ACADEMIC PROGRAM REVIEW
SELF-STUDY REPORT
2007-2013

(Photograph by Sarah Warren)

DEPARTMENT OF ATMOSPHERIC SCIENCES
INSTITUTE OF ATMOSPHERIC PHYSICS

THE UNIVERSITY OF ARIZONA
TUCSON, ARIZONA
February 14, 2014

Department Head and Director: Eric Betterton

Self-study Committee: Xubin Zeng (Chair; professor), Christopher Castro (associate professor), Armin Sorooshian (assistant professor, joint faculty), Michael Leuthold (staff), Aishwarya Raman (graduate student), and Ruth Zollinger (ATMO Advisory Board Chair). All faculty, staff, students, and members of the ATMO Board are thanked for reviewing and helping to revise the document. Board member Kevin R. Petty, faculty members Francina Dominguez, Elizabeth Ritchie, and Ave Arellano are particularly thanked for insightful input.

Staff Support: Lupe Romero and Sarah Warren

THE UNIVERSITY OF ARIZONA.

Graduate Program in Atmospheric Sciences at the University of Arizona

ATMOSPHERIC SCIENCES

UASCIENCE

Core Faculty

Avelino Arellano
Eric Betterton
Christopher Castro
Francina Dominguez
Steven Mullen
Elizabeth Ritchie
Charles Weidman
Dale Ward
Xubin Zeng

The Department of Atmospheric Sciences graduate studies program offers a Master of Science and Doctor of Philosophy degrees.

In our program students receive:

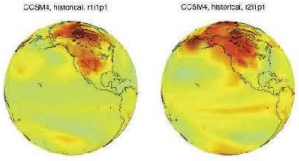
- Research experience; work closely within the department and with the departments of Hydrology and Water Resources, Planetary Sciences, Optical Sciences, Electrical Engineering, Chemical and Environmental Engineering, Geosciences and Applied Mathematics.
- Travel to conferences, seminars, meetings, field experience.
- Over 90% of our students receive funding during schooling
- Practice and develop presentations, scholarly publications and strong work ethics

APPLICATION DEADLINES: FEBRUARY 1ST——DOMESTIC STUDENTS
DECEMBER 1ST——INTERNATIONAL STUDENTS

Lightning & Atmospheric Electricity

Atmospheric Chemistry & Aerosols

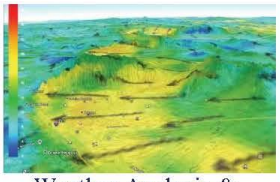
Tropical Meteorology & Tropical Cyclones



Global & Regional Climate Change

Data Assimilation & Modeling

Radiation & Remote Sensing



Weather Analysis & Predictability

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uaAtmo_fcst

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THE UNIVERSITY OF ARIZONA

Graduate Program in Hydrometeorology at the University of Arizona

The first-in-the-nation Hydrometeorology M.S. and Ph.D. program provides graduate students with:

- **comprehensive understanding of the coupled interactions between the atmosphere and the land**
- **skills in hydrometeorological prediction**
- **better understand the impacts of land-atmosphere processes and interactions on human and environmental wellbeing**

UA SCIENCE
THE UNIVERSITY OF ARIZONA. COLLEGE OF SCIENCE

University of Arizona College of Science, was ranked 1st in the nation in the physical sciences by the National Science Foundation in 2010.

The Department of Atmospheric Sciences and the Department of Hydrology and Water Resources are among the top-ranked departments in the nation (NRC rankings).

The core courses include:

- Physical Meteorology
- Surface Water Hydrology
- Dynamic Meteorology
- Hydroclimatology

Core Faculty:

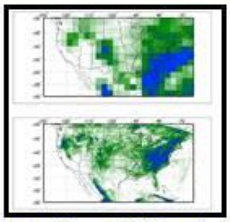
Christopher Castro
Francina Dominguez
Hoshin Gupta
Shirley Papuga
Jim Shuttleworth
Peter Troch
Larry Winter
Xubin Zeng

COSMOS soil moisture measurements

Micromet. Observations

Research

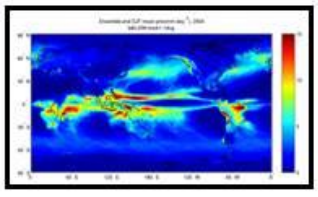
We emphasize improved understanding through theory, observations and models.



Regional Climate Modeling

Liquid water and Vapor Isotopes

Hydrological and Land Surface Modeling



Global Modeling and Analysis

Coupled Climate-Hydrology-Ecology Modeling of the Monsoon System

For more information:
Visit our website:
www.hydromet.arizona.edu

Or contact
Dr. Francina Dominguez (ATMO) francina@atmo.arizona.edu
Dr. Peter Troch (HYDRO) patroch@hwr.arizona.edu

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SELF-STUDY SUMMARY

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A1. Administrative Home

The Department of Atmospheric Sciences (ATMO) is a member of the School of Earth and Environmental Sciences (SEES) at the University of Arizona (UA). ATMO has been a part of the College of Science for more than half a century, and is a founding member of SEES since it was organized in 2009. In addition to ATMO, SEES includes the Department of Geosciences, the Department of Hydrology and Water Resources (HWRS), the Laboratory of Tree-Ring Research, Biosphere 2 (within College of Science), the Department of Soil, Water, and Environmental Sciences, and the School of Natural Resources and Environment, both within the College of Agriculture and Life Sciences. All of the SEES units share common research interests devoted to the understanding, observation, and modeling of the Earth and environment, as well as the dissemination of knowledge to serve local, national, and international communities.

The Institute of Atmospheric Physics (IAP) was established even earlier than ATMO to conduct research in precipitation enhancement. So for historical reasons, research is still officially conducted through IAP while teaching is conducted through ATMO. The Head of ATMO is also the Director of IAP. For simplicity, we use ATMO to refer to the combined ATMO/IAP unit hereafter.

A2. Faculty

As of fall 2013, ATMO includes 7 tenure-track faculty members (4 Full Professors, 1 Associate Professor, and 2 Assistant Professors), 2 Lecturers, and 2 Emeritus Professors who remain active in supporting the department's mission. Through proactive planning in the past 15 years, ATMO has successfully transitioned from the first generation who established our program and brought it to national and international prominence to current faculty members with the ideal age group and rank structure. There are also 9 (voting) joint faculty members from the Departments of Geosciences, Hydrology and Water Resources, Planetary Sciences, Mathematics, Chemical and Environmental Engineering, Geography and Regional Development, and the Laboratory of Tree-Ring Research. Furthermore, ATMO has 2 Research Associate Professors, 2 Research Professors, 6 Postdoctoral Research Scientists and Research Associates.

A3. Programs

Following the recommendations of the previous Academic Program Review, ATMO eliminated its undergraduate program in 2005 due to the small faculty size and concentrated on its graduate programs. However, ATMO continues to teach 300-400 undergraduate students annually, but not as part of a program leading to a B.S. degree (see Fig. D1 and D2). Currently, ATMO offers the following graduate programs:

Graduate level:

- M.S. and Ph.D. degrees in atmospheric sciences;
- M.S. and Ph.D. degrees in hydrometeorology (created jointly in 2010 by ATMO and HWRS, it is the first such degree program in the United States);
- Accelerated M.S. program (4+1 created in collaboration with the Department of Physics).

A4. Self-Study Overview

In this self-study report, we elaborate on the strengths and weaknesses of our program, our faculty and students, outline our mission and goals, and describe our aspirations for the future. For the past five years we, like the rest of the University, have been largely focused on adapting to the declining State funding (approximately 40% reduction) which has influenced ATMO decision making and planning. Yet we have accomplished a great deal since the last Academic Program Review in 2007. Here we highlight some accomplishments and draw your attention to useful summaries provided later in the report in the form of Tables and Figures.

- A #3 ranking in the National Research Council Report (2010) of atmospheric and oceanic science programs in the U.S. and Canada with a similar faculty size, and a #12 ranking of programs of all sizes (Figure D4);
- One of the most efficient departments in the College of Science based on the ratio of research and teaching productivities to State support (Table D1);
- A record number of M.S. and PhD. students with a particularly strong demand from domestic students. The 37 graduate students enrolled represent a 50% increase since the previous Academic Program Review. Making this increase even more impressive is the fact that our tenure-track faculty number has decreased from 8.5 FTE in 2005 to the present 7.0 FTE (Chapter I3).
- Faculty devotion to teaching excellence in both undergraduate and graduate courses (Table E3);
- A highly productive research environment with outstanding external funding (Fig. D3);
- An outstanding faculty, student and staff service record within the University, nationally, and internationally (Chapter E2);

Targeted areas for improvement and growth include:

- Restore traditional strengths through new faculty hires in atmospheric radiative transfer, satellite remote sensing, and radar meteorology;
- Shorten the time for completing Ph.D.; and
- Improve terminal M.S. students' pathways to employment and career training, especially oriented to the private sector.

The University has witnessed a sweeping change in top leadership over the past two years which has resulted in the appointment of a new president, a new provost, and an ongoing search for a new vice-president for research, to name a few.

The University has also embarked on a new financial management system called, Responsibility Centered Management, http://rcm.arizona.edu, which has yet to be fully implemented, challenging our ability to effectively plan for the future.

President Hart released her strategic plan, called *Never Settle*, late last year, and so here we strive to map our planning onto that of the University and the College of Science. The University plan, *Never Settle*, is available here: http://neversettle.arizona.edu.

UNIT DESCRIPTION AND GOALS

B. UNIT DESCRIPTION AND GOALS

Figure B1 summarizes our vision, mission, goals, and alignment with UA's "*Never Settle*" strategic plan that are discussed in detail below.

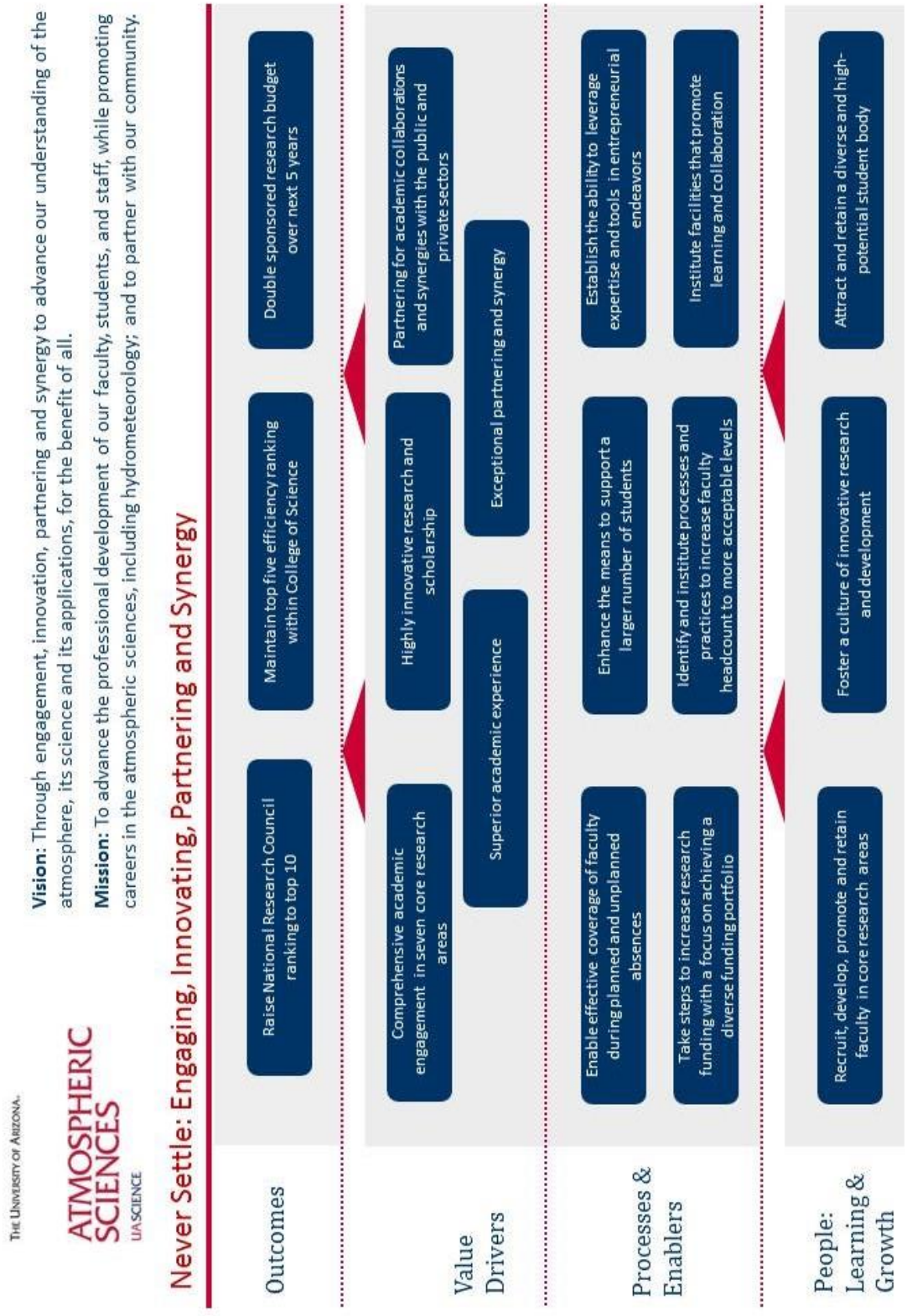

Figure B1. Summary of ATMO's vision, mission, outcomes, and alignment with UA's "*Never Settle*" strategic plan.

B1. Mission, Role and Scope

Vision: Through engagement, innovation, partnering and synergy to advance our understanding of the atmosphere, its science and its applications, for the benefit of all.

Mission: To advance the professional development of our faculty, students and staff, while promoting careers in the atmospheric sciences, including hydrometeorology; and to partner with our community.

ATMO serves the University, the State of Arizona, and the nation by engaging its students in rigorous studies, by conducting innovative research, by partnering with others, including the public and private sectors, and by engaging in synergistic activities so as to avoid isolation. As concerns about climate change, severe weather, water shortages, air pollution and other environmental problems continue to affect society and shape local, national and international policies, the atmospheric sciences will likewise continue to take on increasing importance. In response to these concerns, government agencies, including the National Oceanic and Atmospheric Administration (NOAA), NASA, the Department of Energy (DOE), the Department of Defense (DOD) and the National Science Foundation (NSF) have undertaken major initiatives designed to better observe and understand the weather-climate system (including the atmosphere, the oceans, the cryosphere and the land) and its impact on society.

ATMO, together with its partners on campus, is well positioned to continue competing successfully for research funding from all these sources and to make significant contributions to advancing the science. Our unique geographic location positions ATMO to be a leader in an emerging area of critical world importance: the weather, air quality, climate and sustainability of semiarid regions in a warming and drying climate. The vision for ATMO is to have a research and education program that utilizes our historical and current strengths to address questions that are of regional, national and global importance. Aligning with the UA Strategic Plan and mission as a land-grand university, the Department's goal is threefold:

- To advance the professional careers of our faculty, students and staff by performing and supporting basic and applied research in physical and dynamic meteorology, hydrometeorology and climate;
- To engage our students through excellent teaching of the atmospheric sciences and hydrometeorology at both the undergraduate and graduate levels, including freshman introductory courses, the online undergraduate Bachelor of Applied Science (BAS) meteorology program and M.S. and Ph.D. programs in atmospheric sciences and in hydrometeorology;
- Build relationships with the private and public sectors to better serve society at the local, state, national, and international levels.

Scope:

Our primary academic mission is our graduate program (M.S. and Ph.D., in both atmospheric sciences and in hydrometeorology). Our current enrollment is approximately 40 students. Both M.S. and Ph.D. are research degrees. A non-thesis option is not offered. We require that most new students enroll for the M.S. degree with the intention of either finishing at that level or continuing on for a PhD. Relatively few students enroll directly into the PhD. program because this option is only available to students who already have a M.S. degree in atmospheric sciences, hydrometeorology, or a closely related field (e.g., physical science or engineering).

Also at the graduate level, we offer the accelerated M.S. (4+1) program to provide an opportunity for undergraduate students in physics to graduate with both a B.S. in physics and a M.S. in atmospheric science in 5 years. They are required to take selected math, physics, and atmospheric science courses to fulfill both B.S. and M.S. program requirements. It is well suited for physics students who seek research experience in an applied physical science, and who are interested in pursuing a career in atmospheric sciences.

The Ph.D. Minor in ATMO requires 12 credit hours of ATMO graduate coursework, plus passing the Ph.D. minor written exam. Students electing to do the Ph.D. minor in Atmospheric Sciences must also select a minor Advisor from the ATMO tenure-track faculty.

At the undergraduate level the fully online BAS (meteorology) program (i.e., the Applied Science major with a specialization in Meteorology) was established primarily for military personnel. Its possible conversion into a regular online B.S. program that is open to all UA students is under consideration.

B2. Major Goals and Strategic Plans

Our guiding principle, like that in the University's Strategic Plan, *Never Settle*, is a sustained commitment to excellence through engagement, innovation, partnering and synergy. ATMO values, encourages and rewards superior teaching, scholarship and service. The specific goals of the program are described below.

Goal 1: Engagement – provide a superior graduate education at the M.S. and Ph.D. level

- Provide all graduate students with broad knowledge of the atmospheric sciences, hydrometeorology and related fields;
- Provide advanced training in the atmospheric sciences and hydrometeorology, and an independent, in-depth research experience to Ph.D. students;
- Produce excellent scientists who can think independently, communicate the results of their research effectively and who will be sought after in the work force;
- Maintain and financially support a graduate student body of a sustainable size (currently about 40).

Goal 2: Innovation - develop and maintain excellence in research and scholarship

- Maintain the core expertise of ATMO in :
    - Air quality, dust and aerosols, and atmospheric chemistry (Arellano, Betterton, Conant, Sprigg, Sorooshian);
    - Tropical meteorology and monsoon systems (Ritchie, Serra, Castro, Dominguez, Zeng);
    - Weather forecasting and data assimilation (Arellano, Castro, Mullen, Ritchie);
    - Regional and global climate (Castro, Dominguez, Ritchie, Serra, Zeng);
    - Hydrometeorology (Castro, Dominguez, Mullen, Ritchie, Zeng);
    - Lightning and atmospheric electricity (Cummins, Krider, Weidman);
    - Radiation and remote sensing (Conant, Ritchie, Ward, Zeng, Sorooshian).

Goal 3: Synergistically - serve the needs of local, state, national and international communities

- Serve external communities through professional advising, technology transfer, and consulting on atmospheric and environmental questions
- Promote the importance and relevance of the atmospheric and related sciences at the local, state, national, and international levels
- Promote informed policy decisions by elected officials and the general public

Strategic planning at ATMO is an ongoing process. Soon after we established our first External Advisory Board, we began combining an annual board meeting with a departmental strategic planning meeting, and in this way we have developed our priorities in an open and collaborative

manner, yet we have remained cognizant of the reality of the extremely tight budget. In fact, the Board's direct input has been crucial for this entire APR report.

Strategic Priority 1: Promote and retain strong faculty and programs

- Retain current faculty with adequate resources to retain, promote and maintain success;
- Restore the traditional strength on this campus in satellite remote sensing, atmospheric radiative transfer and radar meteorology by collaborating with SEES and other units to hire three to five new faculty over the next five years. This aligns with SEES, college and university hiring priorities;
- Further strengthen the national and international profile of hydrometeorology through three faculty hires over the next five years that align with university, college and SEES hiring priorities;
- Double the number of postdoctoral research associates and research

Strategic Priority 2: Continue to attract and financially support excellent graduate students

- Maintain and support 30-40 graduate students. With the current faculty size, the current number (37) of graduate students is probably the upper limit without losing advising and mentoring quality. With potential faculty growth, more students could be accepted
- Further increase the number of graduate students with strong quantitative backgrounds (e.g., physics, math, engineering);
- Increase the number of students supported on fellowships (e.g., NSF, DOD and DOE fellowships);
- Seek ways to shorten the time to complete the Ph.D. program.

Strategic Priority 3: Diversify the research support from federal and state agencies, and private sector

- Continue the success in seeking grants from federal and state agencies
- Increase the support from, and partnership with, the private sector
- Aggressively pursue major projects (> $3M)

Strategic Priority 4: Maintain strong service/outreach activities

- Continue the high profile service within UA, nationally, and internationally
- Maintain strong community relations
- Increase connections with alumni through social media
- Maintain a strong advisory board for ATMO

Strategic Priority 5: Maintain and enhance diversity in ATMO

- Maintain our excellent faculty diversity (currently including two females, two Hispanics among the seven tenure-track ATMO faculty members) and appropriate demographics
- Maintain and enhance diversity within student body

We are proud that our vision and mission statements and strategic priorities have been developed with the help of ATMO Board of Advisors, following the key principles outlined in Fig. B2.

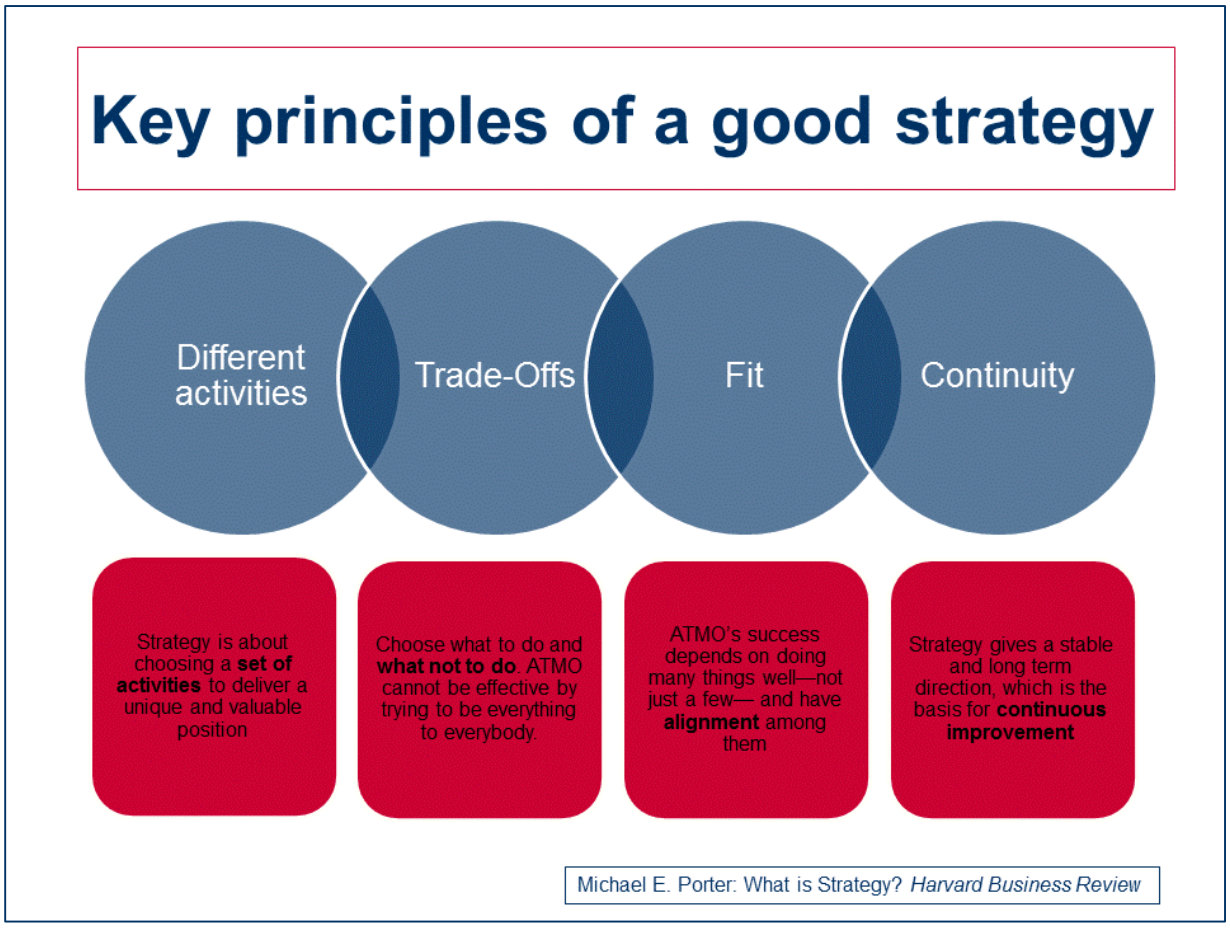

Figure B2. Key principles of a good strategy. ATMO's strategic planning process which led to the development of the mission, goals and priorities was the result of two all day planning sessions over the course of a year and involving the faculty, students and members of the ATMO board. During the second planning session, much of the discussion focused on ensuring that ATMO's plan would align with the University's "*Never Settle*" strategic plan.

B3. Relation to University Mission and Strategic Plan

Our strategic plan, and the goals stated above, demonstrate our commitment to directly align our program with the University's "*Never Settle"* strategic plan that imagines a university where students are all deeply engaged in their education, a university where researchers uncover innovative ways of exploring new challenges, a university that revolutionizes how it connects with the larger world, and a university where interdisciplinary and community partnerships expand access and connection while deepening the university foundations. Specific questions are also proposed for individual units to address in order to translate strategic priorities into action. The tables below demonstrate ATMO's alignment with, and contributions to, the "*Never Settle"* strategic priorities, with a focus on answering those specific (and ATMO-relevant) questions.

"*Never Settle"* strategic priority A: Engage students in the best education. Note that ATMO is primarily a graduate program (and does not have a traditional B.S. program). Although ATMO does not offer an undergraduate degree, we do teach 300 to 400 undergraduate students annually. We also offer an online BAS (meteorology) program.

"*Never Settle*" questions/issues:	**ATMO examples**
Recruit diverse undergraduate, transfer and graduate students	Recruited and maintained a diverse graduate student body (see Chapter I3); Accelerated Master's Program (AMP) with Physics BAS Meteorology on-line program
Work with schools, community colleges, and bridge programs to expand access	Worked closely with Pima Community College (PCC) to establish the undergraduate online BAS meteorology program to expand access to military personnel; Hosted NSF Research for Undergraduates (REU) bridge students from PCC for over a decade in our research labs; All graduate students are financially supported, RA, TA or Fellowship; Elementary school outreach (Ritchie/Weidman)
Optimize student success and increase retention	ATMO offers interdisciplinary research opportunities by working with other units; The Director of Graduate Studies (DGS) works with new and current students, and holds informal and formal student progress meetings; ATMO has a wide-range of attractive course options; Streamlined exam procedures and improved handbooks for graduate students
Provide undergraduate engagement experiences such as internships, laboratory or studio work, serve learning, and study-abroad opportunities	ATMO has offered research opportunities to undergraduate students through the NASA Space Grant Internship Program since its inception; Participated in the UA Undergraduate Biology Research Program (UBRP) in the past
Increase the number of bachelor degrees, especially in high demand fields	Created the Bachelor of Applied Science (BAS) degree as a partnership with Davis-Monthan Air Force Base, UA South, Pima Community College and Outreach College. This program is currently restricted to active military personnel, although ATMO is considering expanding the BAS program to a BS online program for all; Worked with other units in SEES to create the atmospheric science emphasis in the SWES' environmental science B.S. program; Engaging undergraduates through interdisciplinary programs
Educate students who will be sought out by the best employers and graduate and postgraduate programs	Creating/promoting networking opportunities for students through seminars, American Meteorological Society (AMS), American Geophysical Union (AGU), and National Center for Atmospheric Research (NCAR); Contributing to undergrads through interdisciplinary programs (e.g., environmental science B.S. partnership); Military personnel in the BAS program are already employed.
Develop masters programs to meet workforce needs	Developed the hydrometeorology programs, M.S. and Ph.D. (jointly with HWRS) and the Accelerated M.S. program (jointly with Physics Department) to meet workforce needs

"*Never Settle"* strategic priority B: Innovative in an expanding research environment.

"*Never Settle*" questions/issues:	**ATMO examples**
Promote research and scholarship that addresses global challenges	Played leading role in establishing the School of Earth and Environmental Sciences (SEES), which Betterton now directs; Co-authored the SEES Strategic Plan to describe novel cross-cutting research areas such as the Earth Fluids concept; Research on global and regional climate change, land cover and land use, dust modeling, wind & solar forecasting, air quality, water availability, tropical cyclones; Substantial collaborations with scientists in Mexico and South America; Co-chaired NRC committee and NSF white paper on observing facilities (Zeng); Chaired the NASA earth science senior review (Ritchie); Serving on the National Academies Board on Atmospheric Science and Climate (Zeng); STEM outreach and community education
Contribute to core research and clinical strengths in the health science	ATMO faculty members, funded by NIH National Institute of Environmental Health, conduct research on the effects of atmospheric pollutants on humans and the environment; Betterton holds a courtesy appointment in the UA College of Public Health; Sorooshian supervised students working in Public Health through NIEHS joint project
Expand collaborations with researchers in other disciplines	Led or participated in numerous interdisciplinary projects with researchers in other disciplines across the campus. For example: Zeng is the founding director (and Chris Castro is a member of the Executive Committee) of the UA Climate Dynamics and Hydrometeorology Center (CDHC) that involves 45 faculty members from 11 departments in five colleges. He is the Co-PI of the DOE interdisciplinary project on regional Arctic system modeling along with colleagues from eight other institutions; Betterton actively collaborates with faculty in the Department of Chemical and Environmental Engineering, where he holds a courtesy appointment. He also collaborates with the Department of Physics to provide solar forecasts and nowcasts for Tucson Electric Power; Dominguez currently co-chairs the Hydrometeorology graduate program jointly with Hydrology and Water Resources. She and Zeng are also involved in the SWAN project (supported by EU) along with colleagues from other units and four European countries; Castro, Dominguez, Zeng are Co-PIs of the NSF interdisciplinary project on North American monsoon macrosystem along with colleagues from other units and three other universities; 100% of ATMO faculty are involved in interdisciplinary projects; Founding member of SEES;

	Exploring broadcast meteorology course with Channel 4 and with the School of Journalism
Ensure that your promotion criteria and procedures recognize interdisciplinary collaborations and innovations in teaching	ATMO faculty promotion and tenure process explicitly encourages and recognizes interdisciplinary collaborations and teaching innovations, which are also required in the COS P & T guidelines; Requires mentoring of junior faculty
Improve the hiring, support, and retention of diverse, outstanding faculty	Actively participating in the UA Strategic Priorities Faculty Initiative (SPFI) which provides funding to hire faculty who advances diversity priorities; Proactive in the paradigm shift in faculty hires at UA from individual unit-based to "cluster hires"; Teaching load in the first year for new faculty is limited to maximize research and outreach opportunities. New faculty are also encouraged to collaborate with and visit UCAR; Senior faculty mentor junior faculty members on the transfer of core courses, the inclusion of the new faculty on research projects that involve multiple faculty members to help them get a running start; Provide specific assistance in the P&T process (e.g., teaching material evaluation; feedbacks from annual faculty evaluations); Create opportunities for junior faculty members to lead major interdisciplinary efforts
Recruit, engage, and graduate diverse, first-rate doctoral students	Maintain our success in recruiting, engaging, and supporting a diverse group of graduate students; Increase the support of graduate students from fellowship programs including Science Foundation Arizona, Sloan Foundation, and Federal government agencies (NSF, DOD, DOE). 100% of graduate students are funded; Recruited and supported a Navajo graduate student and an Apache undergraduate laboratory research worker
Work to diversify external sources of research support	Continued success in seeking grants from federal agencies; Increased support from, and partnership with, the private sector including Tucson Electric Power (Leuthold), Idaho Power (Leuthold, Zeng), the Salt River Project (Castro), and Arizona Department of Transportation (Betterton)
Work to improve support for major research initiatives	Led or participated in numerous interdisciplinary projects with researchers in other disciplines across the campus (e.g., NSF COSMOS project, NSF macrosystem project, DOE RASM project; EU SWAN project); Zeng is currently leading the campus discussion of a possible NASA Earth Venture Instrument (EVI) proposal ($30M - $65M); Ritchie has led two multi-million interdisciplinary proposal for NSF in the past three years, and is leading another one at present; Arellano and Conant are Co-Is of a NASA EVI-2 proposal ($68M) recently submitted by UA LPL; Obtained support from multiple (external and internal) sources to build a large Linux computer cluster; Zeng co-chaired the community workshop and NSF white paper on observing facilities for climate research

Expand strategic external partnerships	Maintained a close partnership with the NOAA NWS Weather Forecasting Office in Tucson, including co-authoring research proposals (Arellano, Castro, Betterton); Maintained a close partnership with the USAF 25th Operational Weather Squadron at Davis-Monthan Air Force Base. Zeng and Betterton are Honorary Squadron Commanders. Castro's DoD project involves the Squadron as well; As a founding member of UCAR, ATMO faculty have maintained close collaborations with UCAR/NCAR, including helping to develop the UCAR UVISIT (University Visits in Scientific Interaction and Teaching) Program (Dominguez, Arellano) and serving on the UCAR boards and committees (Betterton and Ritchie); Expanded partnership with the private sector [SRP, Idaho Power, TEP (Leuthold, Betterton)], non-profit organizations [UNAVCO in Boulder, CO (Serra)], Latin America [Mexico, Colombia, Brazil (Castro, Dominguez)], and Asia-Pacific region [Australia, China, South Korea, Vietnam (Ritchie, Zeng, Arellano, Castro)]

"*Never Settle"* strategic priority C: Partner in novel and substantive ways.

"*Never Settle*" questions/issues:	**ATMO examples**
Advance the University's land-grant mission with contemporary and global strategies	Our high-resolution weather forecasts (Leuthold) have been used by lettuce farmers in Yuma for freeze forecasts, by utility companies for wind and solar forecasts, the USAF for flight forecasts, the Arizona Department of Transportation for dust storm guidance, and news media for severe weather forecasts; Our online BAS meteorology courses serve students in the state and abroad (such as U.S. soldiers stationed in South Korea and Japan); Our water resource projection (Castro) has been used by utility companies and U.S. Bureau of Reclamation; We plan to enhance research and educational opportunities to address societal concerns with countries in arid and semiarid regions that cover one-third of the global landmass, particularly Latin America (Castro, Dominguez) and Asia-Pacific region (Zeng, Ritchie); Castro is working on future extreme weather and climate projection for U.S. military bases
Enlist community and business partners to foster innovations	Partnership on research and implementation of research results with utility industry and farmers (Leuthold); Partnership with military bases in our region on the impact of future climate change on military operations (Castro); Engaged with aerospace industry, including submitting joint proposals; Establishment of ATMO advisory board whose members include earth science geoscience company CEO (Jones), former chief academic officer (Zollinger), and other leaders from aerospace (Gast), environmental private sector (Petty), broadcast weather forecasting (Sullins), water/electric utilities (Sullivan), NASA (Vann), and USAF (Marsicek);

	Obtained Proof of Concept funding from Tech Launch Arizona to develop solar forecasting technology that has resulted in a patent disclosure (Leuthold, Betterton) and patent application
Use online and other innovations to build capacity in critical and emerging fields	We created the online BAS meteorology program for military forecasters; If resources become available, ATMO will expand the BAS program available to military forecasters only, to a BS online program available to all students; Offering expanded general education courses online throughout the year (including summer)
Develop your program to better meet the cultural, educational, and workforce needs of our region and the world	One of our focus research areas is related to the weather, climate, and hydrometeorology of our semi-arid monsoon region; Developed the BAS program to help fulfill the USAF need; Making our general education course available online; Collaboration with Mexican universities; Denise Moreno (SWES) translates pollution presentations and research for Latino/a community (Betterton)

"*Never Settle*" strategic priority D: Create synergy across disciplines and among people.

"*Never Settle*" questions/issues:	**ATMO examples**
Use Promotion & Tenure (P&T) and other rewards to elevate interdisciplinary collaborations	Both our P&T procedure and Annual Evaluations value and emphasize interdisciplinary collaboration, also because almost all of our major grants were obtained through such collaborations; 100% of ATMO faculty member, without exception, have been actively involved in interdisciplinary collaborations with colleagues on campus and from other institutions
Integrate diversity into your infrastructure to foster accountability	ATMO has been a model for diversity in faculty, staff, and students, and we maintain such diversity as our culture through networking and mentoring. For instance, our seven teaching professors include two female (Dominguez, Ritchie) and two Hispanic (Castro, Dominguez) faculty
Create resources and programs that support global and regional engagements	The UA Climate Dynamics and Hydrometeorology Center was established (by ATMO faculty members in partnership with other colleagues) to coordinate large research efforts and engage regional and global programs; Actively engaged scientists across the Atlantic (e.g., the SWAN project), across the Pacific (e.g., with China), and over the Americas (e.g., with Mexico) in research and education; Providing WRF training to Colombian Air Force (Castro)
Improve your virtual and physical infrastructure to reach external constituencies	We are working with the US Air Force to move airmen from associate degree to bachelor's degree in a 2+2 program, no matter where they are in the world; Our near-real-time weather forecasting is available via our web site to the general public for free;

	Provide online courses for Tier 1 and Tier 2 undergraduate education, including summer courses; Updating ATMO website with current news, using social media (Twitter with real time forecasts, Facebook with news and accomplishments)
Improve your program to increase their performance, impact, and rankings	We are ranked #3 by NRC (2010) for programs with a similar size, and we intend to maintain our leadership position (See Fig. D4)
Improve your budgeting and operations to improve productivity and entrepreneurship	ATMO is already the most efficient among the four SEES units and #8 among the 18 units in College of Science based on teaching and research normalized by FTE (Table D1); We have obtained funding from the private sector (Idaho Power, TEP, SRP); Patent UA13-052 for "Solar Irradiance Measurement System and Weather Model Incorporating Results of Such Measurement" has been filed; As the current SEES Director, Betterton has led the effort toward the establishment of business centers to create consistent budgeting and reporting and utilize expertise in areas where it may not otherwise exist

UNIT HISTORY

C. UNIT HISTORY

The Institute of Atmospheric Physics (IAP) at UA was established in the early 1950s for the purpose of investigating the use of cloud seeding to increase rainfall in the Arizona desert. The Department of Atmospheric Sciences (ATMO) was established in 1957 as a degree granting program, although the research was still done through the Institute, a practice that is followed this day. As mentioned earlier, the acronym ATMO is used to refer to ATMO/IAP for simplicity. Highlights of ATMO's history include;

- The first Head of ATMO, Dr. A. R. Kassander, was also a leading member of the original group that oversaw the establishment of the University Corporation for Atmospheric Research (UCAR) and the National Center for Atmospheric Research (NCAR). In fact, the first UCAR meeting was held on the UA campus in 1959 (Fig. C1).
- ATMO was instrumental in setting up the first campus computing center, the predecessor to the current University Information Technology Services (UITS).
- During the 1960s, ATMO played a major role in bringing Dr. Gerard Kuiper and his Lunar and Planetary group to the UA, and they were housed within our Department. The group later separated from ATMO and founded the world-renowned Lunar and Planetary Laboratory (LPL) and Department of Planetary Sciences.

ATMO focused primarily on radar cloud physics and cloud seeding in those early years, but our research naturally expanded to other areas as the number of faculty grew in response to increasing national interest in the atmospheric sciences. In the late 1980s, ATMO was instrumental in heading a national movement to co-locate NOAA/National Weather Service forecast offices to university campuses, and in convincing NOAA to erect the Environmental and National Resources Building (ENRB1) to house the Tucson Forecast Office and other federal groups (USGS) on campus.

Figure C1. The first UCAR meeting on the UA campus in 1959. The Solar Energy Lab building was demolished in 1969. Pictured from left to right: Dr. M. A. Farrell, Dr. T. P. Wright, Dr. P. S. Macaulay, Mr. C. F. Floe, Mr. J. R. Stinson, Mr. G. L. Lee, Vice-President A. W. Peterson, Dr. H. Neuberger, Dr. M. A. Neiburger, Mr. J. M. Miller, Dr. H. G. Houghton, Mr. H. K. Work, Dr. S. L. Hess, Dr. R. A. Bryson, Dr. J. Spar, Dr. D. F. Leipper, Dr. B. Nichols, Mr. J. C. Calhoun, Dr. W. Baum, Dr. H. R. Byers, Dr. T. F. Malone, Dr. G. S. Benton, Dr. E. W. Hewson, Dr. A. R. Kassander, Jr., Dr. H. D. Rhodes

C1. Major Changes since Last APR in 2006-2007

School of Earth and Environmental Sciences (SEES) was established in 2009 as part of a university-wide transformation plan, and ATMO is one of the founding members. ATMO Head, Eric Betterton, is the SEES Director at present. SEES is a federation of the College of Science units of Atmospheric Sciences, Geosciences, Hydrology and Water Resources, the Laboratory of Tree-Ring Research, Biosphere 2, the Accelerator Mass Spectrometry Laboratory, and the Department of Soil, Water and Environmental Science, and School of Natural Resources and Environment in the College of Agriculture and Life Sciences.

SEES combines field, instrumental, computational and modeling approaches in the earth and environmental sciences within one unit, and facilitates interdisciplinary research, teaching and outreach/extension activities across the participating units. It produces new knowledge about earth and environmental processes and human-environment interactions at all geographic and temporal scales, provides the scientific basis for environmental and climate policy, trains the next generation of earth and environmental scientists, and disseminates knowledge and solutions for the benefit of students and society.

Since SEES was formed, we have collaborated on faculty cluster hires, to streamline business operations, to coordinate university general education course offerings, to synergistically offer environmental science B.S. with various options, to facilitate interdisciplinary collaborations, and to develop SEES strategic plan for all units involved. To date, the benefits of the school are moderate, but the groundwork is being laid for future added value.

Faculty composition. The faculty composition has changed since the last APR in 2006-2007. Professors Ben Herman (radiative transfer and remote sensing) and Phil Krider (lightning and atmospheric electricity) retired, Bill Conant (aerosol-cloud-climate interactions and radiative transfer) transitioned from a tenure-track faculty position to a research faculty position, and Rob Kursinski (radiative transfer and remote sensing) left the program for the private sector to focus on technology development. We have also hired two new assistant professors: Francina Dominguez (hydrometeorology and climate change) and Ave Arellano (data assimilation and atmospheric chemistry).

- The number of faculty has been decreased by 1.5 FTE from 8.5 FTE in 2006/2007 to 7 FTE at present;
- The number of state-funded lecturers has increased from 1 FTE in 2006/2007 to 2 FTE at present;
- The number of joint faculty has increased from 8 in 2006/2007 to 9 at present (one having left UA, and two new joint faculty members were appointed);
- The number of research faculty and research scientists has decreased from 14 in 2006/20077 to 10 at present;
- There was no change in our IT and business support staff;
- The current department front office staff were all hired during this period (see appendix for staff employment history);
- Steve Mullen ended his term as the Department Head, and Eric Betterton became the new Head, July 1, 2007;
- The External Advisory Board was created in 2010.

C2. Summary of Recommendations of Last APR and Responses

The last APR External Committee in December 2006 made both short-term/specific and long-term/broader recommendations. Here we present these recommendations and the current status.

Short-Term/Specific Recommendations:

1. Ensure that new faculty obtain satisfactory facilities

Status: During the previous APR period, for the three new hires (Bill Conant, Chris Castro, and Elizabeth Ritchie), computing facilities provided to all three were satisfactory, which contributed to the success of Castro (promoted to Associate Professor with tenure in 2012) and Ritchie (promoted to Full Professor in 2012).

During the current APR period, for the two new hires (Francina Dominguez and Ave Arellano), computing and instrumentation facilities are overall satisfactory, because of the joint start-up support from various sources (the College of Science, Institute of the Environment, and Biosphere 2). This contributed to the success of Drs. Dominguez and Arellano who have been extremely productive in research, teaching, and service, and have passed their 3-year mid-term evaluations.

2. Formal assessment of incoming students (e.g., interview, diagnostic exam)

Status: We have paid more attention to potential deficiencies of new students during the admission process. If a student with an overall good background is found to be deficient (e.g., in math) through this process and individual interactions, we ask the student to take additional courses before joining our program.

After students join our program, if they are found to be deficient in atmospheric science, we ask them to take ATMO 536: Fundamentals of Atmospheric Sciences (which was developed during this period for this purpose) before they take the more quantitative core courses in physical and dynamic meteorology.

For the core course of ATMO 541: Dynamic Meteorology, a simple diagnostic test is conducted to evaluate students' mathematical backgrounds, and the instructor then would cover the subject outside normal class periods to help the students.

3. Involve students and maximize use of cross-listing in development of current curriculum

Status: This has been done very efficiently (see Chapter I2)

4. Improve ATMO web site

Status: Done. As well as updating our Facebook presence, we also created two Twitter accounts for current weather information, and for the weather forecast. We also installed an eye-catching video display in the lobby to increase our "curb appeal".

5. Make more use of NCAR

Status: We have significantly increased the two-way interactions with NCAR. We have sent students to work at NCAR in summer, including a Navajo student who spent three summers working with the Atmospheric Chemistry Division. We have sent students to attend summer workshops organized by NCAR. We have been collaborating with NCAR scientists in joint publications and proposals.

Eric Betterton serves on the Board of Trustees of UCAR (which manages NCAR). Xubin Zeng Co-chaired the Community Workshop and White Paper on lower-atmosphere observing facilities (LAOF) for climate studies for NSF Atmospheric and Geospatial Science (AGS) Division and NCAR Earth Observing Laboratory (EOL) in 2012-2013. Elizabeth Ritchie serves on the NCAR President's Advisory Committee on University Relations (PACUR). Francina Dominguez served on the NCAR Unidata Committee. Avelino Arellano actively collaborates with the NCAR Atmospheric Chemistry Division.

Long-Term/Broader Recommendations:

1. Organization: Three future options were listed for ATMO: as an independent, self-standing small-scale department; merging with the Department of Hydrology and Water Resources (HWRS); or merging with the Department of Geosciences (GEOS). The external committee also listed the fourth option of ATMO to be incorporated, as integral part, into the proposed School of Earth and Environmental Sciences (SEES) as a cornerstone component.

Status: This issue has been largely resolved as part of the organizational changes at the University and College level in the past seven years (since last APR). First, a number of interdisciplinary schools have been established (including SEES in which ATMO was a founding unit). The offerings of university general education courses in the College of Science and within SEES have been better coordinated. The creation of a 4-department business center is being led by ATMO, and the creation of a 4-department IT center is also being explored. Department heads within SEES have bimonthly meetings to discuss the overall strategy (including faculty and staff hiring plan). Eric Betterton (ATMO Head) is the current SEES Director.

Therefore effectively most of the fourth option has been materialized, and in a sense, all three recommendations have been met.

ATMO was nationally ranked #3 among programs with a similar size and #12 if programs of larger faculty sizes are also considered (National Research Council 2010). ATMO is also one of the most efficient departments in the College of Science based on the ratio of research and teaching productivities relative to state support. The establishment of the popular hydrometeorology M.S and Ph.D. programs jointly with HWRS significantly strengthens both ATMO and HWRS programs. The appointment of joint faculty with full voting rights also significantly strengthens ATMO's interdisciplinary collaborations in research and teaching.

Evidently ATMO is thriving under the current organizational structure. Our strategy for the future includes the following:

- Continue our excellent momentum at present
- Always be proactive in the future evolution of SEES
- Align our faculty growth plan with the faculty hiring plan of SEES and the Institute of Environment (IE) for the benefit of the overall earth and environment enterprise at UA
- Find ways to shorten the time needed to complete the Ph.D. and hence be more efficient in meeting the Arizona Board of Regents graduation requirements for Ph.D.'s

2. Facilities: The facilities allocated to ATMO need to undergo a major renovation or relocation to a more modern and new facility. In the short run, ATMO should consider the option of using the Campus-wide center for its computing resources and computational needs. It is abundantly clear that ATMO should be collocated along with faculty with similar interests or overlapping research and teaching interests. If there is a "merged department" that evolves, then this new department should be co-located together in appropriate, modern, and sufficient space. A new building dedicated to this department or to an even larger Earth and Environmental Sciences Department should be constructed.

Status: With the support of the College of Science, we moved our computer room to the basement of the PAS Building, featuring restricted access, a raised floor, dedicated power and A/C. We now have sufficient room for our computer needs. We house our multiple computer clusters in this room, supplemented by the supercomputer at the UA computer center, and supercomputers at NCAR and other federal computer centers (e.g., NASA, DOE, DOD), as necessary.

The College of Science and UA have no plan to co-locate ATMO with other related units in the same building at present. Even though ATMO played a leading role in attracting the first (Federally-funded) Environment and Natural Resources Building (ENRB1) to campus, ATMO is not among the units that will move into the new (State-funded) ENRB2 currently under construction. Ironically, ENRB2 will primarily house Mathematics, Geography, and the Institute of the Environment, but not SEES. This represents a missed opportunity for the University to collocate and thereby cement the establishment of its School of Earth and Environmental Sciences.

No funds are available to renovate the Physics and Atmospheric Sciences (PAS) building to collocate SEES units here either. There is a remote possibility that within the next decade the Department of Physics will move to a new building to be constructed on the east side of the campus, which would then allow the renovation of PAS, depending on the availability of funds.

3. Focus: The APR Committee feels that the Department's goals are too ambitious and diverse. Based on interests of the faculty and conversations over the two day review meeting, it became clear that "hydrometeorology" is primary overarching theme coupled with aspects of "climate" and "climate change." The APR Committee recommends that the atmospheric electricity program be discontinued with the retirement of Prof. Krider.

Status: We have created the nation's first graduate program in hydrometeorology. Indeed hydrometeorology is primary overarching theme coupled with aspects of climate and climate change, and we have been very successful in this area. However, instead of focusing on this area only, it is much better for ATMO to have a balanced portfolio for several reasons:

- A strong hydrometeorology program needs a balanced excellence in dynamic meteorology, physical meteorology, synoptic meteorology, and data assimilation.
- It is dangerous to "put all our eggs in one basket"
- The addition of joint voting faculty members gives us critical mass in several areas. For instance, only one faculty (Eric Betterton) worked on aerosol and air pollution during the prior APR period. Now we have a critical mass in this important area with Betterton, Ave Arellano (a new hire in ATMO), Armin Sorooshian (a joint ATMO faculty from the Department of Chemical and Environmental Engineering), Paloma Beamer (College of Public Health), and Miranda Loh (College of Public Health).
- The balanced excellence in ATMO (rather than just one focus area) helped bring us the #3 ranking in the NRC (2010) of atmospheric and oceanic science programs in the U.S. and Canada with a similar program size, and #12 ranking if programs of larger sizes are also included
- A balanced excellence in ATMO is also needed for the broad earth and environmental programs on campus.

Following the APR Committee recommendation and our own evaluation, we have reluctantly decided not to hire a replacement in the area of atmospheric electricity. We still maintain a lightning and atmospheric electricity program as Krider (Emeritus Professor) and Ken Cummins (Research Professor) are still active in this area and also because of student demand. We expect that both Krider and Cummins would wind down their research programs over the next 3 years.

The APR External Committee also raised a relevant issue that remains to be addressed by the College of Science and the University: "*The support of ATMO by the University community has been good and multiple groups have helped to hire some excellent new faculty in ATMO. On the other hand, these same groups are hiring what could be considered 'atmospheric scientists' into their own departments. This is at odds to some extent with helping to create a strong ATMO….someone at a higher level (Dean of Sciences for example), needs to play a larger role to help incubate the Department and convince people that if an atmospheric sciences faculty member is needed it should be strongly considered that their home department be ATMO*." Since the last APR, ATMO actively participated in the search for a faculty member in the area of ocean/climate dynamics. Ultimately, the successful candidate was hired by the Department of Geosciences. This is beyond the control of ATMO.

4. Curriculum: The standard teaching loads of the ATMO faculty are below the University standard in the sciences and engineering. With a reorganized and comprehensive curriculum, the required teaching load should be increased unless the level of external research funding would warrant a buy-out of teaching time.

Status: This was a misunderstanding probably because we did not effectively explain it in the prior APR Self-Study Report. The fact is that:

- The ATMO faculty teaching load is the same as those in other College of Science departments (including the SEES units) and consists of teaching one course per semester, graduate student advising, and service on graduate committees.
- The overall ATMO teaching load in terms of student credit hours normalized by faculty FTE (i.e., state support) is one of the highest in the College of Science

5. Student stipend level: Student stipends must be increased to levels that are competitive with other graduate programs. At present, the stipend levels are far below the most competitive universities.

Status: Detailed examination of our student stipend level reveals that it is indeed competitive compared with our peer institutions and at other SEES units (see Chapter I3). Besides, the TA funding levels (which set the RA funding levels) are established at the University level.

6. Visibility: It is absolutely essential that ATMO as a whole becomes more visible as quickly as possible through publications and meetings. This is important both on and off campus.

Status: Substantial progress has been made in this area because of the high-profile leadership of ATMO faculty on and off campus. Some examples of leadership on campus include:

- Founding the UA Climate Dynamics and Hydrometeorology Center (Zeng)
- Founding the Hydrometeorology M.S. and Ph.D. programs (jointly with HWRS) (Zeng)
- Leadership in UA Faculty committees (Betterton-Strategic Planning & Budget Advisory Committee, Ritchie-UA Committee of 11, Castro-Faculty Senate)
- UCAR Board (Betterton)
- AMS Council (Zeng, Ritchie)
- NCAR committees (Ritchie, Dominguez)
- University Distinguished Professor (Betterton)
- SEES Director (Betterton)
- College of Science Galileo Circle Fellow (Krider, Zeng)
- Approximately 30 peer-reviewed publications annually; Website, Facebook, Twitter and lobby display
- Real time weather and solar forecasts for private sector

Some more examples of national and international leadership are also provided in next chapter (Chapter D1).

It is very fortunate that during the past seven years, ATMO has successfully finished the transition from the first generation of faculty members who established our program and brought it to national and international prominence to current faculty members. With the professional growth of our junior faculty members (Castro, Dominguez, and Arellano), the visibility of ATMO will keep increasing in the next few years.

OVERVIEW OF ACADEMIC QUALITY

D. OVERVIEW OF ACADEMIC QUALITY

D1a. Resource Indicators

Teaching: ATMO has done remarkably well in the total student credit hours taught and the full-time equivalent (FTE) number of students (Figs. D1 and D2) compared with other units in the College of Science (to be discussed in Table D1).

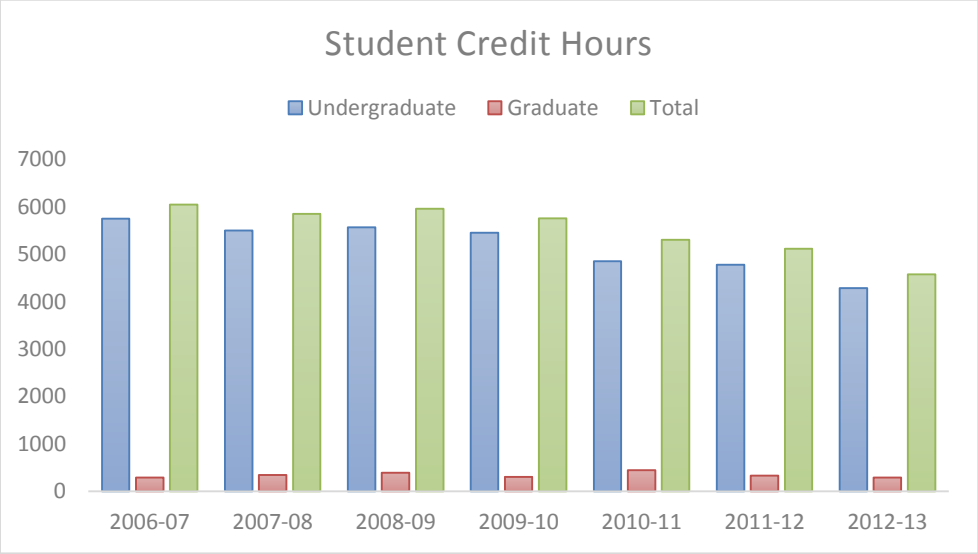

Figure D1 Total student credit hours in courses taught by ATMO faculty during Fiscal Years 2006-2013.

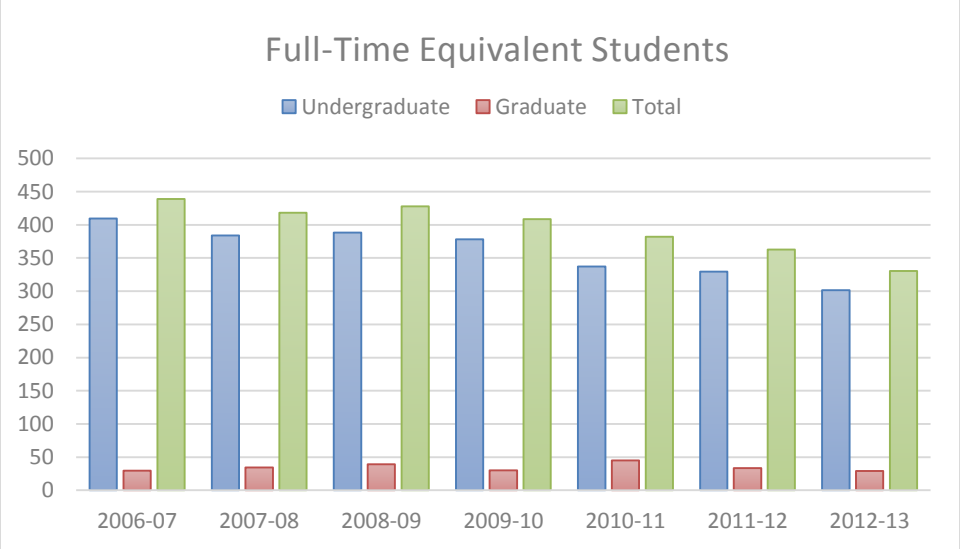

Figure D2 Total full-time equivalent students taught by ATMO faculty during Fiscal Years 2006-2013.

Graduate students. The typical number of applicants each year to all M.S. and Ph.D. programs is about 20 and 13, respectively. The admittance rate ranges 40-50%. There has been a relatively steady influx of approximately 7-8 new incoming M.S. students and 3-5 new incoming Ph.D. students per year since 2007. The total graduate student enrollment has steadily increased over the past seven years, starting from a low of 24 students in 2006 and increasing to 35-37 students

annually during the years 2010-12. The acceptance of international students is much more selective because a Research Assistantship must first be awarded by the Department, and then the international student may not always be able to obtain a U.S. visa. Detailed discussions are provided in Chapter I3.

Expenditures. The total annual expenditures on external grants and contracts in ATMO is about $2.38M with a relatively small (about 10%) interannual variation over the past 7 years (Fig. D3). This level is 20% higher than the average number of $1.8M during the previous APR, representing a major milestone in our research activities. It is also substantially higher than the total amount of state support of ~ $1M.

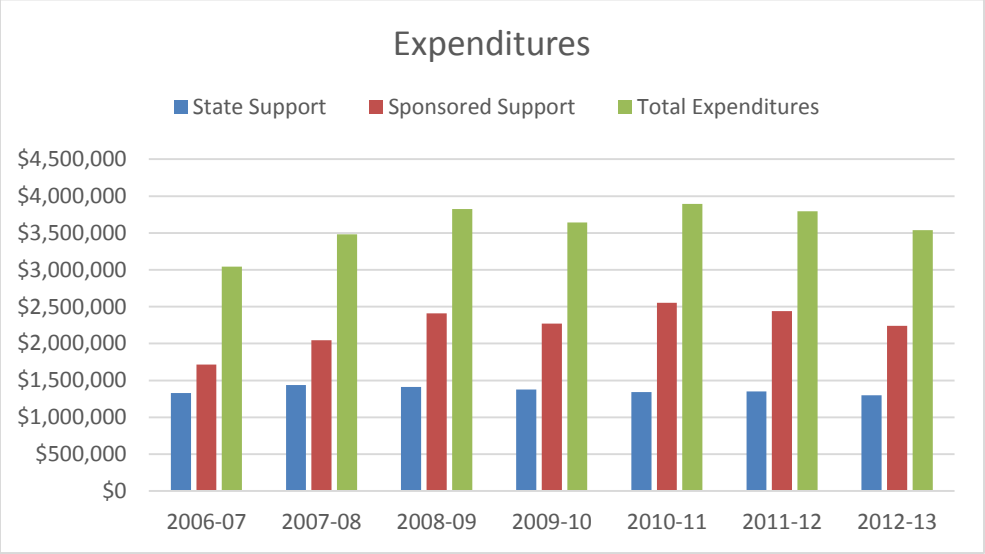

Figure D3 Expenditures from the State and sponsored research projects (including overhead charges) in ATMO for fiscal years 2006-2013.

Comparisons. College of Science has a rigorous comparison of all academic units in terms of teaching and research efficiencies every year, and Table D1 shows the most recent comparison. The conclusions based on the teaching efficiency (i.e., R2 in last column) and overall research grant and teaching efficiency (i.e., R1) are:

- Compared with other SEES units, ATMO's R1 and R2 scores are higher than those for GEOS and much higher than those for HWRS and LTRR
- Within the College of Science (which is the most productive college at UA), ATMO's R1 and R2 scores are above average (#8 among the 18 units)
- Compared with the university average, ATMO's R1 and R2 scores are ~150% greater.

Table D1 Comparison of academic units in the UA College of Science for FY 2013. Permanent state budget includes temporal funding. ICR refers to the indirect cost recovery (or overhead return) to the university. SCH refers to the total credit hours. R1 refers to the ratio of (ICR return to the College of Science + total instruction income) over permanent state budget including temporal funding. R2 refers to the ratio of total instruction income over permanent state budget including temporal funding. The numbers in parentheses in the last two columns refer to the ranking among the 18 units in the College of Science.

Department	State Budget	ICR	SCH	R1 (ranking)	R2 (ranking)
Atmospheric Sciences	$941K	$656K	4,314	1.03 (8)	0.85 (8)
Geosciences	$3,377K	$782K	12,601	0.83 (11)	0.78 (10)
Hydrology/Water Resources	$1,987K	$979K	2,050	0.44 (14)	0.32 (14)
Tree-Ring Laboratory	$1,038K	$375K	2,211	0.43 (15)	0.34 (13)
College of Science Total	$54,355K	$28,015K	217,879	1.01	0.89
University	$617,062K	$86,322K	838,911	0.39	0.35

D1b. Reputation Indicators

Ranking. The National Research Council (NRC) in 2010 ranked all graduate programs in the field of "Oceanography, Atmospheric Sciences, and Meteorology." The NRC report provides two systems of rankings: (1) S-rankings are survey-based where faculty gave weight to 20 characteristics the study committee determined to be important in contributing to program quality, and (2) R-rankings are regression-based and depend on weights calculated from faculty ratings of a sample of programs in their field (http://sites.nationalacademies.org/PGA/Resdoc/PGA_051962). The S-ranking system thus is a bottom-up approach to quantify rankings while the R-rankings are a top-down approach. Since data are reported for the 5th and 95th percentiles, ranges of possible rankings are published for the S- and R-ranking systems, and therefore, one final ranking number is not possible and subject to large uncertainty. As a result, we examine both the 5th and 95th percentile values below.

Figure D4 summarizes the range for the 5th and 95th percentile rankings using both the R- and S-ranking systems. Although our ATMO program is in the smallest size quartile (see color markers), we are in the top 20. Excluding oceanography programs but still including atmospheric and oceanic combined programs, our program would be ranked as #12 in the 5th percentile S-ranking, and ranked as #11 in the 5th percentile R-ranking.

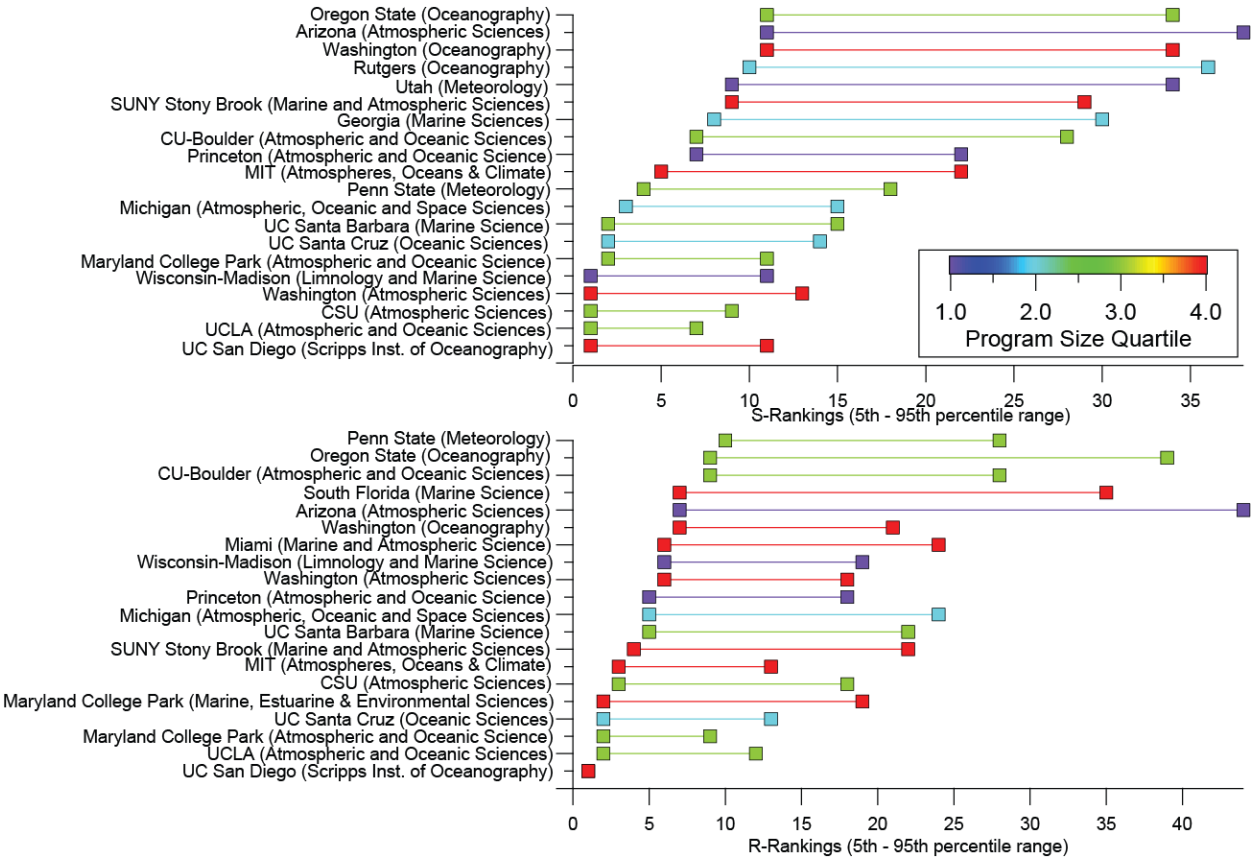

Figure D4. Top 20 programs in "Oceanography, Atmospheric Sciences, and Meteorology" for the two rankings systems used in the NRC (2010) Report. Marker colors correspond to the "Program Size Quartile", where ATMO (University of Arizona) is in the smallest category (value of 1).

Another finding from Fig. D4 is that program size does matter in the NRC ranking. For instance, the top 10 programs have eight in sizes 3 and 4, two in size 2, with zero in size one (smallest) in the R-ranking. The top 10 programs have seven in sizes 3 and 4, two in size 2, and one in size 1 (smallest) in the S-ranking. This suggests that for our program to move into a top 10 program, we have to increase the program size by faculty growth.

Table D2 gives a more appropriate comparison of all programs with the same size 1 (smallest). Our program is approximately ranked as #3 by combining the 5th and 95th percentiles in R- and S-ranks.

There are no annual rankings in the field of "Oceanography, Atmospheric Sciences, and Meteorology" by the *U.S. News and World Report*.

Table D2. NRC (2010) rankings for programs in the smallest program size quartile (1) for a direct comparison to our department. These programs are all among the top 50 for "Oceanography, Atmospheric Sciences, and Meteorology".

Institution Name	Program Name	R Rankings: 5th Percentile	R Rankings: 95th Percentile	S Rankings: 5th Percentile	S Rankings: 95th Percentile
PRINCETON UNIVERSITY	Atmospheric and Oceanic Science	5	18	7	22
UNIVERSITY OF WISCONSIN-MADISON	Limnology and Marine Science	6	19	1	11
UNIVERSITY OF ARIZONA	Atmospheric Sciences	7	44	11	38
UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL	Marine Sciences	11	43	16	45
UNIVERSITY OF NEVADA RENO	Atmospheric Science	16	47	23	47
UNIVERSITY OF UTAH	Meteorology	20	45	9	34
UNIVERSITY OF DELAWARE	Oceanography	23	45	18	46
UNIVERSITY OF TEXAS AT AUSTIN	Marine Science	24	46	21	47
UNIVERSITY OF ALASKA FAIRBANKS	Oceanography	25	47	19	48
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN	Atmospheric Sciences	27	46	19	44
PURDUE UNIVERSITY MAIN CAMPUS	Atmospheric Science	30	47	26	47
OHIO STATE UNIVERSITY MAIN CAMPUS	Atmospheric Sciences	47	50	33	49
UNIVERSITY OF SOUTHERN MISSISSIPPI	Marine Science	49	50	44	50

Reputations. Additional indicators for the reputation of our program include the national and international leadership positions of the ATMO tenure-track faculty (with a more detailed list provided in Chapter E2):

- Elected member, American Meteorological Society (AMS) Council (Ritchie, Zeng) and its 6-person Executive Committee (Zeng)
- Co-chair or member, various National Research Council (NRC) committees (Zeng)
- Chair, National Research Council (NRC) Research Associateship Program Review Panel (Betterton)
- Chair (Ritchie) or member (Ritchie, Zeng), National Aeronautics and Space Administration (NASA) Senior Review Committee of all existing satellite missions
- Member, National Academies Board of Atmospheric Science and Climate (Zeng)
- Chair, American Geophysical Union (AGU) Committee on Public Affairs (Betterton)
- Elected member, University Corporation for Atmospheric Research Board of Trustees (Betterton)
- Elected Fellow, American Meteorological Society (Zeng)
- Co-Chair, National Science Foundation/Atmospheric and Geospace Sciences (NSF/AGS) Community Workshop and White Paper on lower-atmosphere observing facilities (Zeng)
- Member, various national and international program committees (Castro, Ritchie, Zeng)
- Editor, various professional journals (Conant, Ritchie, Zeng)
- Chair, Recommendations committee, World Meteorological Organization (WMO) IWTC-VII, St. Denis, La ReUnion 2010 (Ritchie)
- Chair, Climate Panel, World Federation of Scientists (WFS), 2000-2010 (Sprigg)
- Distinguished Achievement Award, Carleton College Alumni Association, June 2012 (Krider)

Karl Berger Award, 30th International Conference on Lightning Protection (ICLP), Cagliari, Italy, September 13-17, 2010 (with M.A. Uman) (Krider)

- Provost of a major research university (UA) (Comrie)
- Principal Investigator, Depart of Interior (DOI) Southwest Climate Science Center (Overpeck)
- Energy and Climate Partners for the Americas fellow, US Department of State, 2011-present (Cole)
- Executive Committee Member, Association of American Universities (AAU) Association of Graduate Schools (AGS), 2010-2012 (Comrie)
- Lead author, IPCC AR5 Chapter, 2013 (Overpeck)
- Member, U.S. National Academy of Science, Committee on Ecological Impacts of Climate Change, 2008-2009 (Overpeck)
- Member, Board of Directors National Ecological Observatory Network, ongoing (Winter)
- Editor, various professional journals (Comrie, Overpeck)
- Board of Reviewing Editors, Science, (Overpeck)
- Google Science Communications Fellow, 2011 (Cole)
- Kavli Fellow, NRC Frontiers of Science, 2008 (Cole)
- Elected Fellow of the American Association for the Advancement of Science (AAAS), 2009 (Overpeck)
- American Geophysical Union Hydrology Section Walter B. Langbein Lecturer, 2011 (Shuttleworth)
- American Meteorological Society Robert E. Horton Lecturer in Hydrology, 2013 (Shuttleworth)
- Office of Naval Research Young Investigator Program Award, 2010 (Sorooshian)

D1c. Outcome Indicators

Research grants. One of the best indicators of ATMO faculty productivity is the consistent success in obtaining external research funding in terms of the total amount (Fig. D3), and with respect to other academic units in the College of Science (Table D1).

Faculty productivity. On average, faculty and students in ATMO publish 28 peer-reviewed papers/book chapters each year based on their bio sketches (see Table E1 in Chapter E), a number that is comparable to that in our previous APR (even though the tenure-track faculty number has decreased from 8.5FTE to the current 7 FTE).

Individual faculty contributions in research and their honors, awards, and service are summarized in Chapter E.

Student/teaching outcomes: The quality of teaching in ATMO is evaluated using standard course evaluation forms administered each semester by the Office of Institutional Research and Planning Support. ATMO scores have been comparable to those from our peers campus-wide (Table E3). Student outcomes and the results of an alumni survey are provided in Chapter I3.

D2. Comparison to Top 5 Public Institutions

Based on a consensus of ATMO faculty and the NRC (2010) report in Fig. D4, the top eight or so graduate programs in the atmospheric (and oceanic) sciences (but excluding oceanic programs only, such as the UC-San Diego Scripps Institute of Oceanography) in public universities include (alphabetical order, no implied order of rank): Colorado State University (CSU), Pennsylvania State University (PSU), Texas A&M University, University of California-Los Angeles (UCLA), University of Maryland-College Park, University of Oklahoma (OU), University of Washington, and University of Wisconsin-Madison. All of these programs have much more (instructional plus research) faculty. Seven of these programs are affiliated with major cooperative institutes with NOAA, while the other (UCLA) has a joint institute with the NASA Jet Propulsion Laboratory (JPL). These affiliations substantially increase the number of researchers, postdoctoral associates, and graduate students supported.

It is clear that to move our program into the top five nationally, irrespective of size, we need to double our faculty size from the current 7 to 14. To move our program into the top ten, we need to increase our faculty size by 4 (from current 7 to 11). Furthermore, (1) continue our efforts to seek major interdisciplinary research projects and joint institutes and centers with government agencies, and hence significantly increase the size of research scientists/postdoctoral associates and research faculty; and (2) make the best use of our joint faculty in joint publications, projects, and student advising.

FACULTY

E. FACULTY

As of fall 2013, ATMO includes 7 tenure-track faculty members (4 Full professors, 1 Associate Professor, and 2 Assistant Professors), 2 lecturers, and 2 Emeritus Professors who are still active. Through proactive planning in the past years, ATMO has successfully finished the transition from the first generation of faculty members who established our program and brought it to national and international prominence to current faculty members the ideal age group and rank structure. We also have 9 joint (voting) faculty members from Departments of Geosciences, Hydrology and Water Resources, Planetary Sciences, Mathematics, Chemical and Environmental Engineering, Geography and Regional Development, and Laboratory of Tree-Ring Research. Furthermore, we have 4 research faculty, 6 research scientists and postdoctoral research associates, and 15 affiliates/associates.

The starting year at UA (in parenthesis), title, degree/institution/year, and primary areas of interest of the current faculty are listed below. Asterisks indicate the faculty members who have been added since our last APR.

Tenure-track Faculty

*Arellano, Ave (2010), Assistant Professor, Ph.D., Duke University, 2005. Interests: Data assimilation; atmospheric chemistry and composition; chemical transport modeling and data analysis; remote sensing; biogeochemical cycles.

Betterton, Eric A. (1988), Professor, Ph.D., University of Witwatersrand, 1983. Interests: Atmospheric chemistry, aerosols, air pollution, cloud microphysics, water chemistry.

Castro, Christopher L. (2006), Associate Professor, Ph.D., Colorado State University, 2005. Interests: North American monsoon, summer climatology, and dynamical downscaling.

*Dominguez, Francina (2009), Assistant Professor, Ph.D., University of Illinois, Urbana-Champaign, 2006. Interests: Hydroclimatology, land-atmosphere interactions, precipitation recycling, climate change, dynamical and statistical downscaling, surface hydrology, regional climate modeling, atmospheric isotopic water tracers, extreme hydrologic events.

Mullen, Steven L. (1991), Professor, Ph.D., University of Washington, 1985. Interests: Ensemble weather forecasting, precipitation forecasting, hydrometeorology, forecast calibration and verification.

Ritchie, Elizabeth A. (2006), Professor, Ph.D., Monash University, Melbourne, Australia, 1995. Interests: Interaction of North American monsoon system with tropical cyclones, high-resolution weather forecast modeling, mesoscale dynamics, and numerical weather prediction, and hurricanes.

Zeng, Xubin (1994), Professor, Ph.D., Colorado State University, 1992. Interests: Land-atmosphere-ocean interface processes, climate modeling, hydrometeorology, remote sensing, nonlinear dynamics, global value-added data development, and model improvements for weather, climate, and hydrometeorological studies.

Emeritus Faculty

Herman, Benjamin M. (1962), Emeritus Professor, Ph.D., University of Arizona, 1963. Interests: Radiative transfer, atmospheric aerosol optics, remote atmospheric sensing. Retired in 2005.

Krider, E. Philip (1971), Professor, Ph.D., University of Arizona, 1969. Interests: Lightning, lightning detection, atmospheric electricity, thunderstorms. Retired in 2009.

Joint (Voting) Faculty (home unit in brackets)

Cole, Julia E. [Geosciences] (1995), Professor, Ph.D., Lamont-Doherty Geological Observatory of Columbia University, 1992. Interests: Tropical climate systems, natural variability, paleoclimatology.

Comrie, Andrew C. [Geography] (1992), Professor, Ph.D., Pennsylvania State University, 1992. Interests: Synoptic climatology, urban and regional air pollution, climate variability, climate and health.

Hirschboeck, Katherine K. [Laboratory for Tree Ring Research] (1991), Associate Professor, Ph.D., University of Arizona, 1985. Interests: Hydroclimatology, climatology of extreme events, and dendroclimatology.

Overpeck, Jonathan T. [Geosciences, Institute of the Environment] (1999), Professor and Institute of the Environment Co-Director, Ph.D., Brown University 1985. Interests: Earth system science, societal impacts, environmental decision support.

Restrepo, Juan M. [Mathematics] (1997), Professor, Ph.D., Pennsylvania State University 1992. Interests: Geophysical and theoretical fluid dynamics, nonlinear waves, computational science.

Showman, Adam P. [Planetary Sciences] (2001), Professor, Ph.D., California Institute of Technology 1999. Interests: Dynamics and evolution of planetary atmospheres and interiors.

Shuttleworth, W. James [Hydrology and Water Resources] (1993), Professor, Ph.D., Manchester University, 1971. Interests: Hydroclimatology, hydrometeorology, micrometeorology, land-atmosphere modeling.

*Sorooshian, Armin [Chemical and Environmental Engineering] (2009), Assistant Professor, Ph.D., California Institute of Technology, 2008. Interests: Surface and airborne measurements of aerosol composition, size, and water-uptake properties; aerosol-cloud-precipitation interactions; ocean-land-atmosphere interactions; cloud water and precipitation chemistry; satellite data analysis.

*Winter, Larry [Hydrology and Water Resources] (2009), Professor and HWRS Head, Ph.D., University of Arizona, 1985. Interests: Groundwater hydrology, land-atmosphere interaction, applied mathematics.

Lecturer

Weidman, Charles (1987), Lecturer, Ph.D., University of Arizona, 1982. Interests: Lightning, lightning detection, atmospheric electricity.

Ward, Dale (1998), Lecturer, Ph.D., University of Arizona, 1998. Interests: Atmospheric remote sensing, inverse theory, radiative transfer.

Research Faculty

Conant, William C. (2006), Research Associate Professor, Ph.D., University of California at San Diego, 2000. Interests: Aerosol-cloud-climate interactions, radiative processes in the atmosphere, aerosol and cloud physics, and energy budget of the climate system.

Cummins, Kenneth L. (2005), Research Professor, Ph.D., Stanford University, 1978. Interests: Lightning, lightning detection, thunderstorms.

Serra, Yolande (2004), Research Associate Professor, Ph.D, University of California San Diego, 1996. Interests: Tropical intra-seasonal variability, tropical-extra-tropical interactions of the North American monsoon, role of water vapor in convective organization.

Sprigg, William A. (1998), Research Professor, Ph.D., Yale University, 1972. Interests: Global change, climate, societal impacts.

Research Scientists/Postdoctoral Research Associates (Faculty supervisor in brackets)

Brunke, Michael (2000) [Zeng]. M.S., University of Arizona, 2000. Interests: Ocean-atmosphere, sea ice-atmosphere, and land-atmosphere interactions, particularly in climate processes.

*Chang, Hsin-I (2009) [Castro], Ph.D., Purdue University, 2009. Interests. Regional climate modeling, climate change, monsoon.

*Dolling, Klaus (2012) [Ritchie], Ph.D., University of Hawaii, 2011. Interests: Hurricanes and tropical meteorology.

*Hazenburg, Pieter (2012) [Zeng], Ph.D., Wageningen University, the Netherlands, 2013. Interests: Radar precipitation retrieval, global 1 km hybrid 3-D hydrological modeling.

*Kim, Chang Ki (2013) [Betterton], Ph.D., Yonsei University, Korea, 2011. Interests: Aerosols, atmospheric boundary layer, and clouds.

*Wood, Kim (2012) [Ritchie], Ph.D., University of Arizona, 2012, Interests: Hurricanes and tropical meteorology.

Affiliates/Associates

Adams, David: UNAM, Mexico

NOAA National Weather Service Forecast Office, Tucson: Bersack, Evelyn; Brost, John (Science and Operations Officer); Evans, Tom; Kahler, Chad; Lader Glenn; Lockridge, Joseph; Palacio, Kristl; Sampson, Glen (Meteorologist in Charge) ; Schmidt, James, and Zell, Gary.

Curran, Robert: University of Arizona

Nickovic, Slabandan: Geneva

Otarola, Angel: ATOMMS

Pejanovic, Goran: Belgrade

E1. Research and Scholarly Contributions

We have an exceptionally strong faculty that is highly productive in research and scholarships. In spite of our small size, our faculty address a diverse area of atmospheric sciences, and there is dynamic overlap in a number of areas, as evidenced by collaborations across research groups. Here, we briefly highlight the areas of expertise for which ATMO is best known.

Hydrometeorology (Castro, Dominguez, Mullen, Ritchie, Zeng; joint faculty Shuttleworth, Winter, and several other faculty from HWRS and other programs). We established the first hydrometeorology M.S. and Ph.D. programs in the U.S. and our expertise in this area is well known nationally and internationally. For instance, Shuttleworth is widely regarded as the father of hydroclimatology, having been awarded the American Geophysical Union Hydrology Section Walter B. Langbein Lecturer and American Meteorological Society Robert E. Horton Lecturer in Hydrology.

Regional and global climate (Castro, Dominguez, Ritchie, Serra, Zeng; joint faculty Comrie, Cole, Hirschboeck, Overpeck, Showman, Shuttleworth). We cover the broad areas of observational, modeling, and theoretical studies of climate, climate change, paleoclimate, climate applications (e.g., in water resources, agriculture), and planetary atmosphere. Our expertise in this area is well known nationally and internationally. For instance, Zeng is internationally known for his work in developing land and ocean surface parameterizations as well as global value-added data that have been used by National Center for Atmospheric Research (NCAR), National Centers for Environmental Prediction (NCEP), European Center for Medium Range Weather Forecasting (ECMWF), and numerous other groups worldwide. Overpeck is internationally known for his work on paleoclimate and climate applications.

Tropical meteorology and monsoon (Castro, Dominguez, Ritchie, Serra, Zeng; joint faculty Cole, Overpeck, Shuttleworth): We cover hurricanes and tropical meteorology, monsoon and other N. American regions, and ocean-atmosphere interactions. Our expertise in this area is widely recognized. For instance, Ritchie recently chaired the American Meteorological Society (AMS) Committee on Hurricanes and Tropical Meteorology (which is the largest science/technology committee in AMS, probably in the world), and Zeng chaired the AMS Air-Sea Interaction Committee.

Weather forecasting and data assimilation (Arellano, Castro, Mullen, Ritchie; joint faculty Restrepo, and staff member Leuthold). Our recent hire (Arellano) together with our existing expertise joint faculty (Restrepo) put us on the map for data assimilation. This strengthens our overall research at ATMO, as evidenced by the high demand on campus for inviting Arellano for joint proposals. At present, ATMO maintains a near-real-time weather forecasting and daily weather briefing/discussion during the monsoon season primarily by staff member Leuthold, with assistance from several faculty members. As Mullen (a well-known synoptic meteorologist) is near retirement (for health and family reasons), we urgently need a new hire to replace him in the next five years in order to maintain the expertise in weather forecasting. It would be a big loss for students and for the overall research at ATMO without a weather forecasting expert.

Aerosols and air quality (Arellano, Betterton, Conant, Sprigg, joint faculty Comrie, Sorooshian). The recent hire of ATMO tenure-track faculty (Arellano) and joint faculty (Sorooshian) along with our existing expert (Betterton) give us a critical mass in this important area. This is further strengthened by the linkage of air quality and climate to public health (Betterton, Comrie).

Lightning and atmospheric electricity (Cummins, Krider, Weidman). Following the APR Committee recommendation in 2006 and our own evaluations, we have decided not to hire in the area of atmospheric electricity. We still maintain a small lightning and atmospheric electricity program as Krider (Emeritus Professor) and Cummins (research professor) are still active in this area and also because of the student demand, but this is likely to diminish over the next three years.

Radiation and remote sensing (Conant, Ward, Zeng, joint faculty Sorooshian). We have lost our traditional strength, without a tenure-track ATMO core faculty dedicated to this area. We have also lost faculty members in this area in several other departments (SWES, Opitcal Sciences) at UA. This area has been identified by both SEES and IE as crucial for our university (in research, teaching, and potentially bringing big projects) and as a candidate area for future cluster hires. ATMO is looking forward to restoring our expertise in this area.

Summary of faculty productivity. Table E1 summarizes the ATMO publications and invited presentations (excluding joint faculty) with more detailed information provided in individual biosketches in Appendix B. On average, each tenure-track faculty member publishes 4 papers/book chapters and gives 2 invited talks per year. Similarly, each joint faculty publishes 4 papers/book chapters per year with more invited talks.

Table E1. ATMO annual publications and invited presentations. The 7-year average for joint faculty is shown in the final row.

	Peer-Reviewed Articles	Chapters	Invited Talks
2007	21	-	12
2008	21	-	13
2009	29	2	10
2010	27	5	23
2011	16	1	8
2012	34	1	17
2013	31	3	10
7-yr avg (ATMO faculty)	25.57	2.40	13.29
7-yr avg (Joint faculty)	33.14	2.14	45.14

The outstanding record of ATMO in annual research expenditure has been presented in Fig. D3 and Table D1. In particular, Table D1 shows that research overhead return divided by the state support (i.e., R1 – R2 in Table D1) is 0.18 for ATMO, much higher than those (0.05, 0.12, and 0.09) for GEOS, HWRS, and LTRR. It is much higher than that (0.12) for the College of

Science, and substantially higher than that (0.04) for the university. ATMO is one of the few departments to actually make a "profit" in this publicly funded university.

Besides the past annual research expenditure, Table E2 lists the number of currently funded projects, indicating that both ATMO faculty and joint faculty have successfully obtained the research grants necessary for continued growth in research in the next few years.

Table E2. Current number of funded projects as a function of the project ending year by ATMO and by joint faculty. Projects ending before Fall 2013 are not included.

	ATMO	Joint Faculty
2013	10	13
2014	11	10
2015	9	6
2016	7	3
2017	2	5
2018	-	2

During the APR period, a major project was the $5.5M/4yr NSF-funded project to set up a preliminary national network of soil moisture measurement in the U.S. based on the cosmic-ray neutron measurements, for which Zeng (ATMO faculty) and Shuttleworth (joint faculty) were two of the four Co-PIs. For current projects, Castro, Dominguez, and Zeng (all ATMO faculty) are Co-PIs of the NSF-funded $3.0M/5yr project to better understand the processes and patterns in The North American monsoon macrosystem. For the joint faculty, Overpeck is the PI of the NOAA-funded $3.5M/5yr project on adapting to climate variability, thresholds, and extremes in the Southwest (with 10 Co-PIs); he is also the PI of the DOI/USGS-funded $3.1M/5yr project to establish the Southwest Climate Science Center (with 5 Co-PIs). Restrepo is one of the 64 Co-PIs of the $112.5M project to study the effect of Deepwater Horizon oil spill on Gulf of Mexico.

E2. Participation, Leadership, and Influence

ATMO faculty are actively involved within UA and in our professional organizations, and many play prominent leadership roles in the field as a whole. The biosketches in Appendix B provide detailed information about individual faculty, and they are highlighted here (including joint faculty) in seven categories: National/International Committees and Service, Professional Societies, Editorial Service, National/International Awards and Honors, UA Awards and Honors, UA Service, and Community Leadership.

National/International Committees and Service (Aside from the usual roles of anonymous reviewing of journals and research proposals)

ATMO Faculty

- Co-Chair, NCAR Early Career Scientist Assembly (ECSA) Junior Faculty Forum on Future Scientific Directions 2010, 13-15 Jul, NCAR, Boulder, CO (Arellano)
- Member, UCAR Board of Trustees, 2012-present (Betterton)
- UCAR, Members Nominating Committee, Oct 2009-2010 (Betterton)
- National Academy National Research Council, Research Associateship Program Review Panels Chair, 2005-2009 (Betterton)
- National Academy National Research Council, Jefferson Science Fellows program, ongoing (Betterton)

- Contributing lead author, Southwest Climate Change Assessment, 2013 (Castro)
- U.S. Representative to Geophysics Commission, Pan American Institute for Geography and History, 2009-2012 (Castro)
- Invited Member, NASA Lightning Advisory Panel, 2012-present, (Cummins)
- Elected Member, University Corporation for Atmospheric Research (UCAR) President's Advisory Committee on University Relations (PACUR), 2011 – present (Ritchie)
- Chair Recommendations committee, WMO IWTC- VII, St. Denis, La ReUnion 2010 (Ritchie)
- Member, Joint Hurricane Test bed (JHT) Steering Committee, 2008-present (Ritchie)
- Member, National Academies Board on Atmospheric Sciences and Climate (BASC), 2008-2014 (Zeng)
- Co-chair, NRC Committee, 2011-2012 (Zeng)
- OAR/NOAA Outstanding Research Scientific Paper Award 2008 (Mullen)
- Invited Member, Army Research Laboratory Scientific Review Panel 2005-2007 (Mullen)

Joint Faculty

- CLIVAR working group on ENSO Diversity, ongoing (Cole)
- Energy and Climate Partners for the Americas fellow, US Department of State, 2011-present (Cole)
- NOAA Climate Change Task Force, Coral Reef Conservation program, 2008-2009 (Cole)
- Board member, Graduate Record Examination (GRE) Board (incl. service as member of Diversity, Equity & Inclusion Committee and Finance Committee), 2010-2014 (Comrie)
- Executive Committee Member, Association of American Universities (AAU) Association of Graduate Schools (AGS), 2010-2012 (Comrie)
- International Review Panelist, German Universities Excellence Initiative, German Research Foundation (DFG) & German Council of Science and Humanities (WR), 2011 (Comrie)
- Board member and Executive Board member (2010), Council of Graduate Schools, 2008-2010 (Comrie)
- National Stakeholder Advisory Committee for the Professional Science Master's Degree, 2010 (Comrie)
- Lead author, IPCC AR5 Chapter, 2013 (Overpeck)
- Nobel Peace Prize – contributed in leadership role as a Coordinating Lead Author of the Fourth Assessment of the Intergovernmental Panel on Climate Change (IPCC), 2007 (Overpeck)
- Member, U.S. National Academy of Science, Board on Environmental Change and Society, 2012- present (Overpeck)
- Member, Higher Education Climate Adaptation Committee, American College and University President's Climate Commitment, 2011-present (Overpeck)
- Member, Scientific Advisory Committee, Energy and Water in a Warming World Initiative – a partnership led by the Union of Concerned Scientists, 2011-present (Overpeck)
- Member, U.S. National Academy of Science, Committee on Ecological Impacts of Climate Change, 2008-2009 (Overpeck)

- Member, Federal Advisory Committee focused on “Climate change and the United States: Analysis of the effects and projections for the future – Unified Synthesis Product”, 2008-2009 (Overpeck)
- Member, University Corporation for Atmospheric Research Membership Committee, 2008-2011 (Overpeck)
- Member, Science Definition Team (SDT) for the NASA Jupiter System Observer (JSO) mission study, 2007 (Showman)
- Member, Board of Directors National Ecological Observatory Network, ongoing (Winter)
- Member, Advisory Committee, Institute of Arctic and Alpine Research (INSTAAR), ongoing (Winter)

Professional Societies

ATMO Faculty

- American Geophysical Union, Chair, Committee on Public Affairs, 2008-2010 (Betterton)
- American Institute of Physics, Advisory Committee for Public Policy, 2012 (Betterton)
- Invited Member, IEEE WG on Lightning Protection of Distribution Systems, 1995- present (Cummins)
- Elected Councilor American Meteorological Society, 2013-present (Ritchie)
- Organizer, Special Symposium (AMS Annual Meeting, Seattle, WA 2011), 2010 – 2011 (Ritchie)
- Elected Member, Board on Environment and Health, American Meteorological Society (AMS), 2012 – present (Sprigg)
- Chair, Climate Panel, World Federation of Scientists, 2000-2010 (Sprigg)
- Elected Member, Executive Committee of the American Meteorological Society (AMS), 2011-2013 (Zeng)
- Elected Member, Council (governing body) of the American Meteorological Society (AMS), 2010-2013 (Zeng)

Joint Faculty

- AAAS Climate Science Panel, ongoing (Cole)
- Executive Committee Member, Association of American Universities (AAU) Association of Graduate Schools (AGS), 2010-2012 (Comrie)
- Committee of the Division of Planetary Sciences of the American Astronomical Association, 2006-2009 (Showman)
- American Institute of Chemical Engineers (AICHE) Environmental Division Board Member, 2011-present (Sorooshian)

Editorial Service

ATMO Faculty

- Frontiers in Atmospheric Science, ongoing (Arellano)
- Editor, Atmospheric Chemistry and Physics, 2001-2009 (Conant)
- Associate Editor, Journal of Hydrometeorology, 2012-present (Dominguez)

- Editor, Monthly Weather Review, 2007 – 2010 (Ritchie)
- Contributing Editor, 2008-2010, AGU Atmospheric Sciences Newsletter (Serra)
- Editor, Advances in Atmospheric Sciences, 2009-2014 (Zeng)

Joint Faculty

- Editor for the Americas, International Journal of Climatology, 2004-2012 (Comrie)
- Editorial Board, The AAG Review of Books, 2013-present (Comrie)
- Editorial Advisory Board, Progress in Physical Geography, 2009-present (Comrie)
- Editorial Board, Environmental Science & Policy, 2007-present (Comrie)
- Editorial Board, Annals of the Association of American Geographers, 2006-present (Comrie)
- Editorial Advisory Board of the international journal Atmospheric Environment, 2000-2008 (Comrie)
- Member Editorial Advisory Board of The Anthropocene Review (Overpeck)
- Guest Editor – Environmental Research Letters Multi-issue Focus on 'Electricity, water and climate connections', (Overpeck)
- Founding Editor (with M. Miller and B. Morehouse) of the new "Summits: Environmental Science, Law, and Policy" book series, University of Chicago (formally at University of Arizona, (Overpeck)
- Appointed to Board of Reviewing Editors, Science, ? to 2011 (Overpeck)
- Associate Editor, Hydrological Sciences Journal, 1990-2008 (Shuttleworth)
- Associate Editor, Journal of Hydrology, 1990-2008 (Shuttleworth)
- Associate Editor, Hydrological Research, 2008-present (Shuttleworth)
- Associate Editor, Water Resources Research, AGU (ongoing) (Winter)

National/International Awards and Honors

ATMO Faculty

- NCAR Early Career Scientist Assembly (ECSA) award, NCAR 2010 summer (Dominguez)
- Best Paper of the Environmental Modeling and Software Society (for Mahmoud et al. 2009) (Dominguez)
- Distinguished Achievement Award, Carleton College Alumni Association, June 2012 (Krider)
- Karl Berger Award, "For distinguished achievements in the science and engineering of lightning research, developing new fields in theory and practice, modelling and measurements," 30th International Conference on Lightning Protection (ICLP), Cagliari, Italy, September 13-17, 2010 (with M.A. Uman) (Krider)
- 2008 OAR/NOAA Outstanding Research Scientific Paper (Mullen with T. Hamill and J. Whitaker)
- 2nd place poster award at the AMS 9th Conference on Artificial Intelligence and its Applications to the Environmental Sciences, 23-27 Jan, 2011 (Ritchie)
- Group Achievement Award, National Aeronautics and Space Administration, 2011 (Ritchie)

- Overseas Assessor, Chinese Academy of Sciences (CAS), appointed by CAS President, 2004-2007 (Zeng)
- Fellow, American Meteorological Society, 2011 (Zeng)
- Member, National Academies Board on Atmospheric Sciences and Climate (BASC), 2008-2014 (Zeng)

Joint Faculty

- Fellow, ARC Centre of Excellence in Climate System Science, Univ. Melbourne, 2013 (Cole)
- Honorary faculty, University of Melbourne School of Earth Sciences, 2013 (Cole)
- Google Science Communications Fellow, 2011 (Cole)
- Kavli Fellow, NRC Frontiers of Science, 2008 (Cole)
- Leopold Leadership Fellow in environmental policy and communication, 2008 (Cole)
- Elected Fellow of the American Association for the Advancement of Science (AAAS), 2009 (Overpeck)
- Senior Fellow, US Department of State, Energy and Climate Partnership of the Americas (ECPA), 2011 (Overpeck)
- Visiting Fellow, Victorian Centre For Climate Change Adaptation Research (VCCCAR), University of Melbourne, Australia, 2013 (Overpeck)
- Awarded Colorado State Hydrology Days Award (2011) “in recognition of outstanding contributions to hydrologic science with emphasis on evaporation, hydrometeorology, and the application of remote sensing methods in hydrology” (Shuttleworth)
- Selected 2011 American Geophysical Union Hydrology Section Walter B. Langbein Lecturer (Shuttleworth)
- Selected 2013 American Meteorological Society Robert E. Horton Lecturer in Hydrology (Shuttleworth)
- Editors’ Citation for Excellence in Refereeing for Journal of Geophysical Research-Atmospheres (2012) (Sorooshian)
- Invitee: 2013 National Academy of Engineering Frontiers of Engineering Education Symposium (Irvine, CA; 2013) (Sorooshian)
- Office of Naval Research Young Investigator Program Award (2010) (Sorooshian)

UA Awards and Honors

ATMO Faculty

- University Distinguished Professor Award, 2013 (Betterton)
- Professor Leon and Pauline Blitzer Award for Excellence in the Teaching of Physics and Related Sciences, 2012 (Betterton)
- UA at the Leading Edge Recognition, for cutting-edge research, 2012 (Betterton)
- Alumnus of the Year Award, College of Science, University of Arizona, 2012 (Krider)
- Blitzer Award for Excellence in Teaching of Physics and Related Sciences, Department of Physics, University of Arizona, 2008 (Krider)

- Fellow, Galileo Circle, College of Science, University of Arizona, 2008 (Krider)
- Distinguished Achievement in Science Education Award, UA College of Science, 2012 (Ritchie)
- Galileo Circle Fellow, the highest recognition awarded by the UA College of Science, 2011 (Zeng)

Joint Faculty

- Udall Fellowship in Environmental Science and Policy, 2012 (Cole)
- Leading Edge Researcher Award, U. Arizona Office of Economic Development, 2009 (Overpeck)
- Arizona Regents' Professorship University of Arizona, 2009 (Shuttleworth)
- College of Engineering Education Faculty Fellow, 2012-2014 (Sorooshian)

UA Service

ATMO Faculty

- UA NASA Space Grant Executive Committee, ongoing (Betterton)
- University Radiation Safety Committee, 2005-present; elected Chair 2012 (Betterton)
- Member, UA Superfund executive committee, ongoing (Betterton)
- University Faculty Senate, 2012-present (Castro)
- SEES Tier I course committee, 2011 (Castro)
- Sabbatical proposal reviewer, College of Science, 2011 (Castro)
- Local organizing committee, 35th National Weather Association Meeting, Tucson, Arizona, 2010 (Castro)
- Global Change Ph.D. Minor Executive Committee, 2013-present (Dominguez)
- Co-Director of the Hydrometeorology MS and PhD Program 2011-present (Dominguez)
- Search Committee: UA Hydrology and Water Resources Department Head Search, 2010-2011 (Dominguez)
- Member, COS Awards Selection Committee, 2005-present (Mullen)
- Member, COS Teaching and Advising Awards Committee, 2005-present (Mullen)
- Member, Blitzer Excellence in Teaching Committee, College of Science, 2006-2007 (Mullen)
- Member, Blitzer Excellence in Teaching Committee, College of Science, 2008-present (Betterton)
- Member, University of Arizona Committee of Eleven, 2012 – present (Ritchie)
- Director of Graduate Studies, Department of Atmospheric Sciences, 2009-present (Ritchie)
- Founding Director, Climate Dynamics and Hydrometeorology Center (CDHC), 2008-present (Zeng)
- Founding Co-Director, Hydrometeorology M.S. and Ph.D. Degree Program, 2009-2011(Zeng)

- Coordinator, Development of the strategy and white paper for pursuing a possible UA-NOAA partnership, 2007-2010 (including the submission of a White Paper to the NOAA Climate Program Office with 15 UA faculty members in May 2009) (Zeng)
- Member, University Distinguished Professors selection committee, 2008-2010 (appointed by Provost Meredith Hay) (Zeng)
- Member, Advisory Committee of the TRIF Water, Environmental and Energy Solutions (WEES) Initiative at UA (2012-2013) (Zeng)

Joint Faculty

- Board member, University of Arizona Foundation, 2012-present (Comrie)
- Co-Chair, University Space & Capital Committee, 2012-present (Comrie)
- Member, Strategic Planning and Budget Advisory Committee, 2012-present (Comrie)
- Member, Search Committee, Vice President for External Relations, 2011-2012 (Comrie)
- Senator, Faculty Senate & Senate Executive Committee member, 2009-2010 & 2012-present (Comrie)
- Chair, Search Committee, Dean of the College of Agriculture & Life Sciences, 2010-2011(Comrie)
- Global Change Graduate Interdisciplinary Program, Chair (University) (Hirschboeck)
- Campus-wide Reliable Course Management System Group (University) (Hirschboeck)
- Institute of the Environment Faculty Advisory Board (University) (Hirschboeck)
- Institute of the Environment Carson Scholarship Planning Committee (University) (Hirschboeck)
- Member, UA Presidential Advisory Council on Environmental Sustainability, 2010-present (Overpeck)
- Presidents Sustainability Transition Team, 2010-present (Overpeck)
- Coordinator (with D. Liverman) of Provost's Environmental Faculty Hiring Initiative, 2009-2012 (Overpeck)
- College of Science Promotion and Tenure Committee (2010-present, Chair 2011-present) (Shuttleworth)

Community Leadership

ATMO Faculty

- Chair, Pima County Environmental Quality Advisory Council, 2013-present (Betterton)
- Member, Sonoran Environmental Research Institute, Advisory Board, 2007-present (Betterton)
- Expert witness testimony in case State of Arizona vs. James Ray, 2013 (Castro)
- Provided training on the use of the Weather Research and Forecasting Model for operational weather forecasting by the Colombian Air Force, 2012 (Castro)
- Local media interviews or citations: KTVK-3 (Phoenix), KGUN-9 ABC News (Tucson), KOLD-13 CBS News (Tucson), KUAT-6 PBS (Tucson) program Arizona Illustrated, Arizona Republic, Tucson Citizen, Arizona Daily Star, Prescott Daily Courier, (Castro)
- Public Talk: Science Café: The Challenges of Monsoon Science, 2010 (Dominguez)

- Local media interviews or citations: KVOA-4 NBC News (Tucson), KOLD-13 CBS News (Tucson), 2010-2012 (Ritchie)
- Co-organizer, National Association of Geoscience Teachers (NAGT) webinar series for early-career faculty (Ritchie)
- Co-organizer, Adopt-A-School Volunteer Outreach to Tucson Elementary Schools, 2011-present (Ritchie)
- Co-organizer, Hollinger Elementary Science Fair, 2011-present (Ritchie)
- Leader, Early Career Workshop (NSF), College of William and Mary, Williamsburg, VA 2009-2011 (Ritchie)
- Local media interviews or citations: KOLD Channel 13, KVOA Channel 4, Arizona Daily Wildcat, National Geographic (Zeng)

Joint Faculty

- Interviews with local media (most recently: Tucson Green Times cover story, Sept 2010; Fox-11 Focus 30-min live-to-tape interview on Aug. 25 2010; AZ Daily Star science section and interviews with Tom Beal and Tony Davis) (Cole)
- Climate-related interviews with state and local press, radio, and television stations, multiple years (Comrie)
- Visiting speaker for community service organizations, societies, K-12 schools, etc., multiple years (Comrie)
- Member, City of Tucson Climate Change Committee (appointed by Mayor and City Council), 2009-2012 (Overpeck)

E3. Teaching

Classroom teaching in our department is carried out by our seven tenure-track faculty along with two lecturers. Occasionally, research faculty members teach or co-teach a course. Currently the default teaching load in our department for tenure-track faculty who are active in research and graduate training is 2 courses per year (or 1 course per semester) plus co-teaching an additional course in some years. To help new hires, ATMO allows them not to teach during the first semester after arrival. Faculty members who are not actively engaged in productive research are assigned a minimum teaching load of 4 courses per year (or 2 courses per semester). Each faculty member teaches both graduate and undergraduate general education courses following a departmental 2-year rotation.

In recent years we have substantially streamlined our course offerings (see Chapter I2).

The teaching load of our tenure-track faculty (on average about 2.3 courses per year) is comparable with that in other atmospheric science programs in the U.S. It is also comparable with that in other SEES units (GEOS, HWRS, LTRR), and College of Science in general.

The quality of teaching in ATMO is excellent. Across the past seven years, the quality is essentially the same as those for the comparison groups at the University, even though our courses are more rigorous than most of the departments on campus]. Shown in Table E3 are the average university Teacher-Course Evaluation (TCE) ratings for our courses and the effectiveness of our faculty instructors. For general education introductory courses, our scores are slightly lower than those of the comparison groups, partly due to increased difficulty level. For Tier 2 general education courses, and the undergrad courses, the student evaluation results for the comparison groups depend on the number of students enrolled (with higher scores for smaller classes) as expected. Since most of our upper-level general education classes have more than 60 students enrolled, our scores are higher than those for the comparison groups despite our increased difficulty level.

Table E3. Average teacher and course evaluations for (a) undergraduate lower- and upper-level courses and (b) graduate courses for (UA TCE scores) ATMO and UA comparison groups. The 6-year average division (2007-2013) with standard deviations (provided in parentheses) are listed. Scores are listed on 5-point scale with 5 the best (or most difficult). For undergraduate courses, ATMO almost always has > 60 students enrolled in each course, and the comparison group is separated into two categories: with >5 students enrolled and with >60 students enrolled.

(a) Lower and Upper Level Undergraduate Courses

	Freshman Tier 1 Courses			Tier 2 and Undergraduate Courses		
	ATMO	Comparison Groups		ATMO	Comparison Groups	
		>5 stud enrolled	>60 enrolled		>5 enrolled	>60 enrolled
Overall rating of teaching effectiveness	3.83 (1.27)	4.00	4.00	3.95 (.87)	4.10	3.86
Overall rating of the course	3.42 (.98)	3.60	3.69	3.47 (.91)	3.70	3.37
Difficulty level of the course	3.46 (.93)	3.39	3.39	3.41 (.84)	3.60	3.30

(b) Graduate Courses

	Graduate Courses	
	ATMO	Comparison Group
		>5 enrolled
Overall rating of teaching effectiveness	4.21 (.61)	4.21
Overall rating of the course	3.89 (.75)	3.90
Difficulty level of the course	3.51 (.70)	3.50

E4. Faculty Recruiting and Planned Directions for Future Faculty Hires

Faculty recruitment. The faculty composition has changed since the last APR in 2006-2007. Professors Ben Herman and Phil Krider retired, Bill Conant transitioned from a tenure-track faculty position to a research faculty position, and Rob Kursinski left the program to go to the private sector to focus on technology development. We have also hired two new assistant professors: Francina Dominguez and Ave Arellano. With these changes, the number of tenure-track faculty has decreased from 8.5 FTE in 2006/7 to 7 FTE at present, while the number of state-funded lecturers has increased from 1 FTE in 2006/7 to 2 FTE at present.

Future faculty hires. There has been a paradigm shift in faculty hires at UA from individual unit-based to "cluster hires." For this reason, with input from ATMO and other units, SEES and IE proposed several themes for cluster hires. Most relevant to ATMO would be:

- Radiative transfer and remote sensing. Justifications: UA has lost our traditional strength in this area at ATMO and other units; a cluster hire will help us to become a power house from hardware development to satellite missions (LPL, Astronomy, Optical Sciences), from remote sensing retrievals, modeling and data analysis, to satellite applications (ATMO, Aerospace Engineering, School of Natural Resources and Environment, …) – this would then increase our chances for major NASA earth science projects (such as satellite instrument and missions). We expect 1-2 faculty hires for ATMO in this area.
- Water and the environment. Justifications: This issue is critical for our State, the Southwest U.S., and arid and semiarid regions in the world; UA needs to continue and strengthen our national and international leadership position in this area (including hydrometeorology). We urgently need a new hire to replace Mullen in the next five years in order to maintain the expertise in mesoscale modeling, including WRF, and in weather forecasting, a specialty that is relevant to this theme. It would be a big loss for students and for the overall research at ATMO without a weather forecasting expert.

Furthermore, UA Provost has set up the Strategic Priority Funding Initiative (SPFI) funds to hire rising stars and exceptional faculty with a demonstrated track record of using diversity to advance cross-cutting innovations, and we are seeking and recruiting faculty through this initiative.

To be more ambitious (i.e., to move our program into the top five), we need to double our faculty size from current 7 to 14. To move our program into the top ten, we need to increase our faculty size by 4 (from current 7 to 11). With our excellent research and teaching efficiencies (see Table D1), this would be a win-win strategy for the University/College of Science and ATMO.

E5. Faculty Compensation and Comparison with Top 5 Public Institutions

Table E4 compares ATMO faculty salaries with those from UCAR member institutions based on the most recent survey in 2012. For assistant, associate, and full professors, our average salaries are $7K, $13K, and $7K lower than those at UCAR member institutions in atmospheric science.

Compared with other SEES units (GEOS, HWR, and LTRR) in the College of Science, our average are $8K, $10K, and $12K lower at the assistant, associate, and full professor levels, respectively. UA Administration is aware of the low salaries that characterize the entire UA system, not just ATMO, but claim that they are unable to close the gap. In the future this will lead to a situation of ad hoc retention approach for faculty who are offered positions elsewhere, and/or attrition.

Table E4. Comparison of 9-month academic year salary with University Corporation for Atmospheric Research (UCAR) member institutions and UA SEES units (GEOS, HWRS, LTRR) in 2012. UCAR Member Survey was published in February 2013.

Average 9-month Salary Earnings Comparison

	UCAR Salary Earnings		UA SEES Department Salary Earnings			
	All Disciplines	**Atmospheric**	**Atmospherics Sciences**	**Geosciences**	**Hydrology & Water Resources**	**Tree-Ring Laboratory**
Professor	$124,263	$122,535	$115,534	$118,935	$135,704	$128,886
Associate	$ 88,011	$ 85,545	$ 72,931	$ 86,762	$ 83,704	$ 78,058
Assistant	$ 73,053	$ 74,808	$ 67,767	$ 73,744	NA	$ 77,315

E6. Faculty Gender/Race/Ethnicity and Efforts towards Diversity

Our faculty diversity is excellent: among the seven tenure-track faculty members, 2 are females, and 5 males; 2 are Hispanic, 2 Asian, and 3 white. Both lecturers are white male.

E7. Biographical Sketches

Biographic sketches of faculty, joint faculty, and research faculty are included in Appendix B. Each includes professional preparation, appointments, research interests, honors and awards, publications and scholarly work, invited talks, number of contributed talks, current grants and contracts, major services, and synergistic activities. Some of these items are summarized in various chapters (e.g., Tables E1 and E2, Chapter E2).

UNIT ADMINISTRATION

F. UNIT ADMINISTRATION

F1. Organization and Governance Structure

ATMO is administered by a Head, who is appointed by the College of Science Dean (with input from faculty/staff and grad students). The Department Head is responsible for implementing and administering the programs and policies of the Department and representing the faculty to higher administration. As a small department, we do not see the need to officially appoint an Associate Head, but a faculty member (currently Zeng) is appointed by the Head to attend Associate Head meetings in the College of Science and sign Departmental paperwork when the Head is out of office.

The Head and the faculty are advised by an external ATMO Board of Advisors, currently chaired by Ruth Zollinger. The Board was established during the APR period. Its mission is to provide a core group of individuals from the community dedicated to: assisting ATMO in achieving its research and educational goals; and in stimulating interdisciplinary interaction with the School of Earth and Environmental Sciences (SEES) so as to maintain ATMO's preeminence as one of the top ranked departments in the College of Science and in the nation. The bylaws and membership of the Board as well as Board members' biosketches are available at: http://www.atmo.arizona.edu/index.php?section=people&id=board. The outstanding background of the Board includes:

- Gary Jones, President of Earthworks, Chair of ATMO board (on leave), and member of the Board of the College of Science
- Ruth H Zollinger, Ph. D., Vice President of Academic Affairs at Lakeland Community College (retired), Acting Chair of ATMO board, and Member of the College of Science Board
- Karl Gast, Ph.D., Aerospace Engineer at Raytheon
- Michael Marsicek, Commander of the USAF 25th Operational Weather Squadron
- Kevin Petty, Ph.D., Chief Science Officer, Vaisala Inc.
- Amber Sullins, Chief Meteorologist at TV channel ABC15 in Phoenix
- John Sullivan, Salt River Project's Associate General Manager for the Water Group
- Lelia Vann, Ph.D., former Director of the NASA Langley Research Center's Science Directorate.

ATMO has three standing committees: Promotion and Tenure that also handles annual faculty evaluations; graduate advising and admission; and curriculum. The Department Head appoints the chair and members of these committees. Ad hoc committees are formed and dissolved as special needs develop; for instance, faculty searches, special events, academic program review, and fundraising. These committees handle many aspects of the academic program (e.g. curriculum and student advising) and many daily operations of the Department (e.g., computers). The committees provide services and information to all faculty, and some provide services to students and staff, as appropriate. The committee Chairs call meetings on an as-needed basis, with the bulk of the communications being by email. Committee membership includes faculty (tenure-track, joint, and research), staff, and students, as needed. Besides committees, the Department Head appoints coordinators as needed, e.g., the seminar coordinator and the computing coordinator.

All staff, including a business manager, an administrative associate and an administrative assistant in the front office, and two computing staff, report to the Department Head, although additional layers of administrative structure are implemented. For instance, one computing staff reports to another to increase efficiency.

Research faculty report to the Department Head, while graduate students, postdoctoral associate, and research scientists report to the appropriate (tenure-track, research, or joint)

faculty. To encourage leadership, ATMO also allows postdoctoral associates and research scientists to submit proposals as PI.

For Departmental issues, graduate students can talk with faculty and Head directly. They can also communicate formally through their elected representatives who also attends faculty meetings.

Important academic and research matters are discussed and voted on at periodic faculty meetings for tenure-track, research, and joint faculty. Decisions such as graduate admissions, faculty hires, adjunct appointments, and curriculum changes are made by committees followed by a faculty vote. The Head calls meetings whenever needed. Besides faculty members, relevant staff are present at meetings. Furthermore, to increase the faculty-student interaction, a graduate representative is present at meetings.

To encourage closer collaborations, joint faculty have full voting rights and are encouraged to attend all faculty meetings.

F2. Classified and Professional Staff

ATMO has five classified and professional staff dedicated to faculty/student support: one business manager (Sandy Holford), one administrative associate (Lupe Romero) and one administrative assistant (Sarah Warren) in the front office, and two system and information technology staff (Cyrus Jones as a senior information technology support analyst, and Mike Leuthold as principal systems administrator). Four are partially covered by state funds, while one and part of the other four staff are covered by indirect cost revenue (ICR) to the Department.The staff include 3 female/2 male; 1 Hispanic/4 White.

There are currently two other research staff (Mike Brunke and Kyle Rine) who are funded by research grants for specific projects.

F3. Adequacy of Staff Support

The computer support from Leuthold and Jones in ATMO is excellent. Both of these staff members have degrees in atmospheric science (Leuthold, B.S.; Jones, M.S.) and have been working in the Department for 20+ years. They are also a valuable resource to units in SEES and to the Physics Department in the same PAS building.

The administrative support includes financial and grant management, teaching support, student paperwork, support to different committees, and support to the Department Head. With the expansion of our graduate program and research activities, the original staff of two (Holford and Romero) simply could not handle all the work. Therefore the Department decided to hire an administrative assistant (Warren) in early 2013. Now the administrative support by three staff members is adequate.

UNIT RESOURCES

G. UNIT RESOURCES

G1. Appraisal of Support Services

Support for teaching. The University provides a number of centralized resources that support instruction at both the undergraduate and graduate levels. The Office of Instruction and Assessment (OIA) is a campus resource that helps all faculty, instructional personnel, and researchers to integrate technology into academic activities. ATMO faculty take advantage of some aspects of the services provided through OIA, such as web-based tools ("**D**esire**2L**earn", D2L), in-class teaching evaluation and suggestions for improvement, and training material. There is a favorable appraisal of many of these resources.

Website support. The Department's information technology staff provide efficient and effective services, including the development, operation, and maintenance of the ATMO website.

Computing and technology Services. The system and information technology staff (Jones and Leuthold) are responsible for maintaining our email account (@atmo.arizona.edu) and in-house, state-of-the-art computing systems for research and instruction. In 2008, ATMO constructed a new High Performance Computing/Server room in the basement of the PAS building, featuring restricted access, raised floor, dedicated power and A/C. This infrastructure has played a critical part in the rapid expansion of ATMO's computational resources. The room houses three large HPC clusters as well as many disk servers, all connected by a local Infiniband network providing very high speed and low latency communications. The facility contains more than 2200 processor cores and 350 Terabytes of storage making it amongst the largest on campus. ATMO has also upgraded its backup service by expanding the existing tape libraries and adding a large disk based virtual tape library with a capacity of 250TB of space. A partial listing of the networked equipment is given in Table G1.

Besides serving our Department, our staff also assist other departments (e.g., other SEES units, Physics Department) when needed.

Besides the computing resources within the Department, some of the faculty/researchers/students also use the email account @email.arizona.edu and supercomputers available from the University Information Technology Services (UITS). Furthermore, as a result of our research grants from NSF, NOAA, NASA, and DOE, we also get access to the supercomputers at national laboratories/centers for some of our computing needs.

Only by maintaining our own dedicated HPC computing system can we provide operational forecasts i.e. 24/7. By contrast, UITS prioritizes "jobs" and there is no guarantee that a forecast will be run on time.

Table G1. Computing resources at ATMO.

UNIX Servers	
10	High capacity disk servers
3	High Performance Computing clusters
2	Web/Email server, backup server
1	130TB DLT Tape library
UNIX Workstations	
30	Linux desktop workstations
PCs and MACs	
15	Windows based workstations
5	Apple workstations
15	Windows Laptops
5	Apple Laptops
Printers	
4	Networked Color printers
5	Networked B/W printers
5	Color printers dedicated to Windows or OS/X workstations
3	B/W printers dedicated to Windows or OS/X workstations
1	Networked multi-function Color printer/scanner
2	Multi-function Color printer/scanner/FAX connected to a networked Windows workstation
2	B/W Scanners connected to networked Windows workstations

Research support. While computing support for research is adequate, there is a lack of laboratory space for atmospheric physics and chemistry, and for technology development. This will adversely affect the recruitment and retention of faculty and researchers in the future as we strive to double our research funding as described in *Never Settle*.

There is also a lack of institutional support for writing large and sophisticated grant applications. This is not an issue for the Department per se, but it is relevant to us, as ATMO faculty have been proactive in submitting large proposals. The University is currently taking actions to address this issue.

Support for outreach and funding-raising. We do not have dedicated staff in this area. The two staff in the front office (Romero and Warren) and business manager (Holford) provide the support. Faculty, staff, and students volunteer their time and efforts as well. Through SEES, ATMO does have access to a ¼ FTE staff person housed in GEOS, but this is far from adequate to strengthen the support in this area would be to share a staff member or two for all SEES units.

Administrative support. There are a number of University resources that provide excellent support for the department administration. UA Office of Human Resources provide advice and guidance on personnel issues. The Office of Provost offers several support services for department administrators, such as the centralized support of Promotion and Tenure (P&T),

diversity, and academic program review. The College of Science provides advice and guidance on department business management, promotion and tenure, instruction, and other faculty affairs.

Overall. While ATMO has adequate support across a wide range of areas, there is clearly a need for laboratory space and facilities, since these elements are essential for continued success and growth (see next section).

G2. Specific Resource Needs

Office and laboratory space in ATMO. As mentioned in Chapter G1, there is a need for laboratory space facilities. There is also an urgent need for office space:

- With the increase in the student body of our program over the past few years, there is not enough office space for students and researchers. To a large degree, office and laboratory space has become a serious constraint on program building and federal funding levels; we now house 3 graduate students in PHYS office space for the first time.
- Our current PAS building was built in the 1950s and needs major renovations.

In the late 1980's, ATMO was instrumental in heading a national movement to co-locate NOAA/National Weather Service forecast offices to university campuses, and in convincing NOAA to erect the first phase of Environmental and National Resources Building (ENRB1) to house the Tucson National Weather Service Forecast Office and other federal groups (USGS) on campus. UA is now constructing a second building in the ENRB complex (as ENRB2). While ATMO was initially listed to move into this new building, it is surprisingly left out of the final plan in favor of accommodating the needs of the Math Department and Geography. This is a missed opportunity to co-locate SEES faculty under one roof and give some cohesiveness to a widely scattered group of scientists.

Library. We maintain a small library within the Department which is also a very convenient place for science topic discussions, student interactions, and pre-seminar receptions. Our primary library needs (both physical and online resources) are met through the university's main library and science library.

Classrooms and classroom support. Most of our graduate courses are taught in PAS building room 488, and this room, originally used as a laboratory decades ago, is in desperate need of renovation and modernization.

Most of general education courses are taught outside of the PAS Building. In the past few years, the University has made a concerted effort to outfit classrooms with technical equipment including computer projectors and wireless internet connections that facilitate classroom technology utilization, and the support has been excellent. An issue for ATMO and all other units teaching large classes has been the difficulty in finding such classrooms, and the University is continuously addressing this issue.

Office support. The personnel resources as discussed in Chapter F3 are adequate.

Graduate assistants. Teaching assistants are an important support for faculty teaching large classes. Teaching assistantships from the College of Science are adequate. Most of our graduate students are supported by research assistantship from research grants. With our success in seeking and obtaining grants, research assistantship support of graduate students is adequate. With the challenge in federal budget, ATMO, just like all other units, needs to work even more aggressively to continue our success in seeking federal research grants.

G3. Projected Changes if Additional Resources Available

If additional resources are available for faculty expansion and increased office and laboratory space and facilities (through the faculty start-up package), we would anticipate the following

enhancements to our department's quality to contribute more to the "*Never Settle*" strategic priorities:

- "*Never Settle*" strategic priority A: further growth in quality and quantity of our graduate program; enhanced diversity through the ability to attract highly qualified candidates from underrepresented groups; provide a more dynamic educational experience
- "*Never Settle*" strategic priority B: superior investment returns to the University through increased research grants and teaching activities (as demonstrated by our excellence in research and teaching efficiencies); enhanced partnerships with external (national and international) institutions; better positioning to pursue major research opportunities
- "*Never Settle*" strategic priority C: provide the online BAS program to all UA students; better serve the University's land-grant mission with contemporary and global strategies; fostering strategic partnerships with the weather and climate enterprise
- "*Never Settle*" strategic priority D: increased chance of becoming a NRC top-ten atmospheric science program in the U.S.; enhanced interdisciplinary collaborations

UNDERGRADUATE STUDENTS, DEGREE PROGRAMS AND OUTCOMES

H. UNDERGRADUATE STUDENTS, DEGREE PROGRAMS, AND OUTCOMES

H1. Undergraduate Degree Program

ATMO does not offer a B.S. degree in atmospheric science at present. However, we have just developed a new Bachelor of Applied Science (BAS) online program (to be discussed in Chapter H3).

H2. Contributions to General Education

ATMO offers two general education courses for undergraduates at the UA including multiple sections of a large "Tier 1" course (ATMO170A1: Introduction to Weather and Climate) and multiple sections of a smaller "Tier 2" course (ATMO336: Weather, Climate, and Society). Tier courses must be completed by all degree-seeking undergraduate students in order to satisfy the UA's General Education and Foundations requirements that are designed to provide breadth of knowledge and complement the in-depth knowledge provided by the major department. The undergraduate Tier courses are planned by our faculty and coordinated through University-wide General Education Committee. These courses respond to the needs and interests of the general student body.

Besides a lecturer (Weidman), the tenure-track faculty, by rotation, also teaches the large courses (ATMO170A1) each semester. ATMO336 is primarily taught by a lecturer (Ward).

Traditional and web-based courses. With university support, ATMO has also developed the web-based version for these two general education courses, which are offered in summer as well as academic year.

Teaching quality. The quality of our general education courses is regularly assessed using the student evaluations (TCE) at the end of each semester, and in some instances, through instructor-administered evaluations at mid-semester. There are also informal discussions among the Tier instructors at regular intervals. In particular, the scientific level of each course, the effectiveness of the in-class demonstrations and experiments, and the strengths and weaknesses of the available textbooks are discussed.

The high demand from students is reflected by the large number of student credit hours shown in Fig. D1. The student evaluations are also comparable to the peer groups on campus (Table E3).

The instructors of Tier courses periodically attend university-sponsored workshops on undergraduate education administered by the UA Teaching Center seeking ideas on how to improve the overall quality and effectiveness of their teaching. We also confer with instructors at other atmospheric science departments and other departments within the UA for ideas. The content of the ATMO courses is carefully compared with the content of other introductory courses in the UA College of Science (particularly within SEES) to avoid overlaps. Different sections of the Tier courses are now coordinated within ATMO so that the textbooks, syllabi, and the choice and order of presentation of the topics are similar.

Contributions to other undergraduate degrees. Besides General Education courses, ATMO also offers several (junior and senior) undergraduate courses (co-convened with graduate students) to students in other fields (e.g., geoscience, hydrology, environmental science, engineering). To be efficient with our small faculty size, these undergraduate courses are combined with our graduate courses. To maintain the quality of our graduate courses, we only accept undergraduate students with the relevant quantitative background. We have also developed introductory courses (e.g., ATMO436A/536A: Fundamentals of the Atmospheric Sciences) to help graduate students and undergraduate students with less quantitative background to catch up.

H3. The new Bachelor of Applied Science (BAS) online program

ATMO, through the UA-South campus, is offering a Bachelor of Applied Science (BAS) degree for students interested in the study of weather and climate. Initially, we are focusing on the U.S. active-duty military personnel.

UA has been approved by the Air University Associate to Baccalaureate Cooperative Program (AU-ABC) to provide a Meteorology online bachelor's degree program (i.e., Applied Science major with the specialization in Meteorology) for Community College of the Air Force (CCAF) graduates in weather technology (or equivalent). As the only online meteorology program in the United States leading to a BAS degree in Meteorology, this degree has been designed in close collaboration with Pima Community College and the 25th Operational Weather Squadron at Davis-Monthan Air Force Base in Tucson.

The mission of this BAS program is to serve the educational needs of military personnel both locally and abroad to become professional meteorologists eligible for promotion. The program is offered entirely online allowing students to access classes around their work schedules wherever they are located in the world. By applying the AAS credits toward the BAS degree, airmen will effectively eliminate the first two years of study. At full time status a BAS degree can be earned within two years by completing the 60 additional semester hour credits.

Its pre-requisites include:

- Active duty in the United States Military
- Hold an Associate of Applied Science degree with a concentration in weather technology or the equivalent
- Strongly encouraged to have completed coursework in calculus, though completion of pre-calculus is acceptable

The BAS program objectives are:

- To develop scientific skill sets to become effective leaders in weather-related careers
- To utilize the most current scientific concepts to frame and solve meteorological problems
- To develop math and physics skills suitable for use in other scientific disciplines

Currently there are eight active students for Fall Semester 2013 with an additional two new students admitted for Spring 2014 in the BAS program. For instance, these students include US Air Force and Navy active-duty personnel stationed in South Korea and an aircraft carrier. There are also 14 students who did not attend in Fall 2013 but who could have. We have also received 90 inquiries.

The establishment of the BAS demonstrates the teaching creativity of ATMO faculty in meeting the demands with very limited human (i.e., faculty and staff) resources. This also results from the strong support from the College of Science and the Provost's Office. For instance, the Advising Office in the College of Science (rather than ATMO front office) helps to provide academic support service to BAS students. The support of the ATMO Board of Advisors is also crucial in seeking financial support and linkage to community college.

Full evaluation of the BAS program. The BAS program has a great start so far, but it is still so new (with no students graduated yet) that a full evaluation would be premature. Here two relevant problems and our action plans are discussed:

First, in discussions with Pima Community College (PCC), a commitment was made by Pima to convert several of their courses needed for this degree to an online format. Recently it was discovered that with changing administrators at the PCC campus responsible for the

development of all PCC online courses that the third course in the calculus sequence for the BAS degree had not been converted. The director of the PCC online department also indicated that there were no current plans to do so.

ATMO is considering two possible options for students. The first would entail substitution of another Pima Math course which may be comparable to the material needed for students to succeed in the new BAS degree. Another option is that if COS can find the dollars needed for the PCC course to be converted to an online format, PCC's director will try and move the course into an earlier slot in their course development list. However, the time for the conversion to an online format could mean that some students ready to take this third math course would be delayed in their progress toward the BAS degree. They also might not have acquired the skill and knowledge from this course to succeed in subsequent higher level ATMO courses.

The second issue is a more serious one. The BAS offered through UA South has a foreign language requirement which was not noted at the time the degree was approved. It was overlooked because this degree is built on top of a two year Associate of Applied Science (AAS) Air University degree, an innovative but new approach for UA. The normal student coming to UA for a four year degree would be expected to fulfill the language requirement in their first two years of college. The AAS degree from the Air University does not have such a requirement.

The Head of ATMO has been in consultation with the Provost's office and will be submitting a proposal for a waiver of the foreign language requirement for this degree.

Future direction of the BAS program. With the initial success of the BAS program and our experience in online program, the University has encouraged us to consider the conversion of the BAS program into a B.S. online degree program open to all UA students. We will further assess this possibility by getting more feedback from students and colleagues from successful online programs. We will also consider the financial consequences resulting from the implementation of the Responsibility-Centered Management (RCM) business plan across campus. Finally we will need to make sure we (the faculty and staff) do not stretch too thin particularly if there is no opportunity to hire new faculty and staff. It should be noted that the Department did have a successful undergraduate B.S. degree program 10 years ago, and was asked by the University to terminate it for the right reason (i.e., with a small faculty size, the Department should focus on graduate education only).

GRADUATE STUDENTS, DEGREE PROGRAMS AND OUTCOMES

I. GRADUATE STUDENTS, DEGREE PROGRAMS AND OUTCOMES

I1. Graduate Program Description

ATMO has had a graduate degree program since the emergence of atmospheric sciences as a distinct academic discipline in the mid-twentieth century. There are three principal missions that have guided the trajectory of our graduate academic program since our last APR in 2006:

1. To maintain a rigorous curriculum in the atmospheric sciences graduate degree, that contains both breath in fundamentals and depth in key sub-disciplinary focal areas, that continues to build on the accomplishments and seminal disciplinary contributions by our previous faculty through our department's proud history.
2. To offer more cross-disciplinary, innovative curriculum program options beyond a traditional Atmospheric Sciences graduate degree, so as to be academically competitive with our peer institutions, increase graduate student enrollment, and be more synergistically integrated with other academic units within the College of Science.
3. To provide our graduate students the opportunity to participate in cutting-edge research in the atmospheric sciences or closely related field and effectively communicate their research to both the scientific community and public at large.

We currently offer M.S. and Ph.D. degrees in Atmospheric Sciences (CIP code: #40.0401) and in Hydrometeorology (CIP code: #30.1801) (jointly with HWRS) and an Accelerated Master's program (in cooperation with the Department of Physics).

I1a. M.S. and Ph.D. in Atmospheric Sciences

Our traditional Atmospheric Sciences graduate program has been sustained in the department since its inception. The current sub-disciplinary research focal areas are: atmospheric chemistry and aerosols, weather forecasts and data assimilation, regional and global climate, lightning and atmospheric electricity, radiation and remote sensing, tropical meteorology and monsoon, and hydrometeorology.

The degree program has undergone a major overhaul since the previous APR. Notable improvements include the streamlining of graduate examination procedures for the Ph.D. degree, provision of sample curriculum plans, and handbooks that detail Ph.D. and M.S. degree requirements. All of the graduate degree information that is summarized in this section is conveniently posted on-line on the Department website under the Students' link.

M.S. Degree: Requires 33 units of graduate work, including a core of 6 units of dynamic meteorology and 6 units of physical meteorology, a minimum additional 12 units of graduate-level elective coursework, 2 units of seminar, and minimum 3 units of research. Candidates must submit a thesis that has been judged by the student's committee to be acceptable for publication in a peer-reviewed professional journal in atmospheric sciences or closely related field, and present the results formally at the annual Atmospheric and Interdisciplinary Research (AIR) graduate student conference at the University of Arizona and/or at a scientific meeting. The typical course sequence is completed by the end of the second academic year. The majority of new graduate students enroll for the M.S. degree, with the intention of finishing at that level or continuing on for a Ph.D.

Ph.D. degree: Requires completion of at least 36 units of graduate course credit, including the core 6 units of dynamic meteorology and 6 units of physical meteorology, which typically carry over from M.S. degree for continuing students. An additional 18 units of other graduate level atmospheric sciences courses and 6 units of graduate-level elective coursework complete the 36 credit requirement. In addition, the candidate must fulfill a minor degree requirement (normally 12 units, depending on the minor department) and 18 units of dissertation credit. To attain a

Ph.D. degree, the candidate must complete the following in accordance with ATMO departmental and University of Arizona graduate college requirements:

- A departmental qualifying written examination, administered either prior to formal acceptance into the Ph.D. program for a continuing M.S. student or within a year and a half of entering program for a new graduate student that enters the program at the Ph.D. level,

- An advanced written and oral comprehensive examination, administered by the graduate committee, with submission of a dissertation proposal prior to the exams, and

- A dissertation that summarizes the candidate's original research, including an oral defense with a public presentation in the form of a seminar to the department.

- It is a nominal departmental requirement that the bulk of the dissertation document should consist of three separate scientific articles that are suitable for publication in a peer-reviewed professional journal in the atmospheric sciences or closely related field. As with M.S. students, Ph.D. candidates are required to present their research at the Atmospheric and Interdisciplinary Research (AIR).

  http://www.atmo.arizona.edu/index.php?section=grads&id=air) annual graduate student conference and/or a scientific meeting.

I1b. M.S. and Ph.D. in Hydrometeorology

The new graduate program in Hydrometerology, jointly administered by the Department of Atmospheric Sciences and the Department of Hydrology and Water Resources, offers graduate degrees of M.S. and Ph.D. The Hydrometeorology graduate program was formally established in 2010, after final approval from ABOR. This completely new graduate academic program is the first of its kind in the United States and is a major milestone achievement for ATMO since the previous APR, when the program was suggested as only a possible future idea.

The overall objective of the Hydrometeorology graduate program is to provide graduate students with a comprehensive understanding of the coupled hydrological interactions between the atmosphere and land. The core courses include fundamentals of atmospheric and hydrologic sciences. Elective courses are in focal areas of: tools and methods for numerical modeling, prediction; system science and methods; and data sciences and data manipulation tools, including remote sensing and geographic information systems (GIS). Beyond the combination of curriculum from ATMO and HWRS, an alignment of two different departmental cultures was necessary in order to develop a cohesive academic program that has high visibility and attracts top quality graduate students. This process has taken considerable effort from the participating ATMO and HWRS faculty and is ongoing as the program is still in its infancy. For the Ph.D. degree, the examination procedures are slightly different from the Ph.D. requirements for the Atmospheric Science degree and there is no minor requirement. For both M.S. and Ph.D., each student needs to have co-advisors with one from ATMO and another from HWRS. Thesis or dissertation articles should be suitable for publication in a peer-reviewed journal in Atmospheric Sciences, Hydrology, Hydrometeorology, or a closely related field.

M.S. degree: Requires 30 units of graduate course work, including a core of 6 units of fundamentals of atmospheric science courses (Dynamic Meteorology I and Physical Meteorology I) and 6 units of fundamentals of hydrologic sciences courses (Fundamentals in Surface Water Hydrology and Hydroclimatology), a minimum of 6 units from graduate course electives in the focal areas, and a minimum of 3 research credits. Students are encouraged to take all their graduate course electives in selected courses within the focal areas listed above, though there is

flexibility based on course availability and the discretion of the advisors. The thesis submission and presentation requirement and amount of time needed to complete the course sequence are otherwise nearly identical to the Atmospheric Sciences M.S. degree.

Ph.D. degree: Requires completion of 45 units of graduate course work, only in the major field of study. This includes the 12 units of core courses and 6 units in each of the three course elective focal areas. The remaining 15 units are elective courses of the student's choosing with the approval of the advisors. Students are also required to take a minimum of 18 units of dissertation credit in either ATMO or HWRS. To attain a Ph.D. degree, the candidate must complete the jointly established ATMO-HWRS departmental requirements and University of Arizona graduate college requirements. These are nearly identical to those for the Atmospheric Sciences Ph.D. degree, with the major exception that the departmental qualifying examination is both a written and oral examination.

I1c. Atmospheric Sciences Accelerated Master's Program

The new Atmospheric Sciences accelerated master's program (AMP) is designed for advanced undergraduate students at the University of Arizona to complete the B.S. degree in Physics and M.S. degree in Atmospheric Sciences in a total of five years, i.e. a 4+1 program. AMP is well suited for students who aim to gain research experience at the graduate level, and are interested in pursuing a career in atmospheric sciences. The program is not available to undergraduates who have completed a B.S. degree from another institution. AMP students complete undergraduate-level courses during their first three years. By December of the junior year the student must submit an application to the AMP program. Upon acceptance, students continue to fulfill undergraduate requirements during the Spring of the junior year, including the required AMP course Fundamentals of Atmospheric Sciences (PHYS 436a). Students then take a combination of undergraduate and graduates course in their senior year to complete their B.S. degree, including the core graduate-level courses in Physical Meteorology and Atmospheric Dynamics. During this time, the students also begin to develop research ideas for their graduate work. In the fifth and final year, students focus on graduate course work in the Department of Atmospheric Sciences and completion of the thesis requirement. A minimum of 33 credits of courses in ATMO, including research credit, is necessary to attain a M.S. degree in Atmospheric Sciences through AMP.

I2. Graduate Program Curriculum and Courses

Graduate course offerings in ATMO are maintained by a standing course curriculum committee, and curriculum chair. As a smaller department compared to our peer institutions, we leverage the graduate course offerings in other departments, particularly by joint ATMO faculty. The list of faculty approved graduate courses is available at:

http://www.atmo.arizona.edu/index.php?section=grads&id=gradcourses.

Every semester there are always 6 credits of core ATMO graduate courses offered (Physical and Dynamic Meteorology) and typically at least 30 credits of available graduate course electives (10 courses), of which 9-12 credits (3 to 4 courses) are offered by tenure-track ATMO faculty and lecturers. The course curriculum chair maintains a two year course rotation, and an updated version of this rotation is provided annually to ATMO faculty. The current version of this rotation is shown in Fig. I1 and contains a convenient color coding course classification scheme for quick and easy visual interpretation. Adoption of the two-year course rotation since the previous APR has been beneficial to ATMO faculty for the long-term curriculum planning, advising students on their plans of study, and identifying needs for new graduate courses and their sequencing.

Teaching Rotation: Fall 2013-Spring2015 **ATMO – Updated December 2013**

Year Even – Fall 2014		**Year Odd – Spring 2015**	
ATMO 170: (2 sec. x 150 per)	**Mullen, Betterton?**	ATMO 170 (1 sec. x 300)	**Eric Betterton?**
ATMO 170: (2 sec. x 150 per)	Chuck Weidman	ATMO 170 (2 sec. x 150 per)	**Mullen**, Weidman
ATMO 170 online (150)	Steve Mullen	ATMO 170 online (150)	Steve Mullen
ATMO 336 (2 sec.)	Dale Ward	ATMO 336 (2 sec.)	Dale Ward
ATMO 336 online (100)	Dale Ward	ATMO 336 online (100)	Dale Ward
ATMO 441/541a: Dynamics I	Xubin Zeng	ATMO 441/541b: Dynamics II	Liz Ritchie
ATMO 451/551a: Physical I	Francina Dominguez	ATMO 451/551b: Physical II	Ave Arellano
ATMO 469a: Air Pollution I	Ave Arellano	ATMO 595c Observational and Climate Modeling	Xubin Zeng
ATMO 472/572: Weather Analysis (formerly Synoptic Met.)	Chris Castro	ATMO 489/589: Atm. Electricity	Chuck Weidman
ATMO 580: Tropical Meteorology	Liz Ritchie	**ATMO core faculty elective?**	**Francina Dominguez**
ATMO 590: Remote Sensing for study of planet Earth	Van Leeuwen	ATMO 436a/536a: Fundamentals of Weather and Climate	**Steve Mullen?**
ATMO 579: Climate Dynamics	Jianjun Yin	ATMO 469b: Air Pollution II	Armin Sarooshian
GEOS 578: Global Change	Cole, Saleska	ATMO 656: Radiative Transfer and Remote sensing	Caitlin Griffith
HWRS 543A: Risk Assessment	Larry Winter	ATMO 524: Hydroclimatology	Shuttleworth, Niu
ATMO 577: Topics App. Math	**???**	**ATMO 523: Hydrology**	**TBD**
SNRE 527: Carbon Cycle	David Moore	**ATMO 577: Topics App. Math**	**??**
GEOG 539A: Dendrochronology	Trouet or Hughes	ATMO 641: Geophysical Fluid Dynamics	Adam Showman
WSM 560A: Watershed Hydrology	Shirley Papuga	WSM 502: Air and Water: Physics of Environmental Fluids	Shirley Papuga
		WSM 696Q: Practical and Applied Hydrometeorology	Shirley Papuga
		Electives in planning stages?	**??**
2 x ATMO core courses **3x ATMO Core Fac. Electives** **?? x Outside ATMO electives**	**5 x Tier I** **3 x Tier II**	**2 x ATMO core courses** **?? x ATMO Core Fac. Electives** **?? x Outside ATMO electives** **1 x ATMO Broad Interest**	**4 x Tier I** **3 x Tier II**
		NOTES: Chris Castro on sabbatical	
Year Odd – Fall 2013		**Year Even – Spring 2014**	
ATMO 170 (1 sec. x 300)	Steve Mullen	ATMO 170 (1 sec. x 300)	Steve Mullen
ATMO 170 (2 sec. x 150 per)	Chuck Weidman	ATMO 170 (2 sec. x 150 per)	Chuck Weidman
ATMO 170 online (150)	Steve Mullen	ATMO 170 online (150)	Steve Mullen
ATMO 336 (2 sec.)	Dale Ward	ATMO 336 (2 sec.)	Dale Ward
ATMO 336 online (100)	Dale Ward	ATMO 336 online (100)	Dale Ward
ATMO 441/541a: Dynamics I	Xubin Zeng	ATMO 441/541b: Dynamics II	Xubin Zeng
ATMO 451/551a: Physical I	Francina Dominguez	ATMO 451/551b: Physical II	Ave Arellano
ATMO 469a/569a: Air Pollution I	Eric Betterton	ATMO 558: Mesoscale Modeling	Chris Castro
ATMO 529: Objective Analysis	Chris Castro	ATMO 579: Boundary Layer	Francina Dominguez
ATMO 580: Tropical Meteorology	Liz Ritchie	ATMO 436a/536a: Fundamentals of Weather and Climate	Eric Betterton
ATMO 545: Data Assimilation	Ave Arellano	PTYS 517: Atmospheres and Remote Sensing	Adam Showman
HRWS 543A: Risk Assessment	Larry Winter	GEOS 547: Global and Regional Climatology	Hirshboeck, Russell
GEOS 582: Paleoclimatology	Overpeck, Cole	ATMO 524: Hydroclimatology	Shuttleworth, Niu
GEOS 578: Global Change	Cole, Saleska	ATMO 523: Hydrology	Juan Valdes
ATMO 577: Topics Applied Math	Maier	ATMO 573: Earth system modeling	Jianjun Yin
ATMO 530: Remote Sensing for study of planet Earth	van Leeuwen	WSM 502: Physics of Env. Fluids	Shirley Papuga
ATMO 537: Physics of Sun	Giacalone	WSM 696M: MATLAB for Environmental Data Processing	Shirley Papuga
ATMO 579: Climate Dynamics	Jianjun Yin	GEOG 530: The Climate System	Connie Woodhouse
GC 572: Biogeochem. Cycles	Brooks, Leavitt		
WSM 560A: Watershed Hydrology	Shirley Papuga		
GEOG 539A: Dendrochronology	Truet		
GEOS 567: Inverse Problems	Richardson		
2 x ATMO core courses **4 x ATMO Core Fac. Electives** **10 x Outside ATMO electives**	**4 x Tier I** **3 x Tier II**	**2 x ATMO core courses** **2 x ATMO Core Fac. Electives** **1 x ATMO Broad interest** **8x Outside ATMO electives**	**4 x Tier I** **3 x Tier II**
		NOTES: Liz Ritchie on sabbatical	

Purple – ATMO Broad interest **Orange** – ATMO core **Green** –ATMO Electives by core faculty **Cyan** – GenEd Gray: Online
Yellow– Electives with ATMO cross-listings electives or by joint ATMO faculty **White** – Additional electives
* **Red** – STILL UNCERTAIN OR ADDITIONAL INFORMATION NEEDED

Figure I1. ATMO 2-year course rotation.

Graduate course offerings by ATMO faculty: Core required graduate courses in Physical and Dynamic Meteorology are taught every year (coded in Orange in Fig. I1) and graduate course elective offerings are taught once every two years (coded in Green in Fig. I1). The new course Fundamentals in Atmospheric Sciences (ATMO 436a/536a) is an introductory-level course open to graduate students and upper-division undergraduate students pursuing degrees in natural and applied sciences, and is also offered every year. The graduate course elective offerings reflect the sub-disciplinary areas of research specialization of the ATMO faculty. All new faculty hires since the previous APR have been vital to maintaining the overall integrity of the ATMO graduate course curriculum, with respect to both core courses and elective course options in the sub-disciplinary research foci. New graduate course electives taught in the period since the last APR include: Objective Analysis in the Atmospheric and Related Sciences (ATMO 529: Castro), Mesoscale Meteorological Modeling (ATMO 558: Castro), Tropical Meteorology (ATMO 580: Ritchie), Boundary Layer Meteorology (ATMO 579: Dominguez), Data Assimilation (ATMO 545: Arellano), and Physical Climatology (ATMO 521: Conant).

In addition, some of the older elective courses, that existed at the time of the previous APR, have been transferred to new faculty with substantial revamping of course structure, for example Synoptic Meteorology (ATMO 570: Castro) and Air Pollution I (ATMO 569a: Arellano) and Air Pollution II (ATMO 569b: Sorooshian). With the increase in our graduate student enrollments and our success in attracting graduate students from other units, all graduate elective courses have generally sustained a healthy level of enrollment by College of Science criteria, defined as 5 or more students. Enrollment has been buoyed by non-ATMO students for the graduate courses that have been cross-listed. To best utilize the limited faculty resources in recent years due to the discontinuation of two faculty members not yet been replaced, the teaching of graduate courses is currently prioritized to those tenure-track faculty that have actively funded research projects that support funded research assistantship positions in ATMO.

Course offerings by joint and research faculty at ATMO: Integral to a wide variety of graduate course elective offerings is the inclusion of ATMO-approved elective courses from other departments on the University of Arizona campus (coded in yellow and white on Fig. I1). Departments offering these graduate courses are Geosciences (GEOS), Hydrology and Water Resources (HWRS), Lunar and Planetary Laboratory (LPL), and the School of Natural Resources and the Environment (SNRE). ATMO is consulted on the content of course syllabi if the instructor is a joint ATMO faculty member (Yellow in Fig. I1). Though not all of these courses on the list have specifically designated ATMO cross listings, as University of Arizona graduate college is currently abolishing the practice of graduate course cross listing, this issue is not relevant. The availability of these external graduate course offerings provides viable graduate elective course options in the sub-disciplinary areas of atmospheric chemistry, land-atmosphere interactions, climate and global change, and radiation and remote sensing. Our graduate course elective leveraging strategy greatly helps ATMO to maintain academic competitiveness relative to our peer institutions with a larger department and has provided somewhat of a buffer to recent losses in graduate courses taught by former tenure-track ATMO faculty in the area of remote sensing. Besides the courses in Fig. I1, ATMO students also take courses from engineering departments (e.g., electrical and computer engineering).

I2a. Adequacy of Graduate Curriculum and Coursework.

Our required core curricula of Dynamic and Physical meteorology is common to the peer-competitive Atmospheric Science graduate programs in the United States and utilize well-accepted standard textbooks in the Atmospheric Sciences in these subjects (Introduction to Dynamic Meteorology by James Holton, Atmospheric Science-an Introductory Survey, by John Wallace and Peter Hobbs, and Fundamentals of Atmospheric Physics, by Murry L. Salby). The content within our graduate course electives is also generally comparable to our peer institutions, reflecting the professional S&P training of our faculty from institutions with high reputations in the

atmospheric and related sciences, per the current NRC rankings (see Fig. D4). The available course elective options currently cover all of our sub-disciplinary focus areas, albeit some better than others, allowing the majority of our graduate students to tailor a personalized graduate course curriculum to adequately address their research needs. The overall high quality of our graduate academic program is evidenced by our comparison to peer institutions, particularly when considering a similarly small program size (see Table D2). In those instances where the available graduate courses do not address a particular student's research needs, ATMO advisors typically provide professional training opportunities in the scope of their funded research projects, for example short courses at National Center for Atmospheric Research or extended research visits to other academic institutions.

There are several sub-disciplinary research areas in Atmospheric Sciences and Hydrometeorology that are currently in need of graduate elective courses and should be addressed in a longer-term strategy of new faculty hiring within ATMO and the University of Arizona, College of Science as a whole. Of highest priority is the need for graduate elective courses in remote sensing (satellite and radar meteorology) and atmospheric radiation that are taught by an ATMO tenure-track faculty member. Remote sensing and atmospheric radiation were traditional strengths of the program, through the contributions of faculty such as Professors Ben Herman and Sean Twomey. It is necessary to quickly reclaim these strengths to fully exploit the rapid growth of remote sensing technologies for weather and climate monitoring. Other, less urgent, priorities for either new graduate courses or reviving dormant electives already on the books would include: general circulation and modes of climate variability, cloud microphysics, mesoscale meteorology, additional climate statistics (beyond what is already taught in Objective Analysis), (in situ and remote sensing) instrumentation, and oceanography. The past history with new ATMO elective course offerings since the prior APR strongly suggests that additional graduate course electives would be generally attractive to students pursuing graduate degrees in the earth and environmental sciences, consistent with our mission to make ATMO more interdisciplinary and synergistic within the College of Science. ATMO is presently trying to sequence some of these courses in the two-year rotation with our current faculty teaching resources, as open graduate course elective slots become available. Recently, ATMO students have also expressed an interest in courses related to policy, conservation, and energy.

Though the graduate course electives offered outside of ATMO do provide a wide variety of course options for graduate students and are vital to maintain a peer-competitive graduate academic program, there are two issues we need to address. First, these courses sometimes do not fully address the academic needs of ATMO graduate students. Criticisms from ATMO graduate students of these external electives usually fall into one of two categories: a) A lack of an equivalent level of quantitative depth to the graduate course offerings by tenure-track ATMO faculty; or b) the amount of prerequisite technical knowledge required or the way the material is presented, more geared for a different discipline, makes course content too challenging. Second, ATMO does not have the administrative authority to influence the sequencing of any external elective offerings in the two-year course rotation, even by joint ATMO faculty. These courses may be changed or cancelled purely at the discretion of the faculty member's home department, and this may cause disruption to a student's graduate plan of study.

I2b. Active Learning Strategies

Activities within graduate courses

All ATMO graduate courses incorporate aspects that help their students quickly orient them to accessing information through online resources and gain competency in writing and presentation by executing a final term project. Some courses like Physical Meteorology and Air Pollution involve field trips to NWS office or air pollution monitoring stations. Students in the Dynamic Meteorology course also visited the US Air Force 25th Operational Weather Squadron in fall 2013. Some graduate courses, for example Objective Analysis and Data Assimilation, additionally require students to use computer coding and data visualization packages as part of their assignments, in a manner similar to what they might do in a research application. Students are generally encouraged to incorporate aspects of their own research activities directly in their final course projects, and these final course projects may sometimes evolve into components of the student's thesis or dissertation and/or published papers.

Department Colloquium

All first year graduate students are required to attend department colloquiums and write a summary of presented research at these colloquiums for one unit of course credit. Colloquiums are offered at least bi-monthly and are open to all. Speakers include ATMO faculty members, other UA faculty, and visiting faculty and researchers from other institutions. The required attendance at colloquiums helps first-year students quickly orient themselves to current research topics in the atmospheric and related sciences and develop possible ideas for their graduate research projects. The department provides travel support for colloquium speakers from outside the university or the local area.

Teaching Assistantships (TAs)

Some first-year graduate students are supported by teaching assistantships (TAs). TAs provide crucial instructional support to the administration of the department's Tier I and Tier II undergraduate courses (ATMO 336 and ATMO 170a). Responsibilities as a TA typically include grading of homework assignments and exams, preparation of exam questions, holding weekly office hours, and leading exam review sessions. TAs are encouraged, on occasion, to prepare and present class lectures under the supervision of the course instructor. The TA experience provides the graduate student valuable real-world experience in teaching undergraduates and helps solidify the concepts they are already learning in the core ATMO graduate courses during the first year.

Research Experiences

Though not explicitly required as part of the Atmospheric Sciences or Hydrometeorology degree, many of our graduate students participate in unique research experiences during the course of their degree. These experiences generally can be categorized as research visits and short courses at government research laboratories and other universities, within the United States and abroad, participation in field campaigns or data collection, and laboratory work (in the Atmospheric Chemistry lab in PAS). Funding for these types of activities is usually provided by research projects of the major advisor.

I2c. Instructional Technology

Nearly all graduate courses maintain course websites, through ATMO computing systems or by Desire to Learn (D2L) software from the university, and these resources are quite adequate. Some ATMO graduate courses require students to use computer programming and data visualization tools as part of their curriculum, for example C, FORTRAN, and MatLAB, and introduce students to the use of numerical atmospheric models. Licenses for proprietary software like MatLab are available through the university.

A computer server in ATMO fully dedicated for instructional purposes would be helpful for some courses that require specialized software applications or use numerical modeling. ATMO has identified the need for a preparatory course in computer programming for some first year students that may not have this background, and is actively investigating options to address this problem through provision of an additional computer programming course with NCAR.

I2d. Adequacy of Resources

Human resources for teaching of graduate courses

ATMO is successful in maintaining the core graduate course offerings and general education undergraduate courses at the same time. To have a healthy and stable level of graduate elective course offerings in all of the sub-disciplinary focal areas, however, new faculty hires are needed.

ATMO elective graduate courses presently can only be offered once in a two-year rotation, and this can be sometimes problematic for graduate students needing to take specific elective courses for their research projects. The tightness of the two-year course rotation leaves little flexibility to accommodate for faculty leaves of absence, due to family and medical leave or sabbaticals, in coverage of graduate courses. A shortfall in the number of graduate electives by tenure-track ATMO faculty is presently unavoidable, even when faculty absences can be reasonably planned for in the course rotation. Though availability of the external elective graduate offerings do substantially help in that regard, these courses can sometimes be less than optimal for ATMO graduate students, for the reasons previously described in Chapter I2a.

Potential actions that can be taken to alleviate the graduate teaching shortage problem, individually or in combination, in order of preference, are:

- Additional faculty hire(s) that would be housed in ATMO, with the sub-disciplinary area of remote sensing and radiation being highest priority. ATMO should have primary control in any candidate search and hiring process in order to ensure that the background of the candidate best satisfies the department's needs, to the extent that doing so is both feasible and amicable to the College of Science and the University.

- Permanently shifting teaching responsibilities of the general education, undergraduate Tier I and Tier II courses (ATMO 170a and ATMO 336) to lecturer and/or professor of practice positions, which may allow new graduate course electives to be offered absent provision for additional faculty hires. This would probably not diminish the quality or appeal of our Tier I and II courses, and continue the recent trend of prioritizing graduate core instruction to the tenure-track ATMO faculty. As evidence, the current lecturer instructor for ATMO 170a, Dr. Chuck Weidman, consistently receives the best student evaluations for this course.

- Hire specialized lecturers to teach in-house ATMO electives in the sub-disciplinary areas where ATMO faculty expertise is lacking. There is some precedent in the academic history of the department for doing this, for example the offering of a Radar Meteorology graduate course formerly taught by Dr. Robert Maddox. Specialized lecturer positions may provide a route to tap expertise of recently retired faculty or researchers that may still have an interest in teaching and working with graduate students.

Classrooms for administration of graduate courses

Nearly all core-ATMO graduate courses are administered in room 488 in the PAS building. This classroom has modern, multimedia capabilities, equipped with a desktop computer, internet access through an ethernet cable that can be connected to the desktop or a laptop, and overhead projector. ATMO instructors typically utilize these capabilities in their lectures, for example to display educational material from the internet, give lecture presentations, or access computer codes or data visualization software. Otherwise, the furnishings of PAS are outdated and the room is substandard as a graduate classroom. The uncomfortable chairs, well-worn tables, and cabinets with old equipment in the back reflect the original use of this room as a laboratory decades ago.

The Department and ATMO Board of Advisors have discussed the possibility of using private funding, likely from a corporate sponsor, to modernize the room. A more permanent solution would be to consider a complete renovation of ATMO facilities within the PAS building or relocation of the department to a newer building at some point in the future.

Graduate student workspace

All enrolled graduate students in the Atmospheric Sciences program are provided a designated workspace within the ATMO-designated areas in the north wing of the PAS Building, including part of the fourth floor, the entire fifth floor, and a “penthouse” laboratory on the roof. Enrolled Hydrometeorology graduate students may also have workspace in PAS, and typically do so if their major advisor is an ATMO faculty member. A graduate student workspace consists of a desk, some shelving space, and internet access through an ethernet cable in a shared office. Individual computer workstations and wireless connections are usually provided by the major advisor, through their funded research projects. Prioritization for more spacious graduate student workspace is given to more senior graduate students, with new workspace assignments made by the graduate student coordinator at the start of each academic year. The smallest of the graduate student workspaces are those located in PAS 526, referred to as the “bullpen” area with approximately eight cubicles, and by design, these are almost always occupied by first-year students. Graduate students are also free to work in the ATMO library, and this is frequently used by them as a study area during the normal workday.

ATMO currently does not have sufficient graduate student office space within ATMO-designated areas in PAS with our recently increased enrollment. ATMO is currently borrowing additional office space from the Department of Physics within the PAS building. ATMO graduate students have generally commented that crowded graduate student workspaces, in particular the “bullpen” area, can be more difficult physical environment to work productively in if all the students are there at the same time. Like the aforementioned problem with the PAS 488 classroom, provision for graduate workspace should be considered in a long-term renovation or relocation plan.

Graduate computer lab and photocopying

The department maintains several computers and printers in a graduate computer laboratory (PAS 560). There are both color and black and white laser printers that are available for graduate students to print any materials related to their research and coursework. Two photocopiers are

located in the department's mail room (PAS 536) and may be used for authorized purposes only with password protected access. Most of the graduate students that would use these photocopiers are graduating teaching assistants for the undergraduate Tier I and II courses.

Graduate student travel support

In the last several years, ATMO graduate students are able to get partial or full travel support for participation in professional conferences, through ATMO internal resources and other programs on campus (e.g., Institute of the Environment, Water Sustainability Program, Graduate and Professional Student Council). Awards are limited to a maximum of $500. To apply for these awards, a graduate student must submit their meeting abstract, a brief statement of interest, and a letter of support from their major advisor. Most graduate student recipients of these awards attend the annual meetings of the American Meteorological Society or the American Geophysical Union.

I2e. Interdisciplinary Education

Ph.D. students in the Atmospheric Sciences program are required to take at least 12 units of a graduate minor. The choices of minors reflect the other departments that ATMO closely collaborates with on research projects and graduate teaching activities, most of which were already specifically mentioned earlier. Atmospheric Sciences graduate students may also elect to take their minor in Global Change, which provides minor course options in multiple departments within SEES. As the new graduate program in Hydrometeorology is already considered interdisciplinary by the design of its prescribed curriculum, there is no Ph.D. minor requirement for this degree. ATMO graduate elective course offerings are quite integrative within the College of Science as a whole, thereby facilitating research activities that better address pressing societal issues with interdisciplinary research strategies, such as air pollution, global and regional climate change, development of alternative energy, and water resource availability. The strong interdisciplinary nature of ATMO research activities and courses provides the department a unique and competitive niche, as contributing unit within a university that is nationally recognized for its excellence in the area of earth and environmental sciences.

I3. Graduate Students

I3a. Recruitment and Quality of Students

Student recruitment efforts occur through a variety of ways, including:

- Maintaining a student page on the ATMO department website that provides detailed information on all the graduate programs offered (see prior Sections I1a, I1b, and I1c), steps to submit an application package, and contact information for the graduate student advisor.

- Preparation of convenient one page handouts and brochures for the graduate programs in Atmospheric Sciences and Hydrometeorology that are available in the department main office and can be distributed at public events or professional conferences. These are displayed on the cover pages of this Report.

- Having a clearly visible presence at the annual professional meetings of the American Meteorological Society (AMS) and the American Geophysical Union (AGU). ATMO faculty and graduate students staff a Department of Atmospheric Science table at the AMS Career Fair.

- Participation in professional and public events at the University of Arizona that showcase the research activities of graduate students and faculty. For example, the annual Atmospheric and Interdisciplinary Research (AIR) conference is a one-day mini conference of graduate student presentations that is held in the UA Student Union during the month of April.

- Quickly responding (within a week) to interested potential students when they directly email ATMO faculty. These interested students are directed to the student page on the ATMO website and are encouraged to submit an application.

- Providing travel assistance (including lodging and local transportation) to potentially interested graduate students that have applied to the program for a departmental visit (including meeting with faculty, staff,, and students; and touring campus).

- Existing students' participation and presentations at AMS local chapter (SEACAMS).

Table I1. ATMO M.S. applications statistics.

ATMO Master of Science (M.S.) Graduate Program Applications and Admissions								
Academic Year (Fall-Spring)	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	7 Year Average
Characteristics of M.S. Applicants								
# Applicants	25	18	21	17	19	17	22	19.86
Male	15	9	13	8	11	9	8	10.43
Female	10	9	8	9	8	8	14	9.43
Domestic	23	17	20	15	16	11	14	16.57
International	2	1	1	2	3	6	8	3.29
# Admitted	11	5	13	13	7	7	8	9.14
% Admitted	44%	28%	62%	76%	37%	41%	36%	46%
# Matriculated	8	4	8	6	7	7	8	6.86
Characteristics of M.S. Class								
Male	3	2	5	2	5	4	3	3.43
Female	5	2	3	4	2	3	5	3.43
Domestic	8	4	8	5	6	4	6	5.86
International	0	0	0	1	1	3	2	1
Verbal GRE	152.00	159.50	149.50	153.67	151.57	149.57	152.63	152.63
Quantitative GRE	152.50	155.50	154.00	152.33	160.86	153.71	156.13	155.00
Analytical Writing GRE	4.58	4.75	3.83	3.90	4.00	3.71	4.07	4.12
GPA	3.54	3.65	3.31	3.23	3.41	3.52	3.59	3.46

Table I2. ATMO Ph.D. applications statistics.

ATMO Doctor of Philosophy (Ph.D.) Graduate Program Applications and Admissions								
Academic Year (Fall-Spring)	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	7 Year Average
Characteristics of Ph.D. Applicants								
# Applicants	14	12	18	19	9	8	9	12.71
Male	6	7	10	10	7	5	5	7.14
Female	8	5	8	9	2	3	4	5.57
Domestic	11	9	8	11	3	4	3	7.00
International	3	3	10	8	6	4	6	5.71
# Admitted	3	5	9	7	5	4	5	5.43
% Admitted	21%	47%	50%	37%	56%	50%	56%	45%
# Matriculated	1	5	3	4	4	4	5	3.71
Characteristics of Ph.D. Class								
Male	1	2	2	3	3	3	2	2.29
Female	-	3	1	1	1	1	3	1.67
Domestic	1	4	2	4	2	3	2	2.57
International	-	1	1	0	2	1	3	1.33
Verbal GRE	151.00	152.20	145.67	157.50	150.00	147.00	153.00	150.91
Quantitative GRE	155.00	152.80	153.67	156.00	155.67	158.33	157.60	155.58
Analytical Writing GRE	4.50	4.40	3.83	5.17	4.00	3.67	3.60	4.17
GPA	3.56	3.64	3.54	3.80	3.31	3.41	3.65	3.56

The typical number of applicants each year to all M.S. and Ph.D. programs is about 20 and 13, respectively (Tables I2 and I3). There has been greater variability in the number of Ph.D. applicants from year to year, and the Ph.D. applicants include both new incoming students and continuing M.S. students already enrolled in a graduate degree program. The M.S. applicant number does not vary much from year to year (by no more than three students) from its seven-year average of approximately 20. The admittance rate ranges 40-50%, on average, but has varied substantially from year to year, depending on the particular applicant pool. Considering the graduate students that are actually matriculated in the program, there has been a relatively steady influx of approximately 7-8 new incoming M.S. students and 3-5 new incoming Ph.D. students per year since 2007. The number of matriculated students annually is sufficient to maintain the integrity of the graduate program, such that each academic and research faculty member in ATMO has the option to become a major advisor to at least one new graduate student advisee each year and there is a stable enrollment in the core graduate courses, defined as a course enrollment of five students or more.

The quality of our graduate student applicants that have been admitted reflects our ranking as a high-performing, but relatively smaller department, as compared to our peer institutions. Considering the seven-year averages, the M.S. and Ph.D. accepted graduate applicants had the following objectively measured average academic characteristics:

- GRE Scores: 151 for verbal reasoning (49th percentile), 155 for quantitative reasoning (61st percentile), and 4.1 for analytical writing (approximately 58th percentile). Therefore, as a whole, graduate student applicants to the Atmospheric Sciences and Hydrometeorology programs are typically in the top 50% of all students that take the GRE exam and perform relatively stronger in quantitative reasoning and analytical writing.

- GPA: Typically in the range of 3.4 – 3.6, reflecting undergraduate performance in the A and B grade range. The quantitative courses relevant to success in the core graduate courses, especially mathematics and physics, are typically scrutinized on the transcripts that are included in application packages. Applicants with overall GPAs lower than 3.0 or applicants who have poor academic performance in quantitative-related undergraduate courses are typically not admitted to any of our graduate programs.

I3b. Enrollment Trends

The total graduate student enrollment has steadily increased over the past seven years, starting a low of 24 students in 2006 and increasing to 35-37 students annually during the years 2010-12 (Table I3). Part of this recent growth is attributable to the matriculations into the new graduate degree programs of Hydrometeorology and the Accelerated Master's Program (AMP) and part is from an increasing number of M.S. students that have decided to continue on for a Ph.D. Note that the table includes students from the Department of Hydrology that eventually completed Hydrometeorology degrees. In the last three years the small ATMO faculty has been challenged to teach and advise a relatively greater number of graduate students.

Table I3. ATMO graduate student enrollment statistics.

ATMO Graduate Student Enrollment by Program							
	Fall 2006	Fall 2007	Fall 2008	Fall 2009	Fall 2010	Fall 2011	Fall 2012
Masters	13	14	17	17	19	17	16
Doctorate	11*	13*	12*	12	18	18	20
Total Graduate Students	24	27	29	29	37	35	36
Graduate Student Credit Hours	294	346.02	394.01	303	449	333	291
Faculty FTE	9	8	8	9	9	9	8

*Includes graduate students who began their program in hydrology and completed hydrometeorology degrees.

I3c. Gender, Race, and Ethnicity of Graduate Students

Gender: Considering M.S. graduate students, the graduate student body is nearly evenly balanced between male and female (Table I4), and is very comparable overall nationally to programs in Earth, Atmospheric, and Oceanic sciences, according to a recent NSF national survey. However, the number of female Ph.D. graduate students has averaged approximately 30% over the past seven years. This number is lower than the national average, and also lower than the College of Science and the University of Arizona as a whole. Though ATMO does have a greater proportion of female academic and research faculty than in the period prior to 2006, this gender imbalance in Ph.D. graduate students has only slightly improved since then.

Table I4. ATMO graduate student gender distribution.

Degree	Gender	Fall 2006	Fall 2007	Fall 2008	Fall 2009	Fall 2010	Fall 2011	Fall 2012	ATMO 7-yr Avg	COS 7-yr Avg	UA 7-yr Avg	U.S.*
M.S.	F	53.8%	57.1%	41.2%	52.9%	35.3%	38.9%	52.9%	47.5%	58.3%	54.7%	44.2
	M	46.2%	42.9%	58.8%	47.1%	64.7%	61.1%	47.1%	52.5%	41.5%	45.1%	55.8
Ph.D	F	27.3%	23.1%	30.8%	33.3%	33.3%	29.4%	31.6%	29.8%	40.8%	49.4%	44.2
	M	72.7%	76.9%	69.2%	66.7%	66.7%	70.6%	68.4%	70.2%	58.3%	50.5%	55.8

*National data from National Science Foundation (NSF) 2011 Survey for Earth, Atmospheric and Ocean Sciences http://www.nsf.gov/statistics/srvygradpostdoc/

Race/Ethnicity: Considering M.S. graduate students, the percentage of students of underrepresented groups that are U.S. citizens is roughly comparable or better than the national average of programs in Earth, Atmospheric, and Oceanic sciences, according to a recent NSF national survey (Table I5). Two particularly positive highlights for ATMO in the statistics for M.S. graduate students include a greater than average enrollment of Hispanics (7.1%) compared to the national average (5.2%) and the steadily increasing trend in enrollment of underrepresented groups since 2006. However, the same cannot be said for Ph.D. students (Table I6), as the department has not had a U.S. citizen Ph.D. student that is Native American/Pacific Islander, Hispanic, or African American. It should be noted, in spite of the challenge of recruiting U.S. citizen students of underrepresented groups to the Ph.D. program, the percentage of non-resident alien enrollment in M.S. and Ph.D. programs has increased on the order of 10-20%. These non-resident alien students come from countries located in Asia, Latin America, and Europe. The diversity of cultural and linguistic backgrounds of these international students has been an asset to the department in pursuing international research opportunities and has helped to broaden the cultural perspectives within the department. Though ATMO has made great strides in diversifying its faculty, in terms of ethnicity, we are presently continuing our efforts to attract faculty from underrepresented groups. ATMO is currently pursuing potential hiring opportunities through the Strategic Priorities Faculty Initiative (SPFI), which is designed to advance equal opportunity, diversity, and inclusion within the UA (http://facultyaffairs.arizona.edu/sites/default/files/2013-2014-spfi-guidelines.pdf).

Table I5. ATMO M.S. student ethnicity distribution.

Race/Ethnicity of Master of Science Students (%)											
Ethnicity with International	**Fall 2006**	**Fall 2007**	**Fall 2008**	**Fall 2009**	**Fall 2010**	**Fall 2011**	**Fall 2012**	**ATMO 7-yr Avg**	**COS 7-yr Avg**	**UA 7-yr Avg**	**U.S.***
American Indian/Alaska Native	0.0	0.0	11.8	0.0	0.0	5.6	5.9	3.5	2.5	3.8	1.0
Asian American	7.7	0.0	0.0	0.0	5.9	5.6	0.0	2.7	3.7	4.1	2.9
Black/African American	0.0	0.0	0.0	5.9	0.0	0.0	0.0	0.9	1.7	2.8	2.9
Hispanic/Latino	0.0	0.0	5.9	5.9	11.8	11.1	11.8	7.1	7.1	10.5	5.2
Native Hawaiian or Pacific Islander	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.0
Non-Resident Alien	7.7	7.1	5.9	5.9	11.8	22.2	23.5	12.4	17.3	16.4	7.4
Not Specified	15.4	14.3	5.9	11.8	11.8	11.1	0.0	9.7	3.3	4.4	7.9
White/Caucasian	69.2	78.6	70.6	70.6	58.8	44.4	58.8	63.7	64.2	57.8	72.7

*National data from National Science Foundation (NSF) 2011 Survey for Earth, Atmospheric and Ocean Sciences http://www.nsf.gov/statistics/srvygradpostdoc/

Table I6. ATMO Ph.D. student ethnicity distribution.

Race/Ethnicity of Doctor of Philosophy Students											
Ethnicity with International	**Fall 2006**	**Fall 2007**	**Fall 2008**	**Fall 2009**	**Fall 2010**	**Fall 2011**	**Fall 2012**	**ATMO 7-yr Avg**	**COS 7-yr Avg**	**UA 7-yr Avg**	**U.S.***
American Indian/Alaska Native	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.6%	2.6%	1.0%
Asian American	0.0%	7.7%	7.7%	0.0%	0.0%	0.0%	0.0%	1.9%	3.7%	3.6%	2.9%
Black/African American	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	2.2%	2.9%
Hispanic/Latino	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.8%	7.6%	5.2%
Native Hawaiian or Pacific Islander	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%
Non-Resident Alien	27.3 %	30.8 %	30.8 %	33.3 %	33.3 %	47.1 %	52.6 %	37.9 %	32.1 %	29.9 %	7.4%
Not Specified	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.1%	2.7%	7.9%
White/Caucasian	72.7 %	61.5 %	61.5 %	66.7 %	66.7 %	52.9 %	47.4 %	60.2 %	53.8 %	51.2 %	72.7 %

*National data from National Science Foundation (NSF) 2011 Survey for Earth, Atmospheric and Ocean Sciences http://www.nsf.gov/statistics/srvygradpostdoc/

I3d. Adequacy of Graduate Student Stipends and Assistantships

Graduate teaching assistants (GTAs) are supported by funds allocated through the College of Science, whereas Graduate Research Assistants (GRAs) are funded by external grant and department monies. The number of GTA and GRA positions and expenditures is shown in Table I7. The total number of GTAs (at 0.25 FTE or 0.5FTE) has been relatively steady in the range of 7-10 positions annually. However, the 0.5 FTE GTA positions and salary expenditures have been steadily declining, by about 40% in FY 2012-2013 over their peak values in FY 2006-2007, a reflection of state budget cuts. The total number of GRAs, by contrast, has more than tripled in the last three years since FY 2006-2007, from 6 to approximately 22, with a six-fold increase in FTE and salary expenditures. This dramatic increase in funding for GRA position reflects the high productivity and success of ATMO faculty in obtaining external research funding, a feat that has been accomplished even with the greater teaching and advising demands on faculty in the last three years, as noted previously in Section I3b. The growth in external grant funding has been absolutely essential to ensure every graduate student in ATMO is able to be employed as a GTA or GRA.

Table I7. Number and expenditures of GTA and GRA at ATMO.

Number of Funded Graduate Teaching/Research Assistantships and Expenditures							
	FY 2006-2007	FY 2007-2008	FY 2008-2009	FY 2009-2010	FY 2010-2011	FY 2011-2012	FY 2012-2013
Number of Teaching Assistants	9	10	7	10	8	8	7
0.5FTE (state funds)	8.00	8.50	5.25	5.50	6.25	6.00	4.75
Salary Expenditures	$128,816	$137,106	$84,399	$88,418	$92,439	$97,048	$76,805
Number of Research Assistants/Associates	6	8	10	16	23	22	22
FTE (non-state funds)	5.50	6.50	9.25	12.75	21.50	21.00	31.50
Salary Expenditures	$89,810	$104,049	$152,699	$199,891	$333,083	$311,364	$342,901

Academic semester and summer salary rates for GTAs and GRAs are shown in Table I8. The typical first-year M.S. graduate student on a GTA or GRA position has a 0.5 FTE appointment during the academic year and 332 hours during the summer, earning a total annual salary of $22,749. This amount is quite comparable to average rate for such a position at universities nationwide, according to a recent UCAR survey as referenced in Table I8. Similarly, the typical Ph.D. student (after passing the comprehensive exam) on a 0.5 FTE appointment during the academic year with 332 hours during the summer would have an annual salary of $24,625, which is only slightly lower than the national average. It should be noted that ATMO graduate students receive health insurance benefits as part of their employee-related expenses (ERE), currently worth $1,660 annually. At some of our comparable peer institutions such health insurance benefits are paid directly by the graduate student, even though their GTA and GRA salary rates may be nominally higher. Graduate student salary rates increase slightly with seniority. A graduate student may also be paid more or less than the typical 332 hours in summer, as decided by the major advisor. The maximum possible number of hours a student may be paid for summer is 400. Overall, our GTA and GRA support is comparable to the national average.

Table I8. ATMO GTA and GRA salaries and benefits.

Graduate Teaching /Research Assistantship Salary and Health Benefits 2006-2013					
Title/Appointments*	.25 FTE	.50 FTE	Annual Salary	UCAR**	Summer***
Teaching Assistant	$4,019	$8,038	$32,152	$22,426	$6673
M.S. Research Assistant	$4,019	$8,038	$32,152		
Ph.D. Research Assistant	$4,167	$8,334	$33,334		$6919
Ph.D. Research Associate (after comps passed)	$4,315	$8,630	$34,518	$25,404	$7165

*All appointments are academic

** 2012 UCAR post-doctoral and graduate research assistant salary survey

***During the summer, graduate students are paid hourly rates up to 332 hours

	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013
Health Insurance Coverage	$1,264	$1,442	$1,586	$1,553	$1,620	$1,664	$1,660

I3e. Thesis/Dissertation Supervision and Time to Graduate

M.S. and Ph.D. completion information over the reporting period (2006-2012) in Table I9 are computed using: A) the number of students that entered the program (counting the existing students in 2006); B) number of students that successfully graduated; C) number of students still enrolled in the program as of 2013; and D) number of students that withdrew from the program. The graduate completion rate is computed as number of successful graduations divided by the sum of successful graduations plus withdrawals during the period 2006-2012. Considering the graduate students pursuing an M.S. degree, the overall completion rate was 90% with an average completion time of a little over three years; and for Ph.D. graduate students the overall completion rate was 71% with an average completion time of 4.8 years (after M.S.). ATMO is successfully graduating nearly all of the students that are pursuing an M.S. degree, with a modest non-completion rate of 10% that would account for a statistically reasonable number of students that would be expected to withdraw from a graduate program a priori due to personal reasons (e.g. health problems, family situations, etc.). Notable is the upsurge in Ph.D. enrollment subsequent to 2010 as previously noted in Section I3b. A substantial number of these currently enrolled Ph.D. candidates are being advised by the ATMO faculty at the associate and assistant professor level hired after 2006.

The average time to graduate for both M.S. and Ph.D. degrees does need to be shortened (ideally by six months for M.S. and 1 year for Ph.D.), and this statistic requires some additional explanation and specific actions ATMO has undertaken to address the problem. The higher non-completion rate for Ph.D. students is largely due to students that failed a required examination in the Ph.D. sequence that forced them to withdraw from the program. Those Ph.D. students that took longer than 10 years to complete their degree typically faced extraordinary circumstances that necessitated the provision of additional time, while still conforming to UA Graduate College policy. For example, the one Ph.D. student that took the most time to attain his degree (9 years) during the reporting period was performing his dissertation project remotely while working in a foreign country. Newly imposed Ph.D. graduate examination criteria developed within the past five years have been designed specifically with the intent to decrease the amount of time to graduate by sequencing the comprehensive examination in the last year of the M.S. degree for

continuing students or within the first year for new Ph.D. students. These new procedures have been able to objectively identify any clearly unqualified Ph.D. candidate very early on in the process.

Table I9. Completion years of M.S. and Ph.D. degrees in FY2006-2013.

Completion information from FY2006 - 2012	M.S.	Ph.D.
# of students enrolled	54	26
Still enrolled	12	17
Withdrew	4	4
Completed in 2 years	8	
Completed in 2.5 years	13	
Completed in 3 years	5	2
Completed in 4 years		3
Completed in 5 years		1
Completed in 6 years*	12	
Completed in 10 years*		4
Average	3.2 years	4.8 years
Overall completion rate	38/42=90%	10/14=71%
Not completion rate	4/42 =10%	4/14 =29%

* Time limitation for Master's is 6 years with exceptions, and all requirements for the degree of Doctor of Philosophy must be completed within 5 years of passing the Comprehensive Exam (UA Graduate College policy).

Graduate degrees awarded by year in comparison to Arizona Board of Regents (ABOR) threshold for productive graduate programs is shown in Table I10. Overall, ATMO has had relatively more success in graduating students at the M.S. level, as the last three-year total of 22 students is more than double the ABOR threshold. The number of Ph.D. graduate degrees awarded in the last three years is also above the ABOR critical number. If Ph.D. degrees in which an ATMO faculty member served as a co-advisor are included, ATMO is also above the ABOR threshold for Ph.D. degrees during the entire period 2006-13. Note that six Ph.D. degrees were awarded in the most recent reporting year 2012-13, and this substantially increased number is due, in part, to the graduate advising by the new ATMO faculty members hired in 2006 or thereafter. Given the present Ph.D. enrollment, it is expected that this relatively higher level of Ph.D. degrees awarded in 2012-13 should be sustained in the coming years.

Table I10. Graduate Degrees (in Atmospheric Sciences and Hydrometeorology) awarded by Year and Arizona Board of Regents (ABOR) Threshold for Productive Programs

Degree Awarded	FY 06-07	FY 07-08	FY 08-09	FY 09-10	FY 10-11	FY 11-12	FY 12-13	ATMO 7-Yr Total	ATMO 3-Yr Total	ABOR 3-Yr Threshold
MS	1	5	4	6	7	6	9	38	22	9
PHD	1 (3)	1 (1)	1 (3)	0 (2)	1 (2)	0 (1)	6 (1)	10 (13)	**5*** (4)	6

(# of students co-advised by ATMO/IAP faculty for completion doctoral degrees)

(If Hydrometeorology Ph.D. students are included, as they should be, the 3-year total is 7, and ATMO, therefore, exceeds the ABOR threshold. Please see Section M for further clarification.)

Exit Survey: A survey of students who graduated was conducted in Fall 2013 and the results are presented in Table I11. Approximately 40% of former graduate students in ATMO during the period 2006-2013 responded to the survey. Average results to survey questions are summarized in Table I11. Scoring criteria are as follows: 4 = excellent, 3 = very good, 2 = adequate, 1= poor. Students were also provided a section on the exit survey to provide any additional comments.

Table I11. ATMO alumni survey questions and results.

ATMO Alumni Survey Questions	**SCORE**
<u>I. Evaluation of Professional Growth</u>	
Please rate how your graduate education experience has contributed to _____?	
1) Your attainment of professional skills?	3.1
2) Your ability to work with others?	3.4
3) Your ability to professionally communicate?	3.4
4) Your overall preparation for employment or further education?	3
<u>II. Evaluation of the ATMO Program</u>	
Overall, I would rate the quality of:	
5) The instruction in graduate courses I completed as	3
6) The advising and mentoring I received as	3.1
7) The level of financial support through assistantships/fellowships	3.5
<u>III. Course structure and thesis research</u>	
8) The courses provided adequate breadth and depth	3
9) The structure of the academic program met your needs	3.3
10) Choice of graduate research topics were interesting and flexible	3.4

IV. Employment information	
11) Was the graduate education necessary for your current employment?	3.3
12) How helpful was your advisor or faculty in seeking employment?	2.9
V. Overall grading	
13) How would you rank the ATMO program?	3.2
14) What is your overall opinion of you graduate student experience?	3.1

On average, the answers to all of these questions fell in the category of "very good" to "excellent." An important exception is the helpfulness of the advisor or faculty in seeking employment, which was the lowest score. The most consistent comment from former students is that ATMO needs to improve on providing terminal M.S. students clear pathways to employment post-graduation and career training, especially oriented to the private sector. One possible way to address this issue would be to involve the ATMO Board of Advisors, several of which are employed in the private sector, in career advising for these types of students. Another way is to increase the partnerships with private sector companies in areas of M.S. research where there is synergy. Other concerns raised in the student comments included: the heavy required course load for Ph.D. students, the lack of graduate course elective options (particularly in remote sensing), the need for more formalized training in computer programming, and a desire for more practical problem solving in graduate courses.

I3f. Graduate Student Employment After Graduation

Summaries of graduate employment settings of M.S. and Ph.D. graduates in all programs for the period 2006-2013 is respectively shown in Tables I12 and I13. This information was compiled from an exit survey and from first-hand knowledge from faculty advisors who maintained contact with their former graduate student advisees.

M.S. Graduates: 19 out of 38 M.S. graduates (one-half) continued their education into a doctoral program. Nearly all of these continuing students (18) remained at the University of Arizona, with 14 continuing in the doctoral program in Atmospheric Sciences or Hydrometeorology. The remaining 19 terminal M.S. students have been employed in public education, the private sector (renewable energy industry, private weather forecasting companies), state government, federal government, or as researchers in universities. Of these, the most substantial and reliable employer of terminal M.S. students has been the federal government, providing weather forecasting positions and research positions in the National Weather Service (NWS), U.S. Air Force, and NASA, for example. Recent federal government cutbacks and hiring freezes at some of these federal agencies (especially NWS), have meant that terminal M.S. students in the last several years have not been able to find these traditional federal government jobs and have either been unemployed or been forced to seek temporary employment in an unrelated career field post-graduation.

Ph.D. Graduates: The most traditional employment route for students with a Ph.D. in Atmospheric Sciences or Hydrometeorology is a post-doctoral position, at a research laboratory or university. A post-doc position is a typical gateway to higher-level academic and research positions in these fields (e.g. assistant professorship in a university, research scientist at a national laboratory). Ph.D. graduates have been employed in post-doctoral positions throughout the United States and beyond, and these external institutions include Pacific Northwest National Laboratory (PNNL), Desert Research Institute, the University of Vienna, and the University of Melbourne. The

remaining Ph.D. graduates have obtained faculty positions abroad, work in civilian positions in the federal government, or are U.S. military.

Table I12. Employment Settings of M.S. Graduates (2006-2013)

Continued for doctoral degree (19)

Naval Post-Graduate School

Remained at the University of Arizona (18)

Continued into an ATMO-supported doctoral program (14)

Education (1)

Public education, High School Science teacher, Tucson, AZ

Private Sector (7)

Wind Forecaster, Iberdola Renewables, Portland, OR

Supervisor, Wind Logics, St. Paul, NM

Science Management Support Specialist, IM Systems Group, Camp Springs, MD

GIS Coordinator, Alliance Water, Columbia, MO

Information Technology (2), Tucson, AZ

Weather Forecaster, Impact Weather, Houston, TX

State Government (1)

Air Quality/Weather forecaster, Maricopa Association of Government, Phoenix, AZ

Federal (6)

Meteorologist, National Weather Service, Spokane, WA

Meteorologist, National Weather Service, Pendleton, OR

Meteorologist, National Weather Service, San Diego, CA

Scientific management specialist, IM Systems, Camp Springs, MD

Civilian Employee, Davis-Monthan Air Force Base, Tucson, AZ

Physical Scientist, NASA Kennedy Space Center, Florida

Other Research (1)

Software Engineer/Analyst, University of Alaska, Fairbanks, AK

Unemployed or unknown (3)

Table I13. Employment Settings of Ph.D. Graduates (2006-2013)

Post-Doctoral Positions (6)

Climate Scientist, Pacific Northwest National Lab, Richland, WA

Post-Doctoral Researcher, University of Vienna, Vienna, Austria

Post-Doctoral Researcher, University of Arizona, Tucson, AZ (2)

Post-Doctoral Researcher, University of New South Wales, Australia

Post-Doctoral Researcher, Desert Research Institute, Reno, NV

Faculty Positions (4)

Faculty, Department of Physics, University of Sonora, Mexico

Lecturer, Department of Engineering, University of Bristol, UK

Faculty, Nanjing University of Information Science, Nanjing, China

Faculty, Chinese Academy of Sciences, Beijing, China

Federal (2)

Civilian Employee, US Army, White Sands Missile Base, NM

Civilian Employee, United States Air Force

Unemployed or unknown (1)

I3g. Scholarship Activities of Graduate Students

Students are expected to actively communicate their research results, as part of their graduate education experience. The majority of M.S. students prepare their thesis in the form of a professional journal article, for example to the journals of the AMS or AGU. Ph.D. students are nominally required to compose their dissertation with three distinct professional journal articles that have either been already accepted for publication or are nearly ready for submission and prepare a public seminar defense presentation. Graduate students present their research results in the form of an oral or poster presentation at professional conferences, typically at least once for M.S. students and on multiple occasions for Ph.D. students. The most visible venues for showcasing graduate student research are the large annual AMS and AGU meetings. In addition, prior to graduation all students are required to participate in the Annual Atmospheric and Interdisciplinary Research (AIR) Symposium, conducted in the University of Arizona Student Union in April. This one-day mini scientific conference, organized by the graduate students and sponsored by Vaisala, has consistently been a showcase of the compendium of ATMO graduate research work to the entire department and the university. AIR is a component of the larger EarthWeek Symposium in the School of Earth and Environmental Sciences (SEES).

I4. Graduate Student Learning Outcomes Assessments

I4a. Expected Learning Outcomes

The learning outcomes are listed below for M.S. and Ph.D. Degrees in Atmospheric Sciences and Hydrometeorology. Note that “demonstration of competence” in regards to course performance specifically means a student receives a final course grade of B or higher, as graduate students must maintain a grade point average higher than 3.0 to retain their graduate student standing per University of Arizona Graduate College policy.

Expected Learning Outcomes for M.S. in Atmospheric Sciences (and Accelerated M.S. Program)

The mission of ATMO is to provide academic and research training sufficient to achieve the following knowledge outcomes and professional skills for completion of the M.S. degree in Atmospheric Sciences:

- Demonstrate competence in fundamental area of Dynamic Meteorology as covered in the two-semester core course sequence, which encompasses: basic conservation laws, applications of the basic equations, circulation and vorticity, the planetary boundary layer, quasi-geostrophic theory, atmospheric waves, baroclinic instability, and aspects of mesoscale circulations and the general circulation.
- Demonstrate competence in the fundamental area of Physical Meteorology, as covered in the two-semester course sequence, which encompasses: atmospheric thermodynamics, composition and chemistry of the atmosphere, kinetic theory, mechanism of ideal and real fluids, aerosol mechanics, atmospheric radiation, scattering, radiative transfer, atmospheric optics, cloud physics and atmospheric electricity.
- Demonstrate competence in graduate elective courses of study oriented to one or more of the following sub-disciplinary focal areas: atmospheric chemistry and aerosols, climate and climate change, lightning and atmospheric electricity, radiation and remote sensing, tropical meteorology and tropical cyclones, data assimilation, and weather analysis and forecasting.
- Gain experience and professional competence in the use of specific research tools in the atmospheric sciences as related to the student's thesis project and courses, broadly including data analysis and visualization software and computer programming (e.g. C, FORTRAN, MatLab, GrADS, and NCL), numerical atmospheric models, and specialized instrumentation. Participation in laboratory or field work may be a component.
- Compose a written thesis document that summarizes research activities in the atmospheric and related sciences that follows scientific method. Thesis research is conducted under the supervision of a major advisor with the department, and reviewed by a graduate committee comprised of a minimum of three research or academic faculty members. The thesis must demonstrate an ability to carry out a research project, with clear and effective communication of background literature, methodologies, findings, and conclusions. The thesis may be prepared as a professional journal article.
- Present research results at the annual Atmospheric and Interdisciplinary Research (AIR) symposium and/or a professional conference, in the form of an oral or poster presentation.
- Present research results in the form of thesis defense, of which the seminar portion is open to the public.

Expected learning outcomes for a Ph.D. in Atmospheric Sciences

The expected learning outcomes are nearly identical to the M.S. degree in Atmospheric Sciences with the following additional expectations:

- Successful completion of formal Ph.D. examination requirements that objectively establish professional competency in both basic knowledge of atmospheric sciences and the selected sub-disciplinary focal areas of the student's interest
- Completion of a dissertation document that should nominally consist of three professional journal articles, either accepted for publication or nearly ready to be submitted. Similar to the M.S. degree, the dissertation must demonstrate an ability to carry out a novel research project(s), with clear and effective communication of methodological approaches and findings. The dissertation is reviewed by a graduate committee comprised of at least four academic or research faculty.

- Presentation of research results in the form of dissertation defense, of which the seminar portion is open to the public.
- Demonstrate competence in courses within a minor area of study, of the student's choosing.

Expected learning outcomes for a M.S. in Hydrometeorology

The mission of ATMO and HWRS is to provide academic and research training sufficient to achieve the following knowledge outcomes and professional skills for completion of the M.S. degree in Hydrometeorology:

- Demonstrate competence in fundamental area of Dynamic Meteorology as covered in the first semester course of a one-year sequence which encompasses: basic conservation laws, applications of the basic equations, circulation and vorticity, planetary boundary layer, and atmospheric waves.
- Demonstrate competence in the fundamental area of Physical Meteorology, as covered in the first semester course of a one-year sequence which encompasses: atmospheric thermodynamics, composition of the atmosphere, kinetic theory, mechanics of ideal and real fluids, and cloud physics.
- Demonstrate competence in fundamentals of Surface Water Hydrology, as covered in a one-semester course which encompasses: hydrometeorology, evaporation, rainfall-runoff, statistical and probabilistic methods, unit hydrograph method, and flood routing
- Demonstrate competence in Hydroclimatology, as covered in a one-semester course which encompasses: the surface and atmospheric branch of the hydrologic cycle, land surface-atmosphere interaction, surface energy balance, evapotranspiration, heat and moisture fluxes into the soil, and the atmospheric boundary layer.
- Demonstrate competence in required graduate elective courses in the areas of: numerical weather and climate prediction, systems science and methods, and data sciences.
- Gain experience and professional competence in the use of specific research tools in hydrometeorological sciences as related to the student's thesis project and courses, broadly including data analysis and visualization software and computer programming (e.g. C, FORTRAN, MatLab, GrADS, and NCL), numerical atmospheric models and hydrologic models, and specialized instrumentation. Participation in laboratory or field work may be a component.
- Compose a written thesis that summarizes original research activities in hydrometeorology that follows scientific method. Thesis research is conducted under the joint supervision of co-advisors in ATMO and HWRS, and reviewed by a graduate committee comprised of a minimum of three research or academic faculty members. The thesis must demonstrate an ability to carry out a research project, with clear and effective communication of background literature, methodologies, findings, and conclusions. The thesis may be prepared as a professional journal article.
- Oral presentation of research results at the annual Atmospheric and Interdisciplinary Research (AIR) or El Día de Agua symposia during SEES EarthWeek and/or a professional conference, in the form of an oral or poster presentation.

Expected learning outcomes for a Ph.D. in Hydrometeorology

The expected learning outcomes are nearly identical to the M.S. degree in Hydrometeorology with the following additional expectations:

- Successful completion of formal Ph.D. examination requirements that objectively establish professional competency in hydrometeorology

- Completion of a dissertation document that should nominally consist of three professional journal articles, either accepted for publication or nearly ready to be submitted. Similar to the M.S. degree, the dissertation must demonstrate an ability to carry out a novel research project(s), with clear and effective communication of methodological approaches and findings. The dissertation is reviewed by a graduate committee comprised of at least four academic or research faculty affiliated with the Hydrometeorology program.
- Presentation of research results in the form of dissertation defense, of which the seminar portion is open to the public.

I4b. Assessment Activities

Informal assessments of student research and academic performance and progress toward degree completion are provided on a regular basis by the major advisor, chosen by the student after the first semester in the graduate program. The typical assessment activities by the major advisor are one-on-one meetings with graduate student advisees and regularly scheduled group project meetings. The major advisor is also responsible for working with the student advisee to construct a plan of study by the end of the second semester in the graduate program. Graduate student committee members typically provide feedback to students during the course of their research, for example reviewing manuscripts, and are formally required to approve the final thesis or dissertation document. The formalized examinations for M.S. and Ph.D. candidates that ensure professional competency are highlighted below. As the qualifying and comprehensive examination procedures for Atmospheric Sciences and Hydrometeorology Ph.D. are substantially different, these are discussed separately. Completion of all mandatory Ph.D. examinations is now electronically reported to the Graduate College, a change which occurred in just the past several years.

Supplementary examination for M.S. in Atmospheric Sciences

The supplementary examination is required when a student has received a grade of C or lower in one or more of the required ATMO core courses, or transferred equivalents. A written exam covers those core courses where the deficiencies occurred. If a student is required to take the supplementary written examination, it must be done no later than the last semester of course work required for the M.S. degree. An oral examination, between one to two hours long, may also be required if performance on the written examination is marginal. A grade of B or better is considered passing. The supplementary examination may be retaken, with a petition. A student must withdraw from the M.S. program after two failed examination attempts.

Qualifying and comprehensive examinations for Ph.D. in Atmospheric Sciences

The qualifying examination tests the student's breadth of knowledge in the atmospheric sciences, specifically in the core areas of dynamic and physical meteorology. The exam consists of three hours of questions, each 10-20 minutes long, prepared by the faculty. Normally, four hours are allowed to finish the exam. Each question is graded PASS or FAIL. Passing more than half the questions offered is a necessary (but not sufficient) requirement to be awarded a PASS on the entire exam. The final grade is determined by the faculty. M.S. students currently enrolled in the graduate program in Atmospheric Sciences take the exam late in their third semester. New students that enter directly into the Ph.D. program may take the exam in their first or third semester. Students that do not pass the first time are eligible to retake the exam early the following semester. If neither exam attempt is successful the student shall not be allowed to advance into the doctoral program.

Comprehensive examination tests the student's comprehensive, in-depth knowledge of the major subject of study and area of specialization. Students must complete all, or almost all of their non-dissertation credits including minor requirements before taking the comprehensive exam, and it should be sequenced no later than the sixth semester (end of third year) into the Ph.D. program.

- The written component of the comprehensive exam is offered upon pre-arrangement between the student and major advisor and doctoral committee and comprised of two parts: a research prospectus or dissertation proposal and a closed-book, written examination that covers of material in the student's acknowledged area of expertise. The closed book, written examination contains at least eight questions provided by the doctoral committee and is a maximum duration of three hours. Each question is graded PASS or FAIL. Passing at least 6 questions of 8 attempted is a necessary (but not sufficient) requirement to be awarded a PASS on the written exam. The final grade is determined by the Major Advisor and the Doctoral Committee. If the student fails the written comprehensive examination on the initial attempt, one more opportunity will be provided to re-take that portion within four weeks. The student will be terminated from the Ph.D. program upon failure of the written exam on a second attempt or there is no exam re-take within four weeks
- The oral comprehensive examination is conducted before the student's doctoral committee subsequent to successful completion of the written component. The oral examination is a minimum two hours long and covers general fundamental knowledge of both atmospheric sciences and the minor field. Should the doctoral committee vote to fail the student on the oral examination, no second attempt to pass the exam is offered, except if approved by the doctoral committee, the department and the Graduate College.

Qualifying and comprehensive examinations for Ph.D. in Hydrometeorology

The qualifying examination evaluates if the student has a fundamental knowledge of basic concepts of hydrometeorology. It is a combination written and oral exam.

- The written component of the exam consists of four questions, consisting of material from each of the core classes taken. The exam lasts two hours, with thirty minutes allotted for each question
- The oral component of the exam is administered by four faculty members, two from HWRS and two from ATMO. Each faculty member administers one question. The faculty member advising the student may not administer a question, but may be present in the examination room. The exam lasts at least two hours, and a maximum of three hours.

Each of the questions in the written and oral portions of the qualifying examination are graded as PASS or FAIL. Passing at least six questions is required to pass the entire qualifying examination. If the student fails the exam, the exam may be re-taken within four months. A student must withdraw from the Ph.D. program after two failed attempts at the qualifying examination.

The comprehensive examination tests the student's comprehensive, in-depth knowledge of the major subject of study and area of specialization. Students must complete all, or almost all of their non-dissertation credits before taking the comprehensive exam, and it should be sequenced no later than the fifth semester into the Ph.D. program.

- The written component of the comprehensive exam is designed to assess the student's ability to think and conduct independent research. Two open book questions are respectively provided by HWRS and ATMO faculty. The student has one week to complete the questions. Each question is graded PASS or FAIL. Both questions must receive passing grades in order to pass the entire exam. The exam may be re-taken within four months if the student fails. A student must withdraw from the Ph.D. program after two failed attempts at the written component of the comprehensive examination.
- The oral component of the comprehensive exam tests the student's advanced knowledge of hydrometeorology and evaluates a dissertation research proposal, and should be done within six months of the written exam. The dissertation proposal should be written in a manner similar to a NSF proposal, presenting the literature review, research hypotheses/questions, and proposed methodology to address these questions. The oral

comprehensive exam is at least two hours long, and a maximum of three hours and is graded as pass or fail. The doctoral committee decides if the student is eligible to repeat the exam, upon agreement by the department head and Graduate College.

Final Ph.D. dissertation defense examination

Upon completion of the dissertation, the student will take an oral examination defense. The student must submit copies of the draft dissertation for review to the doctoral committee no less than one month before the final dissertation defense. The dissertation and defense examination tests:

- the student's knowledge of the atmospheric or hydrometeorological sciences
- the student's knowledge of the literature, concepts and experimental approaches in the field
- their ability to think and write as a scientist
- their ability to communicate and publish research.

There is no minimum time for the examination, but the entire proceedings, including public seminar and committee questioning, may not exceed three hours. If the committee requires dissertation revision, these must be done in a timely manner, not to exceed one year. If the revisions are not completed by the dissertation submission deadline for the term when the student defends, the student will be required to register for the next semester and will graduate in the semester when the revisions are completed and approved. If the revisions are not done by the end of the time to degree period, the student will have to re-take comprehensive examinations to demonstrate currency of knowledge.

I4c. Assessment Findings

Assessment Findings for M.S. Students

M.S. student performance is best judged by the metric of graduation rate, as graduating students have demonstrated professional competency by their academic performance in the core curriculum and elective courses. As previously discussed in Section I3, the M.S. graduation rate over the period 2006-2013 is 90%. Half of all M.S. graduates continue on for a Ph.D., with nearly all continuing students remaining at the University of Arizona. Note that unlike some other programs within the College of Sciences, students with M.S. degrees in Atmospheric Sciences or Hydrometeorology are not required to take an external professional competency examination.

Assessment Findings for Ph.D. students

Objective scoring statistics for the ATMO Ph.D. qualifying examination exist subsequent to 2009. During this year the qualifying examination procedures underwent a major overhaul. Table I14 summarizes the student performance on this exam, in terms of number of questions with a PASS grade in the exam areas of dynamic and physical meteorology. Nominally, minimum six PASS grades are required to pass the exam, split between three PASS grades on each respective section. Considering the median score, students that pass the exam the first time receive on average 9 grades of PASS, 3 more than the minimum required to pass the exam, and the average performance on the physical meteorology section is slightly stronger than on the dynamics section. Students that fail the exam the first time receive on average 5 PASS grades and again perform relatively worse in dynamics. When these same students, however, re-take the exam, they pass the exam with 7 grades of PASS. More importantly, since 2009 no student that failed the qualifying exam the first time has failed it the second time and been forced to withdraw from the Ph.D. program. Thus, the revised examination procedures, that force a re-take of the qualifying exam early in the following semester, have worked to improve Ph.D. student retention and reduce the withdrawal rate from the program.

Table I14. Qualifying exam statistics for Atmospheric Sciences Ph.D. students (2009-2013)

First Chance Passes (17)	Dynamics Total	Physical Total	Total P
Mean	4.2	5.2	9.4
Median	4.0	5.0	9.0
St. Dev	1.4	1.1	1.9

First Chance Fails (7)	Dynamics Total	Physical Total	Total P
Mean	2.3	2.6	4.9
Median	2.0	3.0	5.0
St. Dev	1.1	1.0	1.2

Second Chance Passes (5)	Dynamics Total	Physical Total	Total P
Mean	4.0	3.4	7.4
Median	4.0	3.0	7.0
St. Dev	1.2	0.5	1.1

*** No one who retook the exam has failed since 2009.**

Only five students have taken the Hydrometeorology qualifying exam under the procedures as described in Section 14b, all after 2012 (statistics not shown). Of these five students, four passed the exam the first time. The one student that failed the qualifying exam the first time was able to pass it on a re-take. The sequencing of the written and oral components of the qualifying examination is definitely an issue, however, as both currently occur near the end of the Fall Semester. ATMO-affiliated Hydrometeorology faculty are currently being forced to administer multiple oral examinations within the same week, at the same time managing end of semester activities in graduate courses and their other research and service activities. Discussion is under way to revise the timing of these oral exams.

In order to move through the doctoral program successfully, Ph.D. students must reach the milestones of the qualifying examination, comprehensive examination, and the final dissertation defense. As previously stated in Section I3, the overall Ph.D. completion rate over the past six years was 71% with an average completion time of 4.8 years. The relatively lower Ph.D. completion rate, as compared to the M.S. completion rate, was largely due to students that dropped out of the program during the period 2006-2009, prior to a major overhaul of Ph.D. examination procedures. This overhaul also included more directed guidance for the sequencing of all examinations, to address the problem of high Ph.D. completion time.

I4d. Changes Made in Response to Findings

Note that this section references changes made in the Atmospheric Sciences M.S. and Ph.D. programs only since the prior academic program review, as the Hydrometeorology graduate program did not yet exist in 2006.

Changes to Atmospheric Sciences M.S. Program Since Last APR Report

The basic academic structure of the Atmospheric Sciences M.S. program has been retained since the prior APR, as it has continued to produce a fairly good outcome in terms of a high student graduation rate. Students within the M.S. program also can satisfy the necessary course requirements for employment in the National Weather Service, and this has been one of the

employment paths for terminal M.S. students. Peripheral changes to the M.S. made in the past six years have had the overarching goal of making the program more broadly accessible and appealing to graduate students, while maintaining academic rigor and efficiency in the sequencing of requirements. The specific changes include:

- More clearly defined tracks of elective courses and faculty in the sub-disciplinary areas have been delineated, to facilitate construction of the student plan of study and the identification of a major advisor. Clearer identification of sub-disciplinary areas addresses the concern identified in the alumni survey in the previous 2000-2006 APR regarding greater choice in research topics.
- A substantial number of new graduate course electives within ATMO have been offered, corresponding to the professional expertise of new faculty hired in 2006 and thereafter. These include: Objective Analysis in the Atmospheric Sciences, Tropical Meteorology, Data Assimilation, Boundary Layer Meteorology, Mesoscale Metorological Modeling, and Physical Climatology. The curriculum of the physical meteorology sequence of core courses and some existing electives also has been substantially changed, to be more in line with that of our peer institutions in atmospheric sciences. New courses or revisions to existing curriculum addressed course topic needs identified in the alumni survey in the previous 200-2006 APR, for example synoptic meteorology, mesoscale meteorology, and computing and numerical methods.
- The new course Fundamentals of Atmospheric Sciences is available to M.S. students who may require an additional preparatory course prior to taking the core courses of Physical Meteorology and Dynamic Meteorology.
- There are now faculty-approved graduate elective options from outside the Department of Atmospheric Sciences, to allow greater flexibility in constructing the plan of study.
- A supplementary examination is now required for students that fail to meet academic requirements in the core courses of Physical Meteorology and Dynamic Meteorology.
- The M.S. student handbook has been completely revised. The handbook now provides more directed guidance with respect to construction of a plan of study, selection of a major advisor and research topic, and the thesis requirement.

There are several remaining or newly identified challenges since the previous APR:

- Terminal M.S. students clearly need to have more formalized career counseling, especially for orientation to the private sector. The ATMO board of advisors may be able to help address this specific need, as some board members have extensive experience working in the private sector. One idea is to invite ATMO board members to conduct a career orientation workshop to target M.S. students in their final academic year. Recent federal government cutbacks that have reduced the number of M.S. entry-level positions in the National Weather Service and other agencies have increased the level of urgency to address this issue.
- ATMO currently has no faculty member who can teach atmospheric radiation and remote sensing courses, following the losses of several faculty members that have not been replaced. There is an urgent need to hire new faculty members in this area.
- More preparatory classes in computing and numerical methods need to be offered. Development of such classes is still in the planning stages.
- More regular course offerings for critical elective courses that terminal M.S. students need for typical atmospheric science career paths in the federal government or private sector (e.g. synoptic and mesoscale meteorology, remote sensing).

Changes made to the Atmospheric Sciences Ph.D. Program Since Last APR Report

More substantial changes have been made to the Atmospheric Sciences Ph.D. program since the last APR report, to address the problems of the relatively lower graduation rate (as compared to the rate for M.S. degrees) and excessive time to graduation. The specific changes to these points include:

- The sequencing of the Ph.D. qualifying examination was changed in 2009. M.S. students who are continuing for a Ph.D. must now take the qualifying examination in the fall of their second year (third semester), prior to entering the program. The exam retake opportunity is now offered within six weeks of the initial exam. These changes have been effective to identify clearly unqualified Ph.D. candidates early on in the process and provide the retake opportunity with a quick turnaround time so students are not spending an additional academic semester studying for a retake exam. Since the implementation of these procedures, no student has ever failed the qualifying exam the second time and Ph.D. enrollment has increased.
- The Ph.D. handbook has been substantially revised, with more directed guidance on construction of a plan of study, sequencing of qualifying and comprehensive examination requirements, and the final dissertation.
- Students have generally had greater flexibility to pursue Ph.D. research projects that are more multidisciplinary, involving several different research areas and/or departments, largely due to the collaborative nature of the new faculty within the university.

The improvements and remaining challenges with respect to course curriculum and offerings as previously discussed in reference to the M.S. program also generally apply to the Ph.D. program. The need for employment counseling for Ph.D. students is not as acute, however, since faculty members have greater professional familiarity with the types of employment opportunities that would require a Ph.D.

Table I15 summarizes our activities in response to each University of Arizona rubric criterion for assessing APR Assessment Plans.

Table I15: University of Arizona graduate student assessment rubric criteria and how they are addressed in Chapter I4.

UA Rubric criteria	ATMO activities and approaches
Expected learning outcomes: Identify intended knowledge, understandings, or abilities that students will acquire through the program	Expected scope of knowledge and skills from the core curriculum and elective courses Specific expected technical and professional skills with respect to M.S. and Ph.D. degrees Research deliverables of theses, dissertations, professional presentations and publications
Assessment Activities: Measure outcomes through direct and indirect measures. State how faculty and staff are involved in the development, implementation and use of student learning outcomes	Individualized assessment activities by the major advisor and the graduate committee Formalized examination procedures for graduate students that ensure graduate students have the appropriate academic depth and breadth from the core curriculum and elective courses and the ability to carry out a successful graduate research project.
Assessment Findings: Describe what was learned from assessment activities, in ways that align with expected outcomes	Evaluation of M.S. student performance through the metric of graduation rate Quantitative assessment of student performance on Ph.D. qualifying examination Ph.D. time to graduate and Ph.D. graduation rate as motivating statistics to improve the structure of the Ph.D. program
Changes in response to findings: Findings used to drive change and improvement in the program, with respect to instruction, curriculum, or strategic planning.	New graduate course offerings and changes to existing courses in response to identified student needs, to make the academic program more broadly accessible and appealing. Sequencing of Ph.D. examinations to reduce the time to graduate and improve graduation rate Overhaul of M.S. and Ph.D. student handbooks, that more clearly define the expected outcomes and timing of the milestones necessary for degree completion. Greater flexibility in curriculum planning, with the addition of elective courses offered by other departments, emphasizing a more multidisciplinary approach. Identification of new or remaining problem issues in the graduate program, especially with respect to terminal M.S. students that should be considered in future strategic planning.
Reporting on the Website:	We have updated ATMO's assessment website: www.assessment.arizona.edu/sci/Atmospheric%20Sciences%20Grad

I5. Post-Doctoral Fellows

Like other programs in atmospheric sciences, ATMO does not have a post-doctoral fellowship program per se or a central means to support post-docs. Individual grant funding has always been the mechanism for hiring post-docs. Also like other programs in atmospheric sciences, postdoc position is usually for 1-3 years. Postdocs contribute to our program in various ways: strengthen our research efforts by doing cutting-edge research; increase interdisciplinary collaborations by acting as a bridge between faculty members from different units or different institutions; and interact with and help mentor graduate students.

With the tight federal budget, the ATMO strategy has been to use the research grants to support graduate students as the top priority (over the hiring of postdocs). At present, ATMO has five postdocs: Klaus Dolling and Kim Wood (working with Ritchie), Pieter Hazenberg and Patrick Broxton (just hired in January 2014) (with Zeng), and Chang Ki Kim (with Betterton). With additional research grants, ATMO intends to hire more postdocs.

After the 1-3 year training, postdocs are expected to move on to more permanent (academic, government, and private sector) positions. As an example, the employment of postdocs who have finished their terms at ATMO in the past two years includes: Hsin-I Chang (worked with Castro/Dominguez; Research Associate at ATMO), Miguel Pineros (worked with Ritchie; Engineer in the private sector), Paul Shao (worked with Zeng; Assistant professor in Chinese Academy of Sciences), and Om Tripathi (worked with Castro/Dominguez; SNAP Project Manager at University of Reading in U.K.).

ACADEMIC OUTREACH

J. ACADEMIC OUTREACH

ATMO welcomes opportunities to provide expertise on atmospheric science to the local, state, national, and global communities. The Department plans to continue its outreach efforts and foresees little change in the nature or number of outreach activities in the future. A sample of some recent outreach activities is described below.

K-12 Presentations. ATMO faculty members have given presentations in K-12 classrooms in local school districts. For instance, Ritchie has been the co-organizer of Adopt-A-School Volunteer Outreach to Tucson Elementary Schools.

Science fairs. Students and faculty have participated in judging local science fairs. For instance, Ritchie has been the co-organizer of the Hollinger Elementary Science Fair.

Undergraduate Research. Faculty in the ATMO have mentored students in the NASA Space Grant Program and NSF REM Bridge program. For instance, Betterton has served on this program's advisory committee.

Department Tours. Weidman has conducted tours of the Department for K-12 students, Cub and Boy Scouts, and other groups that request tours.

Lectures. Faculty members and students have given lectures to local and national service organizations. For instance, Dominguez and Arellano gave a public talk at Science Café and joint faculty member Sorooshian presented to the Arizona Senior Academy.

Media interviews. When requested, ATMO faculty give interviews on various topics in atmospheric science, climate change, and related topics for newspaper articles and radio and TV shows. For example, Castro gave media interviews or citations: KTVK-3 (Phoenix), KGUN-9 ABC News (Tucson), KOLD-13 CBS News (Tucson), KUAT-6 PBS (Tucson) program Arizona Illustrated, Arizona Republic, Tucson Citizen, Arizona Daily Star, and Prescott Daily Courier. Local media interviews or citations of Ritchie include KVOA-4 NBC News (Tucson), KOLD-13 CBS News (Tucson). Local media interviews or citations of Zeng include KOLD Channel 13, KVOA Channel 4, Arizona Daily Wildcat, National Geographic.

Serving the government and NGOs. ATMO faculty have used our expertise to serve government and NGOs. For instance, Betterton has chaired the Pima County Environmental Quality Advisory Council and served on the Advisory Board of the Sonoran Environmental Research Institute. Castro provided sworn expert witness testimony in case State of Arizona vs. James Ray.

Academic mentoring. ATMO faculty have also been active in mentoring early career scientists. For example, Ritchie co-organized the National Association of Geoscience Teachers (NAGT) webinar series for early-career faculty and was the Leader of the Early Career Workshop supported by NSF at College of William and Mary. Castro provided training on the use of the Weather Research and Forecasting Model for operational weather forecasting by the Colombian Air Force.

Other efforts. The ATMO has participated in the Significant Opportunities in the Atmospheric and Related Sciences (SOARS) Program of UCAR. This program attempts to recruit minorities into the atmospheric sciences. Castro was the first tenure-track faculty member out of that program.

COLLABORATION WITH OTHER UNITS

K. COLLABORATION WITH OTHER UNITS

ATMO faculty engages in extensive interaction with other academic units at the University of Arizona. Examples include:

School of Earth and Environmental Sciences (SEES). ATMO is a core member of the SEES and is heavily involved in all related activities. Betterton is the current Director of SEES.

Institute of the Environment (IE). ATMO faculty have been heavily involved in the IE activities. The purpose of IE is to coordinate the campus-wide research and graduate education related to environment. It involves many colleges at the University of Arizona (e.g., College of Science, Eller College of Management, James E. Rogers College of Law). For instance, Zeng serves on the IE Faculty Advisory Committee, and IE Co-Director Overpeck is a joint faculty member of ATMO.

Joint voting faculty. ATMO is one of the few units giving joint faculty the full voting right (rather than just as a courtesy appointment). At present, ATMO has nine joint voting faculty members from Geoscience, Geography, Tree Ring Research, Math, Planetary Science, Hydrology, and Chemical and Environmental Engineering. Joint faculty member Comrie is the Provost of the University of Arizona.

Graduate Interdisciplinary Programs (GIDPs). One of the strengths of the University of Arizona is the many highly successful GIDPs. Many ATMO faculty members belong to one or more GIDPs such as Global Change, Remote Sensing and Spatial Analysis, and Applied Math.

Hydrometeorology. ATMO and HWRS faculty worked closely to establish the successful hydrometeorology M.S. and Ph.D. program that is the first such program in the U.S.

UA Climate Dynamics and Hydrometeorology Center (CDHC). Zeng is the Founding Director (and Castro is a member of the Executive Committee) of the CDHC that involves 45 faculty members from 11 departments in five colleges. Many ATMO faculty members are members of this center.

Furthermore, every single tenure-track faculty member has substantial interactions with colleagues in other departments. These interactions are indicated by joint appointments, co-authorship, joint efforts in funded projects, and serving on M.S. and Ph.D. committees. Here we don't exclude joint efforts in submitting proposals that were not funded. If such efforts are included, the number below would be more than doubled.

Arellano: Laboratory for Tree Ring Research, School of Natural Resources and Environment, Math

Betterton: Chemical and Environmental Engineering; University Medical Center, Respiratory Sciences; College of Public Health; Laboratory for Tree Ring Research

Castro: Laboratory for Tree Ring Research; Hydrology and Water Resources; Biosphere 2; School of Natural Resources and Environment; Geography

Dominguez: Laboratory for Tree Ring Research; Hydrology and Water Resources; Biosphere 2; School of Natural Resources and Environment; Geography

Mullen: Hydrology and Water Resources

Ritchie: Aerospace and Computer Engineering; Optical Sciences

Zeng: Biosphere 2; Ecology and Evolutionary Biology; Hydrology and Water Resources; Geoscience; Chemical and Environmental Engineering; Laboratory for Tree Ring Research; School of Natural Resources and Environment

FACULTY PLANNING

L. FACULTY PLANNING

The ATMO faculty are enthusiastic and happy about most aspects of our program including the research and teaching efficiency as quantified in the College of Science and the NRC ranking based on the reputation in research, teaching, and leadership. The two new hires during the previous seven years (Arellano and Dominguez) are also excellent. As we look to the future, there was good consensus on several points.

Graduate program. Enrollment numbers are excellent for our graduate program. Most of the graduate students are supported by our research grants, while the remaining students are supported by teaching assistantships. For the number of tenure-track faculty in ATMO, we have probably reached the upper limit in the number of graduate students we can accept into our program and supervise without compromising quality and encountering issues with office and laboratory space.

ATMO faculty will do their best to maintain the current high number of graduate enrollments, but we have to overcome two major barriers: the challenging federal budget situation that will further increase the competition for grants; and the increased employee-related expenses (ERE) (now 65%) for graduate research assistants.

ATMO faculty will also find ways to shorten the time needed to complete Ph.D. and hence make ATMO more efficient in meeting the ABOR graduation requirements of Ph.D.s.

Furthermore, ATMO faculty will improve on providing terminal M.S. students clear pathways to employment post-graduation and career training, especially oriented to the private sector.

Undergraduate BAS program. With the initial success of the BAS program, we will continue to explore the possible conversion of the BAS program into a B.S. online degree program open to all UA students, as encouraged by the University. While the advantages of such a conversion to the University is obvious, the disadvantages in terms of financial constraint and faculty constraint (if new faculty are not hired) have to be carefully addressed.

Research scientists. Research scientists (including postdoctoral research associates) are crucial for research productivity. They are entirely funded by grants/contracts. The limited indirect cost revenue (ICR) has been used to support Department staff that are not supported or fully supported by the University. We will attempt to further increase grants (which are already quite successful). In particular, we intend to pursue large interdisciplinary projects to fund more research scientists.

Research faculty. Research faculty are an integral part of our program, as they also support and supervise graduate students. We have been proactive (and fortunate) in attracting research faculty without any direct support from the College of Science or the University. Our strategy has been to provide a friendly working environment (so that research faculty enjoy coming to work in the Department) and full voting rights as tenure-track faculty (so that research faculty feel they are the equal of tenure-track faculty except the funding source). Ultimately, it is desirable to have some support from the College of Science or the University to help recruit and retain research faculty.

Staff. We have a highly efficient staff for administrative and computing support. However, they are just partially supported by the University with the remaining part by indirect cost revenue (ICR). It is desirable to have the University to fully support these five staff so that we can use the research grants (including the ICR) to support research scientists or attract research faculty.

Faculty. Ideally we should have some growth in our faculty in radiative transfer, remote sensing, and radar meteorology (to fill the gap and restore our traditional strength) and in weather forecasting and climate prediction (to continue and strengthen UA's national and international leadership position in water and environment).

To be more ambitious (i.e., to move our program into the top five), we anticipate needing to double our faculty size from current 7 to 14. To move our program into the top ten, we anticipate needing to increase our faculty size by 4 (from current 7 to 11). With our excellent research and teaching efficiencies (see Table D1), this would be a win-win strategy for the University, the College of Science, and ATMO.

Besides recruitment, we also need to retain our tenure-track faculty, and need to achieve and maintain appropriate salaries to do so. Our faculty at assistant, associate, and full professors are underpaid relative to national peers, as well as peers within the SEES. This issue should receive serious attention.

SPECIAL CONSIDERATIONS: DEFINING PRODUCTIVE PROGRAMS

M. SPECIAL CONSIDERATIONS: DEFINING PRODUCTIVE PROGRAMS

M1. Basic Academic Subject

Atmospheric Sciences is considered a basic academic subject at 8 peer institutions which include University of California-Davis, University of California-Los Angeles, University of Illinois at Urbana-Champaign, University of Maryland-College Park, University of Minnesota-Twin Cities, Ohio State University, University of Washington-Seattle Campus and the University of Wisconsin-Madison.

M2. Program Quality

- ATMO's "teaching efficiency" (R1 Ranking is 1.03 (8), highest of all SEES units (Page 27, Table D1)
- ATMO's "overall research grant and teaching efficiency" (R2 Ranking is 0.85 highest of all SEES units (Page 27, Table D1)
- In FY 2013, ATMO ranked 8 of 18 units in the College of Science by both measures
- In FY 2012, ATMO ranked 4th in the College of Science
- In FY 2011, ATMO ranked 5th in the College of Science
- In FY 2010, ATMO ranked 9th in the College of Science
- In FY 2009, ATMO ranked 3rd in the College of Science
- The National Research Council ranks the ATMO program 3rd among small programs behind Princeton and Wisconsin-Madison (Climatology and Marine Science, Page 29, Table D2)
- The University of Arizona's overall results of the National Research Council rankings (http://nrc.arizona.edu/node/155) has ATMO ranked as 7th nationally, one of only 7 top ten programs in College of Science (see chart below)

UA's PhD Programs Ranked in Top 20 (compared to all U.S. universities)

(revised 4/11)

Program	"best" ranking*
Anthropology	3
Applied Mathematics	3
Medical Pharmacology	3
Pharmaceutical Sciences	3
Astronomy	5
Atmospheric Sciences	7
Plant Science	7
Sociology	7
Communication	8
Geography	8
Geosciences	8
Nutritional Science	8
Planetary Sciences	8
Ecology & Evolutionary Biology	9
Nursing	9
Hydrology	10
Physiological Sciences	10
Biomedical Engineering	11
Management	11
Philosophy	13
Systems & Industrial Engineering	13
Aerospace Engineering	14
Linguistics	14
Animal Sciences	15
Neuroscience	15
Soil Water & Environmental Science	15
Environmental Engineering	16
Epidemiology	18
Genetics	19
Immunobiology	19

(Source: http://nrc.arizona.edu/node/155)

- Over the past 7 years, the ATMO Department averaged 28 peer-reviewed paper/books per year (Page 30)
- Annual grants/contracts expenditures of $2.4M are more than double State expenditures (on personnel) ~$1M (Page 26)

- The ATMO Department faculty has excellent reputations. They have served on national and international committees such as:
    - National Academy National Research Council, Jefferson Science Fellows program
    - NASA Lightning Advisory Panel
    - Joint Hurricane Test Bed (JHT) Steering Committee
    - UCAR Board of Trustees
    - American Meteorological Society Council

M3. Centrality to University Mission

According to the 2013 *Never-Settle* plan: Water in Arid Environments is one of 5 strategic growth areas. Prior to 2013, the University's strategic plans consistently listed Climate, Environment, Water and Energy as priority areas.

M4. Contributions to other Programs in the University

In Tier 1 Courses, the Department has an overall rating of teaching effectiveness – 3.83/5.00 vs 4.00/5.00 on the University scale. The overall rating of our courses is 3.42/5.00 vs 3.69/5.00. The difficulty level of ATMO courses is 3.46/5.00 vs 3.39/5.00. (Page 44)

In Tier 2 courses, the Department's overall rating of teaching effectiveness is 3.95/5.00 vs 3.86/5.00, overall course effectiveness is 3.70/5.00 vs 3.37/5.00 and difficulty is 3.60/5.00 vs 3.30/5.00. Our Department is comparable to or exceeds comparison groups, in spite of the higher level of difficulty. At the graduate level, ATMO meets or exceed comparison groups. (Page 45)

M5. Contributions to the Workforce Development

Thirty-eight M.S. students have graduated (2006-2013), 16 graduate students have found employment in the Atmospheric Sciences field, 19 graduate students have continued their education to obtain a Ph.D., and only 3 graduate students are unemployed or unknown. This is a 92% (35/38) success rate for our M.S. students. (Table I12 on Page 75)

The Ph.D. students also have a high success rate, 92% (12/13) finding Postdoctoral, faculty or Federal positions in the field. (Table I13 on Page 76)

- Renewable energy (2 graduates in the wind forecasting private sector)
- Weather forecasting (4 graduates in Federal and State weather forecasting, and 1 in the private weather forecasting sector)
- Science education (1 graduate)
- Civilian Employees with the U.S. Military (3 graduates)

M6. Program Uniqueness

- The **only** Atmospheric Sciences Department in the State of Arizona
- The **first** Hydrometeorology Program in the Nation (Page 56)

Due to the fact that we have departments in Atmospheric Sciences and Hydrology and Water Resources, this makes us the leading US institution for the study of Hydrometeorology. The objective of the Hydrometeorology program is to provide graduate students with a comprehensive understanding of the coupled interactions between the atmosphere and the land. Students will develop skills in hydrometeorological prediction and a have a better understanding of the impacts of land-atmosphere processes (and their interactions) on human and environmental wellbeing.

GRADUATE STUDENTS	PROGRAM	RESPONSIBLE SOURCE OF FUNDING
Bashir, Furrukh	**Ph.D. - Hydrometeorology**	**Atmospheric Sciences**
Bracher, Devon	**M.S. – Hydrometeorology**	**Atmospheric Sciences**
Hu, Huancui	**M.S. – Hydrometeorology**	**Atmospheric Sciences**
Lahmers, Timothy	**M.S. – Hydrometeorology**	**Atmospheric Sciences**
Lytle, Will	**M.S. – Hydrometeorology**	**Atmospheric Sciences**
Martinez, John Alejandro	**M.S. – Hydrometeorology**	**Atmospheric Sciences**
Prado, Maria Cecilia	**M.S. – Hydrometeorology**	**Atmospheric Sciences**
Rivera-Giboyeaux, Arelis	**Ph.D. – Hydrometeorology**	**Atmospheric Sciences**
Stillman, Susan	**Ph.D. – Hydrometeorology**	**Atmospheric Sciences**
Yang, Zhao	**Ph.D. – Hydrometeorology**	**Atmospheric Sciences**

Note that the Hydrometeorology Program is currently 100% advised and funded by the Atmospheric Sciences Department. These students should be included in the official headcount, but they are not.

M7. Program Growth

The Hydrometeorology Graduate Program was created in 2010. Ten students are currently enrolled in the program and 3 of them have graduated from the program.

- There was a 50% increase in graduate students since the last APR
- Two of our M.S. students in Hydrometeorology are continuing in the Department's program to receive their Ph.D.

M8. Program/Unit Revenue

The total annual expenditures on external grants and contracts is $2.38M. This is substantially higher than the total State support of ~$1M.

M9. Access

The BAS Meteorology Program is entirely distance learning for the United States Military. Currently there are ~12 enrolled and the students are located in the United States and U.S. military bases globally (e.g. Korea, Japan and Afghanistan).