Spring 2024

Activities & Work Completed

- Completed formal **Python programming training** to strengthen scientific computing and data processing skills.
- Received training in **WEPPCloud and WEPP** for watershed-scale soil erosion and hydrologic modeling.
- Configured and ran WEPP models for multiple watersheds, including:
  - Hickory Creek
  - Upper Duck Creek
  - Lower Duck Creek
  - Lost Creek
- Developed custom **Python scripts** to:
  - Modify WEPP slope files programmatically
  - Extract and post-process WEPP model outputs
- Initiated early-stage development of **Python-based tools** to support climate data processing workflows.
- Explored and discussed best practices for **NetCDF data storage and conversion**, including formats such as `.npy` and `.npz`.

Skills Learned & Strengthened

- Python for scientific computing and automation
- Watershed modeling using WEPP and WEPPCloud
- Data preprocessing and postprocessing for hydrologic models
- Handling and structuring large climate datasets (NetCDF concepts)
- Scripting for model parameter manipulation and results extraction
- Research-oriented problem solving and workflow design

Project / Research Summary

During Spring 2024, I focused on building a strong technical foundation in watershed modeling and scientific programming. I successfully transitioned from training to applied modeling by configuring and running WEPP simulations across multiple Iowa watersheds. In parallel, I began developing Python scripts to automate repetitive modeling tasks and explored efficient ways to store and process climate datasets. This period marked the start of my long-term work in integrating climate data workflows with physically based hydrologic and erosion models.

Summer 2024

Activities & Work Completed

- Continued software development focused on **GridOPS**, a Python-based climate data processing toolkit.

- Designed and implemented modular functions to support end-to-end climate data workflows, including:
    - Saving processed data to compressed formats (`.npz`)
    - Quality control and validation checks
    - Calendar conversions (e.g., 360-day and no-leap calendars to Gregorian)
    - Unit conversions for climate variables
    - Spatial cropping of gridded datasets
    - Temporal stacking and slicing of time-series data
    - Visualization tools for both 2D and 3D plotting
- Tested functions on real climate datasets to ensure usability and scalability for research applications.

Skills Learned & Strengthened

- Modular software design in Python
- Climate data preprocessing and standardization
- Handling multiple climate model calendar conventions
- Data validation and quality assurance techniques
- Scientific visualization (2D and 3D plots)
- Writing reusable, research-grade code for large datasets

Project / Research Summary

In Summer 2024, I shifted toward focused software development aimed at supporting climate data processing for hydrologic and environmental modeling. I built and tested a suite of reusable Python functions under the GridOPS framework, addressing common challenges such as calendar inconsistencies, unit conversions, and large-scale data handling. This work laid the groundwork for scalable climate data workflows that would later be integrated into watershed and conservation modeling studies.

Fall 2024

Activities & Work Completed

- Taught **ABE 431/531: Design & Evaluation of Soil and Water Conservation Systems**, delivering both laboratory sessions and lectures.
    - Topics taught included soil erosion by water, precipitation processes in the hydrologic cycle, watershed delineation, and RUSLE2-based erosion assessment.
- Designed and presented a **research poster** titled *"Sediment Delivery from Hillslopes with Vegetative Buffers (WEPP)"* at the **Iowa Section Meeting of the American Society of Agricultural and Biological Engineers (ASABE)**.
- Conducted physically based modeling using **WEPP** to evaluate sediment delivery from agricultural hillslopes with varying vegetative buffer widths.
- Attended professional training workshops at the **Pittsburgh Supercomputing Center**, including:
    - High Performance Computing (HPC) Workshop

    - GPU Programming Using OpenACC
- Continued software development by enhancing **GridOPS** with additional climate data processing functionality.

Skills Learned & Strengthened

- Teaching and instructional delivery in soil and water conservation engineering
- Physically based erosion and sediment transport modeling using WEPP
- Analysis of vegetative buffer effectiveness for sediment mitigation
- Interpretation of hillslope geometry effects (concave, linear, convex) on erosion dynamics
- Scientific communication through poster design and technical presentation
- High-performance computing concepts and GPU acceleration fundamentals
- Advanced climate data processing and workflow optimization

Poster / Project Summary

In Fall 2024, I presented a research poster examining **sediment delivery from agricultural hillslopes with vegetative buffers using the WEPP model**, focusing on the **Upper Duck Creek watershed near Davenport, Iowa (92.75 km²)**. The study simulated 21 years of climate data (2000–2020) across representative hillslopes with varied slopes derived from a 30 m DEM and conventional corn–soybean management.

The modeling results demonstrated that **wider buffers are generally more effective at reducing sediment delivery**, with a standard **30-ft buffer achieving approximately 60% sediment reduction**, and diminishing returns observed beyond this width. Grass buffers were found to be the most effective overall, though no statistically significant differences were observed among vegetative buffer types. The analysis further showed that hillslope shape plays a critical role, with concave slopes reducing erosive energy and convex slopes increasing it.

This work highlighted the capability of **WEPP to simulate erosion and sediment transport at HUC-12 scales**, providing actionable insights for targeting Best Management Practices (BMPs) and informing cost-effective conservation planning. The poster strengthened my experience in integrating modeling, spatial data, and scientific communication to address real-world soil and water conservation challenges.

Spring 2025

Activities & Work Completed

- Began development of **climate projection inputs for the NRCS Animal Waste Management (AWM) tool**, with the goal of enabling AWM simulations to incorporate **future climate scenarios** rather than relying solely on historical climate data.
    - Designed workflows to bias-correct and downscale CMIP6/HighResMIP climate projections for direct integration into AWM modeling.

    - Focused on ensuring compatibility with NRCS conservation planning frameworks and operational use.
- Advanced **spatial downscaling workflows** for the CETWI case study, continuing development of scalable climate–hydrologic integration methods.
- Prepared and processed climate datasets for the **AWM case study**, including precipitation and temperature inputs structured for physically based modeling.
- Participated in the **Scott County RCPP: Working Lands for Resilient Communities** kickoff meeting and conducted watershed-level testing across 21 watersheds in collaboration with project partners.
- Contributed workflow figures and technical content to the **NRCS–CPF Technical Report**, supporting climate-informed conservation planning.
- Taught and coordinated the **Watershed Delineation Lab** for *TSM 3240: Soil and Water Conservation Management*, including organization of TauDEM scripts and instructional materials.
- Trained undergraduate and graduate collaborators on **WEPPCloud** workflows for watershed modeling.

Grants & Awards

- **Awarded the Water Resilience Collaborative (WRC) Graduate Student Grant ($5,000)** for the project *"Drops of Resilience: Precision Projections for Iowa's Watersheds"*
- **Awarded the IPCC Scholarship Programme Grant (€30,000)** for the project *"Enhancing Water Resilience with 1-Minute Climate Projections in the Colorado Rockies and Nepal Himalayas"*
    - Selected as a Nepalese PhD student from a Least Developed Country (LDC), supporting advanced climate downscaling research and international capacity building.

Skills Learned & Strengthened

- Climate projection development for decision-support tools (NRCS AWM)
- Bias correction and spatial–temporal downscaling of CMIP6/HighResMIP data
- Structuring climate data for operational conservation models
- Integration of climate projections with hydrologic and erosion models
- Grant writing and project leadership as Principal Investigator
- Technical communication with federal agency stakeholders (NRCS)
- Teaching, mentoring, and research coordination

Project / Research Summary

During Spring 2025, I focused on **bridging the gap between climate projections and applied conservation tools**, particularly through the development of future climate inputs for the **NRCS Animal Waste Management (AWM) model**. This work addressed a key limitation of current AWM applications by enabling simulations under projected climate conditions, improving the tool's relevance for long-term nutrient management and conservation planning.

In parallel, I secured two major competitive awards. The **WRC Graduate Student Grant** supported the development of high-resolution, bias-corrected climate projections for Iowa watersheds, validated using Mesonet and ASOS observations and designed for integration with WEPP and other hydrologic models . The **IPCC Scholarship Programme award** funded the development of a novel hybrid stochastic–machine learning framework to downscale CMIP6 climate data to **1-minute temporal resolution**, with applications in both the Colorado Rockies and Nepal Himalayas.

Together, these efforts advanced my dissertation research by establishing scalable, high-resolution climate data pipelines that connect global climate models to local conservation, hydrologic, and resilience-focused decision-making.

Summer 2025

Activities & Work Completed

- Advanced **Animal Waste Management (AWM) climate integration work**, continuing development of bias-corrected and downscaled climate projection datasets designed for use in the NRCS AWM tool.
    - Focused on structuring precipitation and temperature inputs so AWM can evaluate waste management practices under **future climate conditions**, rather than relying solely on historical climate records.
- Continued work on **CETWI and Agricultural Water Management (AWM) case studies**, including:
    - Finalizing remaining climate inputs and model configurations
    - Running and validating simulations using processed climate projection datasets
- Initiated **temporal downscaling workflows**, building on previously developed bias correction and climate preprocessing pipelines.
- Contributed to **erosivity and mitigation-focused case study discussions**, providing climate data insights relevant to conservation practice evaluation.
- Began drafting a **bias correction-focused research manuscript**, emphasizing preservation of statistical relationships and hydrologic relevance.
- Initiated development of a **Water Resilience Collaborative (WRC) research proposal**, expanding climate–hydrologic integration work beyond existing case studies.

Software Development

- Published the **GridFlow library**, providing tools for downloading, cropping, clipping, and preprocessing CMIP climate products through both command-line and graphical interfaces.
- Continued refining climate data processing utilities to support:
    - Bias correction
    - Temporal aggregation and disaggregation
    - Quality control and reproducibility across large datasets

Dissertation Progress

- Prepared and submitted an **informal dissertation draft update** to advisor (Ryan) by July 31, summarizing progress on climate data workflows, bias correction methods, and applied case studies.
- Clarified dissertation scope around **climate projection refinement and application to conservation and hydrologic modeling**, informed by AWM and watershed-scale studies.

Infrastructure & Computing

- Rebuilt personal research workstation with an **NVIDIA RTX 4070 GPU**, significantly improving capacity for:
    - Large-scale climate data processing
    - Parallel workflows
    - Future machine learning and downscaling experiments

Skills Learned & Strengthened

- Applied climate projections for operational conservation tools (NRCS AWM)
- Temporal downscaling and high-frequency climate data handling
- Research software publication and maintenance
- Large-scale computing and GPU-enabled workflows
- Integrating climate science with applied agricultural decision-support systems
- Managing multi-project research timelines

Project / Research Summary

During Summer 2025, I focused on **operationalizing climate projection workflows for applied conservation modeling**, with particular emphasis on enabling the NRCS Animal Waste Management (AWM) tool to assess future climate impacts. This work strengthened the connection between climate science and real-world conservation planning by preparing climate datasets suitable for long-term nutrient and waste management decisions.

In parallel, I finalized key case study inputs, advanced temporal downscaling methods, and published the GridFlow software library to support scalable climate data processing. Infrastructure upgrades and dissertation planning further positioned my research for efficient execution of high-resolution climate–hydrologic analyses in subsequent semesters.

Fall 2025

Conferences & Presentations

- **Iowa Water Conference (Completed)**
  Title: *Adapting to Extremes: A Scalable Framework for Climate-Resilient Conservation in Iowa*
  Description: Presented a scalable framework that integrates high-resolution climate projections into hydrologic/erosion modeling to evaluate conservation practices in Upper

Duck Creek, including contouring and vegetative buffers, supporting Iowa's nutrient reduction and water quality goals.

- **AGU Conference (Completed)**
  Title: *Integrated SAR Bands for Surface Soil Moisture Retrieval in Vegetated Landscapes (CONUS)*
  What I presented: A physics-constrained machine learning framework showing how **L-band SAR** addresses C-band saturation under dense crop canopies (the Corn Belt "blind spot"), and how **multi-frequency fusion** improves soil moisture retrieval performance at continental scale.

Activities & Work Completed

- Used **future climate projections** to evaluate **erosion and runoff risk under projected climate conditions**, rather than relying only on historical climate.
- Applied and compared **management/conservation practice scenarios** to test whether future erosion increases can be mitigated, including:
  - Contouring
  - Vegetative buffer strips
- Ran watershed-scale simulations in **Upper Duck Creek** to assess conservation performance under future conditions and to support climate-resilient conservation planning.

Skills Learned & Strengthened

- Climate-informed erosion and watershed assessment using projected climate inputs
- Scenario-based evaluation of conservation practices for mitigation under future extremes
- Scientific communication across audiences (Iowa water/conservation stakeholders and AGU scientific community)
- Remote sensing + ML framing for hydrologic variables (soil moisture) under vegetation constraints
- Building "physics-constrained" modeling narratives that generalize beyond location-specific patterns

Project / Presentation Summaries

Climate-resilient conservation modeling (Iowa Water Conference):
In Fall 2025, I presented a framework that integrates high-resolution climate projections into watershed modeling to assess how erosion and water quality risks may evolve under future climate conditions. Using Upper Duck Creek as a testbed, I evaluated whether conservation practices such as contouring and vegetative buffers can reduce increased erosion risks under projected climates, supporting Iowa's nutrient reduction and long-term conservation planning goals.

Soil moisture retrieval under vegetation (AGU 2025):
At AGU 2025, I presented a continental-scale analysis demonstrating that **L-band SAR is essential** for monitoring soil moisture during peak growing season in high-biomass regions

where **C-band saturates** ("blind spot"). By combining L-band structural penetration with C-band surface sensitivity, **multi-frequency fusion** reduced overall error (reported RMSE ≈ 0.012 m^3/m^3) and provided a blueprint for multi-frequency missions like **NISAR**.

Spring 2026

Research, Publications & Software

- **Submitted a systematic review manuscript** titled *"Effectiveness of Multivariate Bias Correction in Hydrology and Agriculture: A Systematic Review"* to **Hydrology and Earth System Sciences (HESS)**.
- **Submitted the GridFlow software library** to the *Journal of Open Source Software (JOSS)*:
  GridFlow: A modular high-performance toolkit for downloading and processing large-scale climate and geospatial datasets
  🔗 https://github.com/shahbhuwan/GridFlow

Water Resilience Collaborative (WRC) Project

- Currently leading research under the **Water Resilience Collaborative (WRC)** project.
- Completed **univariate and multivariate bias correction** for **five CMIP6 climate models**, producing a consistent, future-ready climate ensemble.
- Initiated **spatial downscaling** of the bias-corrected ensemble to support watershed- and farm-scale resilience assessments.
- Applied downscaled climate projections to evaluate infrastructure and conservation vulnerability under future climate conditions.

Urban Heat Island (SUHI) Project

- Completed **all climate and ancillary data acquisition** for the **Surface Urban Heat Island (SUHI)** study.
- Prepared datasets required for figure generation and manuscript development.
- Next steps include:
  - Generating spatial and temporal figures
  - Writing the manuscript
  - Inviting **Dr. Lu (Civil Engineering)** as a co-author

Presentations & Conferences

- **CALS Research Day (Presented)** – February 3, 2026
  Title: *Assessing the Vulnerability of Swine Manure Storage to Extreme Weather Events in Northwest Iowa*
  - Presented climate-informed vulnerability analysis showing how reliance on historical stationarity in NRCS manure storage design can mask future failure risks under intensifying storms.

    - Demonstrated that future climate projections indicate ~17% increases in extreme storm intensity, with implications for emergency pump-outs and environmental compliance.
- **ASABE Annual International Meeting (Abstract Submitted)**
  Title: *Unmasking Buffer Efficiency: Defining Critical Thresholds for Sediment and Nutrient Retention*
- **Soil and Water Conservation Society (SWCS) Conference (Abstract Submitted)**
  Title: *A Revised Soil Vulnerability Index Based on Physical Erosion Modeling of Seasonal Climate Variability*

Skills Learned & Strengthened

- Multivariate climate bias correction and ensemble processing
- Spatial downscaling for climate resilience applications
- Climate-informed infrastructure and conservation risk assessment
- Research software publication and open-source dissemination
- Translating climate projections into NRCS-relevant decision frameworks
- Scientific communication across stakeholder and academic audiences

Project / Research Summary

During Spring 2026, I focused on **operationalizing climate projections for conservation, infrastructure, and resilience planning**. I submitted a systematic review on bias correction methods to HESS and a research-grade software library (GridFlow) to JOSS, strengthening the reproducibility and accessibility of climate data workflows.

My ongoing WRC project advanced from bias correction to spatial downscaling of CMIP6 ensembles, enabling climate-stress testing of agricultural systems under future extremes. At CALS Research Day, I presented results demonstrating how climate non-stationarity challenges current NRCS manure storage design assumptions, highlighting the need for physically based, risk-focused planning approaches. In parallel, I advanced urban heat island research and submitted conference abstracts extending my work on buffer efficiency and soil vulnerability classification under evolving climate conditions.