



**Atmospheric Sciences
Master of Science (M.S.) DEGREE
Departmental REQUIREMENTS**

Fall 2017-Spring 2024

Updated 12/11/24

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NOTE: This document is meant to guide the student through the complicated path of obtaining a graduate degree. It is not to be regarded as a legally binding contract. If you have any questions, please ask.

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APPLICATION & REQUIREMENTS

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DEGREE CHECK

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General Requirements

COURSES

Students seeking a Master's (M.S.) degree in Atmospheric Sciences must complete a minimum of 33 units of graduate course study.

24 units of graduate course work in Atmospheric Sciences

3 elective units of graduate-level course work

3 units minimum of research (ATMO 900/910)

2 units HAS seminar

1 unit additional course (e.g., could be 1 additional unit of research)

33 total credits

The following **core courses**, or their equivalents at other institutions, are **mandatory** for all students:

ATMO 541A Dynamic Meteorology I 3 units

ATMO 541B Dynamic Meteorology II 3 units

ATMO 551A Physical Meteorology I 3 units

ATMO 551B Physical Meteorology II 3 units

AND at least 12 additional units of course work in Atmospheric Sciences at the 500/600 course level.

- A. An additional 3 elective units of graduate-level coursework are required and can be taken in ATMO or any other department at the University of Arizona.
- B. Students are required to take a minimum of 3 units of research credit (ATMO 900/910). Furthermore, while students may take more than 3 credits of 900/910 a maximum of 4 units are allowed towards your degree plan of study.
- C. Students are also required to take a minimum of 2 units of seminar. These credits are graded S, P, and F, and do not count toward the student's overall GPA.

A Typical Master's Program:

Semester	Course	Units
Fall: Year 1	ATMO 541A	3
	ATMO 551A	3
	ATMO XXX (elective)	3
Spring: Year 1	ATMO 541B	3
	ATMO 551B	3
	ATMO XXX (elective)	3
Fall: Year 2	ATMO XXX (elective)	3
	XXXX XXX (elective)	3
	ATMO 900/910 (Research/Thesis)	2
	Seminar	1
Spring: Year 2	ATMO XXX (elective)	3
	ATMO 900/910 (Research/Thesis)	2
	Seminar	1
Total Units		33

MAJOR ADVISOR

During the first semester, the student should select a Major Advisor to chair their committee. The student and Major Advisor then select the Master's Committee members for the student. A Master's committee must consist of a minimum of three members: the Chair (Major Advisor) and two UA Faculty members. At least two members must be tenure-track faculty. If the third member is not a tenure-track UA faculty member, he or she must be approved by the Graduate College as a special member. A member who is not tenure-track will not be eligible to serve as sole chair of the committee but can serve as co-chair if approved to do so by the Graduate College.

CONTINUING STUDENT STATUS

After finishing all course requirements, students must continue to register each Fall and Spring semester for a minimum of 1 graduate research/thesis unit until all degree requirements are met.

FULL-TIME STUDENT STATUS

Students must meet the following **minimum** enrollment requirements:

- A. **Without University Funding/Graduate Assistantship:** Students must enroll with a minimum of nine (9) units of graduate credit each regular semester to maintain full-time student status.
- B. **With Graduate Assistantships:** Students must enroll with a minimum of six (6) units of graduate credit each regular semester. **However, it strongly recommended GAs hired under the Department of Hydrology and Atmospheric Sciences must enroll in minimum of nine (9) units of graduate credit during the first year to complete MS degree in two years.**
- C. **Below the 9-unit enrollment: student** will be considered a part-time student which can affect scholarship or fellowship obligations.
 - a. **International Students:** Must contact the International Student Services Office to request full-time enrollment exemption.
<https://international.arizona.edu/international-students/maintaining-status>

REQUIRED DEMONSTRATION OF COMPETENCE

- A. All students must demonstrate, to the satisfaction of each student's Major Advisor, proficiency in both statistics and computer programming (e.g. FORTRAN, MatLab, GrADS, and NCL), numerical atmospheric models and specialized instrumentation. Participation in laboratory or field work may be a component. This may be demonstrated by the successful completion of approved courses in these subjects, either as an undergraduate or graduate student.

AND

- B. All students will be required to present the results of their research in a formal seminar or presentation at a scientific meeting in the form of an oral or poster presentation. Typically, a student presents at the annual El Día de Agua y la Atmósfera (Spring), AGU (December) or AMS (January) meetings.

GradPath Forms

The Graduate College requires all graduate students to complete official forms in GradPath forms through UAccess Student. The department may require internal forms to be completed in addition to GradPath forms. Please see the Graduate Coordinator for more information.

- Responsible Conduct of Research
- Evaluation of Transfer Credit
- Master's Plan of Study (POS)
- Master's/Specialist Committee Appointment
- Commencement Verification Form
- Master's/Specialist Completion Confirmation

RESPONSIBLE CONDUCT OF RESEARCH

“Fostering a culture and expectation of responsible and ethical conduct of research is a critical component in the advancement of knowledge through research and scholarship. It is a key element in the maintenance of public trust in the research enterprise.” Source: UA Office of Research, Discovery, and Innovation. All students must complete the Responsible Conduct of Research (RCR) Statement form. Additionally, an RCR Workshop is required for any student who is financially supported by an NSF, NIH, or NIFA grant.

EVALUATION OF TRANSFER CREDIT

Submit this form during the first or second semester in residence to obtain approval for any potential Transfer Credit (graduate-level coursework already completed) for later use in the Plan of Study. Discuss details with the Director of Graduate Studies and major advisor.

Graduate credit earned at other approved institutions may be counted toward the requirements of the degree but will not be included in the calculation of the University of Arizona GPA.

Transferred units are subject to the following:

- The credits must be approved by the major or minor department and the Graduate College. Please submit a course syllabus to the Director Graduate Studies.
- The minimum grade for transferred credits must be an A or B or the equivalent at the institution where course was taken.
- Transferred units may not count toward more than one degree.
- No more than 12 units taken in Medicine, Law or Pharmacy Practice may be used toward the degree.
- Grades and the number of units for transfer credits may be adjusted so that they are consistent with the University of Arizona grading and credit system. Transfer credits used on a fully approved Plan of Study appear with a grade of “T” on the University of Arizona transcript and are not calculated in the University of Arizona GPA. The name of the transfer institution appears on the University of Arizona transcript with the number of transfer units from that institution that were brought in towards the graduate degree.

PLAN OF STUDY

In conjunction with your major advisor, each student is responsible for developing a Plan of Study as early as possible during the first few months in residence, to be submitted to the Graduate College no later than the second semester in residence. The Plan of Study must have the approval of the student's major professor and department head (or Director of Graduate Studies) before it is submitted to the Graduate College. All deficiencies must be satisfied before the Plan of Study is approved.

The Plan of Study identifies

1. Courses the student intends to transfer from other institutions.
2. Courses already completed at the University of Arizona which the student intends to apply toward the graduate degree; and
3. Future course work to be completed to fulfill degree requirements.
4. Expected Graduation Date

Your bursar's account will be billed candidacy fees of \$35.00 at the time your Plan of Study is approved by the Graduate Student Academic Services office. These are one-time fees, and you will not be billed again if you change your anticipated graduation date.

MASTER'S/SPECIALIST COMMITTEE APPOINTMENT FORM

Master's committee must consist of three members; at least two must be current tenured, tenure-track, or approved tenure-equivalent UA faculty members. If the third member is not a current tenure-track UA faculty member, he or she must be approved by the Graduate College as a special member. A member who is not a current tenure-track faculty member will not be eligible to serve as sole chair of the committee but can serve as co-chair if approved to do so by the Graduate College.

- Special Member committee request (must be completed before completing the committee appointment form:
 - Submit current short CV (MS/PDF) to the Graduate Coordinator, who will submit the request to the Graduate College. The routing process can take 24-72 hours to complete.

COMMENCEMENT VERIFICATION FORM

Confirm name to be listed in commencement program, address to send diploma and other logistical contact information after graduation. Deadlines apply to ensure accuracy.

MASTER'S/SPECIALIST COMPLETION CONFIRMATION

The student's major advisor and committee members approve the student has completed the final manuscript requirement by contacting the Graduate Coordinator of their approvals before semester deadline. The Graduate Coordinator will submit the form directly to the Graduate College to begin the conferral of the degree.

CONTINUING INTO THE DOCTORAL PROGRAM

Applying to the doctoral program: A student must have received a minimum average grade 2 As and 2 Bs in the four core courses at the master's level to request a waiver of the Qualifying Exam. A student with less than these requirements must pass the Qualifying Exam. Students who wish to continue in the doctoral program must apply to the doctoral program during their 4th or final semester in the Spring to meet the admission deadline of January 15th.

Research

At the discretion of each student's committee, an original research topic, judged to be suitable by the committee members, is required. A student must submit a written document as the final degree requirement.

- A. Non-thesis option: a publishable scholarly paper in the format of the intended journal. Although the requirement states that the paper has only to be suitable for publication and not actually submitted for publication, the latter is implied. It is certainly to the student's advantage to have a paper published, especially if s/he plans to make a career in research.
- B. Thesis option: a scholarly paper in the thesis format (see page, 10)

The choice of a research topic is one of the most important decisions confronting the student. The guidance and advice of the student's Major Advisor should help in making the decision. Although there are no specific rules, the following principles may be helpful:

- Graduate students are expected to write clear and logical accounts of their work in the English language. The Master's Committee may reject a manuscript that is poorly written. The best way a student can learn to write an acceptable paper is through practice, coupled with a careful review of papers on a similar topic that have appeared in the literature. Detailed derivations and explanations are necessary only when they are original and do not appear elsewhere.
- The problem should require the use of material covered in at least some part of the graduate course program.
- Although master's-level research is carried out under the close supervision of a faculty member. Some element of originality on the student's part should be involved. In other words, the problem itself may be new, or a new approach or new method of analysis may be applied to an old problem.
- The problem should be carefully limited in scope. A thorough piece of work on a small problem is generally satisfactory, while a sketchy development of a large problem is not generally acceptable.
- The research problem cannot be secret or classified in the military sense.
- Except in certain special cases, collaboration of two or more students on one thesis is not allowed. Figures should be limited and carefully selected for information content. Generally, there should not be more than one figure per typewritten page.

The Thesis Option

The Graduate College has prepared a detailed **Manual for Theses and Dissertations** for use by graduate students at <http://grad.arizona.edu/academics/degree-certification/diss-theses/manuals>. To be accepted, all theses must comply with these instructions.

Thesis Archiving

A student completing a master's thesis (with enrollment in course number 910) is required to archive the thesis upon final approval of the thesis committee. The thesis will be added to the University of Arizona Campus Repository and to the national archive of dissertations and theses maintained by ProQuest/UMI. There is no charge to the student for archiving the thesis. The thesis must have been successfully defended and approved by the thesis committee with all final edits completed in time for the student to submit it online for archiving by the graduation deadline for the student's graduation term.

Upon submitting the thesis for archiving, the student may elect to file the copyright for it. Students who may wish to file the copyright can refer to this copyright explanation. There is a fee for copyrighting should a student choose that option.

Archiving the thesis does not preclude publication by other methods. Successful master's candidates are encouraged to submit thesis material for publication in scholarly or professional journals. Suitable acknowledgment must indicate the publication to be a thesis, or portion of a thesis, submitted in partial fulfillment of the requirements for a master's degree at the University of Arizona.

<https://grad.arizona.edu/degree-services/dissertations-theses/submitting-and-archiving-your-thesis>

Special Notes

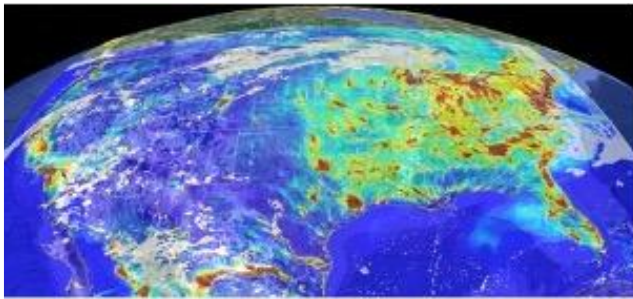
1. Please become familiar with the Departmental forms and procedures located on the HAS website, as well as the Graduate College forms located in GradPath forms accessed through your UAccess Student.
2. All requirements for the master's degree must be completed within 6 years to ensure currency of knowledge. Time-to-degree begins with the earliest course listed on the Plan of Study, including credits transferred from other institutions. Work more than 6 years old is not accepted toward degree requirements.
3. The cumulative grade point average required for granting the master's degree is 3.000, based on A = 4.000, B = 3.000, C = 2.000, D = 1.000, and E = 0.000.
4. The grades of D and E do not carry graduate credit but are included in the grade-point average.
5. The grades of S (Superior) and P (Passing) given for ATMO 900/910 and ATMO596A are not included in the overall grade point average but are included for graduate credit. In special circumstances, grades of C, D or E may be given for ATMO 910; such grades will be used in computing the overall grade point average.
6. Students who change their plans regarding submission of a thesis versus a manuscript must proceed as follows:
 - a. To change from manuscript to thesis, students should enroll in 3 credits of ATMO 910 in their final semester.
 - b. To change from thesis to manuscript, students should enroll in ATMO 900 in their final semester for a minimum 3 credits. ATMO 910 credits must be deleted from the Plan of Study when the Completion of Master's Degree Requirements form is submitted.

Faculty

HAS faculty members are active in the following areas in Hydrology and Atmospheric Sciences:

- Atmospheric dynamics
- Atmospheric chemistry
- Atmospheric physics
- Atmospheric remote sensing
- Climate science
- Hydrometeorology
- Environmental hydrology
- Human-water interactions
- Planetary hydrology
- Subsurface hydrology
- Surface hydrology
- Catchment hydrology
- Hydrogeochemistry and water quality
- Machine learning and Artificial intelligence applications in Hydrology and Atmospheric Sciences

Highlights of HAS faculty research and scholarly contributions are provided below. The activities described are representative of the faculty's contributions to research and science.



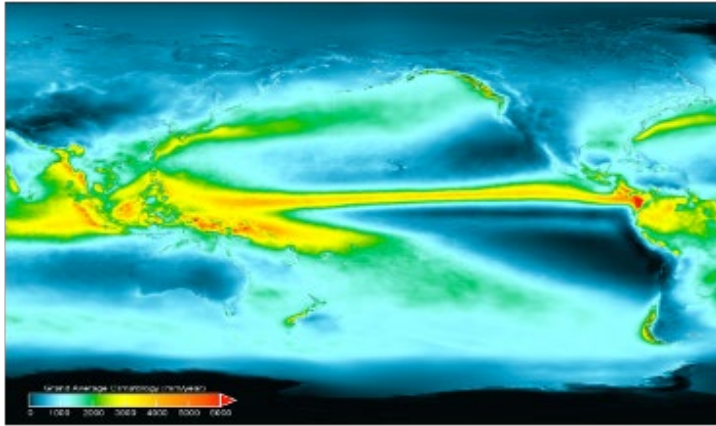
Ave Arellano has received funding from NASA and NOAA to tackle the complex interplay of Air Quality and Greenhouse Gases across scales. By integrating Earth system models with ground-based, aircraft, and satellite data, his research group advances our understanding of how AQ/GHG influences weather, climate, and our environment. They collaborate with UA/Public Health to assess pesticide drift impacts on vulnerable communities and support

the Arizona Department of Environmental Quality (ADEQ) and ASU in addressing ozone non-attainment in Phoenix and Yuma.

Victor Baker's expertise in paleohydrology reaches beyond Earth. He applies hydrological principles to understanding (1) the most extreme flooding phenomena on Earth and (2) the ancient hydrological conditions for the planet Mars. Though the greatest freshwater flooding on Earth involved ice-age conditions, understanding these phenomena led to paleoflood hydrology, a nature-based approach to understanding the flooding that can impact humankind in the current era of exacerbated extremes. This methodology is being applied to risk analyses for dams and nuclear power plants. His



Mars research has documented massive megaflood phenomena that generated episodic formation of ocean-like water bodies that were associated with periods of Earth-like hydrological cycling.



Ali Behrangi and his group are leading the development of the next generation Global Precipitation Climatology Project (GPCP) product under NASA support (2017-2028). GPCP precipitation products have been used in over 5000 scientific journal articles and have become a science community standard for the global precipitation observation record. The GPCP products are used in many major climate reports, such as the Intergovernmental Panel on Climate Change (IPCC) and the annual “State of the Climate”, published by the Bulletin of

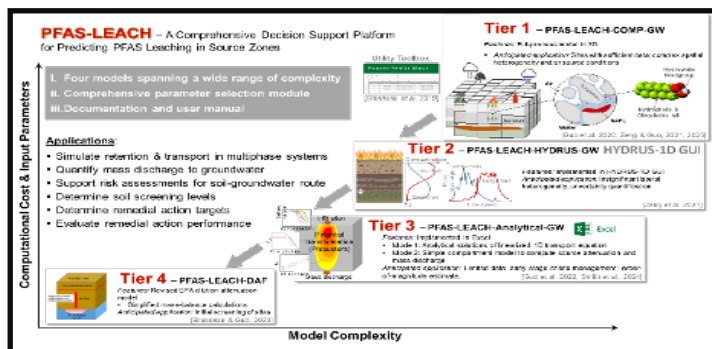
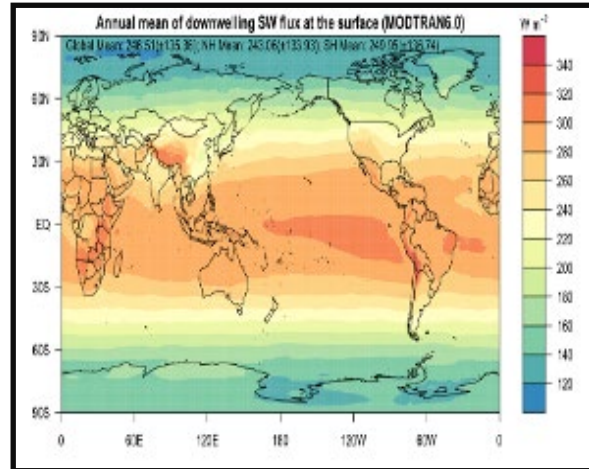
the American Meteorological Society. Behrangi is also a member of the proposing team for the recently selected \$30 M NASA mission “Snow4flow” to study glaciers and precipitation impact on them.

Andrew Bennett is researching cutting edge methods for hydrological modeling, with a focus on developing deep learning methods. His work seamlessly integrates powerful deep learning methods into physically based models of the land surface. He has improved prediction of land-atmosphere interactions and the ability to model long-term water balance by coupling neural networks to process-based hydrologic models. He also developed novel architectures for the emulation of integrated hydrologic models which run a thousand times faster than the original simulators, and is currently developing advanced hybrid modeling techniques that will leverage a wide range of large-scale datasets to improve our understanding and predictions of the hydrologic cycle.



Laura Condon (Laura Lotter) leads a \$6M NSF convergence accelerator project called HydroGEN. Her multi-institutional team of hydrologists, computer scientists and machine learning experts are developing a unique national hydrologic forecasting platform that combines advanced physical hydrology models with national observation networks and machine learning to provide unprecedented views into hydrologic behaviors from the bedrock to the treetops.

Xiquan Dong is the UA-PI for NASA EVC-1 (Earth Venture Continuity-1) project with a total of \$150M during 2021-2031 with UA portion of \$3.5M. In this project, Dr. Dong’s group will provide the global solar fluxes from the Top-of-Atmosphere and the land surface to study the global radiation budgets and their associated global climate changes. This project partially supports two faculty and fully supports two PhD students.



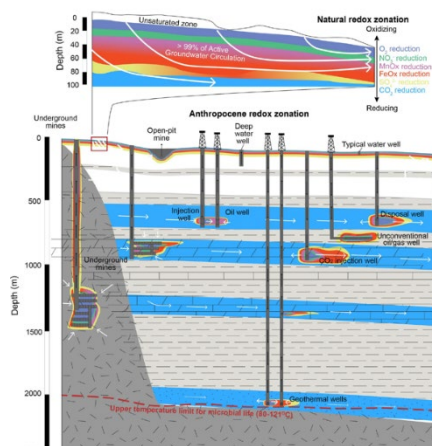
Bo Guo published one of the first papers (Guo et al., 2020, WRR) that provided the foundational understanding of the fate and transport of PFAS in the vadose zone. Building upon this pioneering work, Bo’s group has developed a suite of practical modeling tools (packaged as “PFAS-LEACH”, supported by a \$1.35M DoD project) spanning a wide range of complexities for supporting risk assessment and remediation efforts at

PFAS-contaminated sites. These PFAS-LEACH simulators have been widely used by practitioners in the US and internationally (30+ consulting firms and regulatory agencies to date) for assessing contamination risks at many PFAS-impacted sites.

Hoshin Gupta’s long-term focus has been the theory and practice of Learning with Models and Data, with a particular interest in facilitating scientific discovery. He currently works on bridging “Information Theory” and “Machine Learning” with hydrological science. Rather than an emphasis on predictive accuracy, he focuses on interpretability, generalizability, and support for scientific hypothesis testing. With recent student Yuan Heng Wang, he developed the “Mass Conserving Perceptron” as a foundational unit for interpretable machine-learning of geo-scientific systems from data. With current students, he is further exploring the hydrologically interpretable HydroLSTM machine-learning



architecture that facilitates improved understanding and predictions in ungauged basins.



Jennifer McIntosh’s research contributes to our understanding of sources of water, solutes, and gasses in the Earth’s shallow crust, from the near surface to over several kilometers depth. She leads an NSF FRES project (\$3M) on how fluids and co-existing microbial communities have evolved in response to changes in geologic and

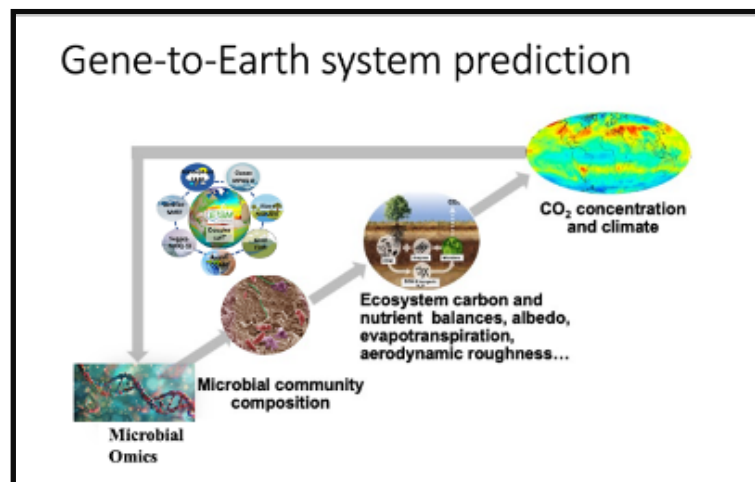
hydrologic forcings across the Colorado Plateau. Her work informs production of subsurface resources (e.g., Li, H₂, He), storage of energy waste-products (e.g., anthropogenic CO₂), and human health (e.g., geogenic contaminants) and has led to several invited talks and advisory groups for the US National Academy of Sciences, UK Royal Society, International Atomic Energy Agency, and US Nuclear Waste Technical Review Board. Results from this work are included in the Earth Science Discovery Program that brings over 600 schoolchildren to UA Flandrau’s Science Center from local title I schools and trains 11 undergraduate students each year to deliver hands-on activities.



Guo-Yue Niu is addressing the question: Why have global drylands been drying? He tested the hypothesis of “dry gets drier, wet gets wetter” globally using the GRACE terrestrial water storage change data and found that global drylands have been drying with the hyperarid and

arid regions showing the most significant decreasing trend. However, the wet regions did not show an apparent wetting trend. These results further suggest that Earth System Models (ESMs) for use in future climate projections and S2S predictions should further include plant adaptation mechanisms.

Soil carbon-climate feedback has been considered one of the big uncertainties in projecting future climate. **Yang Song**’s BIO-ESM lab group is addressing this challenge using gene-to-ecosystem scale data, artificial intelligence, and process-based Earth system models. As the lead PI, she is leading a DOE-sponsored project that collaborates with scientists from DOE Sandia National Lab and Oak Ridge National Lab to investigate the role of microbial functional diversity on soil carbon-climate feedback at the global scale and advance the prediction power of DOE E3SM, which is one of Earth system model participating in the Climate Model Intercomparison Project Phase 6 (CMIP6).

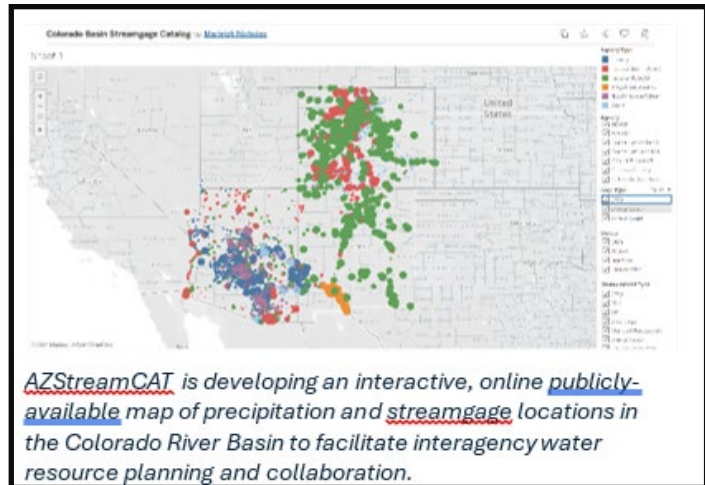


Peter Troch is leading multiple efforts to use the \$40M LEO (Landscape Evolution Observation Laboratory; <http://leo.b2science.org/>) to conduct controlled rainfall-runoff experiments at a unique scale. Each of the three hillslopes of LEO contains a spatially dense sensor and sampler network capable of resolving meter-scale lateral heterogeneity and sub-meter scale vertical heterogeneity in moisture, energy and carbon states. These bare soil landscapes have

been studied for the past 12 years (2013-2024) through hydrologic, geochemical and microbiological foci, resulting in 25 of 43 peer-reviewed papers led by faculty, postdocs and students from HAS. We are now preparing for the next phase of the experiment, when vascular biota in the form of heat- and drought-

tolerant plant communities will be introduced to the landscapes.

Martha Whitaker brings authentic research experiences to undergraduates. She is the PI and co-PI for two undergraduate research teams known as vertically-integrated projects (VIPs): 1) Arizona Streamgage Catalog (AZStreamCat); and 2) Integrated Climate Research: Ecology, Water, Weather (ICREWW). She has also developed a course-based undergraduate research experience (CURE) in HWRS 350 Principles of Hydrology. These programs help undergraduates develop research and communication skills, and the CURE class democratizes students' access to a research experience.



Baike Xi is the co-investigator for the NASA Libera project (2021-2031): \$3.5 million research funding at UA with PI, Dr. Xiquan Dong), providing shortwave, visible, and near-infrared (NIR, 0.7–5 μm) irradiances at the Top-Of-the-Atmosphere and the land surface via radiative transfer models and associated atmospheric profiles, surface, aerosol and cloud properties. The primary goal is to perform the NASA's Earth Radiation Budget climate data record continuity proposed by NASA Libera team. The software can be also used to clean energy (especially solar energy) forecasting. The other research focus is funded by NSF to study the aerosol-cloud-precipitation interaction.

Jim Yeh has been simulating spring discharge using deep learning, considering the spatiotemporal variability of precipitation. This work uses a generative variational autoencoder and is applied to augment precipitation data and improve a long-term memory network for spring discharge prediction. Augmenting precipitation data improves various deep learning models' learning generalization and predictive capability. The generative variation autoencoder offers a



novel solution to address data scarcity issues across diverse research domains.



Xubin Zeng is the deputy PI (with PI Armin Sorooshian, chemical engineering professor with a joint appointment in HAS) of the \$30M/6 year NASA Earth Venture suborbital Mission (ACTIVATE) on the aerosol-cloud -meteorology interactions over the northeast Atlantic. This project includes multiple universities, a NASA center (LaRC), and an international partner. For instance, a recent paper led by Zeng's graduate student (Xu et al. 2024) under this project, on the retrieval of both mixed-layer height and planetary boundary height from airborne high spectral resolution lidar (HSRL-2), got a news release from our university.

<https://news.arizona.edu/news/peeking-invisible-world-atmosphere>).

Marek Zreda has developed a way to measure stream discharge using sound. The derived sound-discharge rating function is linear over a wide range of discharges and has a remarkably high correlation coefficient. Measurements with a hand-held sound level meter take seconds to acquire, allowing for high-resolution, long-term monitoring of stream discharge, campaign surveys, and ad hoc measurements. The method is attractive because: the instrumentation is simple and inexpensive; field deployment requires no built infrastructure; the instrument is suitable for rapid or emergency deployment; the measurements are non-invasive and non-contact, made at a distance from the stream.

