GRADUATE RESEARCH SYMPOSIUM

Environmental, Water Resources and Coastal Engineering

Friday, March 8, 2024

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on Centennial Campus

Department of
Civil, Construction, and
Environmental Engineering

2024 EWC

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The Environmental, Water Resources, and Coastal Engineering (EWC) group convenes an annual research symposium each spring semester. This symposium serves as a platform for graduate students to present their current research through both poster displays and oral presentations. In addition, a distinguished keynote speaker addresses a pressing issue within the realm of EWC. This event highlights the breadth of graduate-level research within the EWC group and fosters invaluable networking opportunities. Industry professionals serve as judges for both poster presentations and oral sessions, ensuring rigorous evaluation and recognition of outstanding contributions.

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KEYNOTE SPEAKER

Paola Passalacqua

University of Texas at Austin

Paola Passalacqua is a Professor of Environmental and Water Resources Engineering in the Maseeh Department of Civil, Architectural and Environmental Engineering at the University of Texas at Austin. She also holds a courtesy appointment in the Department of Earth and Planetary Sciences at the University of Texas at Austin. Dr. Passalacqua graduated summa cum laude from the University of Genoa, Italy, with a BS (2002) in Environmental Engineering, and received a MS (2005) and a PhD (2009) in Civil Engineering from the University of Minnesota. Her research focuses on transport processes along river and delta networks, with particular focus on flooding, river-floodplain connectivity, and coastal resilience. Dr. Passalacqua is the lead PI of SETx-UIFL, a DOE funded Urban Integrated Field Laboratory that focuses on the compounding effects of flooding and air pollution on Southeast Texas communities. Additionally, she is the Chair of Planet Texas 2050, a Grand Challenge at the University of Texas to advance interdisciplinary research on resilience and to co-design adaptation strategies with stakeholders and frontline communities in Texas.

Education

Ph.D., Civil Engineering-Water Resources, University of Minnesota, 2009

M.S., Civil Engineering-Water Resources, University of Minnesota, 2005

B.S. and M.S., Environmental Engineering, University of Genoa, 2002

Honors & Awards

2022 - Ralph Alger Bagnold Medal of the European Geosciences Union

2017 - University of Texas Regents' Outstanding Teaching Award

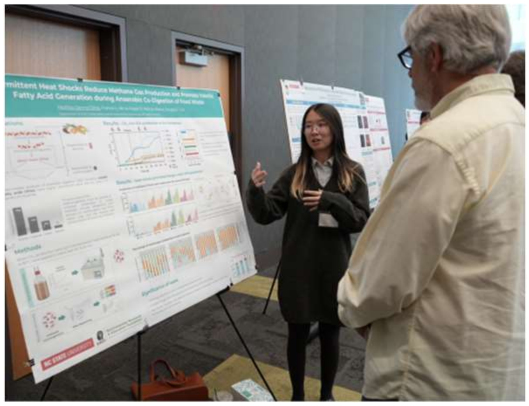
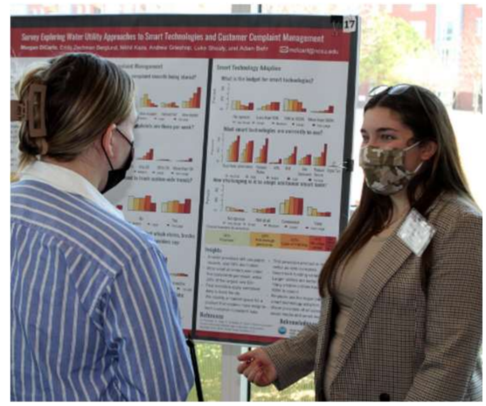
2014 - National Science Foundation CAREER Award

KEYNOTE ABSTRACT

The complex dynamics of low-gradient landscapes

What does it mean for a landscape to be sustainable? And what does sustainability mean for the people living on the landscape? As we address whether landscapes are sustainable or under which conditions we can achieve sustainability, we must realize that the view we get at the system scale can be very different from the view at the human scale. Sustainability can mean different things for the system and its people. The connector between these two views is the river network itself, which is responsible for the distribution of fluxes of water, sediment, and nutrients across the landscape. In this talk, I will cover the analysis of landscapes across scales, focusing on coastal areas: what we learn from a system view, what happens at the local/human scale, and how the network fills the gap between these two views. I will show results from remote sensing data analyses identifying hot spots of geomorphological change and river migration rates. I will show numerical modeling results and discuss some challenges in modeling river-floodplain connectivity and how multi-source data can help address them. Finally, I will link this research to an ongoing project in the coastal area of Southeast Texas, where acute stressors such as flooding impact communities continuously exposed to chronic stressors such as air pollution and discuss how collaboration across disciplines and with local communities can inform the development of adaptation strategies under future climate scenarios.

AGENDA

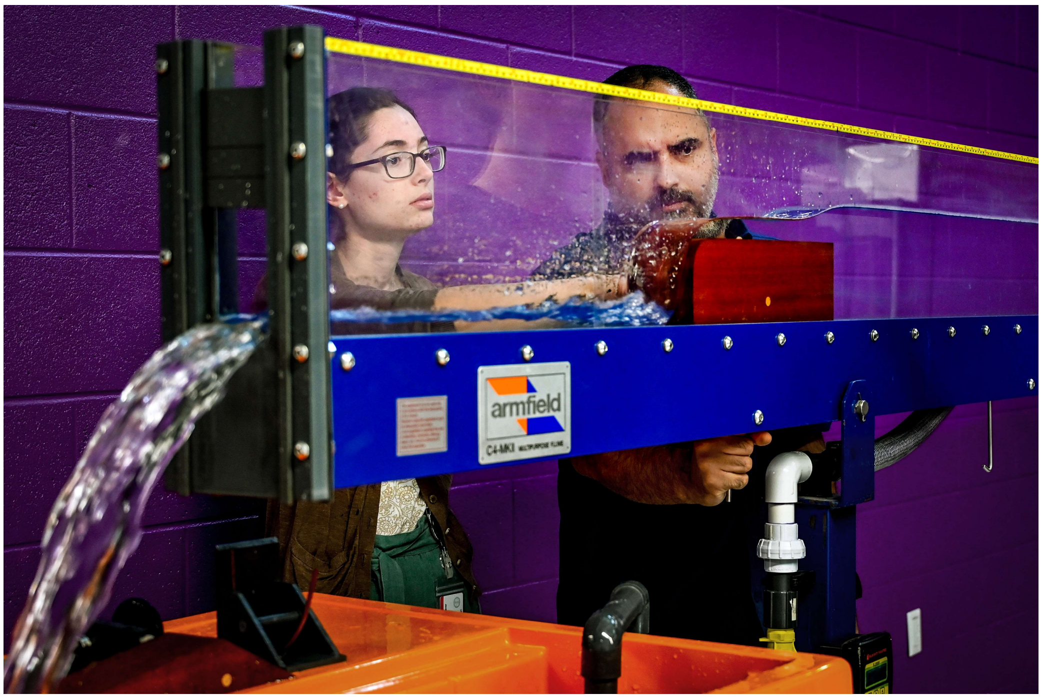
  

Time	Event	Location
11:00 - 1:00	Poster Session and Lunch	Duke Energy Hall

Note: Poster presenters will be at their posters from 11:00-12:00. Lunch will be from 12:00-1:00.

Time	Event	Location
1:15 - 1:55	Oral Presentation Session I Environmental Process Engineering Water Resources	 FWH 2321 FWH 2331
2:10 - 2:50	Oral Presentation Session II Environmental Process Engineering, Coastal Engineering, Air Quality Energy, Modeling, and Systems	 FWH 2321 FWH 2331
2:50 - 3:30	Networking, Poster Viewing, Coffee	Duke Energy Hall
3:30 - 4:45	Keynote Speaker - Paola Passalacqua	Duke Energy Hall
4:45 - 5:00	Awards and Close	Duke Energy Hall

Posters



Environmental, Water Resources and Coastal Engineering

NC State University

Department of Civil, Construction, and Environmental Engineering

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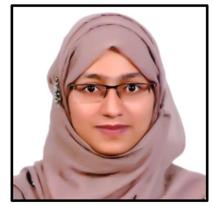
Water Resource Engineering

An Analysis of Fire Emissions in the Northern South America



Presenter: Nafisa Islam

Co-author(s): R. Morales, D. Rojas-Neisa, J. Grey, G. Choi, F. García-Menendez

Research Question: What are the characteristics of fire-related PM2.5 emissions and concentrations in Northern South America?

Biomass burning emissions from deforestation and natural wildfires are one of the largest sources of air pollution in South America. Fine particulate matter (PM) from biomass burning emissions show large spatial and temporal variability in the region. Due to the impacts of PM on human health, it is important to adequately characterize PM2.5 emissions and concentrations near fire-prone areas to quantify and address the detrimental effects of deforestation practices and wildfires. In this study, we analyze the variability in fire-related emissions of PM2.5 and PM10 over northern South America, and areas near Amazonia specifically. We compare fire-related particulate matter emissions in the region derived from the FINNv1.5 and FINNv2.5 inventories and particulate matter concentration predictions generated with the Weather Research Forecast model with Chemistry (WRF-Chem) based on each inventory. Further, we analyze organic carbon (OC) to elemental carbon (EC) ratios in the region to explore the role that fires and secondary organic aerosol formation might play in determining air pollution levels.

Keywords: *PM2.5, Wildfire, Deforestation, Amazon*

Global Temperature Impacts of Household Energy Use Scenarios in Malawi

Presenter: Emily Floess

Co-author(s): A. Grieshop

Research Question: What are the global temperature impacts from different cooking scenarios in Malawi?

Malawi produces 0.04% of global greenhouse gas emissions, yet is one of the most vulnerable countries in the world to climate change. Additionally, country-wide energy sector CO2e emissions, including household energy, are projected to increase by over 700% from 2017 to 2024, showing the importance of decreasing climate-forcing emissions. In its recent Nationally Determined Contributions (NDCs), two big focuses are improved charcoal cookstoves and improved firewood cookstoves. Household solar availability and cleaner charcoal and electricity production are other major focal areas. Many improved cookstoves are carbon-financed, and one such of these cookstoves is the C-Quest Capital TLC Rocket Stove, with over 2 million in Malawi. This stove has a thermal efficiency of 35%, compared to 10-15% for an open fire. This poster focuses on framing estimates of global temperature impacts using use-phase and upstream emissions from different levels of adoption of these stoves. To do this, we use estimated emissions as inputs into the Finite Amplitude Impulse Response (FaIR) model, a reduced-form global climate model, to calculate radiative forcing and global temperature differences associated with different scenarios. Preliminary temperature impact estimates are calculated using prior-field and literature-based stove emission factors for different household cooking energy scenarios, including a traditional wood and charcoal stove, improved biomass and charcoal stove, and LPG and electricity. These results will be compared with the climate impacts of the widespread adoption of the TLC stove. The results from this study could suggest which household cooking interventions could be the most impactful for Malawi from cooking-sector emissions and climate change perspectives.

Keywords: *Climate change, Air quality, Cookstoves, Emissions, Clean cooking*

Development of a Methodological Framework for Data Quality Assurance of Real-World Measurements of Ferry Engine Emissions

Presenter: Juan Sebastian Larrahondo Cruz

Co-author(s): A. Grieshop, T. Wei

Research Question: How to accurately quantify ferry emissions based on real-world measurements.

Maritime activities release pollutants linked to both health issues and climate change. The North Carolina Department of Transportation (NCDOT) manages a fleet of 23 ferry vessels, ranging in age from 2 to 54 years, operating on 7 routes along the state's coast. The fleet comprises a total of 50 main engines for propulsion and 23 auxiliary engines for electricity supply. NCDOT and NC State University are partnering to evaluate this fleet's environmental impact by measuring real-world engine emissions. This poster presents a methodological framework for ensuring the data quality of real-world ferry emissions. Portable emission measurement systems (PEMS) are used to measure second-by-second engine exhaust pollutant concentrations, including CO2, CO, hydrocarbons, NOx, and particulate matter, under actual ferry operations. The quantification of engine emission rates also requires engine activity data, such as mass fuel flow, which are recorded from the electronic control module (ECU) via a datalink scan tool. The quality assurance is essential for two types of data: metadata and measured data. Using metadata, engine specifications and characteristics were employed to characterize the ferry engine fleet. For instance, among the fleet, main engine rated power ranges from 400 to 1150 hp, with 48% of these engines lacking compliance with an EPA emission standard. For measured data, a quality assurance plan is under development to identify and correct errors in measured variables as well as to synchronize second-by-second data streams between PEMS and ECU. This study establishes the foundation for accurate quantification of ferry engine emissions based on real-world measurements.

Keywords: *Ferry, Engine emissions, Portable emission measurement systems, Exhaust concentrations*

Investigation of the Spatial and Temporal Variations in PM2.5 Concentrations and Exposures in Kyiv, Ukraine, Due to War-Related Events

Presenter: Mila Yutskevych

Co-author(s): A. Grieshop

Research Question: What is the impact of warfare-induced pollution, particularly PM2.5 concentrations, on air quality in Kyiv, Ukraine, during the ongoing Russian war against Ukraine.

Amidst the global concern over air pollution, the environmental and health impacts of warfare-induced pollution often go unaddressed. Moreover, research on war-related impacts on the environment and health is scarce. The ongoing Russian war against Ukraine offers a unique opportunity to study the real-time effects of war activities on air quality (AQ). Focusing on Kyiv, Ukraine, this study examines the impact of war-related pollution, particularly PM2.5 concentrations, using AQ data from a network of low-cost sensors collected from January 2019 to December 2023. By analyzing trends during war-related events such as missile attacks and changes in population density and urban activity due to the Russian invasion on February 24, 2022, the research aims to understand how these activities alter baseline pollution levels and impact human health. Preliminary results for the first month of the invasion reveal a notable increase in PM2.5 concentrations in 2022 (+17.83%) and 2023 (+24.94%) in comparison to 2019. A unique aspect of this study enabled by the relatively dense sensor network is the potential to register the effect of individual attacks (e.g. missile strikes) on AQ measured in nearby areas. The study explores the dependency between population density changes and ambient AQ, with preliminary analysis suggesting a decrease in pollution levels during a mass evacuation and subsequent rises of the pollution levels upon the population's return. Future research will focus on localizing attack sites and analyzing AQ before and after events, as well as investigating the link between PM2.5 concentrations and environmental risks.

Keywords: *PM25, War, Air pollution, Air quality, Environmental risk*

Evaluation of Indoor Air Quality Parameter Estimation Methods Based on Numerical Simulations to Support More Accurate Exposure Assessment

Presenter: Sailaja Eluri

Co-author(s): H. Christopher Frey

Research Question: Which indoor air quality parameter estimation method is precise and accurate to quantify air pollution exposure indoors?

Exposure to air pollutants causes adverse human health effects. Air pollution exposure indoors can be quantified using infiltration of ambient air pollution indoors, estimated using infiltration factors (Finf), and indoor generated sources (Cig). Parameter estimates for Finf and Cig can be estimated based on slope and intercept of a linear model of simultaneous indoor and outdoor concentrations. Typically used parameter estimation methods include simple linear regression (SLR) and linear mixed model (LMM). However, there is not clear guidance on which method may be preferable. The objective of the work is to evaluate conditions under which one method is more precise and accurate than the other. Precision and accuracy are affected by factors including sample size, number of groups for LMM, variations in ranges of outdoor concentrations, random measurement errors in indoor and outdoor concentrations, isolated relatively high values in indoor and outdoor concentrations and presence of autocorrelation in residuals. A challenge in evaluating parameter estimation methods is to compare their results to true values of the parameters. Such comparisons are possible with synthetically generated datasets. Numerical simulations with random samples of known population characteristics, "true" Finf and Cig were generated to evaluate precision and accuracy of Finf and Cig estimated from SLR and LMM. Different scenarios for each factor were developed to be representative of situations encountered in empirical datasets. Scenarios of each factor were systematically combined with scenarios of other factors, resulting in 1,260 unique combinations of scenarios. Precision and accuracy of SLR and LMM were evaluated using coefficient of determination, root mean squared error, index of agreement and mean bias error between estimated and true Finf and Cig. The simulation and evaluation methodology has been tested and final simulation results are forthcoming. This work will enable selecting a precise and accurate method to quantify air pollution exposure indoors.

Keywords: *Infiltration Factors, Exposure, Numerical Simulations, Linear Regression, Linear Mixed Model*

Mechanisms of electrically assisted reduction of aqueous organic contaminants using activated carbon electrodes

Presenter: Ethan Quinn

Co-author(s): D. Knappe, D. Call

Research Question: What are the primary properties of activated carbon that facilitate the reductive transformation of aqueous contaminants?

Pyrogenic carbonaceous materials (PCMs), such as activated carbon (AC), can exchange electrons with aqueous contaminants. This reactive behavior may provide new strategies to thoroughly degrade organic contaminants. To realize these benefits, a better understanding of the chemical and physical properties that influence electron exchange is needed. To provide the basis for tailoring PCMs for specific contaminant transformations, we subjected AC cloth to hydrogen peroxide and nitric acid treatments. Mediated electrochemical reduction (MER) tests showed that both treatments increased the electron accepting capacity (EAC) of each AC. In all cases, nitric acid treatment resulted in a higher EAC than hydrogen peroxide-treated AC, reaching up to 409% larger EAC (9.2 mmol e-/g) than the pristine AC (1.8 mmol e-/g). For both treatments, pore volume and sample surface area decreased. Nitric acid treatment resulted in the largest decline in both pore volume and surface area with decreases of 25.9% (0.47 cc/g) and 16.6% (1271.89 m3/g) respectively, compared to pristine AC (0.64 cc/g and 1525.96 m3/g). Conversely, oxygen content measurements for each treated AC revealed ~83% (1.7 mmol/g-AC) and 320% (3.9 mmol/g-AC) increases for hydrogen peroxide and nitric acid treated materials respectively, compared to pristine AC. Currently, several AC electrodes possessing a variety of properties are being studied on their ability to transform a model organic contaminant (Reactive Black 5 dye). Preliminary results indicate significantly enhanced reduction ability based on increased initial oxygen content. These results will provide a foundation for customizing the redox activity of PCMs for organic contaminant transformations.

Keywords: *Pyrogenic carbonaceous materials, Activated carbon, Redox*

Construction of a minimal microbial consortium that effectively degrades oleic acid in enriched anaerobic sludge

Presenter: Sivaranjani Palani

Co-author(s): F. L. de los Reyes III

Research Question: Can a minimal microbial community degrade oleic acid and produce biomethane as effectively as the initial enriched community?

Lipid hydrolysis of vegetable oil and animal fats releases oleic acid (unsaturated long chain fatty acid) into the wastewater, which is considered recalcitrant and toxic in anaerobic digesters beyond certain concentrations. We report the construction of a minimum microbial consortium (MMC), which is the minimum species diversity of microbes essential for optimal community performance of a function; a decrease below this diversity threshold adversely impacts the community's ability to perform its intended function. We developed an MMC that degrades oleic acid in anaerobic digesters (AD) by coupling selective enrichment and dilution-to-extinction techniques. This approach would allow identification of the key players involved in LCFA/lipid degradation in AD systems. Serial dilutions were performed on the oleic acid enriched sludge, and the effect of dilution on the diversity and function of the community was monitored. This resulted in Dilution 2-6 being selected as the optimal dilution to effectively degrade oleic acid with high biomethane production. Three replicates of dilution 2-6 were observed to be able to mineralize 100% of the input oleic acid. The findings will improve our understanding of microbial ecology involved in LCFA degradation, moving us closer towards designing a synthetic microbial consortium or promoting a natural consortium that can effectively degrade lipids in anaerobic digesters.

Keywords: *Anaerobic digestion, Minimal microbial community, Oleic acid*

Does the disposal of PFAS-containing special wastes impact leachate PFAS concentrations?

Presenter: Vie Villafuerte

Co-author(s): M. Barlaz

Research Question: Does the disposal of PFAS-containing special wastes impact leachate PFAS concentrations?

The presence of per- and polyfluoroalkyl substances (PFASs) in landfill leachate is well-documented. Several products that are known to contain PFAS (e.g., textiles, carpet, and food packaging) are disposed as municipal solid waste (MSW) so the presence of PFAS in leachate is not surprising. However, there is no information on whether adding PFAS-containing special wastes to MSW impacts PFAS concentrations in landfill leachate. Under Subtitle D, landfills may also receive non-hazardous solid waste in addition to MSW. The objective of this study was to measure the extent to which the addition of special wastes to MSW contributes to PFAS concentrations and alter the chemical signatures in the leachate. Experiments were conducted in laboratory-scale anaerobic reactors filled with MSW plus a PFAS-containing special waste with an MSW-only reactor as the control. Six types of special wastes were screened for PFAS with a methanol extraction method prior to their addition to reactors: biosolids, soils contaminated with firefighting foam, auto shredder residue (ASR), reverse osmosis (RO) concentrate, granular activated carbon (GAC) and ion exchange (IX) resin from treating landfill leachate. PFAS concentrations in the leachate from reactors containing MSW and MSW plus a special waste were compared. Initial results show that the addition of IX resin, GAC and two contaminated soils resulted in increased PFAS concentrations in the reactor leachate relative to MSW leachate. Future work includes analysis of leachate samples associated with the other wastes and measuring the fraction of the added PFAS that remained stored in the MSW.

***Keywords:** PFAS, Solid waste, Landfill leachate*

Measuring Fungal Activity in Woodchip Bioreactors with Dissolved Organic Matter Snapshots

Presenter: Aaron Zilber Mann

Co-author(s): M. Valbuena, L. Weaver, T. N. Aziz

Research Question: Can fungal degradation of stormwater contaminants be predicted by characterizing dissolved organic matter?

Ongoing research has shown that white-rot fungi grown on woodchips have the potential to degrade stormwater contaminants. However, measuring fungal activity to evaluate the performance of stormwater best management practices (BMPs) can be expensive and uncertain. White-rot fungi are wood-decay fungi that have evolved complex enzyme systems to degrade lignin, making them critical for cycling carbon in the environment. These unique enzyme systems are also responsible for the cometabolism of emerging contaminants observed in previous studies. We hypothesize that measuring the dissolved organic matter (DOM) produced by fungal-inoculated woodchip bioreactors can approximate fungal activity and predict treatment performance for a range of contaminants. To test this hypothesis, bench-scale column reactors were operated through a weekly wet/dry batch cycle, and effluent DOM was measured by spectrofluorometry. The next phase of experiments will monitor DOM, dissolved organic carbon (DOC), and other potential proxies for fungal activity in flow-through reactors with real stormwater influent. The poster presents the experimental design and preliminary results.

***Keywords:** Bioremediation, Stormwater, Fungus, Spectrofluorometry*

Fate of per- and polyfluoroalkyl ether acids in the total oxidizable precursor assay

Presenter: Sarah Teagle

Co-author(s): D. Knappe

Research Question: What oxidation products can be identified and quantified for four PFEAs after undergoing the total oxidizable precursor (TOP) assay?

Per- and polyfluoroalkyl substances (PFAS) are a class of over 10,000 anthropogenic chemicals, of which many pose a risk to human health and the environment. Analytical methods for a majority of compounds are lacking. The total oxidizable precursor (TOP) assay was developed to indirectly measure the concentration of some PFAS that are precursors to commonly observed terminal products in the environment. Previous research discussed the behavior of per- and polyfluoroalkyl ether acids (PFEAs) in the TOP assay. However, oxidation products could not be identified for several PFEAs that degraded in the TOP assay, highlighting the need for more robust analytical methods for oxidation products. The aim of this work is to identify and quantify oxidation products of four PFEAs and one fluorotelomer sulfonic acid (FtS) using liquid chromatography (LC) and tandem mass spectrometry (MS/MS) as well as high resolution mass spectrometry. We hypothesize that oxidation products consist of ultra-short-chain PFAS with 1-3 carbon atoms. Therefore, oxidation products of the five PFAS were analyzed via a novel method that targets ultra-short chain PFAS that would have been missed by previous analytical methods. Results of this work are anticipated to more fully identify oxidizable precursors that may be present in the environment.

Keywords: *PFAS, TOP Assay*

The aftermath of thermal hydrolysis: alleviating microbial inhibition in sidestream treatment

Presenter: Michaela Morales

Co-author(s): F. de los Reyes, K. Bilyk, W. Khunjar

Research Question: How can we alleviate microbial inhibition during sidestream treatment due to relcalcitrant organics released in thermal hydrolysis?

As part of its "Bio-energy Recovery Project," the Neuse River Resource Recovery Facility in Raleigh will implement new processes to be more energy-neutral. In the new system, biosolids will go through a thermal hydrolysis process (THP), anaerobic digestion (AD), and dewatering. While THP will increase biogas production and reduce the overall biosolids production, the liquid from dewatering THP-AD sludge becomes a sidestream that must be further treated due to its high concentration in ammonia. Raleigh Water plans to use ANITA™Mox sidestream treatment with aerobic and anaerobic ammonia oxidizing bacteria (AOB and AMX, respectively) to perform deammonification, which can remove greater than 90% of ammonia and 75-85% of total nitrogen. THP releases recalcitrant organics that are inhibitory to AOB and AMX. The goal of this research is to determine what treatment methods may remove or transform the recalcitrant organics into products that are more readily biodegradable by AOB and AMX. Treatment of the sidestream with powdered activated carbon, alum, and ozone will be tested using batch activity tests for AOB and AMX. The results from this study will provide Raleigh Water with information on how to manage inhibition in the sidestream treatment unit.

Keywords: *Deammonification, Sidestream treatment, Thermal hydrolysis, Anaerobic digestion, Anammox*

PFAS concentration and accumulation history in Jordan Lake Sediments

Presenter: Nadia Sheppard

Co-author(s): D. Knappe, B. McKee

Research Question: Can sediments be used to reconstruct historical PFAS exposure?

Per- and polyfluoroalkyl substances (PFAS) are organic contaminants that widely occur in drinking water sources; however, the behavior of particle-bound PFAS in sediment deposits of lakes and reservoirs is not well understood. This research addresses the role of Jordan Lake bottom sediments as a potential storage reservoir for PFAS in the Cape Fear River system. Samples were extracted using a method based on EPA Method 1633 and analyzed by several LC-MS/MS methods targeting 57 PFAS. Extractions of a sectioned 40 cm core taken near the Haw River inlet to Jordan Lake yielded summed quantifiable PFAS concentrations ranging from 12.0 -138 ng/g dry weight. Compounds detected at the highest concentrations were nMeFOSAA, nEtFOSAA, PFOS, PFOA, and FOSA. Summed PFAS concentrations increased with core depth. Based on Pb-210 geochronology, the analyzed core represented sediment deposition over the last 43 years. Total oxidizable precursor (TOP) assays are underway to better understand distribution of non-quantifiable PFAS. Additional cores will be collected to understand PFAS concentrations in public water sources over time. The results generated in this research will give critical insights into the storage and potential release of PFAS into the water column via sediments.

Keywords: *Historical PFAS deposition, Sediment*

Impact of Hydrogen Source on Mineralization of Per- and Polyfluoroalkyl Substances during Thermal Reactivation of Spent Granular Activated Carbon

Presenter: Nathen Silsby

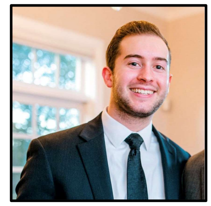
Co-author(s): S. Joseph, B. Preston, S. Jackson, D. Knappe

Research Question: How does different sources of hydrogen effect adsorbed PFOA and PFOS mineralization?

The fate of PFAS at conditions encountered during thermal reactivation of GAC is not well understood. Conditions that promote effective PFAS mineralization during thermal reactivation of spent GAC need to be identified. Information about avoiding possible releases of products of incomplete destruction (PIDs) to air during reactivation of GAC needs to be developed. Previous results indicate that the addition of a source of hydrogen can increase mineralization of some PFAS during thermal reactivation of GAC. This study aims to evaluate the effects of different sources of hydrogen (OH^-, H_2O, fulvic acid, H_2 in a N_2/H_2 99/1% mixture) on adsorbed PFOA and PFOS mineralization in a bench-scale fluidized bed furnace. Constituents in the off-gas from fluidized-bed furnace experiments will be collected with impingers, sorbent tubes, and silicon ceramic lined stainless-steel canisters to determine the fate of PFAS and conduct a fluorine mass balance. Impinger solutions and residuals from the fluidized-bed furnace will be analyzed for anions and cations using ion chromatography (IC). Targeted PFAS analysis of impinger solutions will be performed with liquid chromatography-tandem mass spectrometry (LC-MS/MS). Non-targeted analysis of semi-volatile and volatile fluorinated compounds will be conducted by high-resolution gas chromatograph-mass spectrometry (GC-HRMS). Targeted analysis of volatile fluorinated compounds will be conducted by GC-MS/MS. Results obtained from these experiments will determine the effectiveness of different sources of hydrogen for mineralizing adsorbed PFAS, minimizing the formation of PIDs, and establish reactivation conditions that permit safe and effective reuse of thermally reactivated GAC.

Keywords: *PFAS, Granular activated carbon, Thermal reactivation, Thermolysis, Mineralization*

Detection of Clostridium difficile in Wake County wastewater



Presenter: Benjamin Clark

Co-author(s): N. Turner, B. Warren, A. Barrett, A. Harris

Research Question: Can Clostridium difficile be detected and cultured from wastewater?

C. difficile is a pathogen that causes severe diarrhea that can be life threatening (Smits et al., 2016). It is traditionally thought of as a nosocomial opportunistic pathogen, meaning that the pathogen is usually acquired in a healthcare setting by patients who have a weakened immune system (Smits et al., 2016). In recent years, epidemiologists have observed that the proportion of community-acquired C. difficile has increased (Turner, Grambow, et al., 2019). Although health care facility-associated C. difficile has decreased recently, the presence of community-acquired C. difficile is of concern due to the high costs and negative health impacts that the pathogen can have on a hospital unit (Turner, Grambow, et al., 2019). In 2017 it is estimated that C. difficile racked up 1 billion dollars' worth of healthcare costs, caused 223,900 cases in hospitalized patients, and killed 12,800 people (CDC, 2019). Researchers have pointed towards environmental transmission of this pathogen as an unknown when it comes to transmission of this pathogen (Turner, Smith, et al., 2019). To better understand the diversity of C. difficile and its transmission pathways in the environment, methods for the detection of C. difficile in wastewater and surface waters for eventual ribotyping or sequencing have been developed. Using qPCR, C. difficile was detected in 100% (n = 99) of wastewater samples from two treatment plants in Wake County. PCR positive C. difficile isolates have also been obtained from 7% of wastewater samples thus far, but samples are still being processed.

Keywords: *C. difficile, Wastewater based epidemiology*

Fused Portfolio Optimization for Harnessing Marine Renewable Energy Resources: Exploring Opportunities for Improving Energy Density and Levelized Cost of Electricity

Presenter: Mary Maceda

Co-author(s): V. D. D. Faria, A. R. de Queiroz, C. Vermillion

Research Question: How do we optimally design and deploy a suite of energy-harvesting devices?

Offshore wind and marine hydrokinetic (MHK) energy are vastly underutilized energy resources. Efficiently exploiting these energy resources requires the ability to identify optimal deployment locations for energy harvesting devices. Power extracting devices have the potential to be deployed in tandem such that the suite of devices consistently saturates a given power transmission system. To facilitate the definition of optimal locations and shares of these devices, a portfolio optimization framework has been developed that unifies solutions of resource, technical performance, transmission, and cost model sub-problems into a unique and comprehensive tool to support MRE analysis. This framework uses wind speed and ocean current data alongside robust device models to select optimal locations for wind turbine and kite deployment based on levelized cost of energy (LCOE). By optimizing based on LCOE, the algorithm is able to create a mapping of devices that not only produces the maximum transmittable power and stabilize portfolio variability, but also does so in the most cost-effective manner. Devices such as wind turbines, and MHK kites – as well as any other reliably modeled offshore power extracting device – can be used within this framework. Wind turbines and MHK kites are selected as a case study due to the group having access to reliable device models and data. Results from this case study demonstrate optimal portfolios of devices for a set location off the coast of North Carolina.

Keywords: *Energy, Optimization, Dites, Power, Portfolio*

Convolutional Neural Networks and Transfer Learning Approaches for Enhanced Detection of Rooftop Solar PV Systems in Distributed Power Grids

Presenter: Yen-Hsi Chou

Co-author(s): V. A. D. Faria, A. R. de Queiroz

Research Question: Image segmentation

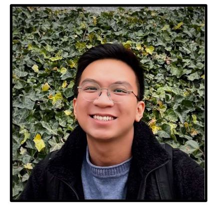
Accurate mapping and characterization of distributed rooftop solar photovoltaic (PV) systems are essential for effective energy planning, techno-economics assessment, net demand forecasting, and policy-making. However, traditional methods of gathering data on distributed electricity generation infrastructure are often laborious, costly, or impractical.

In this study, we leverage advancements in machine learning from recent years and introduce state-of-the-art image segmentation architectures for automated PV panel detection from remotely sensed data. To enhance performance constrained by training time and dataset size, we employ transfer learning by utilizing pre-trained large-scale deep neural networks (DNNs) as feature extractors. Additionally, we propose a novel hard task (HT) mining scheme as an effective learning framework to further improve model performance.

Employing a comprehensive comparative framework, this study examines a range of factors that influence prediction accuracy, including establishing PV array recognition thresholds, architectural characteristics of image segmentation models, sampling strategies for hard task mining, and strategies for parameter freezing of encoders. Our final experimental results demonstrate that our approach achieves superior performance, with an F1 score exceeding 0.94 and an IoU exceeding 0.87 in PV panel extraction.

This research contributes to the advancement of automated methods for infrastructure mapping, offering a scalable and efficient solution for monitoring and managing distributed solar PV systems. Also, ideas developed here for PV systems detection can be further explored in other areas.

Keywords: *Photovoltaic panels, Remote sensing, Image segmentation, Transfer learning, Hard task mining*



Integrating Operational Aspects into Long-term Energy Planning: A Multi-stage Stochastic Programming Approach

Presenter: Duc-Huy Pham

Co-author(s): H. Pham, J. Kern, A. R. de Queiroz

Research Question: Create a multi-stage stochastic programming framework to plan long-term capacity expansion, accounting for broad uncertainties

Energy systems face uncertainties in long-term planning, driven by factors such as regulations, technological advancements, and fluctuating generation costs. These uncertainties have a substantial impact on decision-making in investment and operations within the energy sector. Thus, there is a critical need for integrated modeling frameworks that can effectively address uncertainties in long-term periods. This research focuses on constructing a multi-stage stochastic programming model using Benders' decomposition method to optimize long-term capacity expansion as well as support decision-making process in investment and operations in energy systems.

Keywords: *Multi-stage stochastic programming, Capacity expansion, Energy system modeling*

Exploring the influence of air pollution modeling framework in evaluations of air pollution exposure disparities associated with power generation

Presenter: Bianca Meotti

Co-author(s): J. Johnson, F. G. Menendez

Research Question: How does the selection of an air pollution modeling framework to optimization power system outcomes affect environmental justice analyses?

Emissions from the power sector are a major contributor to ambient air pollution and its adverse impacts on human health. In the United States, black and lower-income populations are exposed to higher air pollution concentrations caused by power sector emissions. Many studies have examined racial-ethnic and socioeconomic disparities in ambient air pollution impacts. However, few have evaluated the uncertainty in estimates of socioeconomic disparities arising from the selection of an air pollution modeling framework.

Here, we assess racial-ethnic and income-based disparities in exposure to air pollution from electricity generation predicted by a least-cost power system optimization model coupled to different air pollution modeling frameworks. Our work simulates ambient air pollution from electricity generation in Texas's power grid using two distinct air quality modeling approaches: (i) CALPUFF, a dispersion model that provides detailed spatial resolution; and (ii) the Community Multiscale Air Quality (CMAQ) modeling system, a chemical transport model that provides air pollution concentrations at a coarser spatial resolution but represents atmospheric processes more comprehensively.

Our research aims to understand how different air pollution modeling frameworks impact the exposure disparities in the outcomes of a power system optimization model. The findings of this work can help mitigate exposure disparities related to power plant emissions by better addressing social equity and informing decision-making.

Keywords: *Environmental justice, Spatial resolution, PM2.5, Air quality, Power systems*

Semantic image segmentation of roadway inundation in coastal communities

Presenter: Ryan McCune

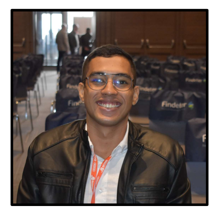
Co-author(s): E. Goldstein, K. Anarde

Research Question: Can machine learning be used to automatically detect and quantify flooding in coastal communities?

Coastal flooding on low-lying roadways can be shallow, hyper-local, and short-lived, making it difficult to monitor with fixed, in situ sensors. Here we use images from low-cost cameras installed at flood hotspots in three North Carolina communities to identify flood incidence and spatial extent using deep learning . We use Doodler (Buscombe et al., 2022) to label image pixels into one of ten classes (water, road, building, vehicle, sidewalk, person, sky, vegetation, object, and other). The labeled dataset is then used to train a deep learning model for each camera. The camera scenes differ in development (urban versus rural) and flood drivers (tides+rainfall versus tides only), which allows us to explore geographic factors that influence the success of semantic image segmentation for determining flood incidence and extent. Preliminary work indicates better success for urban scenes as compared to rural scenes. Further work will assess the utility of model predictions as a vehicle for communicating flood incidence and risk with partner communities.

Keywords: *Coastal flooding, Machine learning, Sea level rise*

Turbulent Dispersion and Residence Time: An Experimental Study of Mixing Mechanisms Through Seagrass Mats



Presenter: Juan Esteban Conde Barrios

Co-author(s): J. San Juan

Research Question: How is the interaction between residence time and turbulent dispersion in unidirectional vegetated flows?

Aquatic vegetation can trap pollutants, attenuate peak concentrations, and potentially decrease the exposure of ecosystems to harmful concentrations. For instance, in coastal ecosystems, seagrass mats improve local water quality by filtering contaminants and nutrients from the water column. Therefore, a pivotal process to assess their vulnerability is flushing time, which relates the hydrodynamics to the mass transport processes in the vegetated aquatic systems. However, most current studies have a simplified physical representation of the vegetation and do not consider plant flexibility. Here, we investigate the mixing mechanisms in vegetated flows by exploring the dependencies between turbulent dispersion and residence time. We conduct experiments in a recirculating flume (unidirectional flow) using seagrass surrogates for different flexible vegetation arrangements and densities. Our seagrass surrogate response to an incoming flow is similar to the bio-mechanical behavior of natural seagrasses upon waves and currents. Two optical methods, Particle Image Velocimetry (PIV) and Laser Induced Fluorescence (LIF), will be used to characterize the flow-vegetation hydrodynamic interactions and mixing of a tracer. Our findings will advance the current understanding of mixing and mass transport processes in vegetated flows, which is crucial for preserving vulnerable coastal ecosystems. In addition, this work can provide guidelines for implementing management practices for seagrasses.

Keywords: *Seagrass, Residence time, Turbulent dispersion, Physical modeling*

Development and validation of a sensor framework for measuring floods on land in rural areas

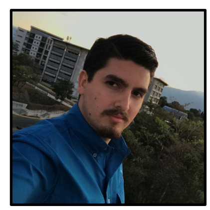
Presenter: Lucas Snoddy

Co-author(s): R. McCune, T. Thelen, K. Anarde

Research Question: What effect does a wetting and drying cycle have on a water level sensor

Coastal flooding due to sea level rise is affecting communities across North Carolina. Currently, we use tide gauges to predict these floods, however, in communities far away from tide gauges, these flood predictions may be poor. Moreover, tide gauges do not capture contributions to floods from land-based factors (rain, groundwater). Here, we describe the design of the second version (V2) of the Sunny Day Flood Sensors (SuDS), which were improved to measure floods on land far from tide gauges. The inner workings of the V2 closely resemble those in the first version (V1), major differences include the housing, different sensor, and V2 being solar powered and cellular connection. In September 2024, we deployed the first V2 sensor in Carolina Beach, with the pressure sensor mounted within a storm drain. Shortly after installation, pressure sensor readings showed sensitivity to wetting and drying by daily tidal fluctuations. Here, we describe a series of laboratory tests where we attempt to replicate wetting and drying conditions observed in the field. The tests involved alternating between placing the sensor in water and air for 1 hour periods for a total of 4 hours. Preliminary results suggest that the porous stone and silicon gel that cover the pressure transducer as a way of protection can affect pressure readings during wetting and drying. Based on these results, moving forward we plan to implement the same wetting and drying test prior to deployment to ensure the porous stone and silicon gel do not influence the quality of measurements.

Keywords: *Coastal Flooding, Wet-Dry Testing, Sea Level Rise*



The Impact of Oyster Reef's Substrate and Density on the Turbulence and Flow Structure

Presenter: Javier Zumbado Gonzalez

Co-author(s): J. San Juan

Research Question: How does the oyster reef affect turbulence and flow structure?

Oyster reefs are valuable habitats that provide ecosystem services and coastal protection, but they have been degraded by human activities and environmental changes. Oyster reef restoration projects aim to restore the lost habitat and enhance the resilience of the coast. However, the hydrodynamic and sedimentary processes over oyster beds are poorly understood, especially the influence of substrate type and oyster density on the flow structure and turbulence. This study investigates the impact of oyster density on the turbulence parameters over oyster beds under varying flow conditions. In a recirculating flume, we will measure and analyze the hydrodynamic parameters over a physical model of the oyster bed with two substrates (limestone and oyster shell) and varying oyster densities. The velocity field near the bed will be measured using Particle Image Velocimetry (PIV), and the turbulence parameters will be estimated (turbulent kinetic energy, dissipation rate, and drag coefficient). Our findings will provide insights into the hydraulic roughness and mixing over subtidal oyster beds and how they vary with substrate type and the reef's developmental stage (oyster density). The turbulence parameters can be used to validate numerical models and to assess the effects of oyster reef restoration on the surrounding areas, such as particle dispersion and sediment transport.

Keywords: *Oyster reef, Turbulence, Hydrodynamic, Coastal resilience*

Comparison of Planet Scope Imagery and Airborne Images for Land Cover Classification in Coastal Areas

Presenter: Roya Sahraei

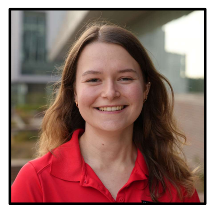
Co-author(s): E. Sciaudone, K. Anarde

Research Question: Assessing satellite data ability to map the land cover

Sandy barrier islands are low-lying, dynamic landforms that change shape in response to natural processes. Once developed, humans seek to minimize the effects of these natural processes to protect infrastructure. To protect roadways from these processes, large dunes are often built to limit overwash, and roads are relocated landward when encroached by eroding shorelines. Animal habitats on barrier islands can be affected by these human actions. For example, piping clovers use washover deposits as nesting grounds, and therefore, by limiting overwash, humans can limit the habitat extent of this bird species. It is important to understand and predict future habitat evolution because these habitats provide ecosystem services, and because shifts in habitat may feedback to alter the evolution of the barrier landscape and future management decisions. We compare the utility of open-source (free) Planet Scope imagery (3 m resolution) with very-high resolution (and costly) airborne images (0.25 m resolution) collected by the North Carolina Department of Transportation (NCDOT). NCDOT collects the airborne images several times a year and these images are used in part to evaluate habitat changes using supervise Maximum likelihood Classification (MLC) combined with digitized habitat classes. In this study, the performance of eXtreme Gradient Boosting (XGBoost) classifier was compared with NCDOT habitat classification approach. We find that XGBoost approach results in higher accuracy classifying satellite imagery dataset (84.08%) rather than 3-band airborne images (75.62%). Conversely, Planet Scope classified images using NCDOT approach did not provide as precise results as airborne classified images.

Keywords: *Barrier Islands, Land Cover, XGBoost*

Design of low-cost sensor instructions to increase access to coastal flooding data collection



Presenter: Perri Woodard

Co-author(s): L. Snoddy, T. Thelen, R. McCune, A. Whipple, K. Anarde

Research Question: How can coastal communities collect flooding data at a low-cost?

As global temperatures increase and the effects of global warming intensify, sea-level rise will continue to impact coastal communities through chronic flooding. Coastal communities face property damage, disruption of daily life due to road closures, deterioration of infrastructure, and the potential for groundwater contamination. Despite the significant effects of chronic flooding on coastal communities, there is a lack of affordable methods to collect and monitor water-level data available to both researchers and communities. We provide step-by-step instructions to build and deploy pressure loggers and cameras capable of monitoring flooding within communities by recording water levels and capturing images. In an online wiki, we have documented the materials required for constructing the pressure logger and communications gateway components of low-cost sensors that may be utilized by both researchers and communities to better understand coastal flooding. Additionally, we have provided further information on the online setup of these sensors, as well as notes on common problems encountered when building the sensors. Communities that have consistent flooding data available to them can make more effective decisions regarding flood mitigation strategies. Looking forward, the wiki can allow other researchers and communities to affordably construct their own sensor networks and collect critical data on a local level.

Keywords: *Coastal flooding, Sea level rise, Wiki*

Subseasonal-to-Seasonal Streamflow Forecasting For Water Resource Management

Presenter: Jessica Levey

Co-author(s): S. Arumugam

Research Question: Is subseasonal-to-seasonal streamflow forecasting useful for water resource management?

Climate change is altering global hydroclimatology and threatening the majority of the world's fresh water sources. In addition to climate change, population and land use change are stressing water sources and will amplify the water scarcity crisis. Rivers are dammed to create reservoirs, which serve various purposes including water supply, flood control, hydropower, and irrigation. Reservoir releases are modified during droughts and floods to meet water demand without increasing downstream risk. Mismanagement of water resources may threaten agriculture and food supply chains, human and environmental health, and regional economies. Accurate streamflow forecasts is essential for effective water resource management and planning. Most reservoirs are operated by only considering short-range inflow forecasts, 1-7 days lead time, which is important for determining daily releases to meet the daily water supply and energy demands and as for managing flash flood and storm-caused flood events. Reservoir operations do not consider forecasts at the subseasonal-to-seasonal (S2S) range, 15-90 days ahead. S2S forecasts are important energy grid planning, meeting storage demands for irrigated agriculture, drought effect mitigation, and maintaining long term storage and flow conditions for meeting ecological demands. This study a) develops a large-scale framework using a multivariate long-short term memory (LSTM) model t0 predict S2S streamflow forecasts for large-scale water resource management and b) evaluates the forecast performance for below normal, normal, and above normal flows. As hydrologic extremes are becoming more frequent and intense, accurate, longer-range forecasts will be crucial for meeting water demand and effectively managing water resources.

Keywords: *Hydroclimatology, Water resources management, LSTM, Droughts & floods*

PipeNetGen: Applying Open Access Data to Create Synthetic Water Distribution Networks

Presenter: Elias Zauscher

Co-author(s): E. Berglund

Research Question: How can we develop pipe network models using open source information?

Water distribution networks are critical infrastructure systems that deliver water at
expected levels of quality, quantity, and pressure across a wide geography to diverse water users. Systems analysis tools, including modeling and optimization, are vital in developing designs and management strategies for building and operating pipe networks. However, Water utilities need to protect data to manage infrastructure security, resulting in limited accessibility of water distribution network models that can be used to develop insight for cities. Existing methods generate pipe network models that can be used in research to test simulation and optimization approaches for managing infrastructure. Model generating methods use open-source data as input and apply Mixed-Integer Linear Programming (MILP) to size pipes. This research extends existing model generating methods by including additional open-source tile map datasets and data describing water infrastructure components, such as water towers. The MILP method is linked with the EPANET hydraulic solver to validate hydraulic assumptions and assess the accuracy of the MILP approach to calculate pressures. The method is demonstrated in this research to generate a representative network for cities using readily available open-source data. This tool can aid researchers in developing and testing water management strategies.

Keywords: *Water distribution networks, Pipe sizing, Linear programming, Open-source data*

Quantifying Variability in Internal Phosphorus Loading Estimates across the United States

Presenter: Smitom Swapna Borah

Co-author(s): D. Obenour

Research Question: Way too long

Upward release of sediment phosphorus (P) can be a significant contributor towards freshwater eutrophication. This internal loading (IPL) can be comparable to the loading from the external sources and is often responsible for delayed water quality improvement following external load reductions. However, IPL estimates are largely absent in regional and national P inventories owing to several challenges in large-scale measurements. Existing IPL models have limited applicability over large spatial scales due to low predictive skill or covariates that are not regularly available. Our previous research proposed a hybrid approach for IPL prediction in U.S. lakes and reservoirs through a combination of machine learning (ML) and regression modeling. We now propose an approach for propagating uncertainties through this predictive framework, and we apply it to quantify uncertainties in IPL estimates in over 5000 U.S. waterbodies. Furthermore, results are presented in the context of regional nutrient budgets. Results suggest wide variability in IPL (~1 to 60 mg/m2/d), with nearly 45% waterbodies having high internal loading (≥ 10 mg/m2/d). These high IPL values are also associated with substantial uncertainty, which is largely due to the uncertainties in water-column P concentration and bottom water temperature inputs (estimated through ML). Interestingly, when compared across all major river basins in the US, our study suggests that summer IPL is likely to be higher than point source loads in nearly 70% of the major river basins. These findings can supplement regional and national P budgets and aid decision makers in developing effective and sustainable P management strategies.

Keywords: *Internal phosphorus loading, Random forest model, Average lake phosphorus*

Enhancing Reservoir Operation Policy Prediction through Hybrid Modeling

Presenter: Jiheun Kim

Co-author(s): S. Arumugam

Research Question: What are the error-prone modes in the previous PLRT model and can we couple ML models with PLRT model to increase performance and preserve transparency at the same time?

Dams are vital for downstream flow regulation, yet integrating reservoir systems into land-surface models (LSMs) poses computational challenges. Moreover, physically-based rainfall-runoff modeling is time-consuming, prompting a shift towards data-driven models. Therefore, recent efforts have turned to data-driven models to capture reservoir operation release patterns. Ford (2023) introduced a general reservoir operation policy using a Piece-wise Linear Regression Tree (PLRT) model. Unlike many other machine learning (ML) models' "black box" nature, this method provides clear parameterizations based on time series data related to reservoir operation. However, there is still room for improvement, as the performance of this method varies within basins due to generalized release patterns. Thus, this study first identifies error-prone modes in the PLRT model and proposes coupling with ML models while preserving transparency. Specifically, this study explores the potential of using the Long Short-Term Memory (LSTM) model, a specialized form of Recurrent Neural Network (RNN). Coupling PLRT and LSTM models enhances performance significantly. For Mode 1, Nash-Sutcliffe Efficiency (NSE) increased from 0.34 to 0.74, and Root Mean Square Error (RMSE) for Mode 9 decreased from 1.09 to 0.27. This hybrid approach promises to enhance overall reservoir operation prediction accuracy.

Keywords: *Reservoir operation policy, Piece-wise Linear Regression Tree (PLRT) model, Long Short-Term Memory (LSTM) model, data-driven model, Recurrent Neural Network (RNN)*

Machine Learning Models for Estimating Water Depth based on Camera Images

Presenter: Hart Henrichsen

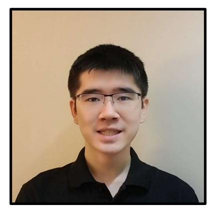
Co-author(s): S. Arumugam, R. Ranjithan

Research Question: Can we use camera images to get water depth?

Flooding is one of the most common and costly disasters in the world. To forecast flooding and to take preventive actions to minimize loss of property and life and environmental damage, hydrologic models are used to understand past flood events and predict future flooding. These flood models use a combination of physical processes and empirical information, both of which depend on observed data to achieve sufficient quality and confidence in their outputs for actionable decision making. A major issue is the limited availability of metered gauges to report water depth at sufficient spatiotemporal resolution. To augment the amount and resolution of available observed water depth data, this study investigates a machine learning (ML)-based approach to estimate water depths by processing images from publicly available fixed cameras (e.g., public safety and surveillance cameras). This approach is being tested on data from 14 cameras and nearby USGS gauge readings in Charlotte, North Carolina. An ML model for each camera location is trained using that camera's images and the corresponding USGS gauge data taken at 5-minute intervals and then tested using another dataset at the same location. We intend to extend the model by incorporating images from multiple camera locations to increase the confidence and accuracy of water depth estimates for each location. ML models could then be used to estimate water depth where camera images are available but not any gauge data. Preliminary results show that single location ML models can estimate water depth with a 95% confidence interval within 1.5 inches.

Keywords: *Hydrology, Machine Learning, Data Collecting, Data Processing, Uncertainty Reduction*

A cost-benefit perspective for assessing alternative approaches to lead prevention among homes relying on private wells



Presenter: Timothy Leung

Co-author(s): J.M. Gibson

Research Question: How can families affected by lead in drinking water be connected to appropriate preventive measures that meets their individual needs?

Lead is a corrosive-resistant, ductile, and malleable metal that is naturally occurring and found in many manufactured products. Although improvements to lead exposure have been significant in recent decades, there is a current misconception that lead exposure is no longer an issue because of its elimination from many products. This is of particular concern for children that obtain drinking water from private wells since they have been found to have increased odds of elevated blood lead levels in comparison to children in homes connected to community water systems regulated under the Safe Drinking Water Act. Due to gaps in resources from societal and economic disparities, it is important for those most impacted by lead exposures to find the prevention options best suited to their circumstances. With new and effective methods for limiting lead, those most affected by harmful exposures should remain not remain under these circumstances. Lead has been well-known to have severe health effects later in life, so providing appropriate and practical solutions to this long-standing issue should be a priority for better public health. Thus this research aims to assist families with finding the optimal exposure reduction and mitigation solutions based on home environments and family circumstances.

Keywords: *Lead, Private wells, Cost-benefit*

Talks

	Fitts-Woolard Hall RM 2321	**Fitts-Woolard Hall RM 2331**
Session 1 1:15 pm – 1:55 pm	Environmental Process Engineering	Water Resources Engineering
Session 2 2:10 pm – 2:50 pm	Environmental Process Engineering Coastal Engineering Air Quality	Energy, Modeling, and Systems

List of Talks

Air Quality

01

Amir Ghajari
Assessing the Air Quality Impacts of Prescribed Burns at North Carolina State Parks with a Regional-Scale Chemical Transport Modeling System

Environmental Process Engineering

02

Stefanie Starr
Behavior of Per- and Polyfluoroalkyl Substances during Thermal Reactivation of Spent Granular Activated Carbon

03

Sarangi Joseph
Fundamental Insights into PFAS Adsorption to Activated Carbon at Adsorption Equilibrium

04

Banks Grubbs
Estimating the Contribution of Private Well Water Consumption to Overall PFAS Exposure

05

Leah Weaver
Life Cycle Analysis of Stormwater Bioretention Cell Media Compositions

06

Savanna Smith
Microbial Community Assembly of Waste and Wastewater Treatment Systems

07

Temi Ibitoye
Assessing SARS-CoV-2 Surveillance Tools: A Comparative Study of RT-ddPCR, Short Read Sequencing, and Long Read Sequencing in Wastewater

Energy, Modeling, and Systems

08

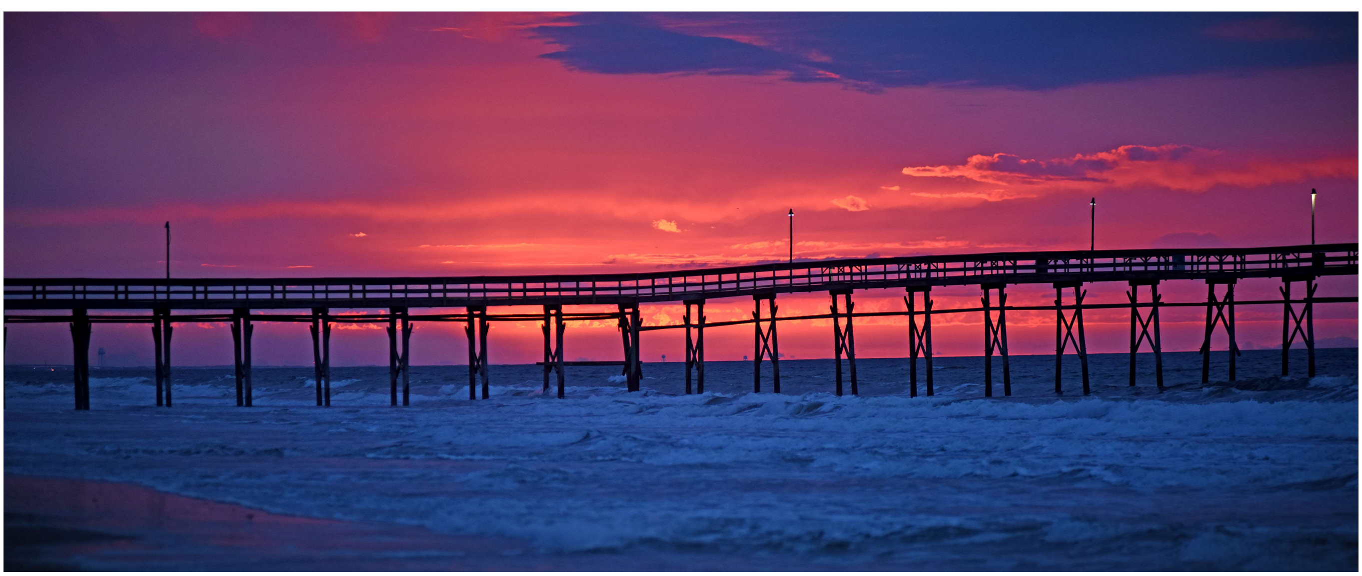
Jethro Ssengonzi
Impact of Varying Renewable Capacity Credit Allocation on Larger Grid Capacity Expansion Planning

09

Gavin Mouat
The Impact of State and Federal Decarbonization on Technological Pathways

10

Henry Ssembatya
How the Dual Effects of Space Heating Electrification and Climate Change Could Impact Seasonal Peaking and Reliability of the Texas Power Grid



Assessing the Air Quality Impacts of Prescribed Burns at North Carolina State Parks with a Regional-Scale Chemical Transport Modeling System

Presenter: Amir Ghajari

Co-author(s): F. García-Menendez

Research Question: How can a state-of-the-science chemical model be used to predict the effects of prescribed burns of different sizes on air quality around North Carolina State Parks?

Prescribed burns are a critical strategy in the management of ecosystems and the prevention of wildfires. By intentionally setting controlled fires, we can significantly reduce the buildup of flammable vegetation, thereby maintaining the ecological health and diversity of various habitats. Moreover, these burns may mitigate air pollution by lessening the severity and likelihood of uncontrollable wildfires, which are major contributors to air quality degradation. To better understand and quantify the air quality impacts of prescribed burns, particularly within North Carolina State Parks, we implement a comprehensive modeling framework. This framework utilizes the BlueSky modeling system to characterize the emissions from prescribed burns based on their size, location, and duration. These emissions data are then integrated with meteorological information derived from Weather Research and Forecast (WRF) model simulations. This combined data is input into the Community Multiscale Air Quality (CMAQ) modeling system, a state-of-the-science atmospheric chemistry and transport model, enabling us to assess the impact of prescribed burns on air quality.

Here, our research focuses on the air quality impacts of five different prescribed fires, varying in size, and occurring in diverse regions across North Carolina. By doing so, we aim to understand how the dispersion of smoke plumes differs across various geographical locations and at different times of the year, influenced by the specific characteristics of each fire. This research can aid the application of comprehensive chemical-transport to predict the impacts of prescribed burning conducted by land management programs, and also contribute to development of strategies to minimize the adverse effects of smoke pollution.

Keywords: *Prescribed Burns, Air Quality Modeling, CMAQ, WRF, BlueSky*

Behavior of Per- and Polyfluoroalkyl Substances during Thermal Reactivation of Spent Granular Activated Carbon

Presenter: Stefanie Starr

Co-author(s): S. Joseph, B. Preston, S. Jackson, D. Knappe

Research Question: What are conditions that effectively mineralize PFAS during the thermal reactivation of PFAS-laden GAC?

Thermal reactivation of spent granular activated carbon (GAC) is a management strategy that permits GAC reuse. The fate of per- and polyfluoroalkyl substances (PFAS) during thermal reactivation of spent GAC is poorly understood. This study aims to identify thermal reactivation conditions that effectively mineralize adsorbed PFAS. Thermogravimetric analysis (TGA) experiments with PFAS, PFAS/hydroxide mixtures, and PFAS/natural organic matter (NOM) mixtures in the absence and presence of GAC were conducted to determine the thermal stability of 4 perfluoroalkyl carboxylic acids (PFCAs), 3 perfluoroalkyl sulfonic acids (PFSAs), and a fluorotelomer sulfonic acid (FtS). Constituents in the off-gas from TGA experiments were collected with XAD sorbent tubes, impingers, and SUMMA canisters. Impinger solutions and TGA pan residues were analyzed for anions and cations using ion chromatography (IC). Targeted PFAS analysis of impinger solutions was performed with liquid chromatography-tandem mass spectrometry (LC-MS/MS). Targeted and non-targeted analysis of (semi-)volatile fluorinated compounds was conducted by high-resolution gas chromatography-mass spectrometry (GC-HRMS). Results to date showed that thermolysis of all tested PFAS in the absence of GAC was complete at temperatures used to reactivate GAC. In contrast, thermolysis of two adsorbed PFAS was not complete at 800°C. Salt forms of PFAS were thermally more persistent than acid forms, and PFSAs were more persistent than PFCAs. Results from IC, LC-MS/MS and GC-HRMS analysis accounted for 11-106 % of the fluorine content of the initially added PFAS and show that the addition of a base or NOM enhances the mineralization of some PFAS.

Keywords: *PFAS, Granular activated carbon, Thermal reactivation, Thermolysis, Mineralization*

Fundamental insights into PFAS adsorption to activated carbon at adsorption equilibrium

Presenter: Sarangi Joseph

Co-author(s): Z. Lin, X. Long, P. Westerhoff, D. Knappe

Research Question: Properties of GAC (including particle size), PFAS, and co-existing constituents in water that influence PFAS adsorption capacity on GAC?

Per- and polyfluoroalkyl substances (PFAS) are synthetic chemicals that occur widely in drinking water sources. Granular activated carbon (GAC) adsorption is commonly used to remediate contaminated water, but the mechanisms of PFAS sorption remain poorly understood. The goal of this research is to determine how GAC and contaminant properties affect accessibility of sorption sites within GAC particles in single and multi-solute systems. Reagglomerated coal-based GAC was loaded with PFHxS to determine intraparticle adsorbate distributions by cryo-focused ion beam and scanning electron microscopy-energy dispersive spectroscopy (cryo-SEM-EDS). Also, batch adsorption/desorption isotherm experiments were conducted with PFAS of different molecular weights with five well-characterized GACs. PFHxS adsorbed uniformly throughout GAC particles with mean diameters of ~20 and ~110 um based on cryo-SEM-EDS analyses. These results are consistent with statistically similar PFHxS adsorption isotherms for the two particle sizes. Furthermore, adsorption and desorption isotherms were statistically similar, indicating that adsorption was completely reversible in single-solute systems. This research will improve our understanding of PFAS-accessible sites in GAC and adsorption/desorption behavior of PFAS in single and multi-solute systems. Findings are expected to support the development of effective adsorbents for PFAS removal as well as policy regarding the disposal of spent GAC in landfills.

Keywords: *PFAS, GAC, Adsorption, Cryo SEM-EDS*

Estimating the Contribution of Private Well Water Consumption to Overall PFAS Exposure

Presenter: Banks Grubbs

Co-author(s): J. M. Gibson

Research Question: What is the contribution of private well water consumption to overall PFAS exposure, and how does the contribution vary depending on PFAS type and proximity to a known PFAS source?

Per- and polyfluoroalkyl substances (PFAS) are ubiquitous in the environment, due in part to their extensive use in various industrial and commercial applications. However, there is great uncertainty and variability in the concentrations of PFAS in different media and in the factors that mediate human exposure. This makes it difficult to estimate exposure with traditional deterministic modeling approaches. In this study, we utilize a probabilistic modeling approach, leveraging Monte Carlo simulations to estimate the risk and uncertainty of PFAS exposure through six major exposure pathways. Probability distributions were generated for most factors in the analysis and sampled 10,000 times to produce exposure estimates. Parameters for these distributions were based on literature values and private well water samples collected in three impacted counties (Washington County, MN; Robeson County, NC; and Spokane County, WA) and one unimpacted county (Monroe County, IN). In the unimpacted region, the estimated exposure via private well water consumption is almost negligible – the median estimate remains below 1% in all age groups but newborn children. However, in regions with a known PFAS source nearby the estimated contribution increases greatly (range: 0.9% - 68.0%, median: 9.3%). Notably, estimated contribution varies greatly between age groups and regions, likely due to differences in exposure factors and groundwater PFAS concentrations. Additionally, there is a great deal of uncertainty in these estimates. This is likely driven by a lack of data on PFAS concentrations in various media, highlighting the need for additional research on the occurrence of PFAS in different media.

Keywords: *PFAS, Exposure Assessment, Probabilistic Modeling, Public Health*

Life Cycle Analysis of Stormwater Bioretention Cell Media Compositions

Presenter: Leah Weaver

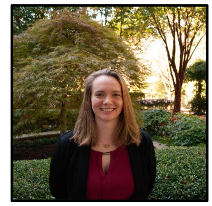
Co-author(s): T. Aziz, J. Johnson

Research Question: How do the environmental impacts of different bioretention cell media amendments compare?

Several engineered media amendments have been proposed to improve contaminant removal in stormwater bioretention cells (BRCs). These amendments, such as activated carbon, metal oxides, and organic carbon sources, could increase removal by promoting certain physical, chemical, and biological removal pathways. However, these amendments are not yet widely used in practice. Before engineered media amendments are widely implemented, engineers and utilities will need to understand the costs and benefits of the amendments over traditional bioretention cell media. We conducted a comparative life cycle assessment of six BRC media compositions: biochar, granular activated carbon, zeolite, iron filings, and wood chip-amended media, and a typical unamended media mixture. The fate of nutrients, metals, polycyclic aromatic hydrocarbons, and emerging contaminants in stormwater entering bioretention cells with the six media mixtures was modeled, and the results were used to inform the environmental impact assessment. The EPA's Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts (TRACI) method and the USEtox method were used to quantify the environmental impacts from the six BRC media mixtures. Comparison of BRC media focused on their ability to improve stormwater quality and the impacts their construction, maintenance, and disposal have on the environment.

Keywords: *Life Cycle Assessment, Bioretention Cell, Stormwater, Water Quality*

Microbial community assembly of waste and wastewater treatment systems



Presenter: Savanna Smith

Co-author(s): F. de los Reyes III

Research Question: Is bioreactor process performance linked to specific microbial community assembly processes?

To improve the performance of bioreactors, we first need to understand the microbial communities that convert waste to desired end products. One approach to this understanding is through analyzing microbial community assembly (MCA). MCA describes the stochastic and deterministic processes through which microbial communities form, helping guide the design and operation of bioreactors so that they can function better, and be more resilient and resistant to stresses. Despite studies that have described MCA processes in bioreactors, there are major challenges before MCA can realistically be used to improve functionality: 1) lack of field-wide acceptance of standardized tool sets for assessing MCA, 2) contradicting conclusions about the relative importance of each MCA process, and 3) unclear steps needed to bridge the gap between MCA theory and actionable means to improve bioreactors. To address these problems, this study 1) applies a proposed community-wide tool set, and 2) assesses different bioreactor systems, placing the results in the context of expected MCA processes. Results from six experiments previously completed by our research group were used. The sample sets comprise studies on: wet and dry mono- and co-digestion of food waste, thermal hydrolysis pretreatment and co-digestion of grease interceptor waste, a partial denitrification anammox biofilter, and pit latrines. These experiments were conducted from the lab- to full-scale, and cover a range of operational, complexities. The results show the relationships between bioreactor characteristics and, the relative influence of each MCA process and provide insights to improving bioreactor, operation and design.

Keywords: *Microbial community assembly, Bioreactors, Process performance*

Assessing SARS-CoV-2 Surveillance Tools: A Comparative Study of RT-ddPCR, Short Read Sequencing, and Long Read Sequencing in Wastewater

Presenter: Temi Ibitoye

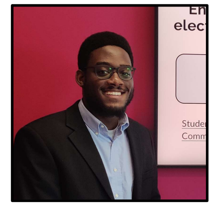
Co-author(s): L. Kepler, L. Harden, L. Raymond, D. Rasmussen, S. Thakur, A. Harris

Research Question: What tool should you use to detect emerging pathogens in wastewater?

Since the start of the COVID-19 pandemic, tracking the prevalence of infection and variants of concern have been critical to understanding and responding to the pandemic. The estimates of prevalence and variants have typically depended on clinical samples, usually taken from symptomatic patients. Many infected individuals go undetected. Wastewater-based epidemiology (WBE) has proven to be helpful in tracking infection trends as it captures all infected individuals. Techniques such as targeted gene analysis and whole genome sequencing are often used in conjunction with WBE to understand the spread and genetic diversity of SARS-CoV-2. However, there has been limited research comparing these tools and elucidating the optimal approach for specific research goals. This study evaluates the use of long-read sequencing, short-read sequencing, and reverse-transcription digital droplet PCR (RT-ddPCR) on wastewater for SARS-CoV-2 variant detection. Wastewater samples collected during the initial Omicron spike were processed with a Nanopore sequencer, an Illumina sequencer, and with RT-ddPCR. Additionally, SARS-CoV-2 from nasopharyngeal swabs were sequenced to compare clinical and wastewater surveillance for variant detection. The findings demonstrate that RT-ddPCR detected Omicron more rapidly than whole genome sequencing, attributed to the assay's heightened sensitivity. Conversely, whole genome sequencing exhibited greater capability in detecting sublineage diversity. Additionally, our findings indicate that clinical surveillance is optimal for early detection of emerging variants, largely due to its high sequencing rate. However, both surveillance techniques provide comparable insights into circulating VOCs. This study serves as a crucial resource for guiding tool selection amidst the wide array of pathogen surveillance techniques available.

Keywords: *SARS-CoV-2, Wastewater-based epidemiology, Wastewater surveillance, Whole genome sequencing, Targeted gene analysis*

Impact of varying renewable capacity credit allocation on larger grid capacity expansion planning



Presenter: Jethro Ssengozi

Co-author(s): A. Sinha, J.X. Johnson

Research Question: We seek to prove that capacity credit allocation for the renewables of focus does in fact have an impact on their deployment into the future.

The wide-scale deployment of variable renewable energy technologies (VREs) offers a pathway to decarbonizing the electric grid. One challenge to reliably operating the grid is ensuring sufficient generating capacity to meet demand at all hours. The capacity benefit of variable renewables – namely wind and solar – can be characterized using the capacity credit metric. Here, we explore how various assumptions for capacity credit can ultimately impact broader resource deployment for an entire electric grid. To do this, we use the Temoa capacity expansion model. Using context-specific capacity credit values can improve long-term decision-making in generation capacity expansion, cultivating more economical long-term resource planning for deep decarbonization. We find significant trends of note when focusing on two major capacity credit allocation scenarios to explore the impact of various photovoltaic solar and wind. In the Scenario 1 category, capacity credit values for wind and solar resources are set to zero. In the Scenario 2 category, capacity credit values are set to static values of various combinations. We find substantial differences in the least-cost deployment of solar and wind power based on the capacity credit assumptions. When we assume non-zero values for capacity credit for both solar and wind, we observe a relative drop in solar deployment and conversely there is a general increase in wind deployment. These major changes in deployment imply that wind outcompetes solar relative to the neutral case in which neither resource receives capacity credit.

Keywords: *Capacity credit, Long term grid planning, Capacity expansion, Energy system modeling, Renewables*

The Impact of State and Federal Decarbonization on Technological Pathways

Presenter: Gavin Mouat

Co-author(s): C. Galik, A. Venkatesh, K. Jordan, A. Sinha, P. Jaramillo, J. Johnson

Research Question: As compared to a federally-led U.S. decarbonization, what are the technology and cost implications of state-led decarbonization efforts?

Macro energy system optimization models are important tools for understanding the possible outcomes of deep decarbonization pathways and can inform the impacts of policy mechanisms that aim to reach net-zero greenhouse gas emissions by mid-century. Given that current U.S. federal climate policy is insufficient to achieve carbon neutrality, state-level decarbonization efforts are of increasing importance. In this research, we use a comprehensive energy systems model (Temoa) to explore the implications of achieving decarbonization goals through either federal or state action. We consider two carbon budget policy scenarios: (1) 23 climate-friendly states set net-zero carbon dioxide emissions targets by 2050; (2) a federal policy that matches the greenhouse gas emissions levels of the state-policy, but with the added flexibility of this being a national constraint. Both scenarios achieve a carbon dioxide emissions reduction of approximately 45% by 2050, but the spatial distribution of emissions limits varies by scenario. We demonstrate that state-driven net-zero carbon pathways select a substantially different least-cost set of technologies relative to the federal policy. Specifically, through state-level climate policy, we see expansion of the electric sector and increased direct air capture use in the California and Northeastern regions. The federally-led decarbonization scenario relies heavily on the utilization of bioenergy with carbon capture and storage (BECCS) systems in the Southeast and increases traditional fuel use within the transport sector. This study offers new understanding of the risks associated with technology lock-in under different decarbonization pathways, highlighting the importance of early planning for long-term action.

Keywords: *Energy Systems Modeling, Decarbonization, Energy Policy*

How the Dual Effects of Space Heating Electrification and Climate Change Could Impact Seasonal Peaking and Reliability of the Texas Power Grid

Presenter: Henry Ssembatya

Co-author(s): K. Oikonomou, N. Voisin, C.D. Burleyson, K.Z. Akdemir, J.D. Kern

Research Question: How could the widespread electrification of residential space heating alongside climate change jointly affect future electricity demand requirements?

Texas typically experiences peak electricity demand in the summer. Around 60% of households rely on electricity for space heating, but as decarbonization efforts surge, more households could switch from using natural gas to electricity, thus significantly increasing winter electricity demand. Simultaneously, climate change will increase summer temperatures and the potential for heat waves. Uncertainty regarding the timing and magnitude of these simultaneous changes raises questions about how they will jointly affect seasonal generation requirements and the firm capacity needed. In this study, we investigate the net effects of residential space heating electrification and climate change on long-term demand patterns and load shedding potential, using climate change projections, a predictive load model, and an open-source nodal power system model of the Texas grid. The results will help system planners to better plan for adequate supply capacity to meet demand.

Keywords: *Decarbonization, Space heating electrification, Heat pumps, Climate change, Power systems reliability*

Community-engaged Coastal Flood Modeling To Evaluate Sea Level Rise Adaptation Strategies

Presenter: Thomas Thelen

Co-author(s): C. Dietrich, M. Hino, K. Anarde

Research Question: How can coastal communities adapt to flooding caused by sea level rise?

Low-lying coastal communities are increasingly inundated by chronic flooding due to sea level rise (SLR). However, approaches for simulating adaptation strategies for chronic coastal flooding are not well-established, as compared to simulation frameworks for floods driven by extreme storms. This is in part because SLR-induced flooding is an emerging hazard, but also because interactions between flood drivers (tides, wind, rainfall, SLR) are poorly understood and spatially complex. Furthermore, the inclusion of stakeholders in the flood-modeling process is an understudied but potentially powerful strategy to develop community-based, locally-tailored SLR adaptation pathways. Here we present a new adaptation modeling framework that engages local officials and community members in testing the effectiveness of community-selected mitigation strategies for floods stemming from SLR. We simulate flooding with a coupled hydrodynamic and stormwater model that captures multiple interacting flood drivers – including tides, wind, rainfall, and stormwater infrastructure. We validate the model by comparing simulation results to water levels measured in storm drains and co-located images of flood extent. Lastly, we use a community survey that includes questions about flood risk perception and adaptation preferences to inform the selection of flood mitigation strategies to model. In the future, we will work with focus groups through an iterative process and refine the model scenarios to evaluate the effectiveness of adaptation strategies most preferred by the community.

Keywords: *Adaptation, Flooding, Sea level rise, Community engagement*

An Agent-Based Modeling Approach to Assess the Socio-Economic and Social Equity Impacts of Dynamic Pricing in Residential Water Management

Presenter: Cade Karrenberg

Co-author(s): E. Edwards, E. Berglund

Research Question: How does dynamic pricing affect the equity of a community of water users?

Climate change, urbanization, aging infrastructure, and rising energy costs require water utility managers to consider policies that manage peak water consumption while meeting the needs of water users with affordable, reliable and safe drinking water. Peak water consumption can exacerbate strains on aging infrastructure and often coincides with peak electricity prices, increasing operation costs for water utilities. Utilities can manage peak water use with dynamic pricing, which increases water prices during periods of peak water use to encourage users to shift their water usage to off-peak times, reducing the strain on infrastructure and the operating cost of the utility. However, dynamic pricing can lead to inequitable water costs across a community. Low-income households may have less flexibility in their time-of-use, limiting their ability to respond to dynamic pricing as strategically as high-income households. The goal of this research is to assess the differential impact dynamic pricing has on heterogeneous water users. This research develops an agent-based model (ABM) to simulate the response of a community of water users to dynamic pricing. The ABM is applied for a case study, and model outcomes assess the impact that dynamic pricing has on the volume of water consumption, time-of-use, and price of water for households that differ in socio-economic characteristics. This research develops an ABM approach that can be used to quantify inequities in water costs based on household attributes and the ability of water users to respond to demand-side management policies.

Keywords: *Agent-based modelling, Dynamic pricing, Water demand management, Social equity, Socioeconomics*

Enteric Pathogen Reservoirs in Coastal Stormwater Infrastructure Impacted by Tidal Flooding

Presenter: Julia Harrison

Co-author(s): M. Carr, C. Woods, K. Anarde, A. Harris, N. Nelson

Research Question: Are coastal stormwater networks reservoirs of enteric pathogens?

As sea levels rise due to climate change, the flooding of coastal infrastructure becomes more frequent, often due to strong tidal forcing that occurs during king tides. These tidal floods inundate underground infrastructure, including stormwater networks, and overtop roadways in many coastal areas. While there is monitoring of the increasing size and frequency of coastal flooding, little is known about the water quality and the potential health risks associated. A study in Beaufort, NC, revealed elevated fecal indicator bacteria (FIB) levels in king tide floodwaters, suggesting FIB reservoirs in stormwater basins. Motivated to investigate potential reservoirs of FIB, we sampled different media from within stormwater basins. During two king tide events, water samples were collected throughout two tidal cycles from within stormwater basins and at outfall points in Taylor's Creek, adjacent to downtown Beaufort's waterfront. Biofilm and sediment samples were also collected from the stormwater basins at low tide. Samples were enumerated for E. coli and Enterococci using IDEXX. A subset of samples were also analyzed for a suite of environmental enteric pathogens using custom TaqMan Array Cards. This study revealed both E. coli and Enterococci in all media and storm networks. E. coli and Enterococci were found at high concentrations in sediment and biofilms, revealing potential reservoirs of pathogens. TAC analysis detected several types of AMR gene indicators, including Class 1 integrons (intl1), and SHV. Bacteria 16S was detected in all environmental water samples. Cryptosporidum 18s was also commonly detected. However, no human-disease-causing pathogens were definitively identified.

Keywords: *Fecal indicator bacteria, Enteric pathogens, Stormwater, Sunny day flooding, Tidal flooding*

Machine Learning-based Holistic Analysis of Leak Characterization in Water Distribution Systems

Presenter: Lochan Basnet

Co-author(s): K. Mahinthakumar, R. Ranjithan, E. Brill

Research Question: How to approach the leak characterization problem in any WDS given its multiple interacting dimensions?

Due to the scarcity of historical data, model-based approaches have become mainstream in leak characterization research. However, most model-based studies on leak characterization, despite being promising, represent fragmented aspects of the complete leak characterization problem. Those studies focused on singular dimensions of the leak characterization problem, which can be myopic and limited by the assumptions they rely upon. The ultimate goal of these research methodologies is to address real-world leak characterization problems in water distribution systems (WDSs); singular focus and constraints associated with available bodies of research significantly limit their practical utility. Our research aims to examine leak characterization holistically by considering multiple interacting dimensions, including the expansiveness of WDSs, different leak characteristics, uncertainties, resolution of leak characterization, sparsity of sensors, optimality of sensor placements, use of inputs from different types of sensors, and the applicability and performance of characterization methods. At the heart of our research is a machine learning (ML) approach, which continues to prove effective for a broad spectrum of problems across diverse fields, including water distribution systems. Considering and selecting from among the wide array of ML models and algorithms, we tailor our approach to the specific needs and nature of the leak characterization challenge. Our ML-based approach for the comprehensive analysis of the leak characterization problem has been tested on a large real-world WDS in a major metropolis in the Western US. The results are promising, as indicated by the high accuracy achieved in our leak characterization experiments.

Keywords: *Leak Characterization, Water Distribution Systems, Machine Learning*

What if winning the lottery increases the chance of being struck by lightning?

Presenter: Kichul Bae

Co-author(s): S. Arumugam

Research Question: What factors contribute to the spatial dependence of flooding, and to what extent do they vary across different regions in the CONUS?

Establishing comprehensive policies for flood response requires information on how often floods occur simultaneously in multiple areas. This aspect, known as spatial dependence, has historically been understudied, particularly concerning extreme floods with return periods of 100-year or longer. In this research, we quantify the spatial dependence of floods by calculating conditional probabilities based on observed data across the coterminous United States (CONUS). Our findings indicate that the spatial dependence of floods varies across regions, influenced by meteorological, climate, and hydrological characteristics of basins. Widespread extreme floods, which are highly likely to cause devastating damage, tend to take place in regions close to the ocean. The probability of such events is found to be 10~30 times higher when considering spatial dependence compared to scenarios where it is ignored.

Keywords: *Floods, Spatial dependence, Co-occurrence, Widespread, Extreme*

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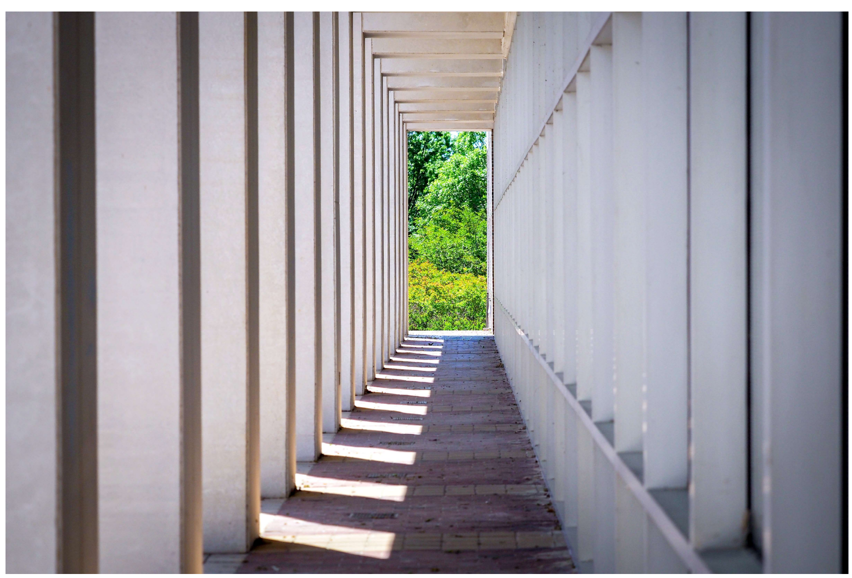

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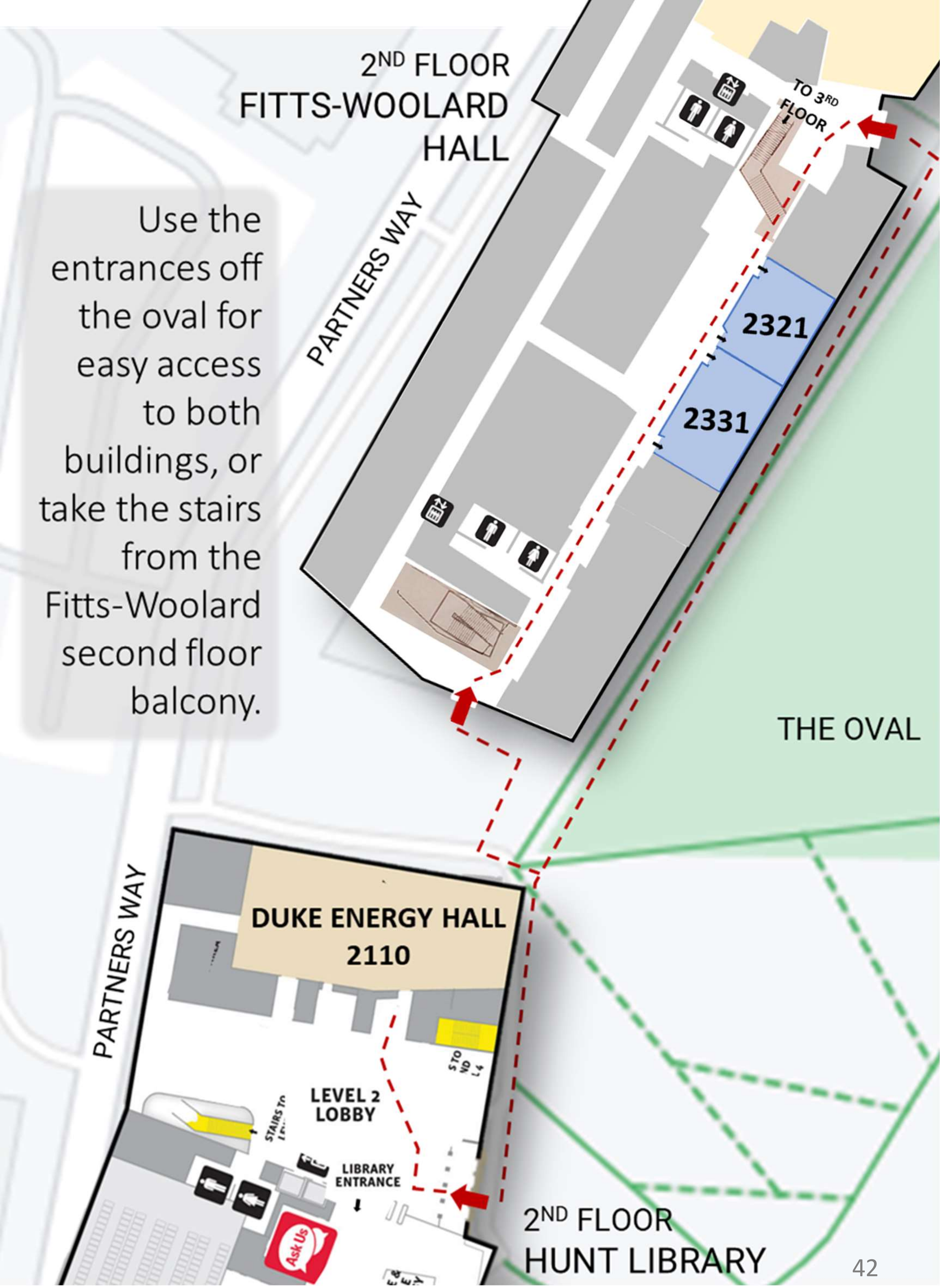

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