plan to address uncertainties in processes regulating sea surface temperatures (SSTs) that lead to biases in the eastern tropical Pacific and reduced skill in El Niño / Southern Oscillation (ENSO) predictions, the Tropical Pacific Observing System First Report recommends implementation of two air-sea interaction process studies: The Pacific Upwelling and Mixing Physics (PUMP) and the Eastern Edge of the Warm Pool (EEWP). The cold tongue and EEWP regions are also identified by the Precipitation Prediction Grand Challenge Strategic Plan as "sources of precipitation predictability." Uncrewed surface vehicles (USVs) like saildrones offer great promise for intensive observations of phenomena like the EEWP that can migrate zonally tens of thousands of kilometers, and for upwelling studies where multiple current profiles around a central point are needed to obtain upwelling estimates. A new award from NOAA's Climate Program Office / Climate Variability and Predictability Program supports the Ocean Climate Stations group at the Pacific Marine Environmental Laboratory (PMEL) to explore approaches to calculate upper-ocean vertical velocity in the PUMP and EEWP domains using Saildrone Acoustic Doppler Current Profiler (ADCP) data. This presentation will walk through how we propose to estimate vertical velocity and what challenges we face. (yserra@uw.edu)

Nan-Hsun Chi (NOAA PMEL), Dongxiao Zhang (UW) and Chidong Zhang (NOAA PMEL)
Saildrone observed inertial wave generation in seasonal ice-free Chukchi Sea

This study investigates the inertial wave activities observed by saildrones in the mostly ice-free eastern Chukchi Sea during summer 2019. The strong inertial currents (~20 cm/s) in early July 2019 were driven by passage of an Arctic storm. The observed inertial wave activities are within a two-layer system as summer heating makes a sharp mixed layer. The meridional wavelength is on the order of 70 km. Our results suggest that the recent accelerated summer sea-ice retreat may lead to elevated inertial wave activities and robust ocean mixing over the Chukchi shelf water, with ramification for ocean dynamics upstream Barrow Canyon, where much of the Pacific water drains into the interior Arctic. (nan-hsun.chi@noaa.gov)

Brodie Pearson (OSU)
The Fate of Sea-ice Across Scales: From Leads to Arctic Communities

The Arctic is rapidly changing across a range of scales and systems. Arctic ice is particularly sensitive to the changing climate, and impact communities locally (e.g., culture and sustenance) and non-locally (e.g., sea level rise). My research program uses numerical models to investigate the ocean and climate systems at various scales. In this presentation, I will highlight two pieces of Arctic research. The first is a small-scale [1-100 m] study of ocean mixing in and around a sea-ice lead, using large-eddy simulations to quantify how the mixing is impacted by ocean surface waves, which are becoming more prevalent with Arctic sea-ice loss. The second is an Arctic-scale study that uses CMIP6 data to project how the timing of land-fast-ice breakup will change in several, ice-reliant communities across the Arctic. (brodie.pearson@oregonstate.edu)

Melanie Fewings (OSU), Craig Risien (OSU) and Brandy Cervantes (OSU)
Seasonal cycles of subsurface ocean conditions and salinity control of density stratification along the Newport Hydrographic Line

The Northern California Current (NCC) system supports major fisheries that respond strongly to seasonal and interannual variability in water properties — such as temperature, salinity, and dissolved oxygen — that directly influence organisms and are affected by density-dependent vertical mixing and circulation. Here, we determine whether the vertical density stratification is controlled by temperature or salinity. Using data collected during 1997–2021 in ~550 biweekly to monthly shipboard CTD transects over the continental shelf and slope off Oregon along the Newport Hydrographic Line (NHL, stations NH01–NH25), we calculated best-fit seasonal cycles of temperature, salinity, density, and spiciness by harmonic fitting. These climatologies enable accurate calculation of anomalies during extreme events and provide context for understanding ecological changes. To determine what controls the vertical density stratification over the shelf and slope, we estimated the spice stratification squared κ^2. The climatology of κ^2 is negative at most depths during most of the year, indicating salinity controls the vertical density stratification. The exception is during July–October in a shallow layer (0–30 m) associated with the seasonal thermocline. Elsewhere, especially near the surface and near the coast during November–June, numerical models of the NCC without rivers will lack dynamics important to the ecosystem. (melanie.fewings@oregonstate.edu)

Natalie Monacci (UAF), Jessica Cross (NOAA PMEL), Linquan Mu (UW), Darren Pilcher (UW) and Adrienne Sutton (NOAA PMEL)
Ocean Acidification Research Center: Observing the marine carbonate system in Alaska

The surface oceans have absorbed greater than 25% of the total anthropogenic carbon dioxide emissions released into the atmosphere from fossil fuel burning and land-use changes, such as deforestation. This gradual absorption of carbon dioxide has increased ocean acidity in a process commonly referred to as ocean acidification. Coastal regions around Alaska are experiencing some of the most rapid onset of ocean acidification events in the United States. The primary goal of this project is to measure the intensity, duration, and extent of ocean acidification through observations of the marine carbonate system in Alaska's four large marine ecosystems. Data sources are from discrete seawater samples collected during repeat hydrographic surveys and autonomous sensors deployed on moored platforms and remotely operated vehicles. Long-term time series and sustained monitoring support several converging research efforts including assessing vulnerability of coastal communities, economic impacts on fisheries, and establishing and tracking current biogeochemical conditions. Assessing conditions in the Gulf of Alaska, Bering Sea, Chukchi Sea, and Beaufort Sea will provide data that will improve the understanding and predictive capability of ocean acidification trends and processes in the Pacific Arctic Region. (nmonacci@alaska.edu)

Caitlin Guerin (UW)
NOAA Potential Location Assessment of Current and Estuarine Surveys (PLACES)

Ocean and river current surveys have been conducted since the mid 1800's. How the National Oceanic and Atmospheric Administration (NOAA) decides where to conduct these surveys is what our GIS tool will accomplish. The most recent method of prioritization, the "Potential Location Assessment of Current and Estuarine Surveys'' (PLACES), is from 2014. This method utilized a combination of spatial analysis software, R, and fuzzy logic to produce an ordered list of locations. We are creating a new GIS-based tool to improve this method. We will take the average value of each parameter per ocean basin polygon, rasterize the data, reclassify, and use a weighted overlay. We will conduct this process in model builder in order to easily change the weight of certain parameters to see its effects on the ranking of locations and to easily share the process with NOAA. It is important to furnish NOAA with the best, most up-to-date metadata information that is used to choose the best locations to provide commercial shipping, fisherman, and recreational users with the most accurate and up-to-date current predictions that NOAA can provide. (caitig@uw.edu)

Wei Cheng (UW), Albert Hermann (UW), Anne Hollowed (AFSC), Kirstin Holsman (AFSC), Kelly Kearney (UW), Darren Pilcher (UW), Charles Stock (NOAA) and Kerim Aydin (AFSC)
Eastern Bering Sea dynamical downscaling from CMIP6: Results and caveats

In this study we present projected changes in the Eastern Bering Sea shelf (EBS) biophysical processes in response to climate forcing scenarios from the Coupled Model Intercomparison Phase 6 (CMIP6). Ensemble mean results suggest that, contrary to an anticipated increase in ocean stratification under warming, diminishing ice cover in the future weakens EBS stratification in the melt season. Modeled ensemble mean phytoplankton and zooplankton biomass exhibits subsurface maxima during the growing season, but the amplitude of these maxima decreases with warming, along with a reduction in primary productivity and oxygen concentration over much of the water column. Phenology of both phytoplankton and zooplankton biomass shifts earlier, leading to an increase (decrease) in biomass averaged between April-July (August-November) while the annual mean biomass decreases under warming. Projected changes of plankton biomass at the end of the 21st century are not well separated between the SSP126 and SSP585 scenario in light of the large inter-model spread under each forcing scenario. However, these results are obtained from a limited ensemble. Increasing the ensemble size using dynamical and/or statistical methods, along with improvement in modeling the essential physical and biogeochemical processes for the region, remains a high priority in our future research. (wcheng@uw.edu)

Natalia Sannikova (CIMAR)
Coastal ocean SCHISM model evaluation

The coastal ocean model SCHISM has been evaluated in terms of water levels, surface currents, water temperature and salinity as a potential candidate for the Unified Forecast System (UFS). UFS is a community-based, coupled comprehensive Earth modeling system that is designed to incorporate NOS oceanographic forecast model core(s) into a simplified NOAA modeling suite. For the evaluation process, SCHISM was applied to the New York City area and perform skill assessments with observations. The high-resolution unstructured mesh was generated to conform to the complex coastline geometry and bathymetry and to increase the modeling accuracy. The testing was performed for two 90 day time periods. The evaluation computation and related collaboration take place on TACC's Frontera supercomputer. The resulting mean total RMSE of amplitude from the phase 1 of testing (tide simulation) does not exceed 4 cm. (natalia.sannikova@noaa.gov)

Yong Wei (UW)
Capacity-building in short- and long-term tsunami forecasting for coastal resilience

At CICOES, we consider two types, short-term and long-term, forecasting and assessment of tsunami hazards for coastal communities at risk. The goal of short-term hazard forecasting is to address real- or near-real-time forecasting of tsunami inundation caused by a specific event in progress. Examples of the short-term assessment include the flooding forecast capability based on data assimilation and the rapid flooding forecast in the near field. Long-term tsunami forecasting is the use of the best-available high-resolution model to identify credible potential impact of tsunami hazards for vulnerable coastlines. In this talk, we highlight CICOES capability-building research efforts towards enhancing the present short- and long-term forecasting ability for coastal resilience. These efforts are conducted in strong collaboration with the NOAA Center for Tsunami Research (NCTR). These enhancements utilize deterministic and probabilistic methods, along with a path of two-decade development of deep-ocean observational and modeling technologies within and outside NOAA. These efforts have largely contributed to NOAA's tsunami warning system, the National Tsunami Hazard Mitigation Program's goal of Tsunami-Ready societies, and state tsunami inundation mapping, as well as to the national and international building codes for structures in tsunami flooding zones. (yongwei@uw.edu)