COLLEGE OF SCIENCE
Hydrology &
Atomospheric Sciences

Hydrology

Doctoral (Ph.D.) Program

Handbook

Valid for AY 2017-2025

Updated 04/01/2025

Doctor of Philosophy

Hydrology

36 units Coursework

18 First series: Primary HAS Faculty

18 Second series: Primary & Other (includes Transfer, 12 max)

+18 units Dissertation, HWRS 920

54 units Major

plus

~12 units Minor*

*Varies, from 9-15 units

Contents

WELCOME

Welcome to the Department of Hydrology and Atmospheric Sciences! Throughout your academic residency, these staff and faculty members will provide student services that support your academic life. Learn more about what staff do at the HAS website Contact page.

Graduate students typically have assigned office space, room access, and key/card access to the building. Students supported through graduate assistant or hourly wage positions are hired through the business office. Students receiving departmental- or college-sponsored financial aid should work with the graduate program coordinator.

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INTRODUCTION

The Doctor of Philosophy degree in Hydrology and Water Resources requires a combination of 1) approved coursework for the Major area of study—Hydrology—and the Minor area of study—a complementary area of study that you will choose, 2) professional development experience, and 3) significant independent research and scholarship.

Enrollment: Once matriculated, you must maintain continuous enrollment during all major semesters (fall and spring) until all degree requirements are met.

If you complete degree requirements (e.g. take final exam and/or submit your dissertation manuscript) *during the summer or winter session,* you do not need to enroll for credit.

Degree requirements must be completed within 10 years, beginning with the *earliest coursework,* to ensure currency of knowledge. The 10-year clock for time-to-degree begins with the first course*,* including transfer credit from another institution.

Coursework: The Doctoral Major Plan of Study in Hydrology requires 36 semester units of coursework and 18 dissertation units (minimum of 54 units for the Major). The Minor Plan of Study typically requires 12 units but varies, ranging from 9 to 15 units. Typically, students complete ~66 units.

- TRANSFER – A maximum of **12** graduate semester units, if deemed appropriate, may be transferred for use in the Major. See the Director of Graduate Studies-Hydrology for advice about courses that may be applied to the Major. Contact the Minor department's Director of Graduate Studies for advice about Minor coursework. No more than 12 graduate semester units taken in **non-degree status** may be used.
- CUM GPA – A minimum cumulative GPA of 3.0 or B average is required to remain in Good Academic Standing with the Department, Graduate College, and University
- QUALITY POINT GRADES – At least half of the coursework listed on the Plan of Study (Major+Minor) must be graded with quality-point grades (A, B)
- PASSING GRADES –A course with a grade of D or lower cannot be included in any graduate degree program
- UNIVERSITY OF ARIZONA UNITS – At least 30 graduate-level semester units must be completed at the University of Arizona
- NO GRO – The department does *not* permit use of the GRO Grade Replacement Opportunity
- AVERAGE TIME-TO-DEGREE COMPLETION – Depending on several factors—undergraduate preparation, the use of transfer coursework (or lack of), the specific topic and scope of research, and the research methodology used—most PHD students complete requirements in 3.5 to 4 years
- GOOD STANDING STATUS – To maintain Good Academic Standing, you must complete degree requirements in a reasonable timeframe as described in the Time-To-Degree

Completion section (p. 18). Degree requirements include completion of required undergraduate prerequisite courses by the end of year 1, completion of fundamental and advanced graduate coursework in the major and minor, satisfactory progress on dissertation research, satisfactory completion of professional development requirements, and timely submission of administrative forms (see Grad Path section below).

Professional Development Experience: You must develop a very high level of oral presentation skills (professional level) by observing student research- and invited speaker-presentation techniques and later demonstrate these skills by presenting your own doctoral research. You will be required to enroll in **HWRS 595A** (1 unit), the Weekly Invited Speaker Colloquium, for one semester during academic residency. During the final semesters of residency when your doctoral research is nearing completion, you will be required to present your research at two (2) approved conferences (*minimum of one oral* presentation). See the Professional Development section of this guide (p. 11) for details.

Independent Research and Scholarship: As a doctoral student, you are required to undertake significant and independent research which culminates in a work that makes a unique and important contribution to the field of hydrology and water resources. Completion and publication of a research-based Doctoral Dissertation, and successfully defending the research, is a hallmark of the doctoral degree program. The Graduate College recognizes this activity by inclusion of 18 dissertation units on the Major Plan of Study, equivalent to 2 full-time semesters (or one Academic Year) for time spent while engaged in research and writing the dissertation.

TRANSFER COURSEWORK

If you have some prior graduate-level coursework completed with grades of A or B from another institution, you may request a transfer of coursework to be applied to the doctoral program. You should also consider the doctoral 10-year clock when making these decisions. Discuss this with the Director of Graduate Studies-Hydrology and your Faculty Advisor to determine which courses might be appropriate for your Major Plan of Study. Also, you may be able to transfer coursework for the Minor Plan of Study, a complementary field of study that you will choose. The Minor department will determine which courses, if any, may be appropriate for inclusion.

You should submit the **Transfer Evaluation Form** in Grad Path by the end of the second semester in residence. Some restrictions apply:

- Unless you completed a Master's degree in HWRS at the University of Arizona, a maximum of **12** graduate semester units may be transferred for use in the Hydrology Major
- Transfer course grades must be quality-point grades (e.g. A or B or their equivalents); courses with grades of S (satisfactory or superior) or P (pass) may not be used

- List courses *as they appear on the official transcript;* do not convert course units or grades
- The Graduate College will make calculations based on the grading scale/legend on the official transcript, the WES scale, or other official reference material
- Courses used to satisfy an undergraduate degree program, regardless of actual course level, are not transferrable
- Correspondence courses and extension courses are not transferrable

DOCTORAL MINOR

You must choose a Minor area of study to complement your academic areas of expertise. Both the Minor Faculty Advisor and the Minor coursework should support your research and scholarship efforts. For Hydrology Majors, some common Minors and their course prefixes are:

- Applied Mathematics (APPL & MATH)
- Arid Lands Resource Science (ARL)
- Biosystems Engineering (ABE)
- Civil Engineering (CE)
- Geography and Development (GEOG)
- Geological Engineering (GEN)
- Geosciences (GEOS)
- Global Change (GC)
- Mining Engineering (MNE)
- Remote Sensing and Spatial Analysis (REM)
- Soil, Water, and Environmental Science (ENVS/SWES)

Consult with your Minor department for details, including the number of units required. Some departments require two faculty advisors, others may require only one. Some may require specific courses and allow you to choose the remaining courses from a list of electives. Some may allow you to transfer one or more courses from a prior graduate degree.

DOCTORAL MAJOR IN HYDROLOGY

Fundamental Core Courses

You are not required to take fundamental core courses—commonly known as Master's Core Courses—although you may find them useful, particularly if your prior education emphasized just one area of hydrology and water resources. In principle, doctoral students are expected to have academic *breadth* in all areas of hydrology and water resources, as well as *depth* in their individual areas of expertise. Your breadth of knowledge will be examined during the Doctoral Qualifying Examination near the middle/end of Year 1, so taking one or more core courses may be very beneficial (see Appendix B, p. 22).

The fundamental core courses are not sequential and may be started in either the fall or spring semesters. Core courses are included in the **first series** of electives, Primary Faculty Courses (p. 9). Undergraduate prerequisite and co-requisite courses must be completed prior to, or concurrent with, the graduate-level course that requires them, and all must be completed by the end of Year 1. Core courses are 3-unit lecture format, unless noted otherwise.

- **HWRS 517A** Fundamentals of Water Quality (Fall)
- **HWRS 518** Fundamentals of Subsurface Hydrology (Fall)
- **HWRS 519** Fundamentals of Surface Hydrology (Spring)
- **HWRS 528** Fundamentals: Systems Approach to Hydrologic Modeling (Fall)

Fundamental water policy courses dealing with economic, social, and legal issues may also be included in the Doctoral Plan of Study in the **second** series of electives (see the section Other Primary, Non-Primary, Transfer, p. 10).

- **HWRS 575** Economics of Water & Environmental Markets/Incentive-Based Policies (Fall)
- **LAW 641** Water Law (Spring)
- **HWRS 576** Natural Resource Law and Economics (Spring)

Field Methods/Synthesis

The HWRS field methods/synthesis two-course sequence is required for all students, and both should be completed in the same calendar year:

- **HWRS 513A** (2) Field Methods (Spring)
- **HWRS 513B** (1) Field Synthesis (Summer)

A field camp experience in Geology does not routinely satisfy this requirement; however, prior experience or employment may warrant a waiver. The waiver process is used primarily by individuals who were formerly (or are currently) employed by government agencies (e.g. USGS, AZGS, and USDA ARS), private consulting firms, or national laboratories. To request a waiver,

- Submit a letter requesting waiver of the requirement to the Director of Graduate Studies-Hydrology
- Include a resume with details of your prior experience or employment that support your request, such as a description of job duties, relevant skills or certifications required, tools or equipment used, and, if appropriate, contact information for a former supervisor of field work
- No academic credit (units, grade, etc.) can be awarded when this requirement is waived. You must replace field methods/synthesis units with other approved coursework to meet degree requirements. See the Director of Graduate Studies-Hydrology for advice.

Primary Faculty Courses = 18 Units

Primary Faculty Courses are the **first** series of electives you will take to satisfy degree requirements. Primary Faculty members in Hydrology include:

Victor Baker
Ali Behrangi
Laura Condon
P.A. Ty Ferré
Bo Guo
Hoshin Gupta
Jennifer McIntosh
Guo-Yue Niu
Yang Song
Peter Troch
T.C. Jim Yeh
Larry Winter
Marek Zreda

A Primary Course is one in which the Primary Faculty teaching load is 50% or more. Courses with multiple instructors where less than 50% is taught by a Primary Faculty member are not included in this category. You must complete a minimum of 18 units in this category.

All Primary Faculty courses use the prefix HWRS (where HWRS is the Home Department) and are 3-unit/lecture-format courses unless noted*.

- **503** Subsurface Fluid Dynamics (Fall)
- **504** Numerical Methods Subsurface Hydrology (Spring)
- **505** Vadose Zone Hydrology (Fall)
- **516** Hydrologic Transport Processes (Fall)
- **517A** Fundamentals of Water Quality (Master's Core—Fall)
- **518** Fundamentals of Subsurface Hydrology (Master's Core—Fall)
- **519** Fundamentals of Surface Hydrology (Master's Core—Spring)
- **521** Water Resources Systems Planning and Management (Fall)
- **524** Hydroclimatology (Spring)
- **528** Fundamentals: Systems Approach to Hydrologic Modeling (Master's Core—Fall)
- **531** Hydrogeology **3 units LEC & 1 unit LAB (Fall)*
- **532** Environmental Hydrogeology **3 units LAB (Spring)*
- **535** Advanced Subsurface Hydrology (Spring)
- **543A** Risk Assessment for Environmental Systems (Fall)
- **549** Statistical Hydrology (Fall)
- **553** Glacial and Quaternary Geology (Baker) **Exception to cross-listed rule; GEOS is home*
- **555** Introduction to Remote Sensing in Atmospheric and Hydrologic Sciences (Behrangi) (Spring) **Exception to cross-listed rule; ATMO is home*
- **570** Computer Simulation Water Quality Processes (Spring)
- **573** Hydrology for Water Resources Management (Fall)
- **580** Isotope Tracers in Hydrogeology (Spring)

- **582** Applied Groundwater Modeling (Spring)
- **596G** Water-Rock-Microbial Interactions (Spring)
- **603A** Well Hydraulics & Pumping Test Analysis (as needed)
- **630** Advanced Catchment Hydrology (Fall)
- **642** Analysis of Hydrologic Systems (Spring)
- **645** Stochastic Methods Subsurface Hydrology (Spring)
- **655** Stochastic Methods Surface Hydrology (Fall)
- **696H** Advanced Topics in Geochemistry of Crustal Fluids (taught as needed)

Independent Study enrollment (e.g. HWRS 599, 699) is not included here and may not be used to replace a 3-unit lecture course. Exception: These units may be used when a course is canceled due to low enrollment (typically less than 5 students) and independent study units are used as a means to continue the course with a smaller number of students. Approval by the Director of Graduate Studies-Hydrology is required to include these units in the Plan of Study. Be aware, however, that independent study units will not receive quality-point grades (e.g. A, B) and will not impact the cumulative GPA. Approval by the Director of Graduate Studies-Hydrology is required to include these units in the Plan of Study.

Other Primary, Non-Primary, Transfer Courses = 18 Units

The **second** series of electives allows some flexibility in choice of remaining coursework and includes:

- **Required Field Methods/Synthesis** course units
- Transfer Coursework
- Additional Primary Faculty courses
- Pre-Approved Non-Primary Faculty courses
- One or more courses from outside the Hydrology course list 1) if relevant to your academic and research goals and 2) if approved by the Director of Graduate Studies-Hydrology and your faculty advisor

Courses in the second series of electives should be sufficiently advanced to warrant inclusion in the Doctoral Plan of Study. In most cases, a co-convened course (i.e. course numbered 4xx-5xx) taught as a combined undergraduate-graduate course ***does not*** meet this requirement. Discuss your choice of courses with the Director of Graduate Studies-Hydrology.

You must complete a minimum of 18 units in this category, including:

- **HWRS 513A** (2) Field Methods (Spring) - Required
- **HWRS 513B** (1) Field Synthesis (Summer) - Required

Non-Primary Faculty Courses (most cross-listed with HWRS) pre-approved for use by Hydrology doctoral majors include the following (home department prefix noted first):

- ATMO/HWRS 529 Objective Analysis in Atmospheric and Related Sciences
- ATMO/HWRS 558 Mesoscale Meteorological Modeling
- ATMO/HWRS 595C General Circulation Observations-Modeling (1-3)
- AREC/HWRS 575 Economics of Water & Environmental Markets and Incentive-based Policies
- AREC/HWRS 576 Natural Resource Law and Economics
- AREC/ HWRS 577 Advanced Topics Economic Environmental Regulation
- ENVS/HWRS 566 Soil and Groundwater Remediation
- ENVS/HWRS/LAW 596B Arizona Water Policy *If enrolled as LAW, permission and registration through College of Law*
- ENVS/WSM 696M Using MATLAB for Environmental Data Processing
- LAW 606 Constitutional Law I *Permission and registration through College of Law*
- LAW/HWRS 641 Water Law *Permission and registration through College of Law*
- PA/HWRS 581 Environmental Policy (3)
- WSM/HWRS 696Q Practical and Applied Meteorology (1-3)

Some HWRS courses listed in the Catalog and Schedule of Classes are **not automatically approved** for the Doctoral Plan of Study. Often, these courses have been cross-listed with HWRS to satisfy other departments' curricular requirements and not necessarily for our students. HWRS Primary Faculty members *do not teach these courses.* Nearly all of these courses are **co-convened** at both the undergraduate and graduate levels and may be less rigorous than graduate-only courses. For a list of some of these courses, see APPENDIX A: EXCLUSIONS – NOT ALL HWRS ARE PRE-APPROVED (p. 21).

Dissertation 920 Units = 18 Units

After you have passed the Doctoral Qualifying Examination, you will be eligible to enroll for HWRS 920 Dissertation units (enroll in your faculty supervisor's individual section number). Ask the program coordinator to enroll you for these units. Dissertation units receive non-quality grades, Superior/S or Pass/P, and do not impact your cumulative GPA. There is no limit to the number of units you can enroll for during academic residency; however, you should include only (exactly) 18 units of HWRS 920 Dissertation on the Doctoral Plan of Study.

PROFESSIONAL DEVELOPMENT

You must develop a very high level of oral presentation skills (professional level) by observing student research- and invited speaker-presentation techniques and later demonstrate these skills by presenting your own doctoral research. There are 2 components of this requirement:

1) You must **enroll in HWRS 595A** (1 unit), the Weekly Invited Speaker Colloquium, for one semester during academic residency. **Do not include this unit on your Doctoral Plan of Study.** When completing the form, classes you have completed may automatically fill the list, so you may have to *delete this unit* from your plan. The Director of Graduate Studies-Hydrology will confirm that you have completed this enrollment requirement during the Plan of Study review process.

2) To **demonstrate competence** in presentation skills, you must present your own doctoral research—minimum one oral presentation—at two (2) approved conferences. If the presentation format at an annual meeting (e.g. AGU, AHS, AMS, EGU, GSA) will be a poster (highly likely), you should make an **oral** presentation at the annual student research conference (El Día).

- An oral (preferred) or poster presentation of your Dissertation research at the department's annual student research symposium, El Día del Agua y la Atmósfera, satisfies 1 of 2 presentations
- The second presentation (poster preferred) should be made at a professional conference or annual meeting (e.g. AHS, AGU, AMS, EGU, GSA)
- Be sure to make at least one oral presentation at an approved conference
    - If you make two poster presentations—e.g. poster at El Día and poster at AGU—you will be required to attend a *third* conference to make an oral presentation!

See the Director of Graduate Studies-Hydrology to discuss any issues you may have in meeting these requirements.

To satisfy these requirements, submit a memo (email) to the Director of Graduate Studies-Hydrology with the names, dates, and locations of the conferences you attended and the titles and formats (oral or poster) of your presentations.

GRAD PATH FORMS

GradPath is the Graduate College's nearly paperless system that makes tracking and monitoring student progress much easier. Students can fill out and submit forms online through UAccess Student. The forms are routed electronically to everyone who needs to review or approve them.

Forms are sequential and each one must be approved before proceeding to the next level. Most are self-explanatory, but more details about *some* of these forms follow this section.

- Responsible Conduct of Research
- Evaluation of Transfer Credit
    - Use only if you include external transfer courses in the Plan of Study

- Doctoral Plan of Study
- Comprehensive Exam Committee Appointment
- Announcement of Doctoral Comprehensive Exam
- Results of Comprehensive Exam
    - Submitted electronically by your faculty advisor and committee chair
    - Candidacy fees are charged to your student Bursar Account upon advancement to doctoral candidacy
- Verification of Prospectus/Proposal Confirmation
    - Send a copy of your dissertation abstract to the program coordinator when you initiate the Comprehensive Exam process
    - The verification form is submitted by the program coordinator
- Doctoral Dissertation Committee Appointment
- Announcement of Final Oral Exam/Defense
    - Must be submitted and approved at least 10 business days before the exam date
- Final Oral Exam (Defense) Instructions (Instructions for committee members)
    - Students: See the Final Oral Exam Process section in this guide for details (p. 15)
- Results of Final Oral Exam/Defense
    - Submitted electronically by your faculty advisor (dissertation director)
- Dissertation Checklist (use after the final defense has been completed)
    - Includes Distribution Rights Form and Survey of Earned Doctorates links
- Submission of Final (Approved) Dissertation for Archiving
- Exit Survey for Graduate College

Refer to the GradPath website for FAQs related to preparing these forms.

Responsible Conduct of Research, Transfer Credit

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.

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.

Transfer Credit: Submit this form during the first or second semester in residence to obtain approval for Transfer Credit (graduate-level coursework already completed) for later use in the Doctoral Plan of Study. Discuss details with the Director of Graduate Studies-Hydrology (see Whitaker).

Doctoral Plan of Study

You should submit the Doctoral Plan of Study form in GradPath by the end of the second semester or early in the third semester in residence. Early submission will give you a concrete and clear path to completing degree program requirements in a reasonable time. You can adjust your Plan of Study in later semesters if circumstances require a change.

You should first arrange an appointment with the Director of Graduate Studies-Hydrology to discuss the Plan and confirm that all degree requirements have been understood and will be satisfied. After that meeting, you can submit the Plan of Study form which should include the graduate units approved by the Director of Graduate Studies-Hydrology and exactly 18 units of HWRS 920 Dissertation.

You may need to delete some entries that autofill on the form:

- *Delete* your enrollment for HWRS 595A (we will confirm this so you don't need to list it)
- *Delete* excess 920 Dissertation units (any number greater than 18)
- *Delete* 599, 699, or 900 independent study/research units you may have taken to meet enrollment requirements for financial aid or an international visa

Comprehensive Exam Process

The Doctoral Comprehensive Examination Process is described in Appendix B (p. 22) of this guide and includes important instructions about:

- When to initiate the exam process
- Understanding the Written and the Oral components
- How to form a committee and prepare for the exam
- Scheduling a room for the exam
- What happens after the exam

Prior to the exam date, the Graduate College will send a link to the Results form directly to your Faculty Advisor (dissertation director), so he or she may report the results of the exam electronically to the Graduate College. Paper forms are not used for this exam.

Committee Appointment Form

After you have passed the Oral Comprehensive Examination and your faculty member has reported the results to the Graduate College, you may submit the **Committee Appointment Form**. Under normal circumstances, this submission is expected at least **6 months** prior to scheduling the Final Oral Examination. This informs the Graduate College 1) which faculty members will serve on your final oral exam (dissertation defense), 2) the working/tentative title

of your dissertation, and 3) what term (semester and year) you expect to complete all degree requirements.

The dissertation committee may or may not be the same as the one you created for the Comprehensive Exam process. (Often it is smaller if the minor chooses not to participate in the defense, but sometimes it's exactly the same.) You must have a minimum of 3 tenured or tenure-track University of Arizona faculty members, and at least 2 of the 3 must be primary Hydrology faculty members.

A fourth member may be a UA tenured or tenure-track faculty member or an approved **Special Member**. A special member could be a UA non-tenured research scientist, a non-UA faculty member from another university, or an approved scientist from an external agency or laboratory. See the program coordinator for advice about obtaining Special Member approval.

Final Oral Exam/Dissertation Defense

Timing: Only you and your faculty advisor can determine when you are ready to defend your dissertation research. Typically, this comes about 1 to 1.5 years after you have completed all coursework for the Major and Minor. When the penultimate draft of your dissertation manuscript has been accepted by your faculty advisors (Major, Minor), you can initiate the final exam process.

Preparation: It is *essential* that you practice your presentation and learn to navigate the impromptu Q&A process which will surely happen during your final oral exam. The "research presentation" component of the Professional Development requirement helps prepare you for formal exams. Every time you present your work at a meeting or conference, you will become more and more comfortable with extemporaneous speaking. Practice at every opportunity until you can talk with confidence about the work you have done. Prior to any formal examination (Comprehensive or Final), you can reserve a conference room in the department to practice presenting to students and faculty members. The more you practice, the better prepared you will be on the day of your formal exam.

Identify committee: Following the Oral Comprehensive Examination, you submitted a Committee Appointment form. Unless members listed on that form have changed, you do not need to submit additional information to the Graduate College. If you wish to revise membership, contact the Graduate College's student services degree auditor and ask him or her to return the Committee Appointment form to you so that you may submit the new information.

Schedule the exam: After members of your committee have approved the penultimate draft, you should propose several dates/times to hold the exam. When a date and time has been agreed upon, contact a HASSA staff member (Romero, Santander, Warren) to reserve a room for the exam. You will need a 2.5- to 3-hour block of time for the exam (e.g. set up, initial public

presentation, closed-door examination by the committee, and deliberation and voting by committee).

- The public presentation should last no more than 1 hour.
- After the presentation, the public should withdraw so that the committee may examine you in private for a more in-depth discussion of research findings, conclusions, and the manuscript as a whole
- There is no minimum time allotted for the exam, although the maximum time (all components) is 3 hours.

You must submit the Announcement of Final Oral Exam/Dissertation Defense form in GradPath at least **10 business days in advance** so that the information can be published in the UA Master Calendar. The initial presentation portion of all doctoral final exams is open to the public.

Paper Forms and Signature Page: Notify the program coordinator about your forthcoming exam, and she will send exam instructions to the dissertation director that provide Graduate College guidelines for conduct of the exam, such as the tone and type of questions which may be asked, the focus of the exam (your dissertation research and conclusions, not general knowledge), the voting requirements for Pass or Fail, and the rules for acceptance of the dissertation with or without revision. She may also ask your dissertation director to physically sign a Change of Grade form (hard copy) for 920 Dissertation units if some of these units are not graded on your transcript.

Print out (regular copy paper) and take a signature page (Page 2 of the Dissertation) to the exam in the event that faculty members are prepared to sign it confirming your completion of the dissertation manuscript.

Your dissertation director must report the results of the exam in GradPath using the **Results of Final Oral Exam Dissertation Defense form**. (The Graduate College will send this link to your advisor after you submit the Announcement of Final Exam form.) There are 3 options on the Results form: 1) Pass with No Revision, 2) Pass with Revision, or 3) Fail.

Post-exam: If you Pass the exam and your manuscript is approved with no revision required (i.e. **Pass with No Revisions**), you will be notified by the Graduate College Student Services office and given instructions on how to submit your dissertation manuscript electronically for archiving by ProQuest/UMI.

If your manuscript requires some revision after your exam (i.e. **Pass with Revisions**), your committee will provide guidance on the specific revisions required and an expected date of completion. The Graduate College requires that all revisions be completed within one year.

- Your faculty advisor should notify the program coordinator when your revisions have been accepted and all members have signed your Page 2 signature page.

If you fail the exam (**Fail**), your committee will vote whether or not to recommend a retake (repeat) of the exam. The Graduate College allows no more than two attempts to pass the exam (first attempt, one re-take).

FORMAL EXAM TIMETABLE

- **~Year 1** Doctoral Qualifying Examination – see APPENDIX B: HAS Graduate Examination Procedures
    - Beginning of the second semester: Contact the program coordinator for exam instructions and committee assignment
- **~Year 2.5 to 3** Comprehensive Examination (Written and Oral) – see APPENDIX B: HAS Graduate Examination Procedures
    - Initiate after ALL coursework has been completed, about Year 2.5-3
    - After passing the Comprehensive Exam process, you must complete degree requirements (e.g. write dissertation, successfully defend, submit manuscript for digital archive) within 5 years or repeat the Comprehensive Exam process
- **~Year 4** Final Oral Examination (Dissertation Defense) – see Final Oral Exam section (p. 15)
    - See the Graduate College Degree Dates and Deadlines website for important "last day/due by" dates related to the Final Oral Exam (Defense) process and submission of the dissertation for archiving

GRADUATION

Commencement: There are multiple ways to celebrate your graduation with friends and family. Depending on the time of year you complete requirements, you may attend the campus-wide Commencement Ceremony in May and/or the College of Science Graduation Convocation (May and December). Students graduating in August or December may attend the campus-wide May commencement ceremony. You must RSVP to attend all ceremonies. Find more information and RSVP links on the HAS website under the **Events** tab.

Exit Interview and Housekeeping: When you are ready to graduate, please **return** any keys and borrowed manuscripts, books, or equipment to the department (see Santander regarding return of keys). It's also important to clean up and tidy your office space and desk for the next student. If you have mail forwarded to the department address, submit a U.S. postal Change of Address card (we will not forward postal mail).

Please arrange an appointment with the Director of Graduate Studies-Hydrology (see Whitaker) for a final exit interview to discuss your experiences in the graduate program. You may be able to complete this online.

ACADEMIC PROGRESS: TIME-TO-DEGREE COMPLETION

Students in Good Academic Standing and making good progress meet these benchmarks:

Year 1

Before/Beginning of Year 1

- Meet with Director of Graduate Studies-Hydrology to discuss undergraduate course deficiencies (if any) and potential graduate coursework for first year
- Make a plan to complete specific courses for the first two semesters
- Submit Responsible Conduct of Research Form in GradPath
- Take RCR *workshops* if required by your funding agency
- Discuss potential transfer coursework with the Director of Graduate Studies and your faculty advisor and submit the Transfer Course Form (optional)

By End of Year 1 (end of second semester in residence)

- Complete all undergraduate course deficiencies, if any (see Director of Graduate Studies-Hydrology)
- Complete all components of the Doctoral Qualifying Exams, Major and Minor (if any)

Year 2

Before/Beginning of Year 2

- Make a plan to complete specific courses for the next two semesters

By End of Year 2

- Make adjustments (add new courses, delete courses not available) to plan to satisfy Major and Minor course requirements
- Submit Doctoral Plan of Study Form (Major/Minor) in GradPath

Year 3

Mid to End of Year 3

- Submit Comprehensive Exam Committee Appointment Form after all coursework for the Major/Minor has been completed (form should include a list all members serving on the Major and Minor committees)
- Follow instructions for the Doctoral Comprehensive Examination process (see Appendix B, p. 22)
- After completing the Written portion of the Comprehensive exam, submit the Announcement of Doctoral Comprehensive Exam Form in GradPath
    - Arrange a time/date/location for the exam with staff (Santander, Romero, Warren) to reserve a room – use this information when submitting the Announcement Form

- Your faculty advisor (dissertation director) will receive a link from the Graduate College to submit the Report of Comprehensive Exam Form (the results, Pass or Fail)
- The 5-Year clock starts: You must complete all doctoral degree requirements within the next 5 years or repeat the Comprehensive Exam process. This clock guarantees "currency of knowledge" in the Major and Minor fields of study.

Year 4 and beyond

Before/Beginning of Year 4

- Submit a copy of your dissertation abstract (aka Prospectus) to the department's program coordinator (copy to be retained in your file at department)
- The program coordinator will submit the Prospectus Confirmation Form on your behalf

Beginning of ***Final Semester***

- Meet with faculty advisor (dissertation director) to discuss timing of the final exam
- Define committee membership and reserve a room for the exam
- Submit the Doctoral Dissertation Committee Appointment Form in GradPath

End of ***Final Semester***

- Complete your work and writing (penultimate draft) and submit to your dissertation director and committee members at least 3 weeks in advance of the exam date
- Submit the Announcement of Final Oral Exam Form at least **10 business days in advance** of the exam date
    - The Graduate College will send an electronic link to the dissertation director to submit the Report of Final Oral Exam/Dissertation Defense Form (the results, Pass Without Revision, Pass With Revision, Fail)
- Submit your abstract to the program coordinator and ask her to announce the date/time/location of your public presentation for the final exam
- Print out the signature page (Page 2) from your dissertation manuscript on regular printer paper and take to the final exam
    - Members of the committee will sign your form when your dissertation manuscript has been accepted, although the director may withhold signature until any required revisions have been completed
- After the Graduate College receives your exam results, they will send you instructions about archiving your dissertation manuscript with ProQuest UMI
- Arrange an appointment or correspond via email with the Director of Graduate Studies-Hydrology for an Exit Interview (you may be able to do this online)
- Return your **KEYS** before leaving campus! (see Santander for details)

GRADUATE PETITIONS

Most students never need to submit a Graduate Petition to the Graduate College; however, you may need to submit a petition for a variety of reasons, such as:

- Petition for a Leave of Absence (e.g. medical leave, non-medical leave, study abroad leave) which temporarily suspends the continuous enrollment requirement for one or two semesters
    - Note: The 10-year time-to-degree CLOCK and the 5-year comprehensive exam CLOCK do not stop during an approved Leave of Absence!
- Petition for extension of time to complete a course
- Petition for a retroactive enrollment change
- Petition for extension of time to complete the degree program

APPENDIX A: **EXCLUSIONS** - NOT ALL HWRS COURSES ARE PRE-APPROVED

Some HWRS courses listed in the Catalog and Schedule of Classes are **not automatically approved** for the Doctoral Plan of Study. Often, these courses have been cross-listed with HWRS to satisfy other departments' curricular requirements and not necessarily for our students. HWRS Primary Faculty members *do not teach these courses.* These courses are generally **co-convened** at both the undergraduate and graduate levels and may be less rigorous than graduate-only courses.

- ATMO/HWRS 436A-536A Fundamentals of Atmospheric Sciences (3)
- CE/HWRS 423-523 Hydrology (3)
- CE/HWRS 427-527 Computer Applications in Hydraulics (3)
- ENVS/HWRS 464-564 Environmental Organic Chemistry (3)
- GEOG 483-583 Geographic Applications of Remote Sensing (3)
- GEOS 439A-539A Introduction to Dendrochronology (4)
- GEOS 450-550 Geomorphology (4)
- GEOS/HWRS 478-578 Global Change (3)
- REM/HWRS 490-590 Remote Sensing for Study of Planet Earth (3)
- RNR 417-517 Geographic Information Systems for Natural and Social Sciences (3)
- RNR/HWRS 473-573 Spatial Analysis and Modeling (3)
- WSM/HWRS 452-552 Dryland Ecohydrology and Vegetation Dynamics (3)
- WSM/HWRS 460A-560A Watershed Hydrology (3)

These courses are *not* automatically approved for inclusion in a Doctoral Plan of Study, regardless of whether they have been approved for another student.

Consult with the Director of Graduate Studies-Hydrology if you wish to include one on the Plan of Study form. If you do, please prepare:

- A letter of petition explaining relevance to your research or project
- Include a copy of the proposed Plan of Study listing all coursework you have completed and plan to take and be specific about which HWRS Primary Faculty courses you have completed or will complete
- Allow 3-4 weeks for review, especially during a priority registration period, the first and last weeks of classes, and when fall or spring classes are not in session

APPENDIX B: HAS GRADUATE EXAMINATION PROCEDURES

Doctoral Qualifying Examination

Year 1

Qual Purpose

- To test a student's basic understanding of their general field of study, their ability to communicate their research interests, and their potential for doing doctoral-level research
- To provide feedback on graduate coursework that may help the student accomplish their career goals
- To increase students' and faculty members' exposure to each other's research interests

Qualifying Exam Waiver for UA HAS Master's Students

The Qualifying Exam will be waived for a UA HAS Master's student continuing in the PHD program if the student:

- Successfully completed a HAS Master's degree at the University of Arizona
- Received at least 2 As and 2 Bs in the fundamental core courses
- Received a unanimous endorsement from the MS final oral exam committee and the faculty advisor requests waiver of the exam

Qual Written Component: Graduate Fellowship Research Application (GFRA)

- You must submit a short research proposal or GFRA in the format of a federally-funded fellowship program, such as NSF, EPA, NASA, or NOAA (an alternative format may be used with prior approval from the HAS Academic Committee)
- You are encouraged, but not required, to submit your proposal to the funding agency whose format you are using
- Proposal length is typically 2-6 pages, single-spaced with 1-inch margins and using a 12-point New Times Roman font (or similar)
- If you started in Fall, submit your proposal by **February 15** of your second semester
- If you started in Spring, submit your proposal by **September 15** of your second semester

Qual Committee Assignment and Oral Component

- Your faculty committee will be assigned by the department, and you will be notified by email about your committee membership by the end of February (for students starting in Fall) or the end of September (for students starting in Spring)

- Committee members will include 4 tenured/tenure-track faculty members (including your faculty advisor), 3 from the HAS major and 1 from another HAS major (e.g. for an ATMO major, 3 ATMO + 1 HWRS or HYMET members OR for a Hydrology major, 3 HWRS + 1 ATMO or HYMET members)
- When notified of committee membership, within the subsequent 4-week period, you should schedule individual meetings (20 minutes each) with the 4 members
- Individual meetings should be scheduled within the same week if possible
- Individual committee members will submit their recommendations to the Program Coordinator within 2 business days of the meeting with you
- You will be notified of the results when all members have submitted their recommendations to the Program Coordinator

Qual Evaluation by Faculty Committee

- *Prior to the meetings,* faculty members will evaluate your research application
- *During the Q&A meetings,* faculty members will ask you questions about your research proposal to test your breadth of knowledge in your field of study and provide feedback on coursework that might help you achieve your research and career goals

Qual Grading

- Written and oral exams will be graded Pass/Fail
- You must receive a Passing grade from at least 3 of the 4 members on both the written and oral components to pass the qualifying exam
- If you fail the *written component,* you must submit a revised research proposal within one month of receiving notice of the failure
- If you fail the *oral component,* you must retake the oral exam within one month of receiving notice of the failure
- There are no retakes after two attempts (the first and the retake)

Doctoral Comprehensive Examination

Year 2.5-3

Comp Purpose

- To evaluate a student's breadth of understanding across your major (Hydrology, Atmospheric Science, or Hydrometeorology)
- To evaluate student's depth of understanding in their chosen field of research, writing and presentation ability, and ability to conduct original research
- To enable student's doctoral committee members to provide feedback on research direction

Comp Timing

- The Comprehensive Exam process should be completed as soon as all coursework (excluding dissertation units) for the Major and Minor has been completed, typically in year 2-2.5 to 3
- To ensure currency of knowledge, once passed, the Comprehensive Exam Clock begins and you will have 5 years to complete all degree requirements, including completion of research, writing the dissertation, successfully passing the Final Oral Examination (Dissertation Defense), and submitting the final approved dissertation manuscript (with any required revision) to the Graduate College for archival by ProQuest/UMI
- If you do not complete all requirements within 5 years, you will be required to repeat the entire Comprehensive Exam process (Written and Oral)

Comp Requirements

- Core Courses: You must have earned at least 2 As and 2 Bs in the core courses required by your doctoral program

Comp Written Component

- **Dissertation Abstract**: To initiate the Comprehensive Exam process, you must submit a 1-page abstract of the Dissertation to your Doctoral Comprehensive Committee (details below) and to the Graduate Program Coordinator
- **Manuscript/Publication or Research Proposal**: At least 2 weeks prior to scheduling your Oral Comprehensive Exam, you must submit either a first-authored research manuscript—"in preparation," "in review," or "published"—**or** a research proposal
- The **Research Manuscript** "in preparation" or "in review" should be formatted to a peer-reviewed scientific journal or, "if published," you can submit the paper to committee members and receive an automatic pass for the written component
- The **Research Proposal** (minimum 10 pages, including figures/tables, but not including references) should be formatted in typical NSF EAR-Directorate style

Comp Oral Component

- This formal Graduate College exam should include a 30-minute (approximate) presentation of your research manuscript/paper or research proposal
- Q&A by committee members will follow the presentation for a minimum of 1 hour but not more than 2 hours

Comp Committee Members (4-5 Members)

- Major Committee: 3 HAS faculty members, including the faculty advisor, who hold tenured/tenure-track positions in your Major and at least 2 of the 3 must be Primary Faculty in the Major (*not* Joint Faculty Members or Research Scientists/Specialists)
- Minor Committee: 1 faculty member who holds a tenured/tenure-track position in your Minor, although some departments require 2 members for the Minor Committee
- External members (Special Members), such as collaborative scientists from agencies or non-UA faculty members, *should not be included in the Comprehensive Exam process* but may be included in the Final Oral Exam/Dissertation Defense committee

Comp Grading

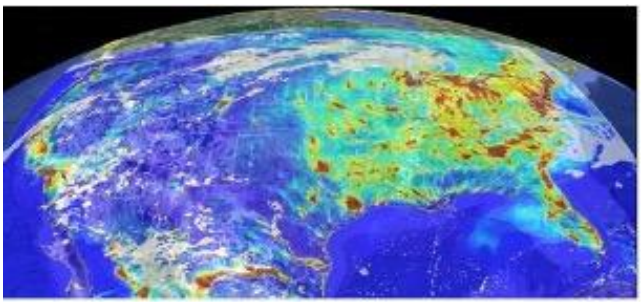
- The Written and Oral components of the Comprehensive Exam process will be graded Pass/Fail
- You must receive a passing grade from at least 3 of the 4+ faculty members on both the Written and Oral components to pass the Comprehensive Exam process
- Your faculty advisor will report the outcomes electronically to the Graduate College for both the Written and Oral components
- If you fail the *written* exam, you must submit a revised manuscript or proposal within 2 months of receiving notice of failure
- If you fail the *oral* exam, you must retake the oral portion of the exam within 2 months of receiving notice of failure
- There are no retakes after two attempts (the first and the retake)

Faculty

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

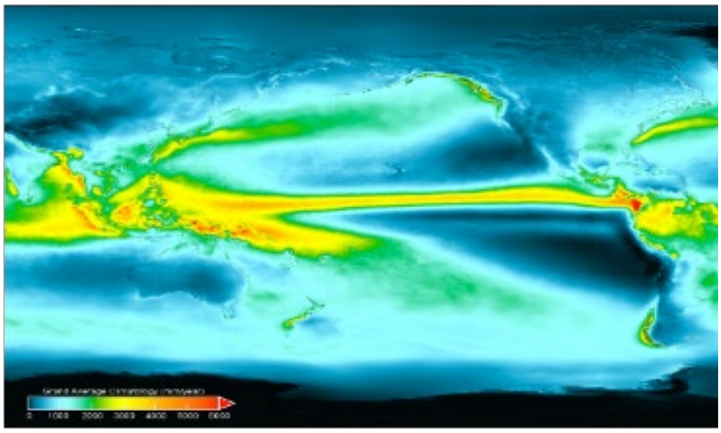
- Atmospheric dynamics
- Atmospheric chemistry
- Atmospheric physics
- Atmospheric remote sensing
- Climate science
- Hydrometeorology
- Environmental hydrology
- Human-water interactions
- Planetary hydrology
- Subsurface hydrology
- Surface hydrology
- Catchment hydrology
- Hydrogeochemistry and water 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.

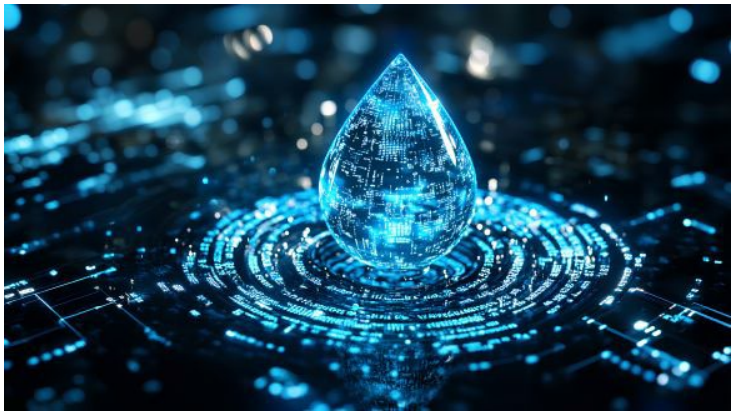


Ave Arellano has received funding from NASA and NOAA to tackle the complex interplay of Air Quality and Greenhouse Gases across scales. By integrating Earth system models with ground-based, aircraft, and satellite data, his research group advances our understanding of how AQ/GHG influences weather, climate, 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.



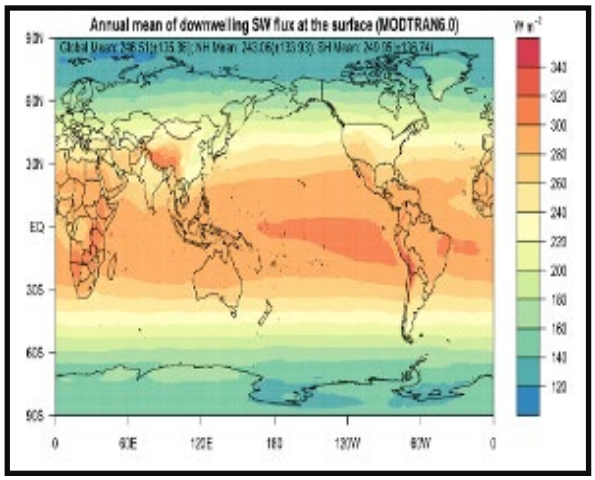
Ali Behrangi and his group are leading the development of the next generation Global Precipitation Climatology Project (GPCP) product under NASA support (2017-2028). GPCP precipitation products have been used in over 5000 scientific journal articles and have become a science community standard for the 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.

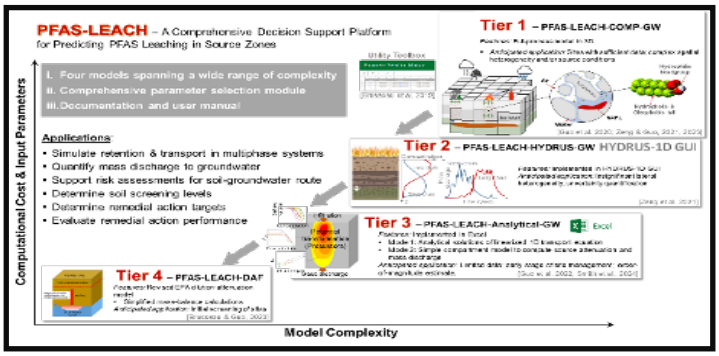


Andrew Bennett is researching cutting edge methods for hydrological modeling, with a focus on developing deep learning methods. His work seamlessly integrates powerful deep learning methods into physically based models of the land surface. He has improved prediction of land-atmosphere interactions and 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.

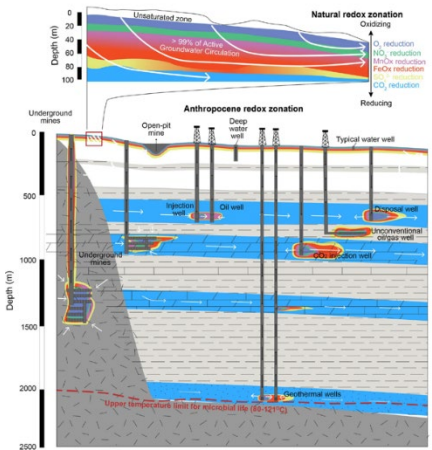
Xiquan Dong is the UA-PI for NASA EVC-1 (Earth Venture Continuty-1) project with a total of $150M during 2021-2031 with UA portion of $3.5M. In this project, Dr. Dong's group will provide the global solar fluxes from the Top-of-Atmosphere and the land surface to study the global radiation budgets and 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 Conservin g 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.

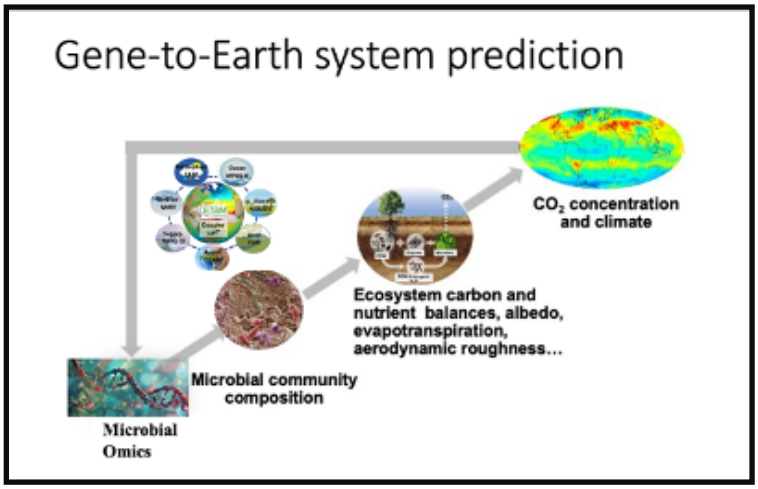


Jennifer McIntosh's research contributes to our understanding of sources of water, solutes, and gasses in the Earth's shallow crust, from the near surface to over several kilometers depth. She leads an NSF FRES project ($3M) on how fluids and co-existing microbial

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, H_2, He), storage of energy waste-products (e.g., anthropogenic CO_2), 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.

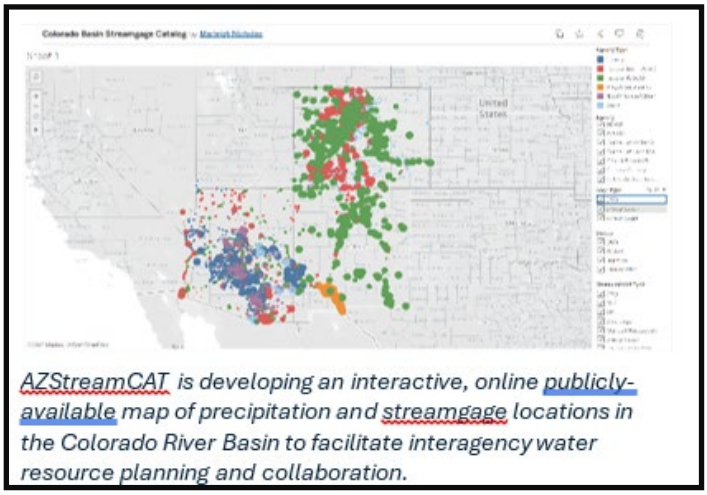
Soil carbon-climate feedback has been considered one of the big uncertainties in projecting future climate. **Yang Song**'s BIO-ESM lab group is addressing this challenge using gene-to-ecosystem scale data, artificial intelligence, and process-based Earth system models. As the lead PI, she is leading 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.



AZStreamCAT is developing an interactive, online publicly-available map of precipitation and streamgage locations in the Colorado River Basin to facilitate interagency water resource planning and collaboration.

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.