Addressing Climate Change in Kentucky through Robotics and AI: Environmental Sensing & Prediction, and Disaster Search & Rescue

Contact: Dan Popa, dan.popa@louisville.edu, Tommy Roussel, Thomas.roussel@louisville.edu

Summary

The proposed research is synergistic with the CHARGE program and brings together recognized leaders from our state who will make contributions to Robotics and Artificial Intelligence (AI) teaming research with applications in climate change research and disaster mitigation in Kentucky. **The main research theme of this effort is that embodied AI components (sensors and robots) will be deployed in the environment to collect and interpret climate and disaster data, use machine learning to perform assessment and prediction, and finally facilitate rescue missions during disaster events.** We will consider several use cases from CHARGE as a motivator for our research and incorporate AI components in different hardware and software embodiments. Our research will use sensors and robots deployed in the environment.

1. Environmental Monitoring by Multiscale Adaptive Sampling of Water Quality and Content

F1) Adaptive Spatio-Temporal Sampling of the Environment (D. Popa, X. Wang, O. Nasraoui).
F2) Optimal and Fair Human-AI Teaming Algorithms (X. Wang, O. Nasraoui, D. Popa).
F3) Edge-assisted Energy-Optimized Collaborative Sensing and Mapping (S. Baidya, A. Lauf, T. Roussel).
F4) Flying 5G Base Station for Connectivity and Crowd-sourced Data Acquisition (S. Baidya, O. Nasraoui).
P1) Optimization of Bio-platforms for Production of Novel Plant-based Materials for Environmental monitoring (M. Running, K. Kate).
P2) Environmentally Friendly Sensor and Robot Materials (K. Kate, T. Roussel, M. Running).

2. First Responder Autonomous UAVs with Flying Edge Computing and Collaborative Sensing Systems for Disaster Assistance

F5) Digital Twin based Collaborative target detection and Multi-target Path Planning
P3) Multi-UAV LiDAR Point Cloud Fusion for Low-Cost Distributed Search, Rescue, and Rapid Structural Integrity Assessment (A. Lauf)
P4) High Performance Control of Winged Electric Vertical Takeoff and Landing Unmanned Aerial Vehicles for High-Speed Landing Approaches (C. Richards, D. Popa).
P5) Autonomous Unmanned Aerial Vehicles for Extreme Weather Monitoring (C. Richards, D. Popa).

Search and Rescue Testbeds – ST	**Environmental Monitoring Testbeds – ET**
1) Search and Rescue UAV team 2) Telepresence search and rescue humanoid robot for indoor disaster environments. 3) Heavy-lift human extraction VTOL for outdoor disaster environments.	1) Mobile 5G/6G wireless infrastructure for monitoring climate change variables and disaster areas. 2) Intelligently coordinated robotic swarm team for climate monitoring and rescue. 3) Virtual and Augmented Reality platforms for simulation of environmental monitoring.

Table 2: Robotics and AI Core Faculty Expertise	**Institution/Department**	**Research**	**Testbeds**
Dan Popa (UofL Lead) – participant in KAMPERS Robotics, control, mobile sensor networks	UofL Electrical and Computer Engineering	F1, F2, P4, P5	ST2, ET2, ET3
Olfa Nasraoui (UofL) - participant in KAMPERS Fair AI, machine learning, and recommender systems	UofL Computer Science and Engineering	F1, F2, F4	ET2, ET3
Christopher Richards – new participant at UofL Control Systems, UAVs, Environmental Mapping for Climate	UofL Mechanical Engineering	P4, P5	ST1, ET2, ET3
Sabur Baidya – new hire at UofL through KAMPERS IoT, Wireless Communications, Drones	UofL Computer Science and Engineering	F3, F4, F5, P1, P3	ST1, ST3, ET1, ET3
Xiaomei Wang – new hire at UofL Human Factors, Human-AI Teaming	UofL Industrial Engineering	F1, F2	ET3
Thomas Roussel - participant in KAMPERS Environmental Sensing, MEMS	UofL Bio Engineering	F3, P2	ST3, ET2
Kunal Kate - participant in KAMPERS Additive Manufacturing, 3D Printed sensors	UofL Mechanical Engineering	P1,P2	ET2
Adrian Lauf – new participant at UofL Swarm Robotics, UAVs, Search and Rescue	UofL Computer Science and Engineering	F4, F5	ST1, ST3, ET1, ET2
Mark Running - participant in KAMPERS Biomaterials, Biofuels	UofL Biology	P1,P2	ET2

Kristy Hopfensperger, Ph.D.
Northern Kentucky University

- Research topics of interest and experience: ecosystem restoration (wetlands, streams, forests, prairies), ecosystem ecology (nutrient cycling soils/water/plants & greenhouse flux), invasive plants, green infrastructure, climate equity & resilience, science communication and public engagement with science
- Proposed Idea (abbreviated): With the threats to Kentucky from climate change and related hazards discussed in the CHARGE white paper, specific populations and communities will bear more impact and negative consequences than others. To build sustainable communities and climate resiliency for the Commonwealth of Kentucky, efforts must begin with the communities most vulnerable and it is imperative that residents are an integral part of the planning process. The need for increased transparency and participation in environmental planning has been recognized by many, including the US EPA. Through collaboration of scientists, policymakers and community members, local residents will actively engage and critically assess where and how interpretations of data should be utilized in local implementation strategies – leading to sustainable, resilient and environmentally just communities. A brief example has taken shape in the City of Cincinnati with its implementation of the Climate Safe Neighborhood Program after the culmination of extensive environmental and socioeconomic data in the Climate Safe Dashboard. The collaborative process to build neighborhood climate resiliency plans will increase environmental literacy, encourage behavior that improves the environment, prioritize environmental justice efforts and create a communal sense of ownership to community success. We propose to collate the successful methods used in other cities to create a model to implement in locations around Kentucky. Work would begin in northern Kentucky cities and be assessed, reviewed and reworked as the plan is employed in multiple locations around the state. Trained, regional leaders would oversee local efforts, while working collaboratively statewide, to change the trajectory towards economic prosperity, environmental sustainability and improved public health for all in the Commonwealth.
- Open to working on other's ideas where my expertise could be used

Assessment, Modeling, and Mitigation of Kentucky Weather, Climate, and Hazardous Events

Contact: Zachary Suriano, zachary.suriano@wku.edu

Summary

This proposed effort seeks to complement and enhance the scope of the current CHARGE program through additions of atmospheric- and climate-focused expertise and research objectives. **Key research contributions of this effort are (a) the detection and analysis of variability and changes in extreme KY weather, climate, and hazardous events, (b) the modeling and analysis of future climate projections in KY, and (c) the development of emergency management and hazard mitigation strategies for potential future high-impact and extreme events.** Within this expanded focus area, there are new opportunities to address NSF funding priorities that enhance the capacity for research to address climate change and climate resilience in Kentucky.

Research contributions

Detection and analysis of variability and changes in extreme KY weather, climate, and hazardous events

- Inter- and intra-annual variability of frequency, intensity, and extremes of meteorological and hydrological phenomena
- Regional-scale atmospheric conditions that lead to high-impact weather/climate events in KY (e.g., tornados, flooding)
- Causal relationships between changes in high-impact events and charges in atmospheric conditions
- Global-scale teleconnection patterns that precondition the atmosphere for the high-impact events

Modeling and analysis of future climate projections in KY

- The range of projected regional climate outcomes across KY
- Local climate indications from high-resolution dynamically downscaled climate projections, especially for high-impact events
- Model simulations of high-impact events based on projected future climatic conditions

Emergency management and hazard mitigation strategies for potential future high-impact and extreme events

- Weather/climate forecast products
- Precipitation-related hydrological products (e.g., flood capacity)

Expertise

- Climate variability and climate change
- Climate modeling, dynamic downscaling, and analysis
- Numerical model simulation of weather/climate events
- Observational instrumentation/climate monitoring networks
- Severe and high-impact weather and climate events
- Hydro-meteorology/-climatology and precipitation science
- Emergency management and climate resiliency mitigation
- Forecasting extreme weather and climate events

Benefits to CHARGE program's competitiveness:

- Strengthened transdisciplinary research team through greater inclusion of atmospheric sciences
- New opportunities to target NSF programs for future funding (e.g., CLD, PDM, FARE, DRRG)
- Enhanced broader impacts in generated outreach materials, student workforce development, and DEIA efforts

Personnel

Zachary Suriano[^], Xingang Fan[^], Joshua Durkee[^], Gregory Goodrich[^], David Oliver[+], Jerald Brotzge[^]

[^] Department of Earth, Environmental, and Atmospheric Sciences, Western Kentucky University

[+] Environmental Health and Safety, Western Kentucky University

RII EPSCoR Track-1: Kentucky Flood Center:

Establishing critical infrastructure and education to mitigate climate change and flash flooding in Kentucky

Contact: Kevin Gardner, kevin.gardner@louisville.edu

BACKGROUND AND OBJECTIVES OF THE KENTUCKY FLOOD CENTER: Kentucky experiences repeated catastrophic floods and geohazards due to its unique hydroclimatic and societal factors, which will be exacerbated by climate change in coming years. This is evidenced by the July 2022 flash floods in eastern Kentucky which resulted in dozens of deaths–including four children–with hundreds of homes destroyed. Flooding is not a new phenomenon in Kentucky. However, *the mechanisms controlling flood generation, the effect of climate change on flooding, and the impact on downstream communities and infrastructure are poorly understood in this region*. To overcome these uncertainties, the PIs propose establishment of the Kentucky Flood Center (Fig. 1). **The objective of the Kentucky Flood Center (KYFC) is to leverage, augment, and fuse available and new data to enhance the basic understanding of floods and associated geohazards in Appalachia and develop actionable practices to reduce flood risk and improve community resiliency throughout Kentucky under a changing climate.** The KYFC will be a collaborative, multi-institute initiative to develop basic and applied research related to flooding in Kentucky. The KYFC will focus on three research tasks: *1) enhanced understanding of flood generation in a changing climate via increased monitoring, detection, and prediction; 2) increased understanding of the variable hydroclimatic drivers of floods and geohazards and the impacts on infrastructure resiliency;* and *3) community improvement and integration tools for real-time flood monitoring, and education/outreach to enhance planning and flash flood awareness*.

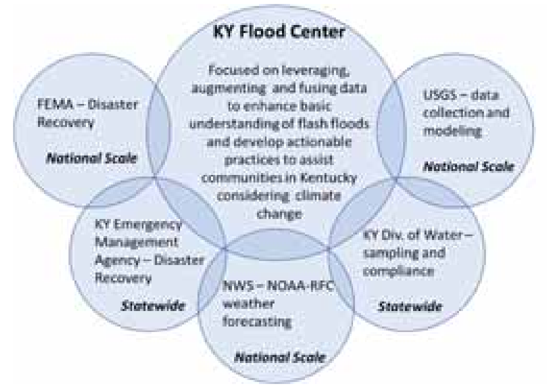

Fig 1. Function of the proposed Kentucky Flood

Task 1: Enhanced Flood Monitoring and Prediction in a Changing Climate: Task 1 focuses on enhancing the basic understanding of the mechanisms of flood generation in Appalachia under climate change via increased infrastructure to monitor, detect, and predict flash floods in real time. Subtasks include the following: *Task 1.1: Build the Appalachian Flood Data Acquisition Network*; *Task 1.2: Flood and climate data warehousing and integration protocols*; *Task 1.3: Model development and data fusion to predict flood mechanisms and impacts of climate change in real-time*; *Task 1.4: Model application to assess downstream water quality impacts of floods*; and *Task 1.5: Real-time data translation, visualization, and communication*.

Task 2: Infrastructure Resiliency and Mitigation of Flood and Geohazard Impacts due to Climate Change: Task 2 will facilitate development in (i) infrastructure planning and management strategies; (ii) resilience-based design methods tailored to mitigate climate hazards; and (iii) emerging technologies to support decision making to mitigate loss of life and property damage. Subtasks include: *Task 2.1: Evaluate resiliency of critical infrastructure under a changing climate; Task 2.2: Investigate impacts of floods on infrastructure under current and future climate change; Task 2.3: Predict geohazards under current and future climate change*; and *Task 2.4: Guidance and recommendations on updated resilient building, road, sewer, and water supply specifications*.

Task 3: Community Improvement and Integration Tools: Task 3 focuses on the development and application of tools to improve community preparedness, awareness, and resiliency during and after flash floods. Subtasks include: *Task 3.1: Develop enhanced visualization tools for flash floods and climate hazards; Task 3.2: Implement an early warning detection system for flash floods; Task 3.3: Development of flash flood mitigation plans and flood communication protocols*; *Task 3.4: Evacuation planning and preparation;* and *Task 3.5: Flood education and community outreach*.

COLLABORATIONS AND INTEGRATION WITH CHARGE PILLARS: The KYFC will integrate with CHARGE to apply gained climate knowledge learned in Pillar 1 to develop engineering and artificial intelligence solutions that will protect the built environment and geoheritage. Specifically, the KYFC will integrate Pillars 2 and 3 of CHARGE as it utilizes artificial intelligence, real-time sensor data, improved modeling and design to both prepare communities for extreme events, and then provide real-time actionable information during the event to prevent loss of life. PIs of the KYFC include civil engineers at UofL with expertise in geotechnical, materials, and water resources engineering. We intend to collaborate with biologists, environmental scientists, social scientists, geographers, computer engineers/scientists, and others at UofL and other universities to collect flood data, apply models to assess flooding and climate change, and increase flash flood awareness in eastern Kentucky. The KYFC will also assist junior faculty establish their research programs and mid-career faculty with continued development and advancement.

A One-Page Idea Paper for "Climate Change Hazards in Appalachia: Towards Resilience & Geoscience Equity in Kentucky"

Ruohao Zhang
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Center College ruohao.zhang@centre.edu

Research Topic:

1. How individuals/households change their behaviors in response to climate changes and natural disasters?
2. What are the effective methods to allocate and distribute the limited resilience resources?
3. How to mitigate social inequity/disparity in climate changes and disaster exposures.

Proposed Idea:
Climate changes are associated with increase in disaster risks, which are distributed disproportionally across different socio-economic groups. Since resilience resources are limited, it is important to learn how to efficiently distribute the existing resources, not only to improve the overall resilience but also mitigate the social inequity in disaster exposure.

We plant to focus on communities located in the areas with high disaster risks/exposure. To better assist local community, before directly investing local resilience, we should first ask why households choose to live in these areas with high disaster risks/exposure. There are two dominant reasons: households have budget constraint so that they cannot afford moving to low-risk neighborhoods, or households have strong preferences on some unique local features and amenities that dominate disaster risks. We plan to survey households living in eastern Kentucky and Appalachia flooding areas about their reasons for living in neighborhoods with high flood risks/exposure, as well as how they prepare for the potential disaster shocks. Such a survey may help identify households with budget limitations for relocation to low-risk areas, to whom financial assistance may be provided to promote equal moving opportunity and mitigate climate injustice, as well as to change high-risk areas to open space and lower the overall flood risks of the whole region. For other high-risk neighborhoods where households do not have budget limitations but are strongly tied to unique local features and amenities, including extended family, direct investment in local resilience is necessary to help them better prepare for disaster shocks.

Expertise: environmental economics, environmental justice and social equity, quantitative analysis, causal inference

Open to collaboration, including other's ideas where my expertise may help.

An Open Access and Inclusive Learning Hub for Developing a Diverse CHARGE Workforce

Jimmy Fox (University of Kentucky, james.fox@uky.edu), Tyler Mahoney (University of Louisville, tyler.mahoney@louisville.edu), Junfeng Zhu (Kentucky Geological Survey, junfeng.zhu@uky.edu), Jason Polk (Western Kentucky University, jason.polk@uky.edu), Estifanos Haile (Eastern Kentucky University, estifanos.haile@eku.edu), Haluk Cetin, (Murray State University, hcetin@murraystate.edu), Chris Lorentz (Thomas Moore University, lorentc@thomasmore.edu)

The goal of our proposed program is to increase diversity in the geoscience and engineering disciplines by training undergraduate students who are classified as under-represented in STEM and developing pathways to match the students with CHARGE faculty for pursuit of graduate degrees. In this way, this sub-program of CHARGE will serve as a catalyst for research conducted by the NSF EPSCoR Track 1 faculty cohort, especially newly hired faculty and early career faculty. Our program will train the undergraduate students in the geoscience and engineering research methods and fundamental concepts of climate change, geophysical processes, and hazards engineering. We will engage students in an open access and inclusive learning hub facilitated *via* a hybrid platform that includes applied, hands-on training and skill development for their future graduate studies and career preparation. Then, at the end of the program, students and faculty can work together to pursue graduate degrees. This will be a 10-month program, each year from August to May, where students receive a stipend and participate as follows:

Prior to August of each year, we will recruit a diverse cohort of undergraduate students who are under-represented in STEM and from rural Appalachian and urban inner-city households. We will engage these students in research through field and laboratory projects at WKU, EKU, MuSU, UofL, TMU, UK, and other partnering universities. At each school, will recruit approximately four undergraduate per year.

In August, prior to the start of classes, all participants from all universities will engage in a week-long field research and orientation program. This intense week-long program will include days at multiple universities where students learn geoscience sensor technology by working with instruments in the field. Graduate students, one per school, will serve as mentors in the field and laboratory.

Each month of the program, we will engage the students as well as interested faculty of the Track 1 cohort in an open access and inclusive hybrid platform that includes: informal, Virtual Hangouts where students and faculty discuss science; and more formal Technical Sessions where students and faculty learn about science and engineering research in Kentucky and receive mentoring from professionals and scientists. The Virtual Hangouts and Technical Sessions target student learning but be open to anyone.

Throughout the 10-month program, we will teach undergraduate students fundamentals of sensor technology useful in geoscience and hazard engineering research through hands-on projects in the field and laboratory that culminates with a poster presentation meeting at the Kentucky Academy of Science Annual Meeting, which is inclusive of all STEM college subjects and students.

Throughout the 10-month program, we will teach students fundamental technical concepts of climate change forcings and processes, earth surface processes, disaster occurrence and propagation, artificial intelligence, and sensing of environmental systems. Students in engineering disciplines will conceptualize methods to improve the resiliency of infrastructure in Kentucky climate-related hazards.

For undergraduate students, at the end of the program, we will facilitate matching of undergraduate students in our program with the Track 1 faculty cohort, especially newly hired faculty and early career faculty, so that they may work together for pursuing graduate degrees. This will be facilitated through the in-house poster presentation and the Virtual Hangouts.

For graduate students, at the end of the program, we will facilitate matching of graduate students in our program with local industry, community, and research institutions (e.g., the KGS, USGS, KDOW, US EPA) leveraging relationships developed between the Track 1 faculty cohort. This will be facilitated through a "shadowing" program where the students will shadow professionals.

Climate Preparedness and Community Resilience in Kentucky

In Support of **Research Pillar II – Climate Change Hazards and Disaster Engineering in Kentucky**

PI: L. Sebastian **Bryson**, UK, Sebastian.Bryson@uky.edu (community resilience, natural hazards)

Co-I's: Y-T. **Wang**, UK (water quality, biological processes); J. **Fox**, UK (hydrologic modelling, climate modelling); M. **Chen**, UK (big data analytics, machine learning); KC. **Mahboub**, UK (sustainable materials); M. **Crawford**, KGS (natural hazards, field instrumentation); B. **Bradford**, KTC (risk and vulnerability)

Research Approach:

Create New Models to Quantify Community Resilience

- Develop methods to map interdependencies of community infrastructure systems
- Development of methodology to assess multi-hazard resilience of communities
- Development of a restoration model to quantify the benefits of restoration and support the resilience assessment
- Assessing vulnerability and criticality within an infrastructure resilience framework

Advance Fundamental Knowledge of How Climate Change Directly Impacts the Severity And Frequency of Natural Hazards

- Instrumented hillslopes and long-term monitoring studies
- Instrumented streams and waterways

Develop New and Novel Materials to Increase the Sustainability and Resiliency of Critical Infrastructure

Building Capacity:

- Strategic Hires: **Geohazards Engineer** focused on the impact of flood-driven geohazards on infrastructure; **Water Quality Specialist** focused on biological approaches for water quality control; **Multi-Hazards Infrastructure Engineer** focused on multi-hazard adaptive and resilient infrastructure; **Sustainable Infrastructure Materials Engineer** focused on emerging technologies for sustainable and resilient materials.
- Research Infrastructure: Statewide network of hydro-geo slope monitoring ground stations; Statewide network of bio-chem-hydro-mech stream and waterways monitoring stations; hyperspectral/lidar drone flight (4 to 6 UAS) to map interdependencies; infrastructure for sustainable materials research.
- Economic Development: Preparedness and Resilience Assessment Tool for Kentucky Communities to reduce economic impacts of climate-driven geohazards.

Connections:

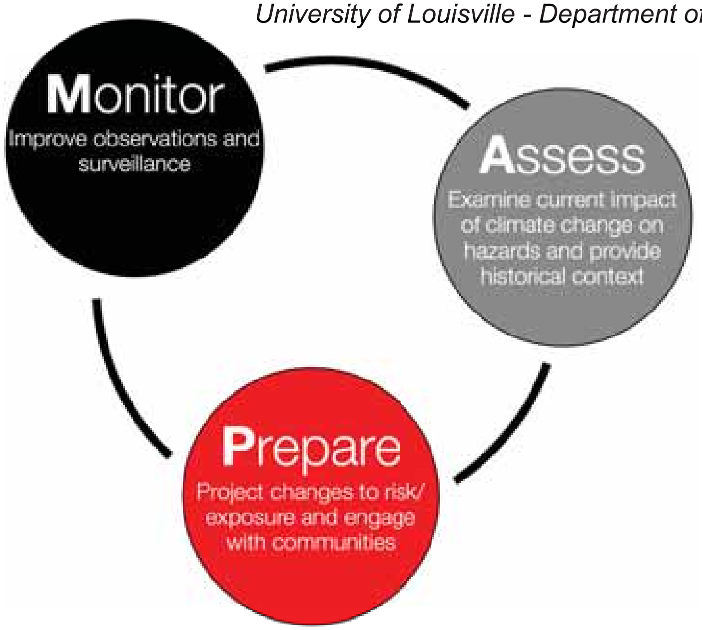
- Connections to Pillar I: Climate science related to land surface changes, water budget, and hydroclimate history is used to develop decadal trends of climate forcing functions that will be used to forecast future climate forcing functions to increase community preparedness and resilience.
- Connections to Pillar III: Big data, geoinformatics, GIS, machine/deep learning, data science, and high-performance computing, needed to analyze, model, and assess the petabytes of field and numerical data.

Follow-on NSF Funding Opportunities:

- Humans, Disasters and the Built Environment, Disaster Resilience Research Grants, Engineering for Civil Infrastructure program, Mid-Level Infrastructure

MAP KY – Monitoring, Assessing, and Preparing for Climate Change and Extremes in Kentucky

University of Louisville - Department of Geographic and Environmental Sciences / Department of Biology / Center for GIS



We aim to establish an integrated approach that addresses change in all "spheres" of the climate system. Through these three goals, our group will be able to provide essential data to communities as they prepare for future climate change.

Expand KY's meteorological observation system (in partnership with the Kentucky Climate Center) to improve early warning detection through the addition of an atmospheric profiling system.

Develop a mobile precipitation array that can be deployed prior to high-impact events or used in the validation of other measurements, hydrologic models, or engineering-based studies.

These networks would make KY institutions more competitive for NSF funding.

Expand KY's paleoclimate record via a high-resolution tree-ring network.

Analyze spatiotemporal trends in hazards such as flash flooding, damaging winds, and hail.

Characterize land cover and land use change through multi-scale remote sensing approaches.

Perform in situ assessment of ecosystem response to changing climate on diversity and ecosystem functioning in the biosphere, in possible partnership with the Kentucky Organization of Field Stations.

Assess the potential spatial influence of local scale basin biophysical characteristics on modifying the overall flood responses to provide further insight into the region's flood history.

Predict trends in exposure to climate hazards.

Generate a data portal where stakeholders, businesses, and other researchers across KY can access and explore the data.

Develop training modules for K-12 teachers to assist in preparing climate change learning material for students.

Employ a "Community-Engaged" Research Scientist to help with dissemination and outreach.

Atmospheric Science / Hydrology Expertise

Jason Naylor (Atmospheric science, Severe storms, Numerical modeling) jason.naylor@louisville.edu
Scott Gunter (Atmospheric science, Hazards, Remote sensing, Meteorological measurements)
Andrew Day (Climate change, Land cover change, Water resources)

Land Systems / Geospatial Expertise

Andrea Gaughan (Land systems, Human-environment, GIS/Remote sensing)
Forrest Stevens (Integrated modeling, Human-environment, GIS/Remote sensing)
DJ Biddle (GIS applications and education, Geospatial community engagement)

Dendrochronology / Ecology Expertise

Maegen Rochner (Dendrochronology, Biogeography, Climate change)
Andrew Mehring (Ecosystem ecology, GHG emissions, Biogeochemistry, Climate change)
Sarah Emery (Plant ecology, Biodiversity, Succession, Restoration)

UK Earth and Environmental Science (EES) Community

- **EES will build capacity, expertise, and infrastructure via CHARGE in order to address four central Pillar 1 hypotheses:**
  1. **The water budget of Kentucky is affected by global warming**
     - Addressed by hiring a critical zone hydrologic scientist (EES hire #1) to model/assess/track surface water resources and availability statewide, supplementing ongoing groundwater research at KGS
  2. **Kentucky's water quality is degraded by climate warming**
     - Addressed by hiring a geomicrobiologist/paleoecologist with expertise in inland waters (EES hire #2; shared with BIO?)
     - Development of a new environmental and ancient DNA laboratory to trace the impact of climate change on harmful algal blooms and biodiversity in Kentucky's rivers, lakes, and reservoirs
  3. **Climate change accelerates hillslope instability in Kentucky**
     - Addressed by hiring an engineering geologist/quantitative geomorphologist to inventory/model the geological and geotechnical controls on landslide susceptibility in suspect terrain (EES hire #3, shared with CE?)
  4. **An expanded (~10,000 yr) hydroclimate history of Kentucky is archived in geological materials**
     - Acquisition of a novel core scanner to facilitate high resolution chemical analyses of archives (sediments, tree rings) for environmental change detection
     - Addressed by hiring a paleo/contemporary climate modeler to facilitate model-proxy data comparisons (EES hire #4)
- **New faculty hires will target underrepresented communities to shift representation in EES, the <u>least</u> <u>diverse</u> STEM discipline**

- **Connections to Pillar 2**
  - Hazards engineering, remediation, and prevention efforts for floods, landslides, and environmental degradation leverage contemporary/retrospective data, mapping, and experiments of CHARGE geoscientists
- **Connections to Pillar 3**
  - Big data, geoinformatics, GIS produced by CHARGE geoscientists forms the feedstock of AI and machine/deep learning, decision analysis, resilience planning

- **NSF Proposal Plan Within CHARGE**
  - Near-Term (1-3 yr.)
    - CAREER (x4)
    - Paleoclimate, Geomorphology/Land Use, Hydrologic Sciences Sedimentary Geology, Geoinformatics, Geochemistry/Geobiology, Environmental Biology
  - Mid-Term (3-5 yr.)
    - Signals in the Soil
    - Frontiers in Earth Science
    - NSF Research Traineeships (NRT)
  - Long-Term (5+ yr.)
    - **Mid-Level Infrastructure "Center for Appalachian Surface Hazards"**

- **EES Community Science Team**
  - McGlue (michael.mcglue@uky.edu), Woolery (ewoolery@uky.edu), Yeager, Thigpen, Zhu, Dortch, Fryar, Erhardt, Crawford, Carpenter, Moecher, Brown, Bryson

Climate Change Hazards in Appalachia: Towards Resilience and Geoscience Equity in Kentucky – Morehead State University Service Region (CHARGE MORE)

Climate Change and Sustainability Science in Kentucky

- **Propose an integrated climatological, flood frequency, watershed impacts, and soil quality and stability study of major watersheds in the service region.**
  - In collaboration with the Kentucky Geological Survey (KGS), Kibria, Hare, J. O'Keefe and students will locate LIDAR-indicated alluvial fan deposits extending onto each streams' floodplain.
  - Near-surface geophysical surveys (GPR, acoustical survey, resistivity, etc.) will be completed for select fans and adjacent floodplains by a **new faculty hire**.
  - Geoprobe cores will be obtained in a transect from the fan apex to the edge of the floodplain (KGS, Kibria, O'Keefe, students).
  - Soil samples will be collected to assess initial soil type, fertility, and strength (Skidmore & Collick).
  - Hydrological study of stream segments adjacent to geophysical study sites will take multiple forms: soil water (Kibria), near-surface water (Kibria and Students), and surface water hydrogeology (Kibria and students); water geochemistry including major and minor ions (Kibria, Thomas, and students) and Perfluoroalkyls (PFAs) and perfluorooctyl sulfonates (PFOSs) (Thomas); and macroinvertebrate surveys to assess stream habitat health (S. O'Keefe). Macroinvertebrates will also be assessed for PFAs & PFOSs levels (S. O'Keefe and Thomas)

Focus on 4 counties in MSU service region most at risk for climate-change related flooding

- Johnson
  - Paint Creek
  - Levisa Fork
- Floyd
  - Beaver Creek
  - Levisa Fork
- Breathitt
  - Troublesome Creek
  - North Fork of the Kentucky River
- Letcher Counties
  - North Fork of the Kentucky River
  - Elkhorn Creek
- Potential collaborative expansion?
  - Pike (Elkhorn Creek, Russel Fork, Levisa Fork)
  - Knott (Troublesome Creek)
  - Perry (North Fork of the Kentucky River)

Expertise

- Amy Collick (a.collick@moreheadstate.edu): watershed modelling and nutrient transport
- Timothy Hare (t.hare@moreheadstate.edu): remote sensing and mapping
- Md Kibria (m.Kibria@moreheadstate.edu): surface, soil, and groundwater hydrogeology and water chemistry; mapping
- Jen O'Keefe (j.okeefe@moreheadstate.edu): palynology-based paleoecology & paleoclimate studies; sedimentology
- Sean O'Keefe (s.okeefe@moreheadstate.edu): aquatic macroinvertebrates as stream habitat health indicators, entomology
- Amanda Skidmore (a.Skidmore@moreheadstate.edu): soil quality and stability
- Elizabeth Thomas (emthomas3@moreheadstate.edu): synthesis and Bio-inorganic analytical chemistry

Using AI in Big Data Mining and Building an AI Curriculum in Climate Science in Kentucky

Aly Farag, Asem Ali and Islam Alkabbany, CVIP Lab, ECE Department, University of Louisville

Abstract: As pertaining to the 3rd pillar of CHARGE (*to build-out the intersection between AI and climate change science in Kentucky, particularly through the development of enhanced sensor networks and machine/deep learning applied to "big data" for extreme hydrological event forecasting, early warning detection, and disaster prevention and management*), the CVIP Lab researchers have the expertise to contribute to AI mining of big data from multisensory information and for developing an AI curriculum for the climate sciences in KY similar to that of Harvard & Stanford.

I. Research on AI for Climate Change

1. *Understand and analyze available data:* huge reservoirs of untapped data (e.g., from stations and satellites) exist, and are ideal for AI/ML modeling of climate change.
2. *Extreme hydrological event forecasting:* AI/ML models can be used for real-time improvement of the discharge forecasts issued by a conceptual-type rainfall-runoff model.
3. *Disaster response:* Big Data tools can be leveraged to process crisis-related data for insights into fast-changing situations and drive an effective disaster response.
4. *Disaster simulation:* AI simulations can model consequences of weather-related disasters, for warning and reduce losses.
5. *Remote sensing:* AI models on remotely sensed data can predict soil moisture and water temperature, understanding stream of geospatial data, and for tracking deforestation.

Example: As an example, for the AI research at the CVIP Lab, we used the sensor network readings of precipitation in the Commonwealth from 1981 to 2022. Noting that the sensors are scattered throughout the Commonwealth forming a unique sensor network with known location (latitude and altitude) to generate a weather map on demand. Shown in Fig. 1 is a sample of five images of the "precipitation map" averaged for Years 1981, 1990, 2000, 2010 & 2020. Such maps are obtained daily; thus, a precipitation video for each year can be formed. From 40 such videos we constructed the trends of precipitation and temperature, which showed that precipitation during 1981-2000 has decreased, while in 2000-2022 it increased, and in these 40 years, the temperature had a positive rise of $0.04\,C°$ conforming with what's commonly known as global warming which estimates that temperature in the earth atmosphere has risen to about $1C°$ since the beginning of the industrial revolution in 1760. Such data are not the only resource, we could include data from satellite, unmanned air vehicles (UAVs) and drones, using various sensors, which would generate an extremely large data reservoir ideal for machine learning and AI-based analysis for deciphering trends of weather and flashfloods and anomalies that caused major disasters such that of 2022 in Western KY.

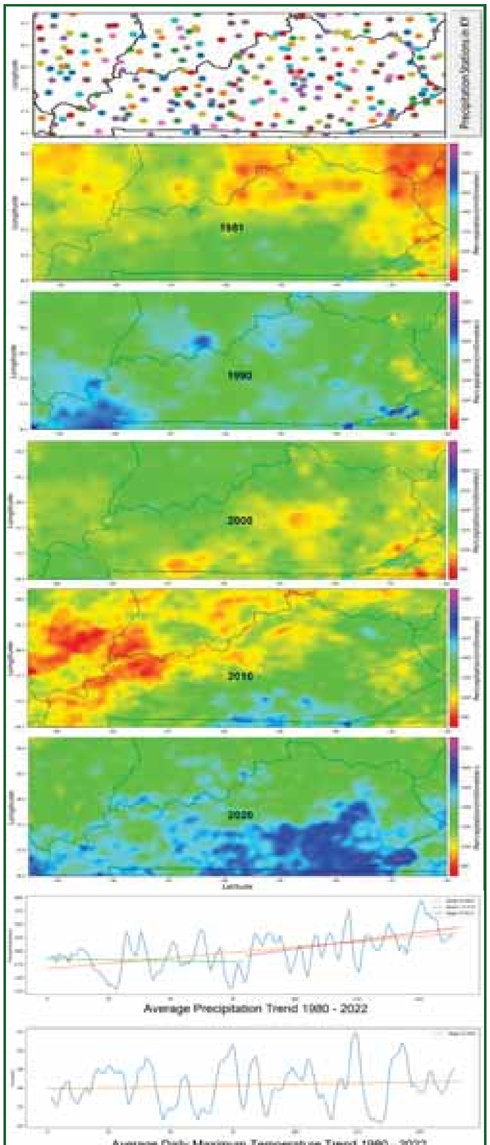


Fig. 1: Sample climate maps in KY and trends in precipitation and temperature during a 40-year period; 1981-2022.

II. AI Curriculum on Climate Change

The CVIP teaches the imaging and AI systems courses at UofL: ECE 618/635 (Image Processing); ECE 619/645 (Computer Vision); ECE 620/655 (Pattern Recognition) and ECE 600 (AI Systems), ECE520/521 (Signal Processing) and ECE530 (Stochastic Processes), which teach the theory, algorithms, and applications of imaging. These subjects include sensors, data representation, object detection, recognition, and tracking, and various aspects of environmental sciences. CHARGE can provide a unique and unprecedented opportunity for academicians in KY to collaborate on AI and build a state-wide KY AI Network (KAIN) for R&D in various fronts of AI, besides a focus on the climate. Extensive discussion on this regard has been conducted with Dr. Brent Seales, CS Department at UK, Dr. Farhad Ashrafzadeh of EE Department at WKU and over 30 researchers at KY. We have also discussed our capabilities vis-à-vis CHARGE with colleagues in the Geography Departments at UofL (Drs. Gaughan, Forrest, Naylor, and Gunter) and UK (Drs. Woolery, Curl and Dortch). Furthermore, we have been following the courses developed at Harvard & Stanford for Climate Change which can serve as footprints for designing a curriculum or certificate for climate sciences at UofL & UK, to educate the citizens of the Commonwealth and train students at KY institutions about the Climate.

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AI-based Unified Learning Framework from Multimedia Disaster Information

Contact: Abdullah-Al-Zubaer Imran, aimran@uky.edu

Natural disasters can cause negative impact on a community and leave scars aftermath, with loss of lives, property damage, and massive economic setbacks. Particularly, the Kentuckians have experienced severe natural disasters over the years. Of them, floods, tornadoes, winter storms, and forest fires are the most common ones. The Central Appalachia flooding in mid-2022 has been a tragedy for its devastating effects. Better preparedness or precautionary measures can help mitigate the damages. But it is also extremely important to understand the extents and damages which can be performed through the analysis of satellite images. Satellite imagery enables analyzing large temporal and spatial regions. Additionally, we could leverage the mass dissemination of data from social media (Twitter, Facebook, Instagram, Flickr, etc.). However, it will be a cumbersome and error-prone process to analyze such multimedia information with human observers. Therefore, we plan to leverage AI/ML for the automated analysis of large multimedia information in a unified learning manner for fast and accurate disaster detection, severity assessment, and potential appropriate emergency responses. **Such unified framework could help mitigate the damage as well as build resource-constraint models for future unseen event data.**

Research Objectives: We aim to develop AI/ML models integrating multimedia disaster information from different sources.

1. Natural Language Processing: The preliminary AI model will be built on Twitter texts via natural language processing (NLP). Feeding Twitter posts and upon preprocessing, we could get the disaster location or damage information from our NLP model.

2. Social Media Image Analysis: Based on the images shared over social media along with the user-provided metadata, we will train a deep multimodal learning model for automated disaster detection and damage assessment through image segmentation and object detection.

3. Video Analysis: Videos captured by personal devices shared on social media or unmanned aerial vehicles could provide more detailed information. Therefore, our automatic disaster detection and assessment could further be improved with video processing.

4. Satellite Imagery: We will build a deep learning-based model for detecting and assessing natural disasters using satellite images.

5. Multimedia Information: While the individual models have their unique challenges, a unified model will play a key role in learning from data from different sources for more accurate and robust predictions. Our goal is to develop a unified learning framework based on multimedia data linking social media texts, images, and videos with the satellite images.

Teaching Component: In addition to developing unified learning objectives of the proposal, to further motivate the cause and educate the next generation scientists, we plan to develop a seminar course on Climate Change AI jointly offered by UK Computer Science and the Earth & Environmental Sciences.

Personnel:
Abdullah-Al-Zubaer Imran (Artificial Intelligence, Image Processing)
Department of Computer Science, UK

Junfeng Zhu (Karst Hazards, Remote Sensing)
Kentucky Geological Survey, UK

Combating Climate Change using Construction Additive Manufacturing

KCTCS ADDITIVE MANUFACTURING CENTER @ SOMERSET COMMUNITY COLLEGE

SUMMARY

This project will begin to steer Kentucky and its workforce away from the negative climatic impacts of conventional construction by researching and implementing automated additive construction statewide using giant 3D printers to fabricate A.I.-generated structures from concrete for residential and commercial use, as well as concrete products that can be used for stormwater drainage, agricultural products, embankment stabilization, etc.

PROPOSAL

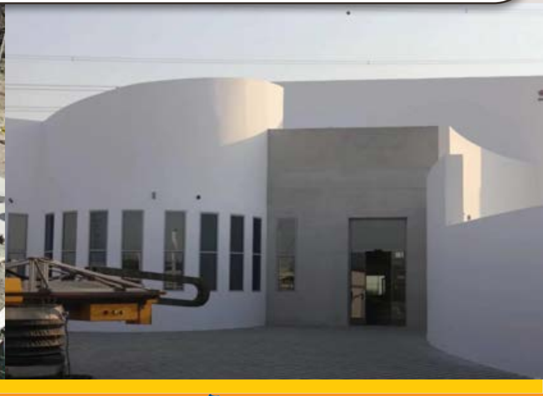
The KCTCS Additive Manufacturing Center (AMC) is seeking partners to:

- Combine resources in material science, A.I. applications, and other fields
- Prepare the Kentucky workforce, both at the engineering and technician level, in application of the technology.
- Research KY native and reclaimed materials that can be most effectively employed as a structural material.
- Physical testing of additive structures both for housing and environmental impact controls.
- Potential climatic modeling impacts and infrastructure resiliency planning.
- Awareness campaigns regarding addressing climatic change through better design.

This project will not only begin the shift of the Kentucky construction sector towards a better economic and environmental direction, but will also create a host of additional research opportunities, especially those involving DOE, DOD, NSF, and USACE funding. The project will enable the transition from the conventional manual labor and time intensive wood construction methodology to the automated process of 3D printing houses and buildings where building structures can be optimized through complex shape manipulation to resist catastrophic seismic and climatic events. Structural infrastructure can be rapidly mobilized and built in a matter of days instead of months or years. Material waste can be drastically reduced and the victims of natural disasters can quickly have a home far better than the one they lost.

OUR EXPERTISE

Second only to UofL's AMIST in technology, the KCTCS AMC is one of Kentucky's most advanced additive manufacturing production centers, incorporating a host of advanced 3D printing technologies, material recycling and composite production systems, A.I. based design systems, automated AM production, and Kentucky's largest FDM 3D printer. The AMC utilizes advanced Virtual Reality technology as part of their research, analysis, and design applications. Director Wooldridge is the only educator and researcher in Kentucky that is a registered Architect, double licensed Professional Engineer, holds a M.S. specializing in additive manufacturing engineering, and has nearly 20 years of private practice in both residential and commercial building design including structural, mechanical, and electrical engineering services. Wooldridge has extensive professional networks within the political, private equity, agricultural, and building code enforcement realms.



Contact: Eric Wooldridge PE, RA, eric.wooldridge@kctcs.edu

KENTUCKY COMMUNITY & TECHNICAL COLLEGE SYSTEM

Combating Climate Change in Kentucky using Low-Cost VR

KCTCS VIRTUAL REALITY ACCESS CENTER @
SOMERSET COMMUNITY COLLEGE

SUMMARY

Understanding climate change and its potential impacts is often difficult as it is fairly abstract, and in many ways a slow change over time. Pictures, charts, and video simulations often do not move people to take action. But when climatic change is experienced at a personal, immersive, and/or emotional level, humans are much more motivated to act. This project will create that experience using low-cost virtual reality (LCVR) immersive technology. It will allow users, including students, parents, educators, industry, and community leaders, to experience climatic events and changes at a personal and emotional level. It will also create opportunities for researchers to visualize and study climatic impacts, data, and design solutions within three dimensional and immersive environments, making it possible to finally study and present the impacts of climate change in a way that moves people to take action.

PROPOSAL

The KCTCS Virtual Reality Access Center is seeking partners to:

- Combine expertise and resources to develop a CHARGE LCVR platform that can be used for research visualization and awareness campaigns related to climatic change events.
- Train students and educators in immersive LCVR module creation using open source software and equipment that is readily accessible.
- Develop new A.I. methods of VR content generation for rapid and much more cost effective creation.
- Create new relevant VR software modules where climatic events are visualized and experienced at a personal point of view level.
- Send out teams of graduate and undergraduate students with LCVR equipment on climatic awareness campaigns.
- Create a new workforce body within the Commonwealth that is VR literate and capable of using the technology in a variety of new ways, but is also much more emotionally aware of the impacts due to climatic changes.

OUR EXPERTISE

The KCTCS Virtual Reality Access Center (VRAC) is the first research center in the nation to develop DIY low cost VR applications and training for students, educators, and researchers. Incorporating both advanced and readily available VR technologies, the VRAC team is experienced in developing cutting edge visualization, learning, and collaboration tools. The center uses A.I., block coding, and advancements in the video gaming industry to aid in the VR development process. In a very short time, VRAC has created a highly effective set of VR tools, training, and national collaboration network of developers while also exploring experimental VR technologies such as low cost haptic feedback, hand tracking, eye tracking, and facial recognition to enhance emotional data collection and analysis and user interfacing to experience data versus just reviewing a 2D graph or tabulation. This approach will lead to a host of new potential research tools such as VR spreadsheets, VR data point clouds, and haptic data feedback.

Contact: Eric Wooldridge PE, RA, eric.wooldridge@kctcs.edu

KENTUCKY COMMUNITY & TECHNICAL COLLEGE SYSTEM

Title: Modular and Portable Solar-Hydrogen-Battery Emergency Power Supply for Disaster-Affected Communities

Team: Yang-Tse Cheng, Jiangbiao He, Doo Young Kim, University of Kentucky

Overview:

Based on FEMA data, Kentucky is one of the states most devastatingly affected by natural disasters including hurricane and flooding in the past few years. These disasters have posed severe threats to utility power grids in Kentucky. Once a power blackout occurs, it can cause immense economic losses and it may take many weeks or even months to restore the grid. In this project, we propose to develop several concepts and technologies that enable quick deployment of modular, portable, and sustainable emergency electrical power to disaster-affected communities. The team will explore storage, transportation, distribution, and use of energy and power generated by renewable energy available in Kentucky. Specifically, solar panels and mechanically-rechargeable high energy metal-air batteries can provide electric power directly to the affected communities. Moreover, clean hydrogen is an ideal fuel for emergency rescue, due to its versatility as energy carrier, fast charging, high gravimetric-energy-density and carbon zero-emission. This project will investigate generation, storage, transportation of clean hydrogen, and its dispense for powering fuel cells and internal combustion engine, along with modular and portable high energy and high power battery systems, to provide heat and electricity to disaster-affected community.

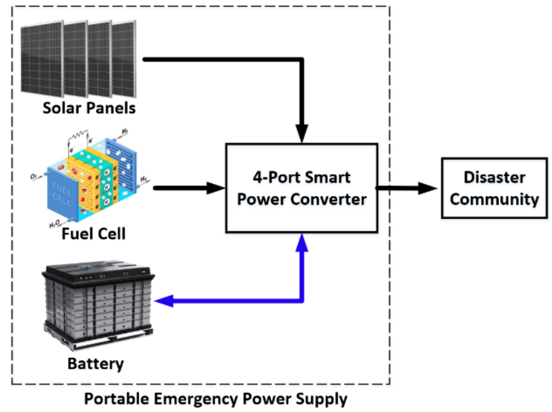


Fig. 1 Portable emergency power supply system

The specific research tasks include:

- Mechanically-rechargeable metal-air batteries, such as Zn-air, Al-air, and Mg-air batteries.

These batteries have much higher energy and power densities than today's lithium ion batteries. For long term storage, the batteries are in the hibernate or dormant state because they are assembled without the liquid electrolyte. For emergency power, the liquid electrolyte is added to the batteries to produce immediate electrical power and energy. Once the Zn, Al, or Mg metal electrodes are consumed, they can be readily replaced to "mechanically recharge" the batteries. The task will focus on developing modular and portable battery systems with appropriate aqueous electrolytes and additives that can be deployed in modular forms by various means (e.g., roads, rivers, and air) to disaster-affected regions.

- Cost-effective clean hydrogen production and portable hydrogen-powered fuel cell systems.

The project will advance the technology of water electrolysis process powered by renewable energy. This advance will contribute to achieving the DOE goal (1$ per 1kg clean hydrogen within 1 decade, "111") by lowering capital cost of electrolyzer and operation cost of water electrolysis. For emergency rescue, portable fuel cell systems with medium- or heavy-duty will be developed. The project will seek advanced hydrogen storage, transportation, and the speedy re-fueling of fuel cells. Hydrogen fuel cells can be filled with 10 kg of compressed hydrogen gas (300 bar) in 1 minute and 10 kg hydrogen will generate 335 kWh of usable energy for emergency rescue.

- High-efficiency multi-port power electronic converter and system optimization

Power electronic converters play a critical role in managing the power between the proposed solar-hydrogen-battery emergency power supply and the residential microgrid. The performance of the proposed emergency power supply is closely related to the operation of the power converters and controls. Different from all the conventional power supplies, a 4-port power converter is required here to intelligently interconnect multiple power resources with the microgrid. Also, high energy efficiency and high power density have to be considered to maximize the systematic energy efficiency. In this project, we propose to develop a 4-port power converter, as shown in Fig. 1. In this new converter topology, each power port has a H-bridge power electronic circuit, with a phase-shifting magnetic transformer interconnecting all the four power ports together. The power flow can be controlled by regulating the phase shift angles between any of the two power ports. Meanwhile, the transformer will provide galvanic isolation among the 4 power ports, eliminating high-frequency electromagnetic interference crossing between various power ports. The 4-port converter will be developed based on the emerging Silicon Carbide (SiC) transistors, which can be switched at high frequency to minimize the physical size of the transformer. Furthermore, we will conduct system optimization to design and size modular emergency power supplies based on power demand of disaster-affected communities.

Renewable Energy Readiness for Climate Change and Impacts on Health & Environment: Natural disaster mitigation strategies in Kentucky

Summary

In support of **CHARGE Pillar III, "Artificial Intelligence and Climate Change in Kentucky,"** this research effort proposes to develop augmented artificial intelligence (AI)-assisted models of how renewable energy generation in KY will be impacted by expected climate change. Based on global models, we will develop KY-specific climate and weather models and climate change impacts on the health and environment of KY, including eastern KY. The proposed models will be used to quantify the socio-economic impacts on combined health, environment, and climate benefits of transitioning to renewable energy in KY communities, optimized for weather and climate variability in KY. Considering the uncertainty parameters such as frequency, duration, and intensity of health and environmental threats linked to climate change, we will systematically model the KY-specific general trend of weather and climates, renewable energy, and health and environmental impact during natural disasters in light of energy generation.

1. Improve renewable energy forecast accuracy based on climate change-impacted weather

- Localize comprehensive climate and weather models with KY uncertainty parameters (i.e. frequency, duration, and intensity of extreme weather events) using collected historical data from climate archives of KY.
- Optimize renewable energy models using renewable energy generation data (solar, wind, bioenergy) linked to historical climate and weather trends.
- Improve renewable energy forecast accuracy based on augmented AI models of climate and weather considering weather patterns, climate variability, and natural disasters tailoring to KY communities.

2. Assess health and environment impacts of climate change associated with renewable energy systems

To date, no study has been made on health and environmental impact associated with renewable energy in KY.

- Identify regional variation factors and conditions that advance scientific knowledge about public health (i.e. cardiovascular, respiratory, etc.) and environments, directly and indirectly, linked to climate change.
- Analyze and assess the the trend of public health and environmental impacts based on localized climate and renewable energy models.
- Evaluate KY-specific socio-economic impact on combined health, environmental, and climate benefits from renewable energy based on weather climate variability.
- Provide a guideline for renewable energy readiness strategies pre- and post- natural disasters influenced by climate change.

Additional Connection to NSF Funding Priority: "Advances in Equity in Science and Engineering"

This proposal will strengthen equity and diversity of learning opportunities by engaging students from a community college (Bluegrass Community and Technical College), a regional university (Morehead State University), and the University of Kentucky, establishing pipelines for training and education of students among KY institutions.

Team member:

Jian Shi (j.shi@uky.edu – Biosystems Engineering)[1], Jin Chen (chen.jin@uky.edu – Computer Science, Internal Medicine)[1], Wayne Sanderson (wayne.sanderson@uky.edu – Public Health, Biosystems Engineering)[1], Matthew Dixon (matt.Dixon@uky.edu – UK Ag Weather Center)[1], Philip Lee (philip.lee@uky.edu – Engineering Technology)[1], Kent Price (k.price@moreheadstate.edu - Physics, Earth Science & Space Systems Engineering)[2],
[1]University of Kentucky, [2]Morehead State University

Improving the Readiness and Resilience of Kentucky's Built Environment: a Plant Developmental Genetics Approach

Mark Running, Department of Biology, University of Louisville

Goals

We propose to improve the readiness and resilience of Kentucky's built environment by adding biology-based mitigation to decrease the severity of climate-based disasters such as drought, landslides, and flooding. This approach augments the proposed approach in CHARGE Pillar II, Climate Change Hazards and Disaster Engineering in Kentucky, using a plant biology perspective.

Specific Aims

1. Survey native plants from Kentucky and Tennessee, investigating the growth of identified plant species in a variety of soils, examining the extent of their root system, and examining their degree of drought and heat tolerance. Identify plants that can replace vegetation lost to drought, fires, or other causes in at-risk hillslopes that are identified by monitoring systems proposed in Pillar II.

2. Investigate the role of root development genes in candidate native plants with the goal of enhancing root production, augmenting their drought tolerance and contributing to soil stability and reducing water runoff and soil erosion. We will use marker-assisted selective breeding and/or CRISPR/Cas9 approaches, building on the extensive knowledge of root development genes in model organisms such as *Arabidopsis.*

3. Test the response of native plants to treatments with compounds known to enhance drought tolerance in certain plants (Quinabactin, Opabactin, etc.) If shown to be effective on native plants, these compounds can also serve to enhance the survival of plants during extreme drought.

Expertise

Plant Molecular Biology, Genetics, Development, Biochemistry, Biomaterials.

Contact Info

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Ideas for Contribution to Climate Change Hazards and Disaster Engineering in Kentucky (CHARGE)

- Estimate the probability of slope instability for various climate-change-driven precipitation scenarios by incorporating lidar-derived digital elevation maps with physics-based slope stability models to produce probabilistic landslide hazard maps.

- Examine how precipitation events impact slopes with frequent (weekly/monthly) but long-term (years) repeat monitoring of both known landslides and adjacent slopes using drone-based lidar and/or structure-from-motion photogrammetry and synthetic radar aperture (SAR). The vertical and horizontal components of slope deformation will be quantified and correlated with precipitation events and long-term trends in precipitation. This could also incorporate surface or subsurface monitoring. The impact of precipitation on existing landslides and the initiation of new landslides on previously stable slopes can be examined, and this relationship could lead to an early warning system for slope failures.

These proposed studies can contribute to the CHARGE priority of long-term monitoring studies that aid in prediction and afford early warning of slope failures.

Areas of experience:
- Engineering geology
- Quantitative geomorphology, digital terrain analysis
- Landslides, debris flows
- Machine learning for geologic mapping
- Vertical and horizontal change detection for slope monitoring
- Drone-based lidar and photogrammetric data acquisition and analysis
- Remote sensing analysis

I am open to collaborate with other's ideas where my experience might help.

Nivanthi Mihindukyulasooriya, Assistant Professor of Geology, Northern Kentucky University, mihindukul1@nku.edu

- Research Topic 1 - Understanding Holocene climatic changes by expanding the proxy records
- Connection to Pilar 1- expand the climate change archives of Kentucky from their current state (<200 years) to ~10,000 years using geological and atmospheric datasets

Increase in sea surface temperature associated with anthropogenic warming can affect the Atlantic meridional overturn circulation (AMOC). AMOC exhibits variability in decadal to daily time scales and is an important factor controlling the short-term climatic variability of the Eastern United States. Positive feedback mechanisms associated with anthropogenic radiative forcing can lead to non-linear changes to the climate system that can lead to catastrophic events. Proxy data from multiple archives are required to accurately model future climatic changes, and to understand the microclimatic conditions within the region. Additionally, high-resolution paleoclimatic proxies are required to study the decadal variability of the past climate system. Considering the geological and climatic conditions in Kentucky, cave sediments and speleothems would be the most feasible paleoclimatic archives that can provide such high-resolution paleoclimatic records.

- Objective: Identify Holocene climate variability, and periodicity in order to understand factors controlling short-term (decadal to century-scale) climatic changes.

- Research Topic 2 - Rapid, cost-effective monitoring of water quality
- Connection to Pilar 2- developing enhanced environmental visualization tools for algal bloom monitoring

With a warming climate increasing the prevalence of HABs, frequent water quality monitoring programs are necessary to provide sufficient early warnings to the public. In addition to HABs, fine sediments often degrade aquatic habitats by creating hypoxia and transporting pollutants attached to them. We propose to use visible derivative reflectance spectroscopy (VDS) methods for monitoring water quality in large waterbodies. VDS is a rapid, cost-effective approach to identifying color-producing agents in water, including phytoplankton and suspended minerals.

- Objective 1- Qualitative monitoring of phytoplankton groups in large water bodies.
- Objective 2: Identifying sediment composition and tracing the source of suspended sediments in order to help implement sediment control management practices

Open to collaborations, including other's ideas where my expertise may help. Contact mihindukul1@nku.edu