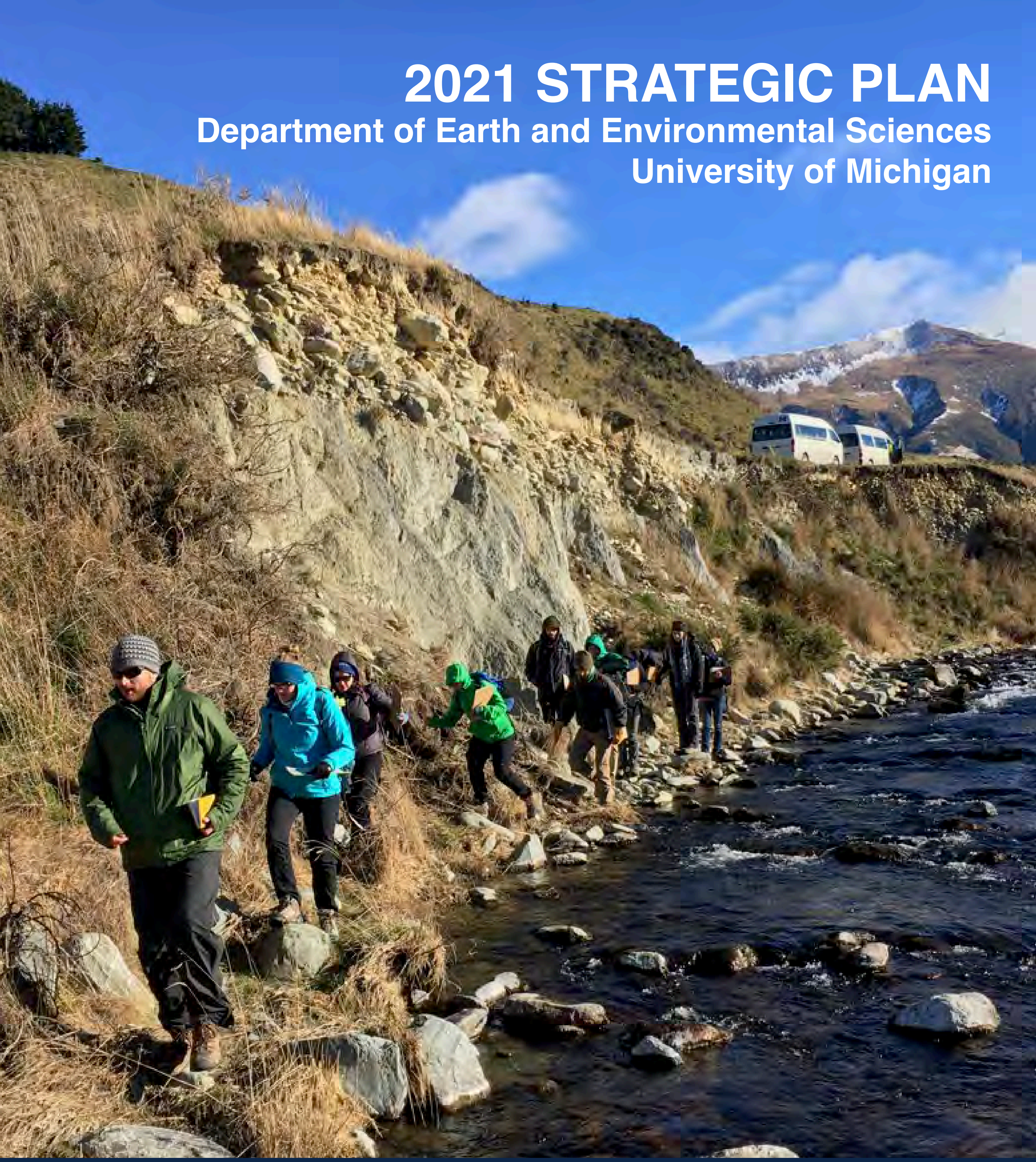
2021 STRATEGIC PLAN

Department of Earth and Environmental Sciences
University of Michigan



M EARTH

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Department Mission Statement

The Department of Earth and Environmental Sciences (EARTH) community advances the fundamental knowledge of Earth – its history, structure, dynamics, climate, life, resources, and sustainability – and shares these insights widely, with the scientific community, stakeholders, and the public. Our tenure-track and research faculty, lecturers, postdoctoral fellows, and staff work closely with all students to advance their knowledge of Earth as a system by providing important experiential learning opportunities in the laboratory and field, and training in advanced computational and quantitative methods. Collectively, we share in the production of new science and promote the success of students and early career scientists as they move through our program and beyond. We strive to maintain a diverse, inclusive, congenial, and mutually respectful culture that enables students, staff, researchers, lecturers, and faculty to thrive together.

Contents

I. Preamble – Objectives

We prepared this decadal strategic plan as a part of the external review process in the College of Literature, Arts and Sciences (LSA). It follows the previous departmental plan and external review prepared in 2008, which was significantly revised and adopted in 2011. The 2021 plan assesses progress toward goals outlined in the 2011 plan, evaluates recent metrics of our research enterprise and our educational programs, examines how our demographics and research interests have changed, and projects future shifts in our identity. These identity shifts include five strategic research directions and increasing diversity at all levels of the unit.

Importantly, we assess how we can advance our department mission; build a stronger, more cohesive unit; and accelerate our research programs during a decade of anticipated resource constraints and modest shrinking of faculty numbers across LSA. To accomplish this, we evaluate where we have common interests within the department and to other units on campus. Our proposals range from corrective actions and cultural shifts to new initiatives aimed at strengthening the intellectual environment of our unit. Recognizing that advancement will require a diverse group of individuals from all backgrounds, we present steps for systemic change at the department level. We propose aggressive target performance indicators around student program growth, equity and diversity across all levels of the unit, and integration of anti-racist pedagogy into the teaching of science.

In developing this plan, we emphasized use of data and broad department input. Leadership of individual sections was assumed by the Department Chair (Clark), Associate Chairs (Dick and Levin), an ad hoc Strategic Planning Committee (Arbic, Cole, Hetland, Lange, and Niemi), the departmental Diversity, Equity, and Inclusion (DEI) committee (Castro, Johnson, Smith, Wilson, and Zhang), lead of the Alumni committee (Lohmann), and the past and present Chief Administrators (Haggerty and Hooper). Input to these various sections was solicited through faculty meetings, department town halls, subgroup feedback sessions, and four offsite retreats. Our meetings were a combination of informational (i.e., sharing data and analysis), brainstorming, and consensus-building workshops. We utilized a professional facilitator (Sarah Kurtz McKinnon, McKinnon Creative), for planning and execution of the consensus-building workshops and for facilitating realignment of the Alumni Advisory Board (AAB) purpose with department goals. Further input was gathered via email and comments on early drafts and a complete version of the entire plan. Stakeholders in the unit include tenure-track and research faculty, lecturers, administrative and technical staff, postdocs, and graduate students. For undergraduate input, we relied on recent student surveys and anecdotal evidence provided by departmental undergraduate advisors.

Interrupted by the COVID-19 pandemic, the strategic planning process took place in two intervals: September 2019 - March 2020 and November 2020 - July 2021. While challenging to restart the planning process during an academic year when faculty, staff, and students were overwhelmed and enervated, the opportunity for strategic planning became an unexpectedly effective team-building exercise that provided much needed connection and collaboration during a protracted period of physical separation. The process itself has been vital to our sense of community and provides momentum for our return to campus.

II. Executive Summary of Key Accomplishments Since the 2011 Plan

The department has seen major gains over the past ten years as we implemented many initiatives of the 2011 plan and 2015 Rackham review (Table II-1). These initiatives have led to progress in hiring and retention, number and percentage of female faculty, research productivity, undergraduate enrollment, graduate student retention, and participation of women and people from underrepresented minority groups (URM) in our student programs. As a result, the department has retained its national prominance in Earth and environmental sciences research and education.

We currently have 32 faculty with effort-bearing appointments in EARTH (33 in Fall of 2021). Sixteen faculty have been hired since the last plan, replacing eleven faculty that either retired (8) or left at mid-career stages (3).

Our percentage of female faculty increased from 23% (2011) to 40% (2021). This percentage is the highest among our respective peer and aspirational peer departments, and well above the national average (20%).

We have maintained a top-10 ranking in Earth Science (U.S. News and World Report) and top-5 rankings in three subdisciplines. Average citation indices (h-index slope) has increased since 2011 from 1.1 to 1.6, and we have held an average rank of 12 in the Nature Index for Earth and environmental sciences since 2015.

We recently had our first faculty member elected to the National Academy of Sciences (Blum), and numerous other faculty have been elected to major societies since 2011.

The number of research active faculty (i.e. with at least one funded external grant in the last five years) lies in the upper quartile of top-ranked department peers.

The completion rates for our PhD program increased between the 2006-2010 and the 2011-2015 cohort groups (i.e. incoming year) from 63% to 79%, coinciding with programmatic changes in admissions, a first-year seminar, cohort building, and the candidacy exam.

The number of URM students in our graduate program increased from 6% to 14%, coinciding with the establishment of the Fall Preview recruitment program.

The number of undergraduate student majors in our department increased 166% (from 71 to 189) and the number of student credit hours offered per academic year increased 36% (from 10,874 to 14,802).

We implemented a major revision to the undergraduate curriculum in 2010 and added sub-plans to complement the flexible major in 2018.

We improved DEI efforts across the program, including initiatives to recruit and support undergraduate students from underrepresented backgrounds (Earth Camp, M-Sci, Wolverine Pathways).

In 2019, we completed the largest capital project in the history of our field station, renovating the student cabins at a cost of approximately $6M.

We revitalized our department laboratory and computing facilities (40% of labs are new or have undergone major renovation).

Table II-1. *Key accomplishments since the 2011 plan.*

III. Executive Summary of Recommendations for the 2021 Plan

EARTH advances the fundamental knowledge of Earth – its history, structure, dynamics, climate, life, resources, and sustainability. Our expertise has evolved over the past decade to include a stronger presence in climate (past and present), environmental science, and geobiology, which complements established strengths in geology, geochemistry, paleontology, and geophysics. A novel text analysis from published faculty abstracts illustrates two departmental cohorts: one that studies "solid" Earth (its rocky surface and interior), and another that we refer to as "wet" Earth, with interests in Earth's surface (sediments, oceans, and atmosphere) and life. Between these two cohorts, we observe more collaboration within the department and with other units on campus among the "wet" subdisciplines and less integration within "solid" Earth.

We defined future research directions based on common interest, exciting opportunities in sub-disciplines, and our ability to maximize department resources. Through a series of brainstorming and consensus-building activities, five themes emerged: (1) Water on a Changing Planet, (2) Climate, Ecosystems, and Biogeochemistry, (3) Earth's Surface and Its Hazards, (4) Evolution of Life and the Rock Record, and (5) Solid Earth Dynamics. Not surprisingly, some of these themes fall completely or mostly within one of the two department cohorts. But several others integrate traditionally siloed aspects of our intellectual enterprise, which developed organically as a part of the strategic planning process. Most themes also connect with other units on campus where we have already established relationships and highlight where we could develop future ones. Recognizing that our department will experience slow or flat growth in the next decade, we also sought ways to leverage current resources and support existing faculty. We looked closely at many aspects of external funding as an avenue for increasing research revenue and identified strategic measures such as support for larger grant proposals and approaches to ensure continuity of funding. Analysis of our research productivity, as measured by citation indices point to strong intellectual productivity.

Our educational programs have seen strong improvements in retention and growth over the past decade. We have far exceeded our expected undergraduate major enrollment from goals set in our previous plan. Growth is substantial in environmental science related fields, which largely explains our sharp increase in majors and student credit hours since 2017. This growth coincides with changes to the major curriculum, which we believe provides a clear path for environmental science studies. We are responding to the growing importance of interdisciplinary team work, communication, quantitative skills, and data science with a stronger focus on core concepts and skills, and how these map onto our curriculum. We propose to infuse the curriculum with data science, preparing students for the data-intensive nature and future of the Earth and environmental sciences. Our graduate enrollments are steady, but we have made major gains in retention over the last five years, following substantial revision to our graduate admissions, candidacy exam, and professional development. Here we renew our focus on a student-centered experience by adding more structure to student mentoring, proposing additional staff support for mental health and DEI, and fully assessing our curriculum and student outcomes.

Since our last strategic plan, we made significant progress towards gender parity amongst our faculty (now 40% women), but struggled to increase our numbers of underrepresented minority faculty. Addressing various forms of identity and underrepresentation within our ranks is essential to our goal of increasing diversity during the coming decade, and our efforts both past and future are detailed in this plan.

Postdoctoral fellows, research faculty, lecturers, and staff have participated more fully in the development of this plan than previous ones. We recognize the need to provide more professional development to these groups and articulate their current and potential contributions to our educational and research mission. Substantial capital investment has been made to both our departmental laboratories as well as Camp Davis, our field station in Wyoming, in the past decade. Future opportunities to build on these capital investments and our program at large can be leveraged with vibrant, dedicated alumni support. Through renewed commitment to our department, our AAB provides opportunities to engage alumni in fundraising and provide students with professional connections within and beyond the academy.

IV. Overview of EARTH: Faculty Demographics, Disciplinary Evolution, and Research Identity

We began our strategic planning process with a self study of disciplinary composition and connections centered on research identity. We started by evaluating the grouping and definitions of existing faculty research areas. We compared these groupings to our past and looked at long-term trends. The purpose was to represent the intellectual organization and disciplinary structure of the department, to define research themes for strategic focus, and to communicate to the outside world (e.g., deans, prospective students, faculty peers at other institutions) who we are. In our discussions, we considered faculty turnover patterns as they relate to future changes and hiring needs, considering both trends in enrollment and funding.

Research group membership plays into department intellectual culture in important ways by offering:

- Opportunities for internal co-authorship, collaborative proposals
- Opportunities for informal research interactions and exchange of expertise
- Members for qualifying exam and thesis committees
- Intellectual hubs that strengthen our graduate program by broadening mentoring and course opportunities and improve recruitment
- Opportunities to develop centers of expertise that define EARTH in the scientific community

A. Faculty Demographics

Notable trends in the demographics of the faculty include a dramatic increase in the number of female faculty (currently 40%), as well as a variable but well-balanced distribution of professorial ranks (Fig. IV-A.1). Our percentage of female faculty is highest among our respective peer and aspirational peer departments, which range from 20-37%; national data at four-year institutions average 20% (AGI, 2019). The recent "younging" of the faculty is due in part to a large number of retirements (8) and mid-career departures (2) in the past decade. Over the same period, we hired at the assistant or associate rank (9), through junior faculty Provost initiatives (3), with only one senior hire. Three faculty left for other institutions or left academic science, representing about one-third of total departures (a rate consistent with earlier periods). The low number of departures to other institutions suggests that we do not have an issue with retention. URM faculty remain low and have declined over the past decade; this is an urgent situation that demands attention in our future hiring plan (Section V-A5). Last, we note significant turnover in the past decade; more than a third of current faculty were hired since our last strategic plan.

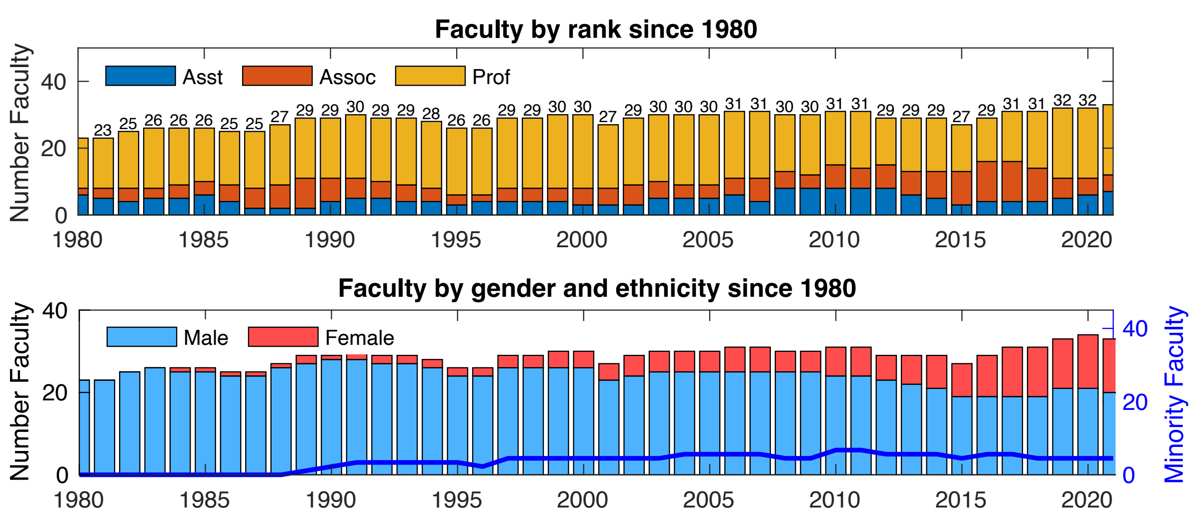


Fig. IV-A.1 (Top) *Faculty by rank since 1980, demonstrating, in particular, a transition of assistant professors to full professors since the last strategic plan (2011), and recent hires (past four years) at the assistant professor rank. (Bottom) Faculty by gender since 1980. Gender diversity with the faculty has grown substantially since 1980, with significant growth since our last strategic plan. The number of minority faculty has declined in the past decade.*

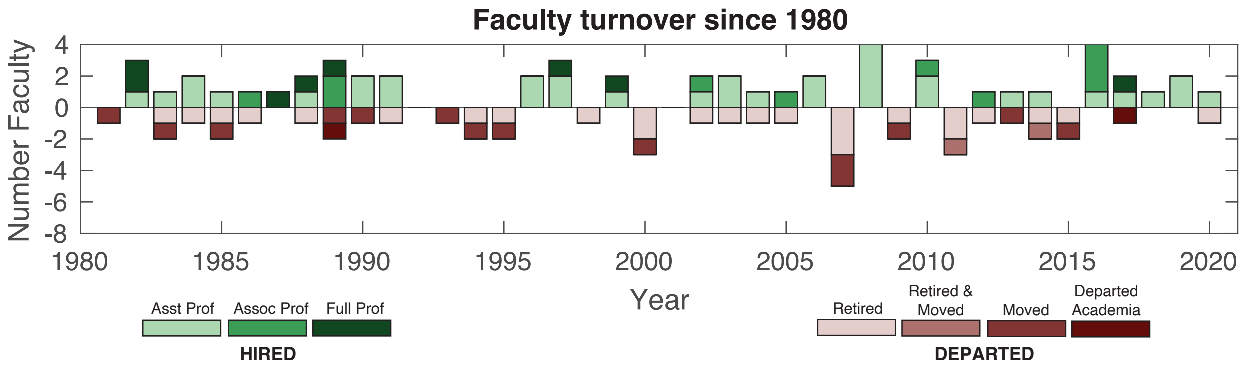


Fig. IV-A.2 *Faculty turnover since 1980. Although faculty turnover in the past decade has not been as dramatic as the turnover in 2007/2008, roughly 33% of the current faculty has been hired since the last strategic plan.*

B. Analysis of Research Areas and Disciplinary Change

Broadly speaking, EARTH has two cohorts: one that studies "solid" Earth (its rocky surface and interior), and another with interests in Earth's surface (sediments, oceans, and atmosphere) and life. Faculty were surveyed to self-identify research categories, allowing us to develop a picture of how we organize and connect. Fig. IV-B.1 illustrates the number of faculty in particular areas and the degree to which faculty self-identify with more than one category (external "dry" appointments are also included). For example, a faculty member with only one affiliation will lie on the perimeter of the circle, whereas a faculty member who chooses multiple categories will plot toward the center, equidistant to the categories chosen.

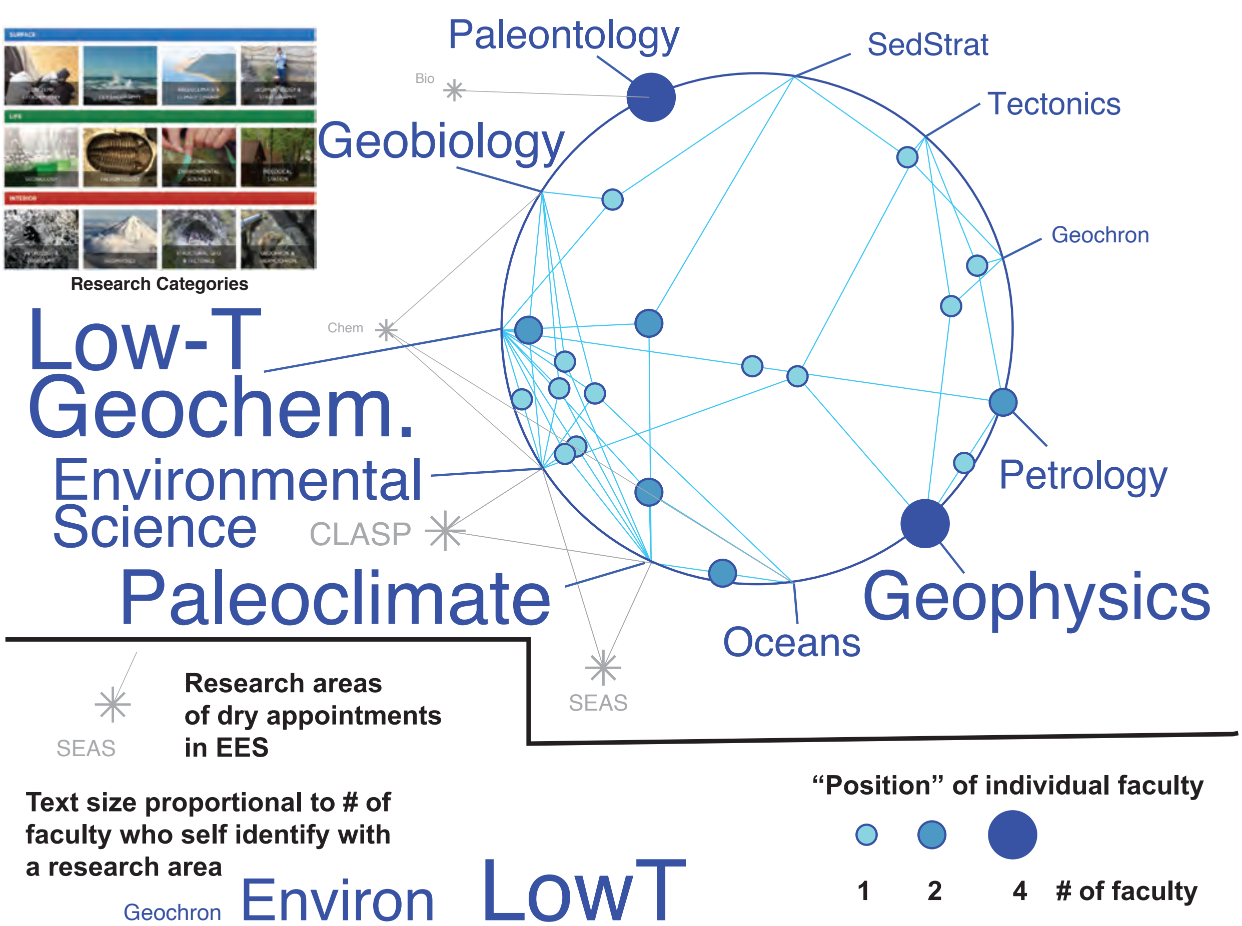


Fig. IV-B.1 *Distribution of tenure-track faculty (blue) and faculty with dry appointments (gray) based on self-identification with research categories. Faculty can identify with more than one research category, and are plotted equidistant from all categories with which they identify. Size of colored dots represents the number of faculty with a given unique research identification. Size of text labels for research categories is proportional to the number of faculty who identify with that category.*

Outcomes We observe that subfields in low temperature geochemistry, environmental science, paleoclimate, and oceans have more connections within our department and to other units on campus as compared to "solid" Earth subfields. For a historical perspective, we assigned categories to past faculty membership back to 1980 (Fig. IV-B.2) and observe: (1) a reduction in solid Earth science; (2) growth in paleoclimate, environmental science, and low-temperature geochemistry; and (3) a commensurate increase in interdisciplinary research. Two prominent phases of faculty growth (1980-1990 and 2010-2020) largely reflect growth in environmental science, low temperature geochemistry, geobiology, and paleoclimate with commensurate declines in tectonics, petrology, geochronology, and sedimentology/stratigraphy. The latter period follows the renaming of the department from Geological Sciences to Earth and Environmental Sciences. We observe that faculty associate with simulation/data analysis, laboratory/chemistry, and field expertise in roughly equal proportions (Fig. IV-B.2). Data analysis is more common than simulation, though the latter has grown among our faculty over time. Likewise, laboratory research is primarily based in geochemical analysis, though experimental laboratories have seen steady growth.

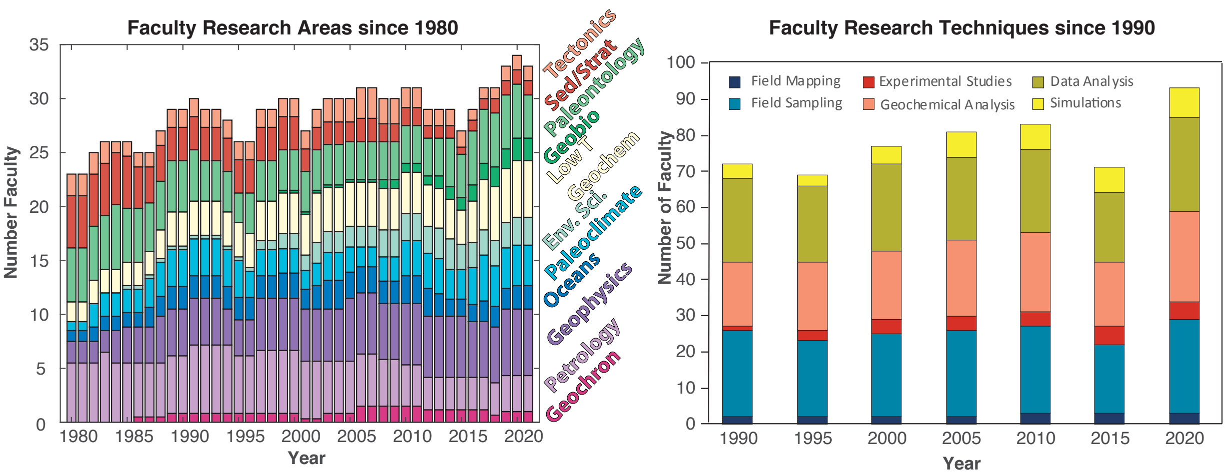


Fig. IV-B.2 *Trends in faculty research. The left panel tabulates faculty primary research category affiliation over the past 40 years. Primary research categories were self-identified and are exclusive; each faculty member has a single primary affiliation. The right panel illustrates the distribution of research tools and techniques used in the department over the past 30 years. These categories were not self-identified and are not exclusive (i.e., faculty can use multiple tools or techniques).*

C. Analysis of Faculty Research Areas Using Text Analysis

To investigate research connections and collaborations beyond faculty self-identification, we analyzed abstracts[1] published by the tenure-track faculty from 2015-2019. The simplest analysis explored connections through co-authorship. A second analysis of the abstracts' text assessed similarities in research as defined by shared vocabulary[2], based on the frequency with which given terms were used across the faculty, and minimizing the total disparity of vocabulary use.

Outcomes The analysis of co-authorship demonstrates two clear features. First, nearly every faculty member (largely with the exception of recent hires) has co-authored an abstract with another faculty member in the department during the past five years (Fig. IV-C.1). The second clear feature is a marked divide between two large groups of collaboration networks. These two networks fall along the division described above, separating the solid Earth and climate/environmental/biology sides of the department, with more intricate patterns of collaboration within paleoclimate and geobiology.

[1]Abstracts were from peer-reviewed papers, meetings, and grant proposals, and included 1,088 unique abstracts.

[2]Vocabulary, in this context, only included words that could be used as nouns or for which the grammatical sense could not be resolved using an automated grammatical identification. Words were contracted to a common base-form, and terms related to days, months, or dimensions/units were removed, resulting in 10,143 terms used in total 120,685 times across the abstracts.

To first order, clustering follows co-authorship networks, due to shared abstract text and commonalities of research questions. At higher orders, we find several interesting features, including connections based on shared methodology despite differences in research questions, commonality in the time period studied, and “connector” clusters or individuals bridging between larger clusters (e.g., branch 2a and DF, respectively). Dissimilarity between paleontology faculty is greatest, affected by differences in taxonomic terminology. Branch 4, with 11 faculty, has the highest interconnectedness in terms of co-authorship, highlighting an important area of intellectual cohesiveness in the department. In contrast, branches 1 and 2b have sparser connection within their co-author network, despite the close proximity of those faculty in the clustering, suggesting unrealized collaborations or the relatively lower number of faculty in those clusters. We plan to utilize this text analysis to gain objective insight into how a potential new faculty member (or proposed area of expertise for a new hire) might fit into, or revise, the landscape of the department.

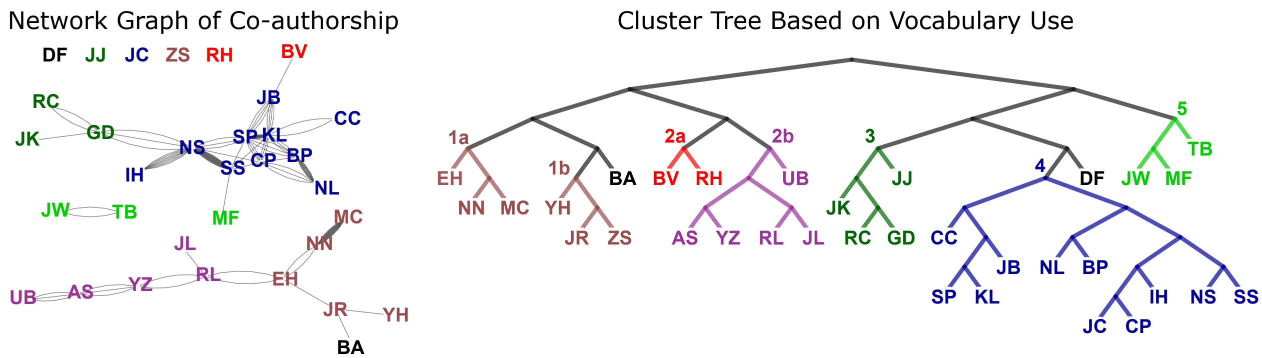


Fig. IV-C.1 (Left) *Network graph showing co-authorship; each co-authored abstract between faculty indicates one co-authored abstract.* (Right) *Cluster tree grouping faculty based on shared vocabulary.*

V. Self-study Sections

This portion of the report contains nine main sections and is essentially the heart of the self-study and future planning exercise. The first three sections overview EARTH in terms of our research enterprise and student programs. Each contains a response to the 2011 plan, evaluation of our current status, and recommendations for the coming decade. DEI and departmental climate are addressed in sections V-D and V-E, and remaining sections cover staff, departmental organization, infrastructure and alumni relations.

We collectively developed five research directions for priority focus, as reflected in the research section. These are much broader than hiring plans; they include description of the connections we make to one another and to other units on campus based on shared research interests. These research directions are our assessment of how we can advance our department mission, build a stronger and more cohesive unit, and accelerate our research programs. What's exciting is how much these themes intersect and connect our department in new ways within our unit and across campus.

A. Research Enterprise

A1. Response to Previous Plan; Key Research Accomplishments Since Previous Plan

The department's last strategic plan was submitted in 2011 as a revision to the strategic plan submitted in 2008. An external review conducted during 2008 identified several imperatives that had not been addressed in the submitted plan: (1) increasing levels of external funding, (2) ensuring high-quality mentoring for junior faculty, (3) developing a fair and optimal set of criteria for technical support to labs, (4) improving the infrastructure and equipment in department labs, and (5) developing a plan for future hiring that did not involve expansion. Review of that plan also raised concerns with regard to student programs, which are addressed in sections V-B2 and V-C2 (undergraduate program) and V-C3 (graduate program).

1. **External Funding** The 2011 strategic plan set a goal to increase and diversify our external funding for research. The 2008 external review raised concerns that the department's external fundraising was below that of peer top-ten institutions. Moreover, we were not reaching optimal external funding levels across all ranks of faculty, and thus needed to make substantial improvements. The external funding in the department had dipped to a low level at the time of our 2008 external review but had dramatically increased by 2011, largely due to a stabilization of the high faculty turnover in the years prior to the 2008 review (43% turnover across the six years prior to the report). Our 2011 plan focused on ways to increase and diversify our external funding to support research, and three initiatives were proposed to increase external funding levels: (1) invite each faculty member to compare their funding levels with peer faculty at other institutions as part of their annual reviews; (2) encourage and assist faculty in the diversification of their sources of external funding; (3) consider potential for external fundraising as an important criterion when discussing potential subfields to search in and in evaluating faculty candidates.

   Outcomes All three initiatives involved faculty-wide discussions and encouragement, but without specific benchmarks. Initiative 1 was deemed to be unworkable and abandoned. Initiatives 2 and 3 were realized. The issue of funding landscape has permeated our discussions of future hires, although the quality of science and relevance of that science to our department drive our hiring decisions. We realize that we have yet to achieve steady levels of high external funding commensurate with our peers, with a concerning dip in funding 2013–2018. We examine funding issues at length in Section V-A3.

2. **Junior Faculty Mentoring** The 2011 plan outlined three initiatives to increase mentoring of junior faculty: (1) clearly separate mentoring and evaluation activities, (2) institute individual meetings with junior faculty and the Chair to discuss annual reviews, and (3) institute monthly cohort-building meet-

ings for Assistant Professors.

Outcomes All three of the initiatives were realized immediately. To achieve Initiative 1, we discontinued our practice of Assistant Professors meeting annually with the Executive Committee (EC), which commingled review of past performance with mentoring from senior faculty in one meeting. We implemented separate mentoring and review meetings in the Fall and Winter terms, respectively; this practice will become formal departmental policy upon vote by our EC this fall. Assistant Professors, and Associate Professors at their discretion, meet with their senior mentor and the Chair for an annual fall mentoring meeting, the first half devoted to teaching, where the Associate Chair of Curriculum joins, and the second half to research, where up to two senior faculty members can be invited by the junior faculty member. All faculty are still reviewed annually by the EC, and the Chair provides a written summary of this review. Assistant and Associate Professors meet annually or biennially, respectively, with the Chair to discuss this review during the Winter term (Initiative 2). Initiative 3 resulted in department-hosted monthly meetings of pre-tenure faculty, which have been successful in cohort building and providing informal exchange of information related to navigating the pre-tenure period. Junior faculty also benefit from their ADVANCE Launch committee during their first year, in which they are mentored by senior faculty within and beyond their home department.

3. **Lab Technical Support** The 2011 plan outlined the need for an equitable division of support to laboratory technicians and established a new set of criteria to determine levels of department support.

   Outcomes This initiative was largely implemented, with the exception of regular EC review as a prerequisite for continued funding. To an even greater extent than in 2011, our 2021 research program relies heavily on chemical/physical/biological measurements or experiments conducted in department facilities where research productivity and student training are enhanced with the support of technical staff. Twenty-three of our 33 current faculty members operate a department chemistry or experimental laboratory, with most laboratories supporting external recharge and non-EARTH users at UM. We currently employ twelve skilled technicians with long-term salaried appointments. Maintaining stable support of high-quality, trained laboratory technicians remains a central issue for our department, as does an equitable distribution of department resources that subsidize their support. We looked closely at these issues in early 2020, but did not agree on revisions to the technician support policy. Revisiting this issue in the coming year will be a high priority. One of the primary recommendations is to incentivize sharing of technical staff by multiple Principal Investigators (PIs), which not only reduces the financial burden but also broadens professional development opportunities for our technical staff, as addressed in Section V-E.

4. **Lab Infrastructure** Highly productive analytical and experimental laboratories are critically important to the department's research footprint. A key tenet of the 2011 plan was to revitalize department laboratories. This plan was not only realized, but was far exceeded due to several hires that followed. Accomplishments related to facility upgrades and new laboratories are further described in Section V-H.

5. **Hiring** The hiring plan outlined in the 2011 plan was cast entirely in terms of the FTE allocation to the department at that time. We indicated five areas to target for future hires: (1) energy/mineral resources, (2) global climate change (with emphasis on the water cycle), (3) geochronology, (4) aqueous geochemistry, and (5) early Earth.

   Outcomes Areas 1, 3, 4, and 5 were realized with the hires of Simon (2012), Holder (2020), Cory (2013), and Johnson (2018), respectively. We searched in area 2, and ultimately did not find a suitable candidate working specifically on the water cycle, and thus we expanded our scope more broadly to climate and hired Levin and Passey (2016). The hires of Cole (2017) and Petersen (2017) also fall within area 2, but also without emphasis on the water cycle. Additional hires that were not explicitly a part of the 2011 plan include: Smith (2014) in paleobiology; Friedman (2016), a joint position in the Museum of Paleontology; Huang (2016) and Spica (2020) in geophysics; and Kharbush (2021) in biogeochemistry.

A2. Department Ranking and Faculty Accomplishments, Comparison to Peer Institutions

Our department was ranked 10th in Earth sciences in recent U.S. News and World Report (USNWR) rankings (2018) (Fig. V-A2.1), and between 5th and 10th since 2002; we consistently have subspecialty rankings in geology, geochemistry, and paleontology that surpass the overall ranking. The department has not been ranked in environmental sciences or geophysics (the latter of which has the strongest correlation with overall USNWR ranking). Stratification of departments in the USNWR rankings is significant, with departments consistently ranking within either the top five or the next five over 16 years, with departments only shifting ranking within ranks of 1–5 or 6–10. Within the top 15 departments, overall ranking is positively correlated with faculty size (Fig. V-A2.2); top-ranked departments also tend to be embedded in schools or colleges of Earth Sciences, or are associated with soft-money research institutions.

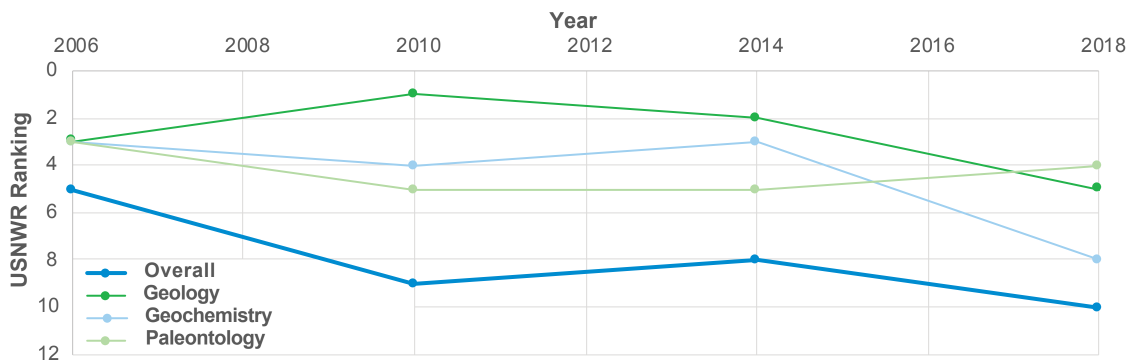


Fig. V-A2.1 *Overall and speciality rankings for EARTH since 2006 from U.S. News and World Report. Rankings for science graduate programs are updated every four years.*

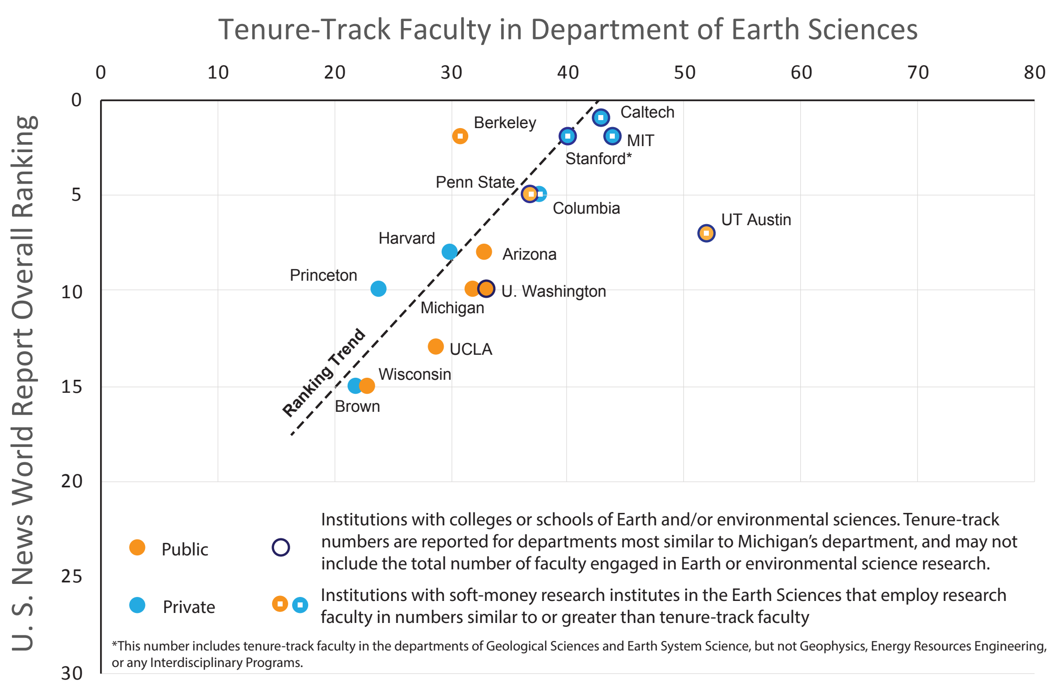


Fig. V-A2.2 *Comparison of department ranking (overall from U.S. News and World Report) with faculty size. Department ranking is positively correlated with faculty size, although top-ranked departments also tend to be embedded in schools or colleges of Earth Sciences, and to be associated with soft-money research institutions.*

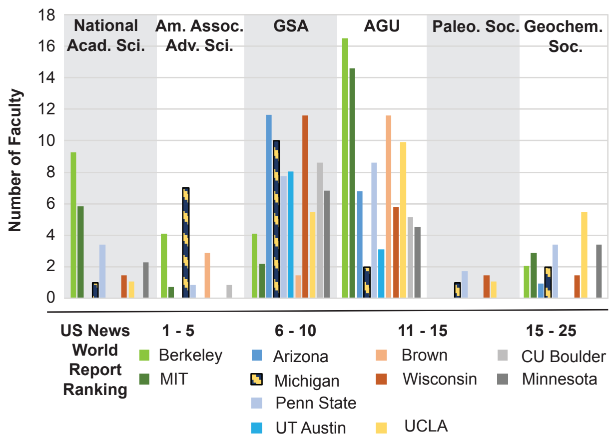


Fig. V-A2.3 *Chart of faculty members at Michigan and 10 peer institutions who have achieved honors and fellowships. Peers are color-coded and organized by U.S. News and World Report Overall ranking.*

The number of faculty that have been awarded fellowships in societies provides another measure of faculty accomplishment and peer comparison. Fellowship in six societies (Fig. V-A2.3) was determined for the faculty of eleven institutions across the range of USNWR rankings, adjusted to median faculty size (the same institutions were analyzed for funding, in Section V-A3). We considered only fellowships with public databases and ones that can be compared across our peer institutions. The top five institutions have greater representation in the National Academy of Sciences than other institutions, as well as larger numbers of American Geophysical Union (AGU) Fellows. These institutions are also highly ranked in the subspeciality of geophysics. In contrast, institutions ranking from 6-10 in USNWR are characterized by greater numbers of Geological Society of America (GSA) Fellows and subspeciality strength in geology. Our department is well-represented in American Association for the Advancement of Science and GSA compared to our peers, but is underrepresented with respect to AGU Fellows. The number of Paleontological Society and Geochemical Society fellows in our department is low compared to our ranking in those subspecialities, but not substantially different from our peers. Faculty biosketches (Appendix A1) provide a full listing of all fellowships and honors.

We recognize the relationship of subspecialty rankings to overall rankings, and that the visibility accompanying fellowships at AGU, Paleontological Society, and Geochemical Society factors into departmental reputation. Increasing our national ranking may also benefit from achieving ranking in geophysics, which correlates with overall ranking. It is important to note that many sub-field specialties in EARTH that contribute strongly to our national reputation are simply not captured by the USNWR subspecialties.

Publication indices are the third evaluation metric we used to assess faculty productivity. The h-index measures the cumulative impact of an author's scholarly output and performance and is calculated by counting the number of publications for which an author has been cited at least that same number of times (Hirsch, 2005). For example, an h-index of 15 means that the scientist has published at least 15 papers that have each been cited at least 15 times. An individual's h-index generally increases in time, so it is common to plot h-index as a function of years since PhD (Fig. V-A2.4). The average slope (h index divided by years since PhD, or *m*–value) for the entire faculty is 1.6, up from 1.2 in 2011 and 1.0 in 2007, based on citation data collected from Google Scholar in July 2021.

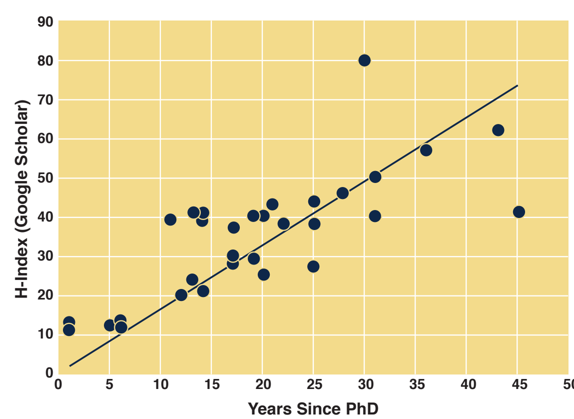


Fig. V-A2.4. *h-index vs. years since PhD for 31 of the 32 tenure-track faculty in EARTH (July 2021).*

The Nature Index Share metric reflects the sum of fractional author contribution to papers published in 82 high profile journals. Nature Index also publishes a Share metric specific to the Earth and environmental sciences; which specific journals are included in this topical metric are not reported; reviewing the full list, eleven of the journals are Earth or environmental science focused. UM is among a group of 24 institutions that have been ranked in the top 25 in the Earth and environmental sciences Share metric each year from 2015-2020 (Fig. V-A2.5). The Share metric assigns an equal fraction to an institution for each co-author on a paper in the tracked journal list (e.g., if four co-authors from different institutions published a paper in Nature, each institution would be allocated a 0.25 Share for that paper). Michigan is consistently ranked around 11th among United States academic institutions in the Share metric (tied with Penn State). One interpretation of the Share metric is that it represents the equivalent number of sole-author papers

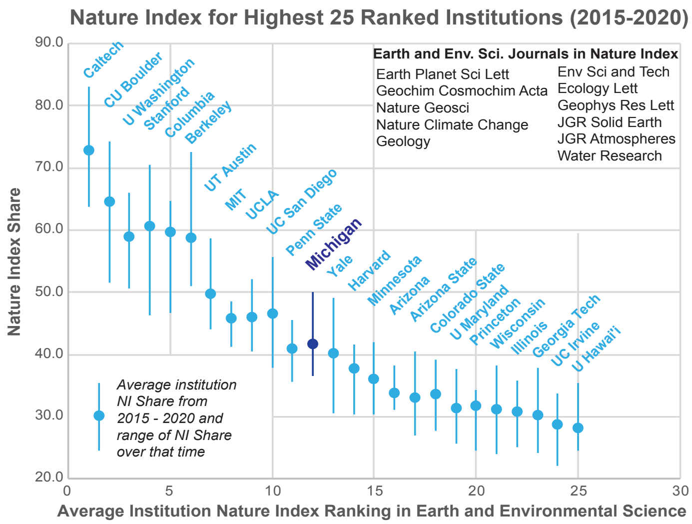


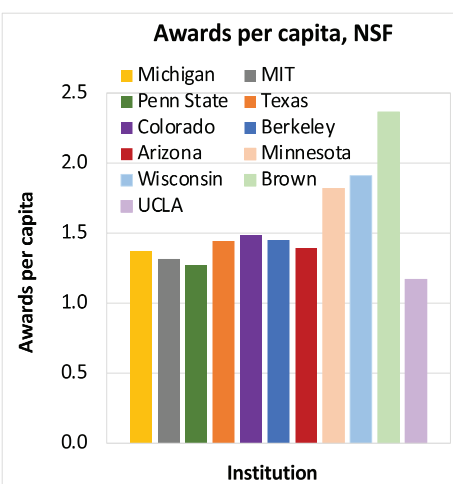
Fig. V-A2.5 *Nature Index Share metrics for 25 top-ranked Earth and environmental sciences institutions in the United States. Error bars represent range in Share over the period 2015-2020. Eleven journals with an Earth or environmental science focus from Nature Index's list of 82 tracked journals are shown at the upper right, although Nature Index does not explicitly list the journals tracked in the Earth and environmental science rankings.*

from a given institution published each year in the tracked Earth and environmental sciences journals. In such a framework, Michigan publishes the equivalent of 41 sole-author papers in these journals each year, a higher number than all but 10 other institutions (Fig. V-A2.5). Because Nature Index data are organized by institution, individual departmental contributions cannot be tracked (at UM, or at other institutions); however, the data speak broadly to institutional strengths in Earth and environmental sciences that our research themes, discussed below, can build on.

A3. Sponsored Research Funding, Comparison to Peer Institutions

To evaluate our funding strength, we compare our department with ten peer Earth and geoscience programs in the US, including public and private, of varying size and breadth of field (e.g., some include planetary and/or atmospheric sciences). We use publicly available awards data for major funding agencies (NSF, NASA, NOAA, DOE, and DOD), spanning January 2015 through May 2021 (Fig. V-A3.1; Appendix A2, Fig. AppA2-1). We extracted data on grant awards using the April 2021 tenure-track faculty from department websites, and that number of faculty provides the basis for per-faculty calculations. We did not include research faculty, emeriti, or faculty who left a department before 2021; this approach underestimates total funding over the 2015-2021 interval, but provides the most consistent basis for comparisons. Our main findings are below; additional graphs are provided in Appendix A2.

Our department's funding depends strongly on NSF, particularly the Earth science division (EAR) in the Geosciences (GEO) directorate. EAR funding comprises 74% of our NSF dollars and 58% of our total funds from all agencies. Within NSF, we receive 12% of our funds from Ocean Sciences, and smaller amounts from Atmospheric and Geospatial Sciences (4.7%), Integrative and Collaborative Education and Research (4.1%), Office of Polar Programs (2%), and non-GEO (3.2%) sources. These percentages are



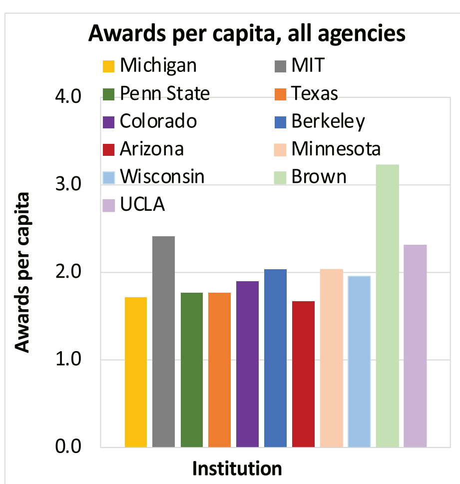


Fig. V-A3.1 *Awards per faculty member for EARTH (yellow) and 10 peer departments. Left panel indicates the number of NSF awards per faculty member; right panel indicates the same metric including awards from NSF, NASA, DOE, NOAA, and DOD. (1/2015-5/2021).*

similar to many of our peers (see Appendix A2, Fig. AppA2-2 and 3), although this varies by department composition. However, our total NSF grant activity ranks in the lower third of our peer group. In terms of number of awards per faculty, six of the eleven peers rank above us, three rank lower, and one is a virtual tie. In terms of NSF dollars per capita, we rank below all peers. Our mean award size is small relative to most peers, although our median size is in the top half (see Appendix A2, Fig. AppA2-4). Our NSF budgets do not include graduate tuition for graduate research assistants, a departmental subsidy that has averaged $277,375 per year over the past 3 years (at that rate, $1.7M over the 6-year period of this funding analysis). Whether this affects our grant budgets is difficult to assess; some faculty report that they write smaller-budget proposals to be more competitive, whereas others aim for the same total request with increased funding in non-tuition categories.

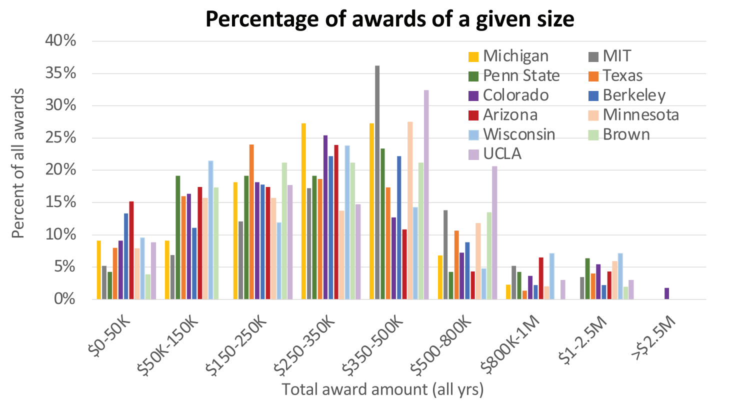


Fig. V-A3.2 *Comparison of NSF award sizes for EARTH (yellow) and 10 peer departments, expressed as a percentage of all NSF awards received by this department over the analysis period (1/2015-5/2021).*

The lower funding levels likely reflect a difference in award size between our department and our peers (Fig. V-A3.2 and Appendix A2 fig. AppA2-5). More than 50% of our grants fall in the $250-500K range, typical of one- or two-PI projects funded by core programs in NSF-EAR, with no awards over $1M. Virtually all our peers have one or more large (>$1M) awards; these include large interdisciplinary programs (e.g., critical zone), educational support, community lab facilities, and program offices. Our mean and median award sizes are nearly the same; our peers show larger mean-median differences as a consequence of a few big awards (see Appendix A2 Figs. AppA2-4, 5).

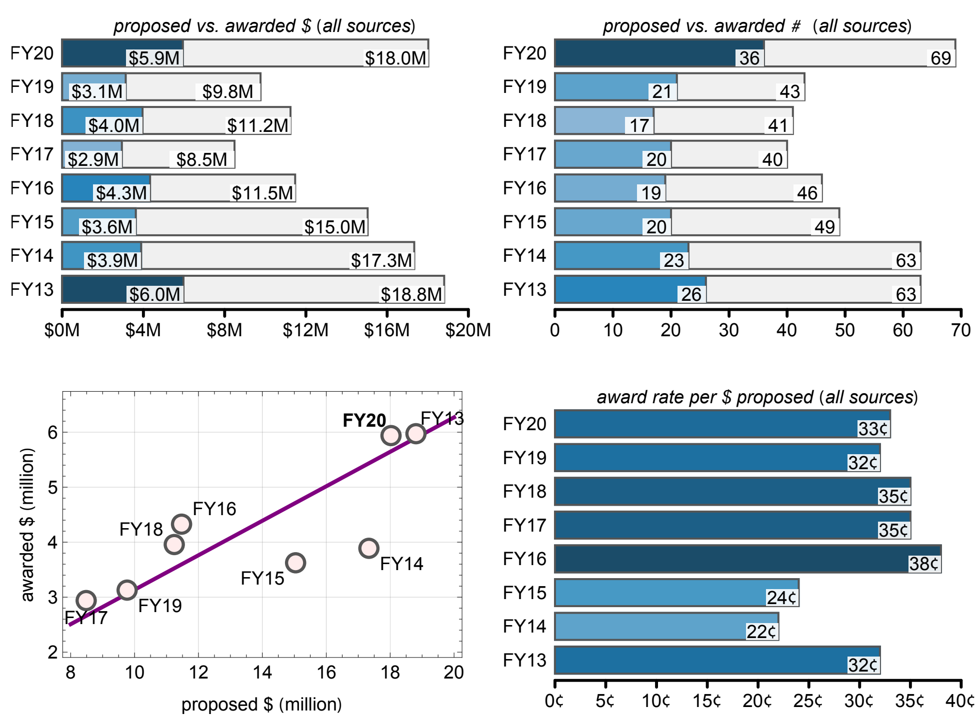


Fig. V-A3.3. *Trend in dollars proposed vs. dollars awarded for EARTH external funding FY13-FY20. (Top Left) All funding sources, total $. (Top Right) All funding, total number of awards. Total award amount is counted in the fiscal year of submission. Proposed dollars correlate with awarded amounts at relatively constant success rates regardless of the amount proposed (bottom).*

Outside of GEO, we tap a narrower range of NSF programs, although the numbers are relatively small: the 11 studied departments have 37 awards from 17 non-GEO NSF programs, and EARTH has 2 of these, both from NSF's Division of Environmental Biology (BIO-DEB). Of the eleven departments, seven have three or more non-GEO NSF awards. Looking beyond NSF, we receive 21% of our funding from other federal agencies (mostly NASA), in areas of ocean modeling, astrobiology, planetary geochemistry, and surface hazards. This percentage is comparable to the subset of peer departments who, like us, do not include atmospheric or planetary sciences (excludes MIT, Berkeley, Brown, UCLA). However, our funding per capita remains at the bottom of our peer group when non-NSF sources are added (Fig. V-A3.1; Appendix A2 fig. AppA2-6).

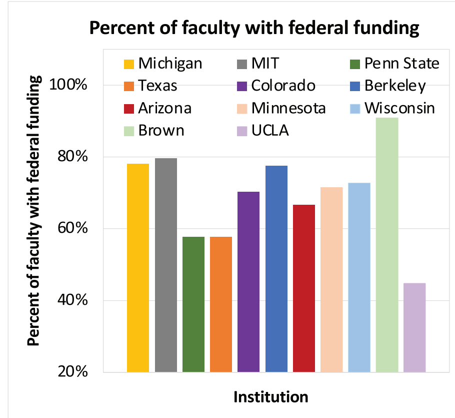


Fig. V-A3.4. *Comparison of the percentage of faculty with federal funding (NSF, NASA, NOAA, DOE, DOD) in EARTH (yellow) and the ten peer departments.*

A few years ago, we recognized with concern a declining trend in awards, accompanied by fewer proposal submissions (Fig V-A3.3). This trend mirrors the steep decrease in total submissions to GEO from 2014-2018 as NSF removed deadlines from most core programs. A promising reversal of this trend occurred in FY20 after considerable focus and discussion by the faculty. Our current picture shows a high level of faculty participation in grant funding: 78% hold some form of federal grant award (i.e., active within the last five years), placing us third in the group of eleven (behind only Brown and MIT; Fig. V-A3.4). This metric points to a strong culture of grant-writing that can become a foundation for growing and sustaining our grant activity. We also note a high success rate: averaged as 44% expressed as the number of awards (31% in terms of per dollar proposed) over the period of FY13-20 (Fig. V-A3.3). These rates are higher with the average success rate per number of awards published by NSF for GEO (32 and 37%) and EAR (37% and 27%) for FY 2017 and 2018 respectively.

Recommendations regarding sponsored research funding:

1. **Improve communication with faculty about funding opportunities**. Opportunities to submit large interdisciplinary grants often are short-lived and fall outside the NSF core programs. Direct communication from sponsored research offices (e.g., Randall Business, UM Office of Research) about such opportunities will ensure that faculty are aware of funding opportunities outside their core programs with sufficient lead time to prepare successful team proposals. Outside NSF, faculty may be unaware of potential sources of support; regular updates on other federal opportunities, as well as relevant foundation, state, and other sources, would help us diversify our funding base.
2. **Develop and institutionalize ways to sustain strong grant activity**. Most of our faculty are engaged in grant writing and are successful at a higher rate than average. We will focus on continuity of funding through encouragement of regular grant submissions and resubmissions of declined proposals. Our recently adopted teaching policy supports this goal. For those faculty who are struggling to prepare successful proposals, we will further develop peer-mentorship in addition to existing support given by the Department Chair and senior faculty.
3. **For faculty who opt to lead large proposals, find ways to effectively facilitate this effort**. The department could promote this activity in a variety of ways, for example by reducing the service load for faculty leading large grant proposals, providing staff support for proposal organization and development, supporting mock panel review, or meeting other program-specific needs.

A4. Recommendations for 2021-2030, Including Five Research Themes

The following section was developed by the tenure-track and research faculty in a consensus workshop led by our consultant Sarah Kurtz McKinnon. These themes represent broad areas of scholarly interest that range beyond faculty hiring and include a range of ways that the intellectual environment of the department can be advanced. The five themes include:

- **Water on a Changing Planet**
- **Climate, Ecosystems, and Biogeochemistry**
- **Earth's Surface and Its Hazards**
- **Evolution of Life and the Rock Record**
- **Solid Earth Dynamics**

These themes are described in the following sections, and we discuss issues that pervade all of these themes, along with specific hiring priorities, in Section V-A5.

A4.1 Water on a Changing Planet

Overview: Among the greatest environmental challenges of the coming decades is ensuring a safe, sustainable, and equitably distributed water supply. The hydrological cycle supports our food, energy, and water needs; regulates climate; shapes Earth's surface; and underpins ecosystem health. Human activity is modifying hydrological systems at increasing rates and scales, from local diversions to fundamental changes in water partitioning, and is altering aquatic chemistry and ecosystems through contaminant and nutrient pollution, invasive species, and other disruptions. The Laurentian Great Lakes hold >90% of the nation's freshwater supply, and we witness firsthand how the changing climate is impacting the quantity, quality, and sustainability of this resource. To develop a leading program in water science, we propose leveraging existing expertise, building cross-disciplinary bridges on and beyond campus, and recruiting new researchers and educators. We expect this direction to engage a growing number of students at all levels and position us to lead science that is critical for regional and global sustainability.

Building on strengths and addressing gaps: Our core and adjunct faculty already lead in many areas of water research, including surface and groundwater chemistry, microbial ecosystems, and the intersection of climate change with hydrology, oceanography, limnology, soil science, geomorphology, and cryospheric studies. We use observations and models to document the past and present behavior of aquatic systems, and we apply these insights to projections of future change. Our labs support water chemistry analysis through stable and radiogenic isotopes, element concentrations, and noble gases. EARTH faculty research the microbiological and chemical controls on the production, cycling, and emissions of toxins, nutrients, and greenhouse gases in and from fresh water. Several paleoclimate faculty emphasize hydroclimatic changes and their large-scale controls.

We intend to build on these strengths to elevate our department's water science enterprise, increase funding, attract more students at all levels, and grow our reputation as a center of excellence. A strategic effort to develop collaborative projects, engage cross-campus partners, and target opportunities to recruit new researchers in this area would position our program to address the societal challenges posed by water in a changing world, and to be recognized as a leading institution in water science. We identify opportunities to establish and grow complementary partnerships with other UM entities, including Civil and Environmental Engineering (CEE); Climate, Atmospheric and Space Sciences (CLASP); Ecology and Evolutionary Biology (EEB); the School for Environment and Sustainability (SEAS); the Graham Institute Water Center; and the UM-NOAA Cooperative Institute for Great Lakes Research (CIGLR). Other local partners could include the US Geological Survey and NOAA Sea Grant. Field and lab infrastructure at the UM Biostation (Pellston, MI) and Camp Davis (Jackson, WY) could strengthen research and educational programs in water science.

A strategic focus on water science will expand the scope of our societally impactful research and widen opportunities for our students, including in remote sensing, data science, stakeholder-driven research, risk analysis, and policy-relevant science. We anticipate that expanding our students' preparation for careers accessible with a bachelor's degree, along with non-academic opportunities for our MS and PhD graduates, will attract a greater number and diversity of students. This direction would fill a gap in our expertise on modern Earth system processes that would bolster other research areas, particularly climate, hazards, geomorphology, and contaminant fate and transport.

Synergies, new directions, and opportunities: Water-related research that would build on established strengths include:

- Integrated (physical, biogeochemical, ecosystem) modeling of the Great Lakes and their watersheds, including regional linkages to climate, groundwater, and land use;
- Local and global impacts of water cycle changes in high-latitude regions;
- Paleoclimate-informed assessments of water availability in water-stressed regions;
- Systematic analysis of water-related hazards (e.g., flood, drought, landslides, storms, algal blooms);
- Linking terrestrial systems (e.g., critical zone, land use, ecosystems) with the water cycle;
- Modeling that leverages analytical strengths, (e.g., reactive transport, isotopic).

We identify additional promise in expanding into remote sensing of the hydrologic cycle, for example, linked to the upcoming NASA Surface Water and Ocean Topography (SWOT) mission that will provide unprecedented data stream on the extent and fluxes of surface water. Our department is underrepresented in NOAA and NASA funding compared to many of our peers (Section V-A2). We would also benefit from adding strength at the interface of basic and applied water science, including expertise in how water science advises disaster preparedness and response, water management practice and policy, (hydro)climate risk analysis, resource extraction, climate adaptation strategies, and issues of equitability and justice around water accessibility, quality, and hazards. We see opportunities to establish ties with those who work in the emerging discipline of socio-hydrology, in collaboration with other campus units. Linking basic water research with applied and policy studies will help us attract and prepare more students to work in this growing field.

Finally, water science holds synergies with other research themes, including theme A4.2 (Climate, Ecosystems, and Biogeochemistry) climate, theme A4.3 (Earth's Surface and Its Hazards), and theme A4.4 (Evolution of Life and the Rock Record). Common themes include hazards related to physical, chemical, and biological aspects of water; biogeochemical fluxes linked to the changing water cycle; critical zone processes; and climate controls on water availability.

A4.2 Climate, Ecosystems, and Biogeochemistry

Overview: Climate, ecosystem, and biogeochemical processes are fundamental to the environmental changes occurring around us now, and to the uncertainties that surround them. The accelerating pace of these changes highlights the urgency to understand, anticipate, and mitigate their impacts. Current environmental changes are unprecedented and not easily predictable: anthropogenic warming fundamentally alters how greenhouse gases are cycled, how water is partitioned, whether ecosystems can thrive, when and where climate hazards will happen, and how we meet basic human needs for food, water, and energy in just and sustainable ways. Key to advancing science in this area is greater integration and synthesis among subfields, across scales of time and space, between data and theory, and among disciplinary practices to link basic science with human needs. Our current strengths in climate change, geobiology, and biogeochemistry position us to engage more broadly across disciplines and address these issues.

Building on strengths and addressing gaps: Our department supports strong research programs in environmental science and global change; half our faculty connect with this theme and incorporate inter- or cross-disciplinary approaches to modern or past environmental change. Notable programs include data and model studies of the paleoclimate record across human to geologic time scales. We host a particularly vigorous light stable isotope program that includes past and modern applications in ocean and atmosphere variability, integration with climate models, ecosystem processes (microbes to megafauna), and biogeochemical dynamics. Our notable research in microbial ecology and biogeochemistry explores carbon and nutrient cycling, harmful algal blooms, early life on Earth, microbe-mineral interactions, and trace elements in terrestrial ecosystems. Ocean-focused programs emphasize modeling, paleoceanography, biogeochemistry, and microbial systems.

Our footprint in this research theme is robust, but driven by individual labs; the desire to expand inter-lab projects is strong, but limited by resources and people-hours. We see opportunities to leverage our strengths by developing collaborations among groups within the department and across campus. Through adjunct faculty and postdoctoral appointments, we have established links with CLASP, SEAS, EEB, CGLR, and the UM Department of Chemistry. Collaborations with these programs could be strengthened and expanded to support the interdisciplinary science needed to address critical problems of environmental change. Similar appointments with a wider range of researchers (e.g., in the areas of social science, policy, and law; government agency experts) could expand our department's reach with respect to societal impact and policy applications.

Synergies, new directions, and opportunities: Here we identify three pathways with the potential to bring together existing research strengths around larger, integrative themes and address cutting-edge questions in global change science.

First, integrated modeling provides a point of integration around which larger interdisciplinary projects can nucleate. Modeling allows us to characterize linkages among components of Earth's climate and environment and enables scaling up from process-based understanding at the local or micro level to regional and global impacts. Strategically growing the modeling component of our program (for example, in Earth system modeling or coupled ecological-physical-biogeochemical models) may catalyze new and fruitful research progress.

Second, we highlight the need to build research strength in modern processes and mechanisms of climate, biogeochemical, and ecosystem change. This could take many forms, from remote sensing of ecosystem, land surface, or water cycle features, to ecosystem-scale instrumentation for microclimate and biogeochemical fluxes. Strengthening our focus on modern climate-ecosystem-biogeochemical processes will position us to better address current trends and risks (e.g., ecosystem stability, water cycle modification, greenhouse gas fluxes) and improve our insight into past changes.

Third, we identify the need to better characterize impacts and risks of environmental change at local to global scales, and to connect these with people. In a warming, less predictable, and ecologically fragile world, human needs (e.g., food, clean water, ecosystem goods and services, safety) are more difficult to meet, especially for vulnerable populations and in places that face increased risks in the near future. The differential impacts of environmental change are manifest globally, regionally, and locally. Within this theme, there is potential to expand our foundation of basic science into more applied directions that serve human needs related to characterizing and mitigating risks, assisting adaptation, (bio)remediation, and informing policy and other solutions.

This research direction includes significant overlap with those on themes A4.1 (Water on a Changing Planet) and A4.3 (Earth's Surface and Its Hazards). For example, in the Arctic, warming is driving unprecedented hydrologic changes, with major impacts on ecosystems, biogeochemical fluxes, land surface stability, radiative feedbacks, and Indigenous ways of life. More broadly, many climate and ecological hazards (e.g. drought, fire, flood, ecosystem collapse, algal blooms) connect with water science and undermine human well-being. Recent reports on this scientific area (e.g. from the National Academy of Sciences and funding agencies) prioritize cross-scale modeling, deep integration across disciplines, high-latitude and coastal regions, and linking science to decision-making. Increasing emphasis on connecting science to human needs could improve access to a broader range of funding streams (e.g., NSF's Navigating the New Arctic; Coastlines and People; Science, Engineering, and Education for Sustainability; and Dynamics of Integrated Socio-Environmental Systems). In these applied interdisciplinary areas, EARTH researchers could benefit from stronger collaborations across campus, including with CLASP, SEAS, EEB, and new partners as appropriate.

A4.3 Earth's Surface and Its Hazards

Overview: Research in this theme lies at the intersection of society and Earth. Topics encompass both scientific understanding of landscape dynamics and natural hazards and the development of novel methods to interrogate surface processes. Seismic and geodetic data are used to quantify surface processes acting in ice sheets, rivers, lakes and oceans, and those data are integral to monitoring resources (e.g., geothermal, aquifers) and hazards (e.g., earthquake, volcanism). The development of novel methods for use of remotely sensed data is a compelling avenue under this theme. The data explosion that is underway, both in terms of the volume of data and the number of data-streams, together with the development of machine learning approaches adapted to problems in the Earth and environmental sciences, forms an exciting frontier. Finally, issues of societal resilience, forecasting/risk assessment, how our changing climate may affect natural hazards in the future, and equity of the impact of natural hazards permeate this research theme.

Building on strengths and addressing gaps: Research under this theme builds on existing faculty expertise of processes acting at Earth's surface, including solid Earth, ocean/climate, and environmental perspectives. This theme can provide an intellectual bridge between the solid Earth and environmental facets of our department, as well as between EARTH and departments in UM's College of Engineering and SEAS. The bridge between these facets can be achieved either through filling existing disciplinary gaps, research questions which transcend domains, or utilization of expertise that is normally siloed. EARTH has long-standing, critical gaps in geomorphology and sedimentology — subject areas that overlap both Earth and environmental sciences — and adding expertise addressing, for instance, water-landscape interactions or critical zone research, can fill these gaps. Research on coupled hazards (e.g., drought-fire-landslide hazards) or hazards on the boundary between solid Earth and ocean/atmosphere (e.g., floods, storm surge) lend themselves to transdisciplinary approaches. Using geophysical methods to interrogate surface processes, for instance the burgeoning field of environmental seismology or geodesy, is another direction under this theme with the potential to build bridges across the department, leveraging the department's existing expertise in seismology and geodesy. The department's newly acquired distributed acoustic sensing (DAS) interrogator, making EARTH one of the few departments in the world with such a technology, can be used to interrogate a wide range of processes. Expansion in geophysical approaches under this theme can increase our visibility in geophysics and seismology, a subspecialty area in which we have yet to achieve a USNWR ranking.

The concept of transdisciplinarity is a fundamental aspect to this research theme, crossing boundaries and divides between disciplines and combining expertise irrespective of the subfield with which that expertise is normally associated. Faculty across the department have expertise in data analysis, machine learning (including regression and classification techniques), high performance computing applications, and the use of remote sensing and geodetic data, expertise that can be brought to bear on this research theme. The final aspect of the transdisciplinarity of this theme pertains to societal issues, either related to hazards (e.g., risk assessment, mitigation, equity of impacts) or landscape (e.g., land-use, stormwater/surge issues).

Synergies, new directions, and opportunities: Urbanization, climate change, and the vulnerability of marginalized social groups demand new approaches to natural disaster research, addressing mitigation, response to reduce future losses, and improve social equity (SDR, 2021). These approaches should utilize rapidly evolving technologies, advances in communication, and leverage novel techniques that transcend disciplinary boundaries. Issues of resilience and the inequity of natural hazard impacts will expand the social relevance of research in EARTH and build bridges to social science departments and other entities across campus. Furthermore, STEM education is rapidly evolving, as educators seek to meet the growing demands for a future workforce trained in understanding geospatial, geophysical, and geological data/concepts, to address the most pressing societal and economic issues. Educators seek reforms that better enable graduate students and early career scientists of all backgrounds to adequately translate deep, technical knowledge into skills and expertise that can be applied to real-world problems (NASEM, 2018). Any envisioned future research directions should focus on the development of collaborative solutions that promote the exchange of knowledge and training that will foster leadership and equity in the next generation of scientists and engineers.

We envision synergies between this research theme and Themes A4.1 (Water on a Changing Planet) and A4.2 (Climate, Ecosystems, and Biogeochemistry) through hydrological or climatological hazards, such as floods, drought, debris flows, extreme weather, and storms. Hazard research also overlaps with Theme A4.5 (Solid Earth Dynamics), for example through volcanism. New opportunities through NSF Convergence Accelerator, as well as programs at the Department of the Interior and NASA, also focus on applied geoscience objectives related to natural hazards. Finally, the imminent launch of the NISAR mission by NASA/ISRO (Indian Space Research Organization) will provide an exciting new data stream with which Earth's surface and hazards can be investigated.

A4.4 Evolution of Life and the Rock Record

Overview: The strategic direction of Evolution of Life and the Rock Record recognizes that the evolution of life and the planet itself are inextricably intertwined. Major extinction events throughout Earth's history punctuate this connection and capture the public's imagination. However, the interdependence between life and Earth spans much of planet's history, from the exsolution of volatiles to form an atmosphere, to the onset of plate tectonics and planetary-scale geochemical cycling, to the potential interconnections between the rise of oxygen in the atmosphere and the chemical and physical evolution of the solid Earth; life and Earth have co-evolved.

Understood in this way, this research direction has the potential to encompass a wide range of topics that build on expertise and interests in our department, including planetary habitability, early life on Earth, interpreting and dating the rock record, and integrating paleontologic, paleoclimatic, and paleogeographic perspectives on the evolution of Earth. While understanding Earth's history and evolution is a key aim of this research direction, extrapolating the biotic response to environmental forcing, as understood from the geologic record, is also critical for adapting to our rapidly changing planet, and understanding the potential feedbacks between climate change, loss of biodiversity, and Earth surface processes.

Building on strengths and addressing gaps: A strategic initiative built around the evolution of life and the rock record would provide a natural direction to synergize activities among multiple groups in our department, and to capitalize on ongoing research, including investigating the early evolution of life (geobiology and geomicrobiology) and the generation of a habitable planet (petrology), the evolution of macroscopic life (paleontology), conditions necessary to support various forms of life (paleoclimate), and the study of the rock record that preserves information about the evolution of our planet through time (geology). We are particularly well-poised to leverage existing strengths in the Museum of Paleontology, through both collections and joint faculty hiring, and to accelerate the research opportunities for recent hires focused on the Precambrian record of biogeochemical processes, geochronology, and the co-evolution of plate tectonics and life. The development of a geochronology lab at Michigan specifically targeted at early Earth processes is an additional strength to leverage in this research direction, in concert with existing analytical facilities for X-ray CRT, stable isotope, and electron microbeam analysis.

A focus on evolution of life and the rock record would also offer an avenue to address research gaps in our department. Two critical gaps were identified during the course of this self-study. The first is recent retirements in the Museum of Paleontology. The life and rock record is a natural opportunity to address this need, and to strengthen bridges among geobiology, paleontology, and geology research areas, as well as expand the research areas within the paleontology group to encompass ecosystem modeling and connections between life and Earth. The second critical gap is a shrinking number of faculty with expertise in field geologic studies, particularly related to clastic sedimentology and stratigraphy, sedimentary dynamics, and deposition and preservation of the rock record. Expanding the department's footprint in clastic sedimentology, sedimentary transport processes, and sediment mechanics would bridge field geologic studies, physical and numerical modeling, hazards, and interpretation of the rock record and Earth evolution. Addressing this expertise reflects a need driven by retirements and departures from the department, that will be amplified by future retirements.

Synergies, new directions, and opportunities: The department has a number of ongoing research projects that form natural connections and synergies around the theme of the evolution of life and the rock record. Four natural research areas that could be fostered by this strategic research direction are: (1) planetary habitability, global tectonics, and the origin and evolution of early life; (2) paleoenvironmental and paleoecological controls on evolution and the origin of key biological innovations; (3) interactions and feedbacks between biotic, chemical, and physical processes that shape Earth's surface, habitability, and material properties; and (4) development of new techniques and tools in stratigraphy and geochronology to quantify the timing and rates of evolutionary change in deep geologic time. There are clear connections between these themes and the other proposed strategic research directions, particularly Climate, Ecosystems, and Biogeochemistry, through comparison of modern to geologic processes; Earth's Surface and Its Hazards through connections to geospatial modeling, geomorphic processes and mass wasting; and Solid Earth Dynamics, through early planetary formation and the rock record of tectonic processes.

This strategic research direction would provide fertile ground to bridge new research collaborations with other groups on campus studying planetary formation and evolution in astronomy, climate and space sciences, and engineering. Certain threads of this research direction, particularly early life and planetary habitability, could position the department to compete for funding from sources that have not traditionally been tapped (e.g., NASA). Public interest in the evolution of life on Earth also provides opportunities for outreach and public awareness, particularly in connection with the Natural History Museum.

A4.5 Solid Earth Dynamics

Overview: This research direction views all of Earth's components — from its core to its atmosphere — as inextricably linked systems that have evolved through time, continue to interact, and shape our planet today. The formation and differentiation of Earth, including the genesis of the Moon and development of the atmosphere/hydrosphere, set the stage for the emergence of life and subsequent evolution of Earth. Plate tectonics and mantle convection cool the planet and cycle key elements between the surface and the interior. The associated geochemical cycling concentrates elements vital to modern society as mineral deposits and, along with the generation of the magnetic field in Earth's core, maintains a dynamically habitable climate over geological time. Magmatism/volcanism at mid-ocean ridges and subduction zones drive the formation of oceanic and continental crust (a dichotomy unique to Earth in the Solar System). Plate tectonics continually rework the lithosphere, altering the surface, including formation of mountain belts and sedimentary basins, as well as causing natural hazards such as earthquakes, landslides, and volcanos. While the emphasis of this research direction is Earth, it also provides insights into other terrestrial planets and exoplanets.

Building on strengths and addressing weaknesses: A strategic initiative in Solid Earth Dynamics can leverage existing faculty expertise and significant department facilities, from geophysics to high-temperature geochemistry, and hence can engage a number of faculty in the department who work on related problems yet do not formally collaborate. Current geophysics research in EARTH covers seismic imaging of Earth (from global-scale tomography to the shallow Earth), geodesy, and earthquake physics. Faculty in geophysics have expertise in machine learning, advanced statistical tools, and computation. In the area of high-temperature geochemistry, there is broad expertise in chemical thermodynamics and kinetics applied to processes in the core, mantle, and crust. Four experimental laboratories collectively enable the study of mineral-melt-fluid equilibrium and kinetics over all pressure-temperature conditions within Earth, and the department's electron microbeam analytical facility (EMAL) enables high-quality images and analyses of experimental run products. In tectonics, the department has both a surface focus with strength in neotectonics (rates and kinematics of active faults), tectonic geomorphology and crustal scale geodynamics and mountain building, as well as geologic expertise in ancient, deep crustal deformation processes. While the department has recently lost an argon geochronology lab, two new geochronology laboratories have been added to the department over the last decade. In 2013, a new low temperature thermochronology laboratory was built, which is capable of determining the age at which key accessory minerals in crystalline rocks have cooled past their closure temperatures. We are also building a new laser-ablation inductively-coupled-plasma mass spectrometry (LA-ICP-MS) laboratory to perform uranium-lead dating capable of measuring specific reactions visible in a petrographic thin section.

Some research questions under this direction would require global geodynamics expertise, which the department currently lacks. EARTH has expertise in seismology and mineral physics, which contribute to our understanding of the structure of the mantle and core, and their compositions, phase assemblages, and anisotropy. Geodynamics would complement our expertise in these facets, positioning those faculty to collectively address mixing of whole-mantle heterogeneities, which impacts geochemical budgets. Geodynamics is also relevant to research questions that address how and why plate tectonic regimes and geodynamo on Earth have changed through time, in addition to questions concerning the origin and evolution of other planetary bodies and exoplanets.

Among our faculty, several collaborations that fall under this research theme have recently emerged. These collaborations range from between faculty with overlapping expertise (e.g., the physics of earthquakes, faulting processes, and the effects of earthquakes) to a funded collaboration integrating numerical modeling and petrology with an aim to understand the origin and evolution of effusive volcanic systems in the western United States. There is considerable opportunity to extend this type of collaboration to other tectonic settings, such as subduction zones. Moreover, we identify the possibility to engage a wider group of faculty on research pertaining to volcanic processes, linking geochemical and petrological expertise with seismic and geodetic imaging of volcanic systems. While research on volcanic systems would benefit from additional expertise (i.e., magma dynamics, remote sensing), a critical mass of current EARTH faculty could spearhead a larger project in this realm. Finally, research in subduction zone processes provides opportunities to integrate departmental expertise in tectonics, seismology, petrology, and mineral deposits.

Synergies, new directions, and opportunities*:* Research directions in volcanism and subduction have strong synergies with research Theme A4.3 (Earth's surface and Its Hazards). NSF has a history of targeting subduction zones, most recently through the Subduction Zones 4D (SZ4D) program. Mineral resources are often linked to subduction zones and volcanism, and ensuring a sustainable supply of mineral resources is a national priority, as evidenced by Presidential Executive Order 13817 (A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals), with bipartisan support.

There are several research directions under this theme that have synergies with research theme A4.4 (Evolution of Life and the Rock Record), for example, the development of sedimentary basins. Catastrophic volcanic events throughout Earth's history impact climate and atmospheric composition and are clearly linked to mass extinction events — a synergy with Theme A4.2 (Climate, Ecosystems, and Biogeochemistry). Finally, we note numerous opportunities to collaborate across UM, such as with Astronomy and CLASP, to learn about Earth through comparative study of other planetary bodies, both within and beyond our solar system.

A5. Recommendations: Research Enterprise and Hiring, 2021-2030

Perspective: The research enterprise in EARTH has evolved over the past decade, as 33% of current faculty were hired since our last strategic plan (Fig. IV-A3.2). Our growth occurs as the need for Earth and environmental science expertise is expanding, particularly in areas such as hazards, environmental change, and clean water availability, where the human impacts are acute. Added to this is the critical and broadly shared concern that our faculty, as in most Earth science departments, does not represent the diversity of our region and the nation. Recognizing that the college is entering a period of contraction, we seek to develop creative and effective strategies to leverage new hiring opportunities: to address multiple interest areas, bring in new tools and approaches, serve our students, catalyze new directions, and become more representative of the communities we inhabit and serve. We also identify how our approach to hiring must change, both to attract a wider diversity of applicants and to serve broader constituencies.

Common goals: In preparing this document, the EARTH faculty engaged in several distinct and structured exercises in imagining our future. A simple question that asked us to envision a future successful department revealed a widespread desire for more interaction and integration: shared intellectual pursuits, enhanced collaboration across labs/groups, and connecting more broadly with others (in the department and across campus) to create new synergies. In related comments, faculty criticized research "silos" and argued for more porous boundaries among lab groups to enable students to work collaboratively among multiple PIs. In prioritizing research attributes for future hiring, faculty identified leading edge and broadly useful approaches including remote sensing, integrated modeling, and data science, that serve multiple research directions. Faculty who wield these tools effectively can connect groups of researchers in transformative ways around big-picture, interdisciplinary questions — breaking down disciplinary, departmental, and other implicit barriers. Many faculty pointed to the importance of (and our relative weakness in) science that addresses societally relevant questions and directly supports human well-being — including the inequities associated with people's needs and vulnerabilities. Equally widespread was the recognition that as a department, we must do more to hire faculty that reflect the diversity of the region, state, and nation (see below).

New faculty recruitment strategies: The need to expand representation, equity, and inclusivity among our community is widely recognized; here we focus on recruiting diverse faculty (see Section V-D for a more comprehensive discussion). Although we aim to diversify at all levels, adding diverse faculty is especially critical to attracting and retaining diverse students, researchers, and staff. We highlight the potential to recruit faculty through the LSA Collegiate Fellows and the Presidential Postdoctoral Fellows Programs. These programs, which target individuals with substantial DEI impact, are designed to bring in early career researchers as postdoctoral fellows who transition to regular faculty appointments after two years. We plan to take a more systematic approach to recruiting via these programs starting in 2021. UM also supports targeted, "person-specific" hires in the case of particularly excellent senior candidates who present distinctive opportunities for departments. Partnering with other campus units, notably the new Institute for Global Change Biology, also offers promise. Finally, although we emphasize tenure-track faculty hiring here, we recognize alternative pathways towards our long-term goals. Hosting visiting URM faculty (e.g., on sabbatical from minority-serving institutions) or postdocs, whose research broadly aligns with some aspect of our department's research portfolio, could create opportunities to expand collaborations and pipelines to more diverse organizations.

In a faculty-wide conversation on inclusive hiring, we reviewed best practices and identified additional ways we can improve. Our approach to future research directions is designed to help us use broader job descriptions when advertising. More generally, we hope that increasing a focus on human impacts in various research areas will make our department more attractive to a broader range of researchers and students attuned to the differential impacts of Earth and environmental hazards, climate change, and access to resources, and whose research addresses the need for just and sustainable solutions. Among the additional actions we are taking, we are diversifying our lecture series across a variety of dimensions and establishing a standing fellows/faculty "scouting" committee to develop networks and identify hiring opportunities.

Attributes of future faculty: Over several months, we collaboratively identified the five research themes described above, in a non-exclusive structure (i.e., faculty contributed to multiple groups). Because of anticipated limits on future hires, we deliberately avoided listing explicit position descriptions that would serve the research themes in Section V-A4 or a constituent group (Section IV-B) in the department. Instead, within each research theme, we identified desired research attributes of new faculty hires defined as disciplinary expertise and research methods. By clearly identifying areas of growth and desired attributes, we provide the groundwork to create, evaluate, and maximize opportunities more effectively. Table A5.1 identifies attributes listed within each research direction.

Table A5.1: Research Attributes for Future Hires in Earth Research Theme

Water on a Changing Planet
Interdisciplinary Great Lakes-focused science
The water cycle, terrestrial fluxes, and climate change
Address human needs and just solutions via engineering, social science collaborations
Surface-groundwater physical and chemical linkages
Water quality, contaminant behavior and transport, bioremediation
Big data for big questions: remote sensing, modeling, data science
Climate, Ecosystems, and Biogeochemistry
Linkages among climate, biogeochemistry, and biomes across time and space
Partnering with vulnerable populations to identify environmental change impacts and inform just and sustainable adaptations
Interactions among land, ocean, atmosphere, biosphere, cryosphere
Separating natural and anthropogenic environmental change
Feedbacks among climate, water, biology, and biogeochemistry
Integrate across data, processes, and models
Earth's Surface and Its Hazards
High data use: geophysical and geological data streams, novel remote sensing applications
Novel analysis tools: machine learning, data assimilation, data analysis, data mining
Effect of climate change on hazards and climate/weather extremes
Use of remote sensing and seismic wavefield to investigate surface processes
Critical zone and water/landscape interactions including near-surface geophysics
Research connected to resilience, equity, and hazard risk reduction
Evolution of Life and the Rock Record
Clastic sedimentology, sediment transport, and the physical processes of rock formation
Feedbacks between planetary and biological evolution and earth-life transitions
Expertise in field observations of the stratigraphic record and the preserved record of life
Ecosystem modeling of fossils, paleoenvironmental and geologic context; big data approaches
Evolution of biogeochemical cycles - linking mantle processes to surface biogeochemistry
Early earth evolution and the origin of life in the context of other habitable planets
Solid Earth Dynamics
Subduction zones: dynamics, integration of geophysical and geochemical data, mineral resources
Global geodynamics with focus on Earth's thermal and chemical budgets
Magma physics, magma-rock interactions, and/or volcanic processes
Rock physics and rheologies
Modeling of plate tectonics and core dynamo from past to present on Earth and other planets/exoplanets
Novel machine learning and geophysical methods to interrogate dynamic processes

A6. Postdoctoral Fellows and Research Faculty

Postdoctoral fellows and research faculty are key contributors to our research enterprise and play an important role in our educational mission through mentoring and training of graduate and undergraduate students. Specifically, they have the potential to drive and facilitate collaborations that can translate into more funding and scientific innovation, provide direct mentorship and training opportunities for our students, and contribute to departmental change as they often bring fresh perspectives. Early career scientists are particularly vulnerable to downturns in the job market and attention to their unique circumstances should be a department priority.

Postdoctoral Fellows: There are currently fifteen postdocs in the department (10 year avg = 13.3), who are funded by both external and internal sources, through faculty PIs, external fellowships, and UM fellowships (e.g., Michigan Society of Fellows, LSA Collegiate Fellows Program, President's Postdoctoral Fellowship). They represent a vibrant group of early career scholars who could play critical roles in meeting many goals in this plan. We suggest taking multiple steps to increase the numbers of postdocs and their role in our department's mission, which might include: (1) developing a stronger culture among faculty to recruit postdocs through external fellowship opportunities, (2) reallocating department resources for support of postdocs with an aim to invest in research themes articulated in Section V-A4 and the DEI goals of our department (sections V-D, V-E), and (3) creating more explicit mentoring for and community among postdocs (see section V-E3). Recruiting postdocs, including through the LSA/Presidential postdoc fellowships, should be part of the plan to diversify our department.

Research Faculty: The department currently has five research faculty, who are funded primarily from external sources, some of whom also serve as lecturers. This is a small but active group who are committed to both research and teaching. They currently teach at Camp Davis, advise graduate students, serve on dissertation committees, provide technical training to students in laboratories, and mentor undergraduates, graduates, and postdocs. Research faculty are eager to engage in the department more substantively,and they should be included in our efforts to expand our research footprint, the scope of our teaching, mentorship, and training opportunities for our students.

B. Undergraduate Program

B1. Current Status and Recent Trends

Our department has a broad teaching mission at the undergraduate level. We aim to give students the disciplinary training needed for careers in Earth and environmental sciences in academia, industry, and government. We also recognize that many of our students will choose careers in other fields, such as teaching, law, and business. Thus, we focus on teaching skills and concepts that are transferable and valuable in the development of versatile and adaptable professionals. Our major (Earth and Environmental Sciences) includes two focused sub-plans (Earth Sciences or Environmental Sciences) as well as a more flexible "open" sub-plan. We also offer five minors: Earth Sciences, Environmental Geology, Geology, Oceanography, and Paleontology.

Our undergraduate program has grown substantially in the past 10 years, increasing from 71 to 189 majors from 2011 to 2021 (Fig. V-B1.1). We have also seen a dramatic increase in total student credit hours (SCH) taught by our department, from 9,457 in 2010 to 14,802 in 2020 (Fig. V-B1.2), with the fastest growth occurring in the past three years (upper level SCH grew from 2,311 to 3,709 from 2017 to 2020). Growth in the number of degrees granted per year has been more modest (from 28 in 2010 to 37 in 2020, with a peak of 60 in 2016); however, this metric is misleading because it does not include double majors who declared their first major in another unit (we currently have 44 double majors, 18 of whom declared in another unit first). Increases in the number of enrolled majors coincide with creation of the new flexible major (2010), the change of department name (2011), and the addition of sub-plans (2017). Much of the increased enrollment since 2017 has been in Environmental Science; more than twice as many students (35) are now in the Environmental Sciences sub-plan compared to the Earth Sciences sub-plan (15). Total enrollment in Environmental Sciences core courses since 2017 was 1,169, compared to 457 in Earth Sciences core classes. In contrast, growth during 2012–2015 was relatively evenly divided across Environmental and Earth core courses. The decline in our degrees awarded from 2016-2019 paralleled the national trend for geosciences (Fig. V-B1.1). Given our current enrollment trends, we anticipate exceeding our record degrees awards from 2016 (60) in a few years' time. This increase in SCH, together with the growth of enrollment in our environmental sciences courses and number of majors that coincided with curricular changes in the past three years (Fig. V-B1.2), we conclude that we are now in a new phase of program growth driven primarily by student interest in environmental science.

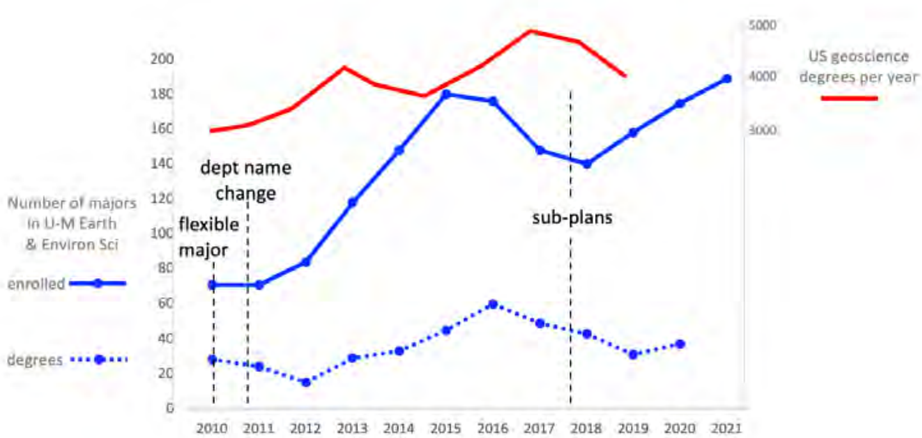


Fig. V-B1.1 *Number of students majoring in Earth and Environmental Sciences (left axis) by enrollment (solid blue line) and degrees awarded per academic year (dashed blue line) compared to number of geoscience degrees awarded per year in the United States (right axis, red line; data from the American Geosciences Institute). Black dotted lines show major changes to the curriculum and department.*

Several trends in the demographics of our student population are apparent (Fig. V-B1.3). The proportion of student majors who are female increased from 43% to 65% since 2016, well above the college-wide percentage of 56%. This increase coincides with the growth of environmental science enrollment and an increased number of female faculty. The proportions of majors from out of state and outside the US have both declined over the past 10 years and are now much lower than the college-wide demographics. This is a potential concern in that it may indicate barriers to our major for these demographics. This needs to be understood and addressed with, for instance, focused recruitment and/or policies to eliminate barriers to these demographics. The proportion of our majors that are transfer students has increased and is now above the college-wide percentage. Finally, the proportion of underrepresented students in our department has grown to an average of 12.4% over the last 5 years, similar to the college average, whereas our average was 7.5% during 2000-2015. While modest, it is important to put this recent growth, and parity with the college, in context that nationally the geosciences are the least diverse of all STEM fields. In particular, we see growth in the number of Black students due to our efforts with a local high-school outreach program (Earth Camp, described in Section V-B2.2). While still new, the approximately 2–3 majors we gain per year has doubled the number of Black students in our department. With additional transfers and continued improvement in our recruiting, curriculum, and college application workshops, we expect to triple our baseline number of Black student majors in the next three years based on these trends. This is particularly significant because the number of Black students earning bachelor's degrees in geosciences nationwide is static and especially low (2.1%) compared to other STEM fields (NSF, 2017).

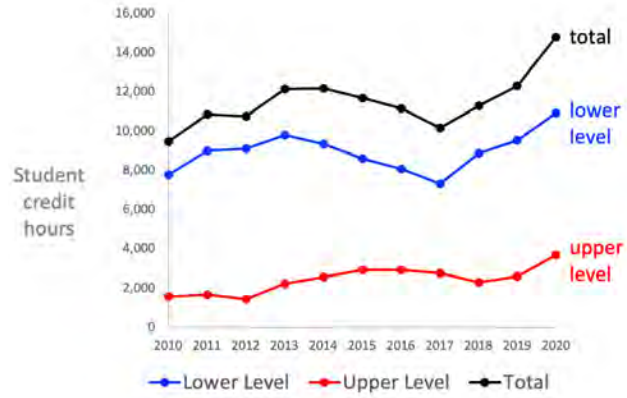


Fig. V-B1.2 Annual *student credit hours taught since 2010.*

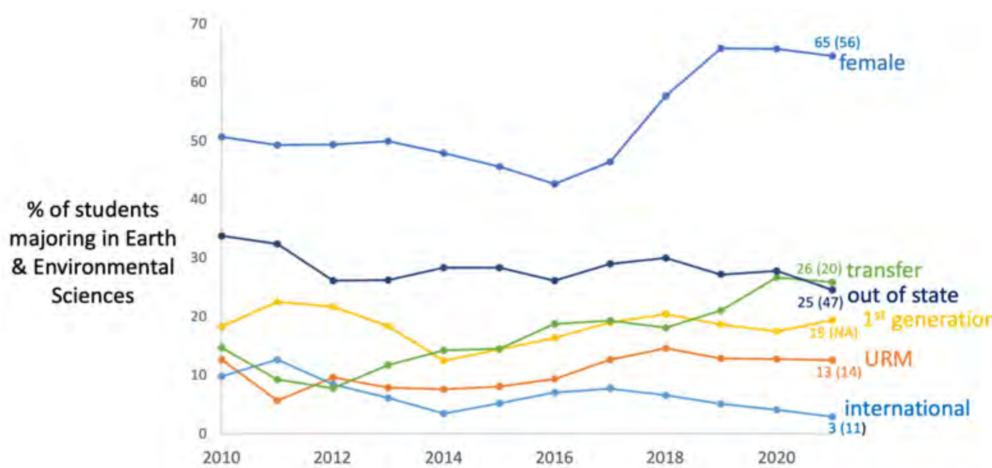


Fig. V-B1.3 *Demographics of students majoring in Earth and Environmental Sciences from 2010 to 2021. Numbers in 2021 indicate percentages for our department compared to our college (LSA, in parentheses). NA, not available.*

The number of minors has decreased steadily from 134 to 68 over the past seven years. This decline was mainly due to a decline in the Geology minor, down from 49 students in 2014 to 5 in 2021, while the other minors have remained steady. The lack of growth and decline may be related to their lackluster framing (i.e., titles), especially relative to competing minors in other units, which have minors with titles that invoke societal challenges (Water, Environment, Sustainability, Food, and Energy Science and Policy).

In 2020, the department changed its policy on teaching load, from a credit-based model (8 credits per 1.0 FTE per year) to a course-based model, which varies based on research mentoring and external funding

(2.0–4.0 courses per FTE per year). We note that our student credit hours have increased in the year following the change in teaching load policy.

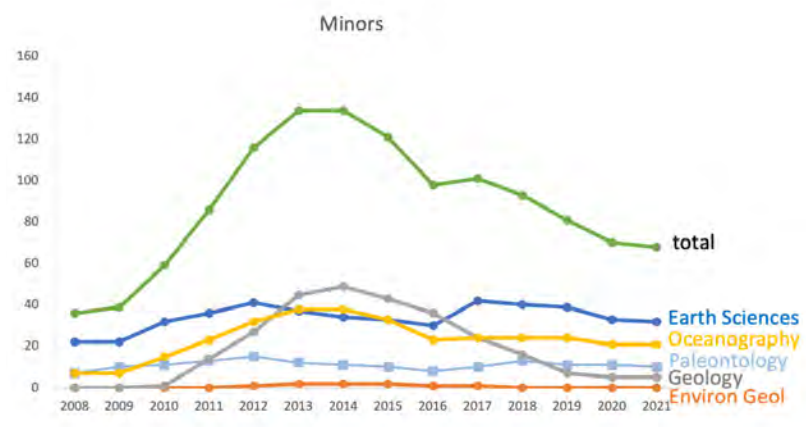


Fig. V-B1.4 *Number of students in minors within the Dept of Earth & Environmental Sciences.*

B2. Response and Key Accomplishments Since Previous Plan

One of the six goals identified in the 2011 Strategic Long-Term Plan was to increase the number of undergraduate majors in our department. We aimed to increase the 2008 number of majors from 43 to >90 via three main initiatives: (1) a substantial revision to the undergraduate curriculum, (2) enhanced research opportunities for undergraduates, and (3) better communication of opportunities to students. The overall goal was met with resounding success — we had 189 students majoring in Earth and Environmental Sciences in 2021. In addition to the strategies above, factors that likely contributed to the successful growth of our program include the department name change, expanded and improved gateway courses, an increase in the number of female faculty and instructors, and enhancement of our environmental sciences curriculum. We describe these accomplishments and strategies below.

B2.1 Implementation of Initiatives from the 2011 Strategic Plan

The first initiative was to substantially revise our undergraduate curriculum, coinciding with the department name change in 2011 from Geological Sciences to Earth and Environmental Sciences, reflecting the broadening and diversification of faculty disciplines. In Fall 2010, a new undergraduate curriculum was established. Three tracks were discontinued and replaced with a single, flexible major in Earth and Environmental Sciences. In addition, the Earth System Science Concentration (joint with CLASP) was discontinued as the low number of ESS concentrators and generated SCH did not justify the teaching effort by EARTH faculty. We also developed a series of new 100- and 200-level courses on topics of societal relevance, as well as three new upper-level writing requirement courses.

The second initiative was to enhance the student experience by increasing research opportunities for undergraduates. We created a website with information on research opportunities and a mechanism to match faculty research projects with student interests. However, the matching system was not widely used by either party and was discontinued. We offered financial support of undergraduate student research, including travel and research costs, via a departmental student award fund (Turner awards). In addition, we started a program to provide an hourly wage to students from underrepresented and/or nontraditional backgrounds (e.g., first-generation, transfer) for their work in labs, recognizing that the need for financial compensation is often a barrier to voluntary research opportunities. Despite these efforts, undergraduate research as measured by enrollment in independent study has not increased over the past 10 years. Although this measure of undergraduate research does not capture all student research (e.g., it misses the popular Undergraduate Research Opportunities Program, some students cannot register for independent study because they are at maximum credits), it suggests that issues such as laboratory space, interest, and/or lack of incentives for faculty is hindering our undergraduate research.

Finally, we developed new mechanisms to recruit majors and support existing students within EARTH. We instituted information sessions for prospective majors and minors, and we provide a slide deck on career opportunities to instructors for use in introductory courses. The department website now highlights student activities (field trips and Geoclub, our student organization) and hosts a new web page on career resources. This includes a job board to capture all internship and job postings from our email lists, as well as links to external resources (professional societies, large employers, etc.). We hired Rosie Jowitt, a professional geologist, to serve as a career advisor to students. Working part-time, she assists students in developing and improving resumes, finding internships, and preparing for careers in the geosciences. We hold a career panel with our AAB each fall (as proposed in the 2011 strategic plan), and we now support graduate student-organized career panels with alumni and other professionals. We have also developed a close relationship with the Newnan Advising Center, which provides general advising to LSA students. Through regular communication with Newnan we advertise courses, alert LSA advisors to new courses, and answer questions about our programs.

B2.2 Adjustments and Additions to the 2011 Strategic Plan

Implementation of sub-plans: While the flexible major in Earth and Environmental Sciences adopted in 2010 succeeded in growing our undergraduate program, it had several perceived weaknesses. First, faculty, students, and members of the alumni board were concerned that students were not receiving enough guidance to complete coursework that sufficiently prepared them for a career or graduate school in the Earth sciences. Second, while we were attracting many students who were interested in environmental sciences, there was no clear path through our curriculum to prepare for a career or graduate school in that field. Although we offered many courses in the environmental sciences at the introductory and upper levels, we lacked a strong core of upper-division courses. To address these issues, without sacrificing the flexibility that attracts many students and that is appropriate for those pursuing diverse degrees and careers (e.g., law, business, sustainability), we created sub-plans in Earth Science and in Environmental Science in 2017. These sub-plans are optional and housed within the current major, with the ability to complete the "open sub-plan" still available. We also added additional environmental science courses at the core level. While most students continue to do the open sub-plan (currently 91 compared to 35 and 15 in the Environmental Sciences and Earth Sciences sub-plans, respectively), the defined sub-plan provided a clear path for environmental science and coincided with rapid growth of enrollment in environmental core courses and in the number of majors from 2017 to 2021.

Additional initiatives: Another strategy to grow our undergraduate program has been to expand and enhance our "gateway courses" (i.e., prerequisites to the major). We developed a new *Earth and Environmental Chemistry* course that covers general chemistry through the lens of our field. Consistent with our department name change, we also developed a new *Introduction to Environmental Science* course, which now enrolls >100 students every semester. We expanded the size and frequency of other popular introductory classes including *Geology of the National Parks*, *Physical Geography*, and mini-courses.

Diversity, equity, and inclusion (DEI): Whereas DEI issues were not prominent in the 2011 strategic plan, we have invested substantially in these efforts over the past 10 years. First, we created and/or joined programs to recruit students from underrepresented backgrounds. We developed Earth Camp, a 3-year residential summer program to provide historically underrepresented high school students with field experiences, information on career pathways, and mentoring in preparing for and applying to college. We developed a new summer course for Wolverine Pathways, which recruits high school students from low-income, ethnically diverse areas of Michigan. We recruited community college students through the transfer student fair, created a website for transfer students, and updated the transfer credit equivalency database with courses from community colleges. Second, we developed structures to support and retain students. For example, we participate in M-Sci (a college-wide program that provides support structures to students), provide funding to support students conducting research, have a DEI Committee that holds office hours for undergraduate students, and conduct an annual survey of students to identify climate issues. Third, we participate in a number of campus-wide and national anti-racism initiatives, including UM Center for Research on Learning and Teaching (CRLT) inclusive teaching and anti-racism workshops and grants, Unlearning Racism in Geosciences (URGE), and SciAll.org. Finally, we developed a new course for Fall 2021, *Welcome to Earth*, that introduces students to departmental resources, opportunities, and practices, covering both hard and soft skills.

B3. Recommendations for 2021-2030

The department is committed to improving the undergraduate student experience and promoting access and growth of our undergraduate program. Below we describe seven key recommendations that emerged from faculty discussions on what steps we can take to achieve these goals in the next 10 years.

B3.1 Map Core Concepts and Skills onto the Curriculum and Measure Outcomes

Our faculty recognize core concepts and skills that our undergraduate students should master, but these core concepts and skills have never been formally defined within our program, much less mapped onto the curriculum to show when and how they are introduced, developed, and mastered. Given the interdisciplinary nature of our department and the flexibility of the curriculum, students could possibly slip through our program without mastering such critical concepts and skills. Thus, we identify an urgent need to conduct curriculum mapping exercises in which we delineate when and how the concepts and skills are taught.

From 2014 to 2020, over 1,000 geoscientists participating in NSF's *The Future of Undergraduate Education* initiative developed a consensus of what concepts and skills undergraduate students need to succeed in graduate school and the workforce. Our faculty used this community consensus as a starting point to define our own adapted set of concepts and skills (Table B3.1 and B3.2). As next steps, we recommend: (1) determining when and how these concepts and skills are currently taught within our curriculum, (2) creating a process for measuring our effectiveness in teaching these skills and concepts, and (3) addressing deficiencies in new courses and/or extracurricular programs, prioritizing a regular and robust offering of upper level courses that develop concepts and skills.

Table B3.1: Undergraduate Core Concepts, Skills, and Competencies

Core Concepts	Core Skills and Competencies
Climate change	Critical & systems thinking and problem solving
Deep time	Understanding & using research methods
Earth as a complex system	Communicating effectively (written and oral)
Earth materials	Quantitative skills
Earth structure	Data analysis & computational skills
History of life and role in the Earth system	Teamwork & management of interdisciplinary projects
Natural resources	Field skills
Oceanography	Workplace readiness
Surface processes	Critical & systems thinking and problem solving
Water science	Understanding & using research methods

B3.2 Infuse the Curriculum with Data Science

Our self-study revealed that students are often lacking basic quantitative skills. This is a major concern, especially given the data-intensive nature of science in the modern era and the importance of quantitative skills and programming across employment sectors. There is an enormous demand for Earth and environmental scientists with expertise in data science (encompassing statistics, machine learning, computation, data management, and communication of data). We plan to infuse data science into our curriculum in the following ways. First, we will develop an introductory two-course sequence focused on basic quantitative skills, programming, and statistics. Second, leveraging curriculum mapping (B3.1), we will work to ensure that data science and/or programming are integrated into existing courses at all levels so that students are able to build on and master these skills as they progress through the curriculum. Third, the Curriculum Committee will develop a new minor in geospatial science and/or geoinformatics. Finally, we will forge links with data science units and initiatives across campus and in other natural sciences departments.

B3.3 Revise Field Courses to Create Inclusive Capstone Experiences

The major in Earth and Environmental Sciences requires an upper-level field course. Nearly all students satisfy this requirement through one of two courses at our Camp Davis Field Station, *Field Geology* and *Ecosystem Science*. While faculty recognize the value of field courses, there is also widespread concern that they are a barrier for some students due to cost, requirement for strenuous physical activity, student aversion to field work, and a four-week commitment in the summer, which conflicts with summer jobs, internships, and other activities such as caregiving. Many of these barriers are particularly prominent for students from underrepresented racial and ethnic communities, low socioeconomic status backgrounds, and those with physical disabilities, among others. We will review existing field courses with an aim to minimize potential barriers, and consider development of a new Ann Arbor-based hands-on course. This is an opportunity to develop a set of inclusive capstone courses that reflect the breadth of the Earth and environmental sciences, have common learning goals and curricular alignment, and have links to career paths. The existing courses should be modified to draw on concepts and skills developed throughout the curriculum (leveraging B3.1) with enforced core-level coursework as prerequisites. The new Ann Arbor-based course could take advantage of experimental, analytical, and computational facilities, focussing on environmental issues in southeastern Michigan. The department may also consider formalizing a process in which other experiences (e.g., summer-long internships) can satisfy the capstone requirement, as is currently done on occasion and by request.

B3.4 Build on Diversity, Equity, and Inclusion Initiatives

Our EARTH community has demonstrated its commitment to DEI issues and has identified several issues that require our focus: building incentives for faculty DEI efforts; resistance to including social and diversity issues in science classes from both students and faculty; discomfort and unfamiliarity with inclusive teaching practices; lack of diversity among faculty and students; and disparate perceptions of the importance of international and domestic diversity. The following activities are recommended to address these issues and build on momentum in DEI initiatives:

- Hold regular workshops on inclusive and anti-racist teaching and create an annual forum in which instructors share their experiences, lessons learned, and best practices;
- Encourage faculty to synthesize existing materials and develop new materials on environmental justice for both integration into existing courses and creation of new introductory and mini-courses. This may be facilitated by CRLT funding of graduate students to develop case studies and other course materials;
- Continue to support Earth Camp. Recent success of faculty grants involving Earth Camp are evidence of its value and highlight its potential to attract financial support. Recent collaborations with the Wolverine Pathways program have also improved student outcomes and lowered the cost.

B3.5 Build Community

A strong community is essential to the success and well-being of our undergraduate students; however, there are challenges to our sense of community, exacerbated by the pandemic. For example, there is no common “entry time” for new majors; students trickle in as they declare the major and minors at different points in their careers, and many students (including transfers) do not enter our program until their junior year. The following steps are recommended to (re)build and integrate the student community:

- The new *Welcome to Earth* course, which introduces students to department opportunities, resources, and practices, will be required of all majors, open to minors, and offered every term;

- Undertake a “halls and walls” campaign to showcase our discipline; show profiles of diverse and prominent UM alumni (e.g., Marie Tharp, Ruth Blake) and current graduate and undergraduate students; and advertise Camp Davis, field trips, and current courses.
- Support undergraduate thesis students by (i) creating an event in which students present and showcase their work and (ii) developing a writing course;
- Consider pairing undergraduate students with graduate student and postdoc mentors. Mentees could be limited to volunteers and/or underserved students;
- Engage undergraduate students through participation in department committees and activities (e.g., DEI committee, Curriculum Committee for feedback on policies);
- Host an open house and/or other events (e.g., Earth Day activities, advertisements of courses following the popular PitE “Pizza with Professors” model, Geoclub events).

B3.6 Realign Minors Towards Current Trends in Student Interest

Our minors are an important way to attract students to our program and to highlight particular components of our curriculum (e.g., oceanography, paleontology), but as described above enrollment in our minors has decreased over the past seven years. Two minors, Geology and Environmental Geology, now have <5 students enrolled, are somewhat redundant with the Earth Science minor, and will be discontinued. The curriculum committee will consider developing new minors based on our current curriculum. For example:

- A flexible Environmental Science minor would likely appeal to a broad array of students, in parallel to our popular Earth Science minor.
- A Geographical Information Systems/Geospatial minor: GIS is a highly employable skill in many sectors and it is one of our more popular elective courses. A Geospatial minor would likely attract students from other units across campus, and there is substantial interest among our own students and faculty to expand our offerings in this area.
- A minor on Earth’s Sustainable Future could focus on the science of meeting the world’s growing need for (and dwindling supply of) natural resources such as clean water and materials required for the renewable energy revolution. While there are many climate and ecology-focused sustainability programs on campus, a geology-centered minor would find an open niche and student demand.
- A minor in Environmental Biology and Chemistry or Environmental Contaminants would focus on geochemical, biological, or applied components of our curriculum. We anticipate that these areas would be compelling to students from policy, engineering, and chemistry, and leverage existing strengths and student demand for environmental biology and chemistry.

B3.7 Expand Undergraduate Research Experiences by Incentivizing Faculty

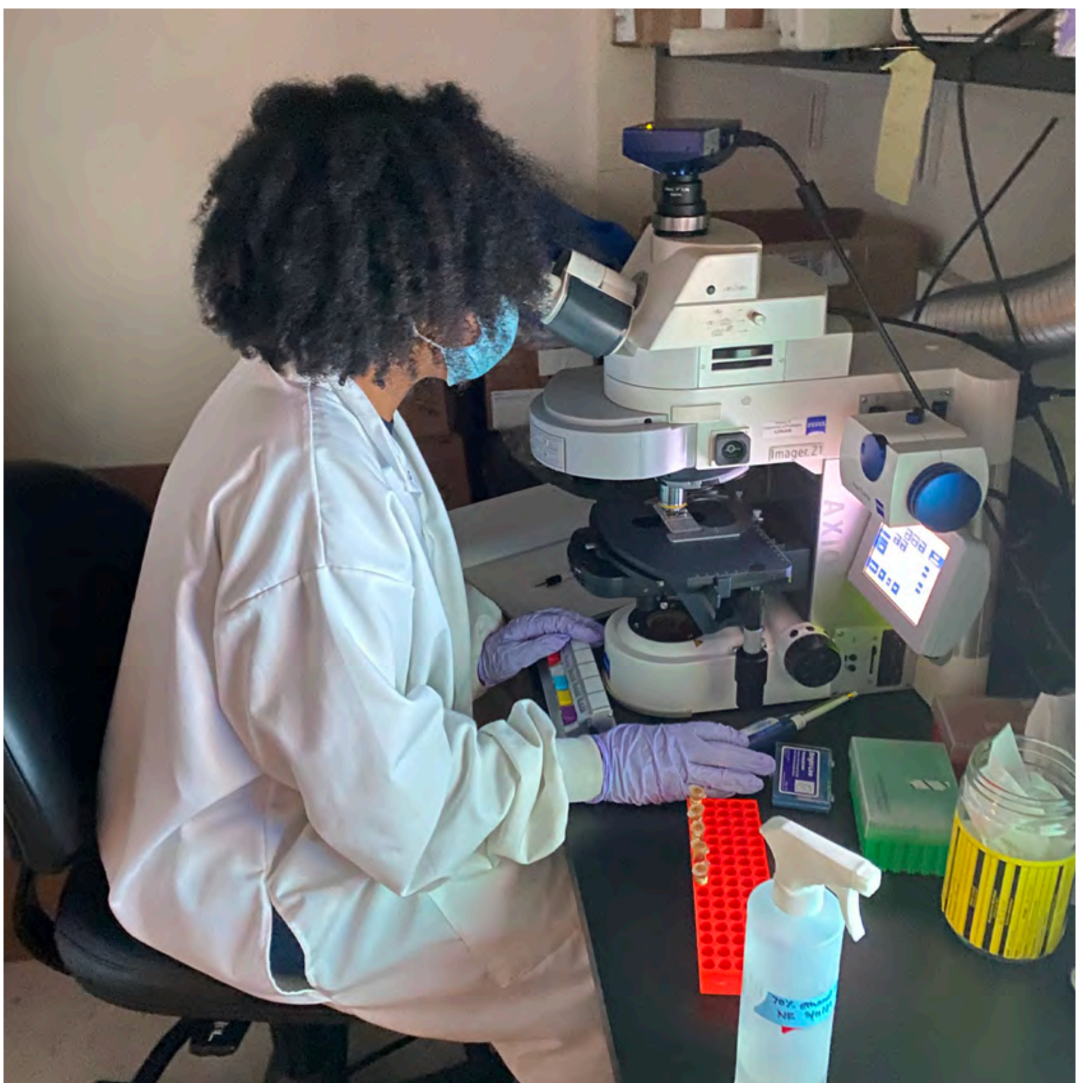
As described above, the department did not achieve the goal of the 2011 strategic plan to expand undergraduate research. This is a critical issue in that authentic research experience is essential preparation for graduate school and valuable for many career paths. The importance of this issue has grown along with the size of our undergraduate program; demand from students is high, competition for research positions has increased, and many high-caliber students who want to do independent research are unable to secure positions. To date, this need is anecdotal; an important first step is to quantify how many students want to do independent research. The department is well positioned to offer undergraduate research relative to other programs (e.g., PitE) because we have a large faculty with advanced laboratory facilities that conduct cutting-edge research. However, faculty cite lack of time, incentives, and funding constraints as factors that limit mentoring of undergraduate research. Some faculty are not interested in mentoring undergraduate student research and/or feel that their research is not suitable given challenges of packaging projects such that their scope and required training is manageable for undergrads. Given the risk of poor mentorship under these circumstances, mandating mentoring of undergraduate research is not advised. Further, the 2020 review of faculty teaching load concluded that mentoring of undergraduate students should not be substituted for regular teaching given our challenges with staffing classes and the pressure to boost key performance indicators. With these constraints in mind, the department will explore ways to incentivize mentoring of undergraduate research. Three options are provided as examples:

- Develop a series of “authentic research experience” courses to scale up research projects that are suitable for >12 students, and thus satisfying part of the regular faculty teaching load. Such courses could also build hard and soft skills associated with research (writing, data analysis, etc.)
- Develop an NSF Research Experiences for Undergraduates (REU) program that could accommodate some of our students while recruiting underrepresented students to our department and graduate program.
- Provide discretionary research funds to faculty, research scientists, postdocs, and/or graduate students who mentor undergraduate student research.

Regardless of the strategy chosen, clear guidelines, templates, and support structure should be provided to undergraduate mentors, and mechanisms for evaluating the quality of the undergraduate research mentoring should be established and employed by the Curriculum Committee.

B3.8 Strengthen Curricular Coverage of LSA Degree Requirements

Offering courses that satisfy LSA degree requirements is a promising strategy to attract students to our program and an important service to our College. Several of the initiatives above can be synergized with this goal: courses with heavy data analysis or computation would satisfy Quantitative Reasoning requirements; writing is a core skill and our majors would benefit from additional Upper Level Writing Requirements; coursework in environmental justice could be focused such that they could satisfy the Race and Ethnicity requirement.



C. Graduate Program

C1. Current Status and Recent Trends

The graduate program aims to engage and train students in the scientific process. As part of their research and teaching, students gain technical expertise and an understanding of fundamental principles of science, as well as skills in systems thinking, problem solving, communication and collaboration. Students in our program pursue both PhD and MS degrees. The number of enrolled PhD students has been steady for the last ten years (average 65 students; Fig. V-C1.1). An average of eight MS students per year are in a thesis-based program, as either the fifth year MS program for UM undergraduates or the two-year MS program (Fig. V-C1a). The number of PhD and MS degrees awarded per year averages ten and six respectively, but varies with cohort size. For example, spikes in PhD degrees in 2016 and 2021 (Fig.V-C1c) reflect the large PhD cohort sizes of 2013 and 2017 (Fig. V-C1a). For the current academic year, each tenure-track faculty is supervising, on average, 2.2 graduate students.

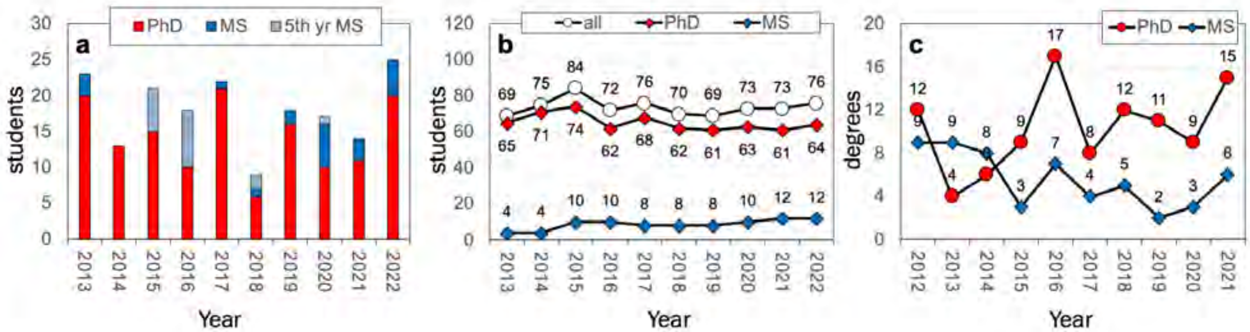


Fig. V-C1.1 *Trends in enrollment and degrees for the past 10 years. a) the size of the first year cohort (e.g., the 2022 class starts in Fall 2021), b) student enrollments, and c) number of degrees awarded by year. Students enrolled in the Concurrent Undergraduate Graduate Studies (CUGS) program are included in the 5th year MS category. In (b) the MS numbers do not distinguish between those only enrolled in the MS program and those enrolled in the PhD program and also pursuing an embedded MS degree (currently n = 9 and n = 3). In (c) the number of MS degrees include those earned by PhD students who also earned an embedded MS.*

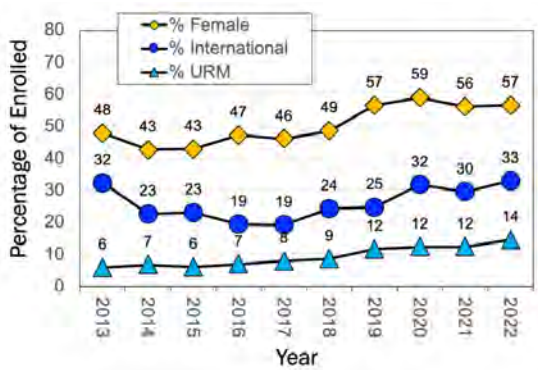


Fig. V-C1.2 *Demographics of students enrolled in the PhD and MS programs for the past 10 years. The URM student category uses the Federal definition, which relates only to domestic students identifying as Black, Native American, Hispanic, or Pacific Islander.*

In the past ten years, the proportion of female students has increased to 58% and students identified as URM have increased to 14% (Fig. V-C1.2). The proportion of international students dipped to 19% in 2016–2017 but increased to 33% by 2022, 33%. Our current international students originate from Brazil, China, Colombia, Costa Rica, Egypt, India, Jamaica, South Korea, Mexico, Nepal, Saudi Arabia, and Singapore. There are no significant distinctions in these demographics between our PhD and MS students.

C1.2 Admissions and Funding

Individual faculty make admission decisions from a pool of acceptable candidates determined by the department admissions committee. These faculty commit to mentor and financially support their admitted students (the funding commitment is backed by the department). Student funding comes from (1) Graduate

Student Research Assistantships (GSRA) or Museum Assistantships, (2) Graduate Student Instructor (GSI) positions, and (3) internal or external fellowships; department-wide, we utilize these funding categories in roughly equal proportions. The department provides tuition remission for externally funded GSRA positions. Our students are successful at competitive fellowships through Rackham and prestigious external fellowships, such as the NSF Graduate Research Fellowships Program (Fig. V-C1.3). As undergraduate enrollments have grown in the past decade, there has been a commensurate rise in GSI positions, which we have increasingly filled with students from other departments (Fig. V-C1.4). The availability of GSI positions represents additional capacity for funding our graduate program.

Our PhD students typically reach candidacy in 1.8 years. The average time to completion for the PhD has been 5.0 years over the last 10 years. After graduating, students pursue a range of careers, with 52% in tenure-track faculty positions and 36% in business or industry ten years after completion of their PhD. Currently, we do not collect commensurate data for the graduates of our MS program.

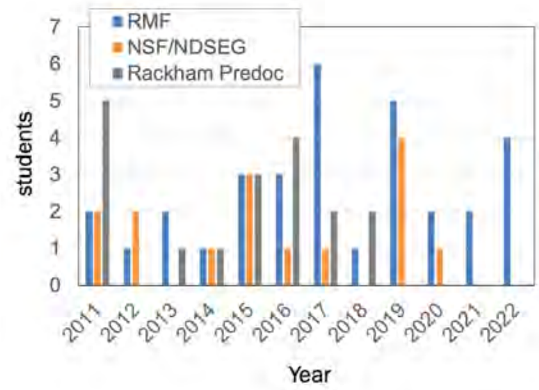


Fig.V-C1.3 *Trends in student fellowships from Rackham (e.g., RMF, PreDoc) and federal agencies (e.g., NSF, DoD) by incoming cohort. Note that only senior PhD students are eligible for Rackham Predoctoral fellowships; those from the 2020–2022 cohorts have not yet applied. The absence of federal fellowships in 2018 was due to the small cohort and limited eligibility for them, as many came in with MS degrees or were international students.*

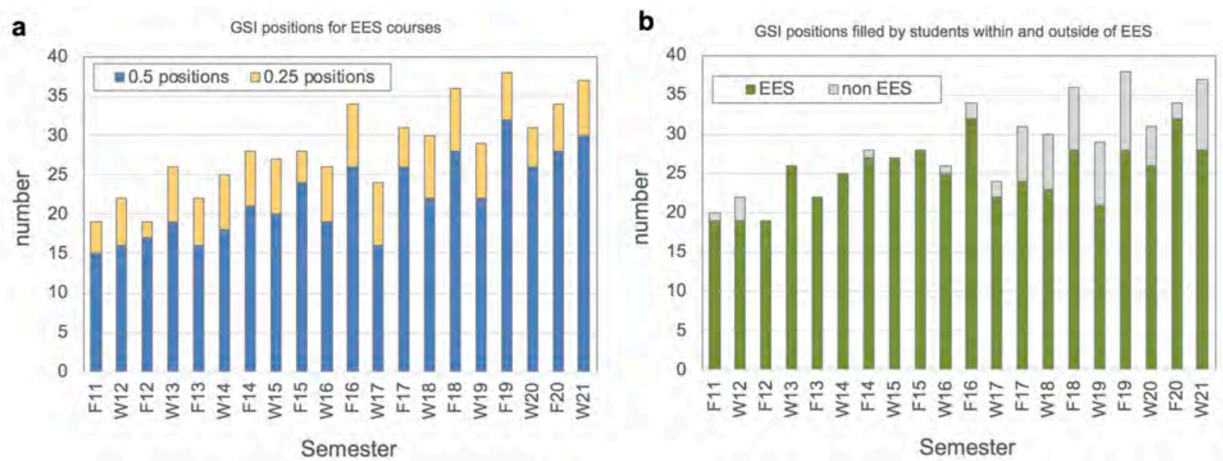


Fig. V-C1.4 *GSI positions by Fall and Winter semesters, plotted as a) type (0.5 = 20 hrs/wk, 0.25 = 10 hrs/wk) and b) filled by EARTH and non-EARTH graduate students. The plot does not include ~14 GSI positions per year in the Spring/Summer term, most of which support classes at our field station.*

C2. Key Accomplishments Since 2011 Plan

The 2011 strategic plan identified recommendations to expand graduate student recruiting, grow the program, improve training in scientific communication, and increase alumni engagement.

Recruiting and admissions: We significantly expanded our recruiting with the development of a “Fall Preview” program, aimed at students who would contribute to the department’s DEI goals. Since the start of the Fall Preview program in Fall 2014, we have hosted 110 students, of whom 54 have applied for admission to our graduate program, 24 have been admitted, and 14 have matriculated (Fig. V-C2). Fall Preview has increased the visibility of our program and our capacity to attract applications from diverse students. It coincides with increases in applications to our program (Fig. V-C2), student RMF funding (Fig. V-C1.3), and numbers of enrolled URM students (Fig. V-C1.2). At the same time, we modified our admissions practices to improve the quality and diversity of our students by limiting admissions to the top ~50th percentile of the committee ranking, adopting a holistic review process, and, in 2021, eliminating the GRE requirement.

Program growth: Despite efforts in recruiting and the growth in applicants (Fig. V-C2), enrollments have been steady (Fig. V-C1.1), which may be due to faculty turnover and demographics, competition with other programs, and availability of faculty funds. However, we have recently improved retention rates among graduate students and this may be reflected in an increase in awarded degrees (Fig. V-C1a), although we need to track our program over a longer time interval to evaluate these trends.

Scientific communication: Our efforts to improve training for communication included: (1) revisions to the PhD candidacy exam to include a 15-page research writing sample on which students receive written feedback from each committee member, (2) student opportunities to write grant proposals for departmental research funds (Turner grants) and receive feedback from two faculty members via a rubric and individualized comments, (3) writing retreats and workshops by the UM Sweetland Center for Writing, and (4) peer review feedback in presentation and proposal writing as part of the first-year graduate seminar. Many of these efforts are geared towards student retention, as discussed below.

Alumni engagement: We currently engage our active AAB by using annual meetings to receive feedback on our program and provide opportunities for students to interact with members through career events. Section V-I discusses our AAB in depth.

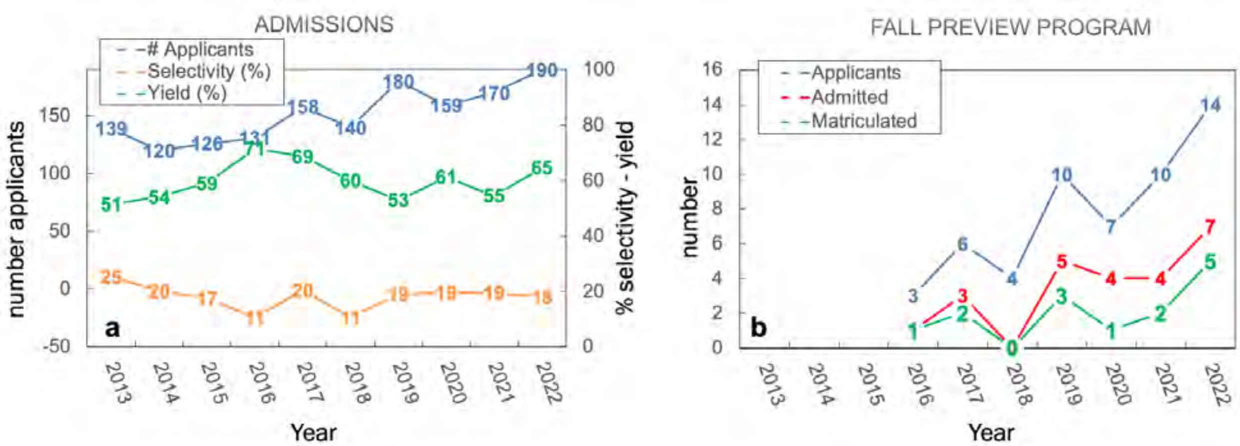


Fig. V-C2 *Metrics for a) admissions to the graduate program and b) the Fall Preview Program by the year of the incoming cohort. Fall Preview started in Fall 2014; the first students were admitted to our program in Fall 2015 as part of the 2016 cohort. Selectivity is the proportion of students admitted to those who applied; yield is the ratio of matriculated to admitted students.*

C3. Response to 2014-15 Rackham Review

Students in our program are part of the University of Michigan Rackham Graduate School, which enrolls over 8,300 graduate students. Our students and our program benefit from the resources and focus on graduate education that Rackham provides. Many recent changes to our program stem from recommendations made in the Program Review that the Rackham Graduate School conducts every five years. We summarize our response to the most recent Rackham Program Review (2014–2015) below.

C3.1 MS Program: Changes After 2015

Changes to the MS program focused on two issues: (1) strengthening the admissions criteria for the fifth-year MS program and (2) improving retention in our entire program by reducing barriers for recruiting directly to the traditional MS program. For the fifth-year MS program, which began in 2014 and represented most of the MS students at that time (Fig. V-C1), there were issues with student performance. We addressed this by raising the standards for admission and requiring research plans from the students and advisor. For the traditional MS program, we expanded funding opportunities to MS students to include GSI positions and tuition remission supported on GSRA funding, with the aim of making it easier for faculty to recruit students who might otherwise enter the PhD program prematurely or not attend UM at all. The increased number of students in our traditional MS program since 2016 reflects this change (Fig. V-C1a), which coincides with higher retention rates in our PhD program (see Section V-C3.2).

C3.2 PhD Program: Changes After 2015

In response to the 2015 Rackham review, we made adjustments to the PhD program related to recruiting, retention, the candidacy exam, professional development, and mentoring.

Recruiting: At the time of the Rackham Review, the Fall Preview program had just started. The subsequent rise in participation in the program and its popularity among our faculty have made it an important part of our recruiting (see Section V-C2 for description).

Student retention: We made several changes to address the low PhD completion rates (63%) between 2006–2010. The major adjustments were policy changes, approved by faculty vote, including changes to our admissions criteria (admission of students ranked <50th percentile only after petition) and revisions to our candidacy exam described in the next point. Following implementation of these policies, the average completion rate has increased to 79% (for cohorts 2011–2015). Current PhD students on track to complete their dissertations are on course to improve these outcomes further. As part of increasing student completion rates, we prioritized cohort building and revamped our first-year seminar, EARTH 531, to focus on strategies for student success. This seminar is now geared toward addressing key needs of students as they start graduate school; topics include research skills, building a constructive relationship with their research advisors, and developing professional skills. This onboarding class is now seen as so critical that there is interest among faculty and students to expand it beyond the first semester (see Section V-C4, below). In further recognition of the importance of student interactions, we have instituted multiple programs in the past several years to facilitate student community building, such as a graduate student retreat, a buddy system for incoming students, and regular "tea times" (both in person and virtual).

Revised candidacy exam: We made significant changes to the candidacy exam. The knowledge-based written exam has been replaced with a research project writing sample in manuscript or prospectus form. The oral exam focuses on scientific literacy and critical thinking relevant to a student's research, with the aim of evaluating student aptitude for independent scientific research as a prerequisite for advancement to PhD candidacy.

Professional development: The revised first-year seminar described above is required and focuses on professional development skills, providing structure for students to attend career events and workshops (Cooke et al., 2021). Professional development continues in the ethics course, EARTH 495, which is required for all first-year graduate students and covers responsible conduct in research and professional interactions. Additionally, we host career events with our alumni board, a dedicated Graduate Career Support Coordinator, Rosie Jowitt, and a student-organized career panel series. Our weekly seminar series, the Smith Lecture, provides opportunities for students to meet speakers in an informal setting, network, and obtain career advice.

Mentoring: In 2016, our faculty met with representatives from Rackham's Faculty Committee on Mentoring (MORE) to discuss mentoring. As part of this effort, we revised the Individual Development Plan (IDP), an annual review process initiated in 2013 that all students must complete with their advisors, ensuring that they receive regular, written feedback on their progress each year. It was clear from the 2015 Rackham student survey that many students did not recognize the IDP as a mentoring tool. In response, we renamed the form Individual Development and Mentoring Plan, added several specific mentions of mentoring in the document, and emphasized the tool with graduate students in the first-year seminar as part of the landscape of mentoring strategies. The form also functions to record student progress in cases of under-performance, with marginal or unsatisfactory performance requiring a meeting with the Grad Chair and the faculty advisor. Completion of the IDP is emphasized; current policy states that the department can withhold tuition remission for GSRAs if mentoring plans are not developed. Faculty and students are also reminded each semester of the importance of good mentoring and the range of mentoring resources through Rackham.

C4. Recommendations for 2021-2030

To maintain a vibrant program in the next ten years, we must grow our program and expand the diversity of our students. The need for diversification is urgent in Geosciences, where the proportion of doctorates held by underrepresented minorities is 6% (the lowest proportion among all STEM fields) and has remained stagnant in the last 40 years (Bernard and Cooperdock, 2018). As part of this imperative, we must continue to assess and modify our program so it can be a place where students from different backgrounds thrive. We outline our vision for achieving this progress below. Many of these recommendations require that our program becomes more student-centered, reflecting needs articulated by Rackham's 2020 Strategic Vision, which follows a 2018 NASEM report on STEM graduate education.

C4.1 Recruiting and Program Growth

Building on the success of Fall Preview in increasing applicants and student diversity we must expand our recruiting to include new efforts such as: 1) joining the AGU Bridge Program and participating in the Inclusive Graduate Education Network and 2) actively targeting participants in NSF REU programs or by developing our own REU program in partnership with Rackham, which has deep experience in broadening participation in graduate education. In tandem, our faculty will work to ensure higher matriculation rates and continue to invest in student success and retention. As part of this, we recommend that the Grad Chair lead a review of the department's financial support for students in our PhD and MS program, with an eye to maximizing graduate program growth, diversity, and student success. We anticipate that these efforts will yield a graduate student population that is 25% URM in the next 5 years.

C4.2 Mentoring

Our faculty recognizes the need for more comprehensive mentoring that promotes collaboration and intellectual exchange, prepares students to work across disciplines, and connects students to more people and resources. To do this, we recommend institutionalizing an expanded mentoring system for all graduate students (PhD and MS students), revising the IDP, and extending the cohort support system beyond the single semester first-year seminar.

Additional faculty mentor: We propose that a working group of faculty, including the Grad Chair, is tasked with developing a new mentoring structure such that every graduate student consults with a second faculty member beyond their research advisor(s) about topics that might include coursework, research progress, and professional development. This might manifest as an assigned academic advisor from a pool of faculty academic advisors serving all grad students; this would be a service assignment for participating faculty. Along with this new mentoring structure, we will consider modifications to student committee meetings (i.e., timing, frequency, structure).

Revised IDP: There is interest among faculty and students in clarifying the accountability associated with the IDP described above and using it as a more effective tool for mentoring. This can be achieved with improved communication about how the IDP works, clarifying the accountability measures already in place, and restructuring the form itself to facilitate more faculty-student interaction by adding elements to scaffold the advisor-advisee partnership for successful mentoring. Other modifications may include adding a self-assessment, shortening it by coupling submission with an updated CV, and modifying it so portions are due throughout the year and explicitly included as part of committee meetings. These changes will build on our existing practices in which the Grad Chair actively promotes mentoring tools and works with individual students and advisors to provide mentoring support.

Cohort building: As part of providing more structured mentoring to students, we propose that the Grad Chair works with other faculty to extend elements of our first-year seminar course beyond the first semester and add regular cohort meetings timed to prepare students for aspects of the program as they encounter them (e.g., the candidacy exam, initiating the IDP, seeking internships, job applications), instead of front-loading everything in the first semester. The meetings will provide information to students when they need it and contribute to peer support among students. The Grad Chair and DEI committee will also work with student groups (e.g., Geoclub, DEI student reps) to plan interactions that promote student camaraderie.

C4.3 Curriculum and Professional Development

As we look to the next 10 years, our program must prepare students for a range of careers with attention to training in scientific literacy, technical expertise, command of fundamentals, problem solving, teamwork, communication, and professional preparation. While we currently do this in multiple ways, described above, the faculty will continue to assess student needs and how our program meets them. We suggest that after thorough assessment of the career paths of our alumni and current student needs through a survey developed with Rackham, the curriculum committee will assess our graduate curriculum as part of the curriculum mapping exercise mentioned in Section V-B of this report. In response, the curriculum committee should then (1) develop a plan to revise course offerings to meet needs identified in the mapping exercise; (2) identify opportunities outside of courses to expand career preparation, including ways to support student internships; (3) institute a tiered plan for student presentations as a required part of the program; (4) provide opportunities to take writing courses and participate in writing workshops and groups, developed with the Sweetland Center for Writing; and (5) build ways for students to interact more closely and regularly with our alumni, beyond events associated with the annual AAB meeting. We recommend that the curriculum committee is also charged with mapping skills onto the graduate experience so that there is greater transparency about how and where students are taught particular skill sets.

C4.4 Investing in an Inclusive Environment and Student Well-being

Our graduate program success depends on ensuring that it is a place where students from different experiences can thrive. To this end, attending to the wellness and mental health of graduate students is a pressing need, as highlighted by Rackham, the Council of Graduate Schools and in the NASEM report on 21st Century STEM Graduate Education. To build an inclusive, equitable and accessible graduate program that focuses on student well being, we will have to change the way we operate (Ali et al. 2021). We envision doing this in the following ways:

Wellness: Based on feedback from our own students, we know that Counseling and Psychological Services (CAPS) and Wolverine Wellness are not serving our students' needs, resulting in the need to seek assistance outside UM or not receive the help they need. This is a major disservice to our students and a hindrance to our academic mission. To address the pressing need to support student well-being, we recommend hiring a Wellness and Inclusion Advocate (WIA). See detailed plan in Section V-D.

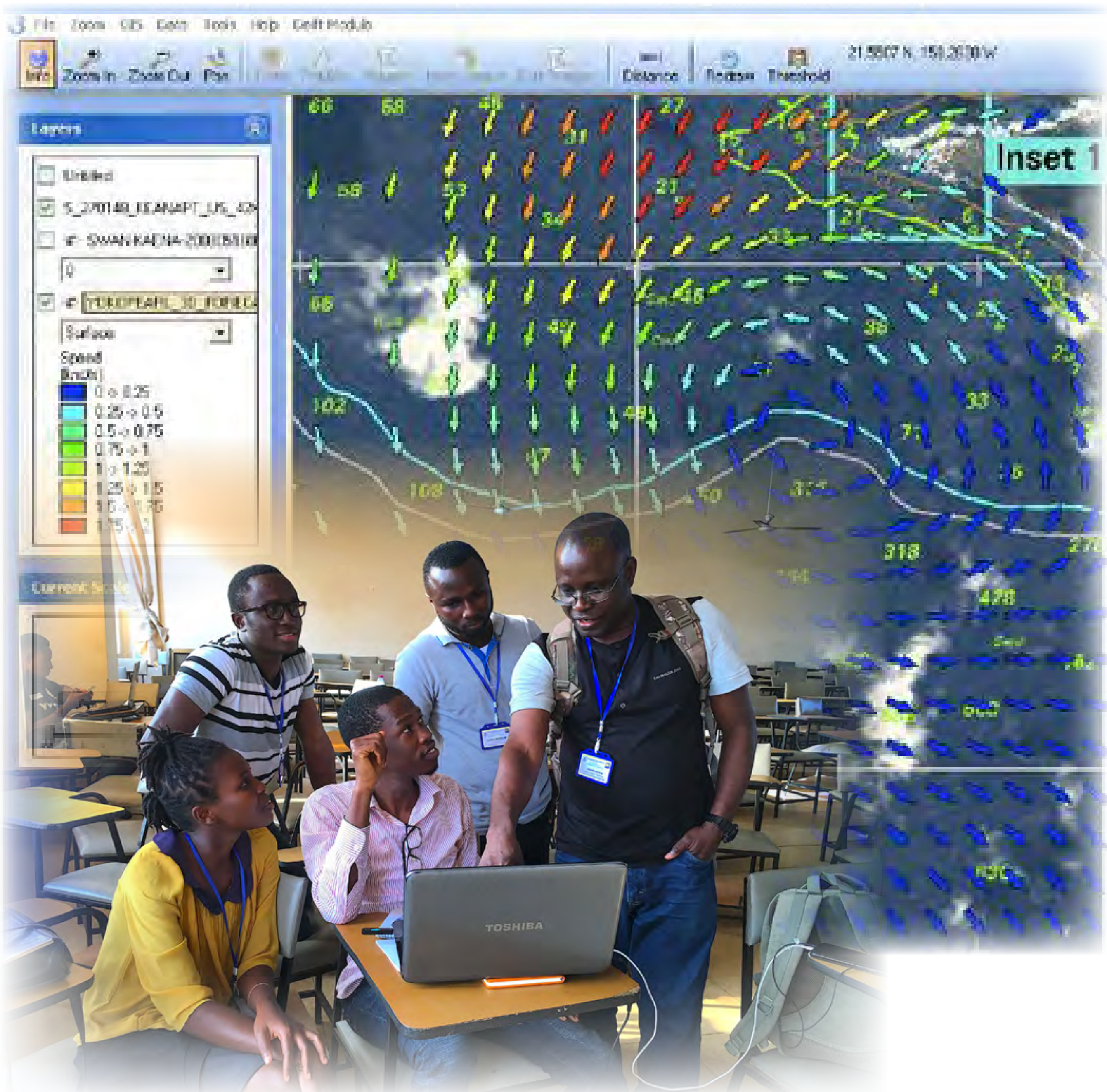
Community: We see investment in community-building as critical to the vibrancy of our graduate program and department. We propose to promote this by continuing to encourage peer interactions and cohort building, recognizing the power of peers. We also recommend fostering student engagement in intellectual communities by (1) codifying the best practices for discipline-based seminars (already common in some groups), (2) instituting annual department-supported lunches for each department sub-discipline so new students get to know faculty, postdocs, staff, and other students, and (3) encouraging peer-review groups for writing and presentations. We recommend that the Grad Chair works with "leads" in each sub-discipline (identified by the faculty in each sub-discipline) to coordinate these efforts. In addition, we recommend that the Grad Chair with the sub-discipline leads organize an annual Fall Open House, where each lab or facility is open to tours for all departmental members, including new graduate students and undergraduates. The WIA and the DEI committee will play a critical role in community efforts (see Section V-D for more detail).

Education for inclusion: To make our department a truly inclusive environment, we must continue to work to understand how we must change as individuals and as an institution, purposefully. For recommendations, see Section V-D.

Improving communication: Ensuring student success requires that students and faculty have a clear understanding of departmental policies and initiatives, systems for communicating with each other, and clear access to resources. To do this, we recommend that a working group of faculty, in coordination with the Grad Chair, Chief Administrator, DEI committee, and the WIA is tasked with (1) compiling a graduate program handbook where policies relevant to the graduate program are aggregated, accessible, and updated annually; (2) building checklists and timelines to facilitate critical conversations and information transfer about mentoring, GSI responsibilities, field trip safety, lab ethics, and publication plans (e.g., Teaching Team Communication Form); and (3) posting policies and guidelines throughout the department that summarize departmental- and university-level policies for vacation time and leaves, resources for supporting mental health, and an inclusive workplace. This will complement the regular cohort meetings described above and the recently developed GSI handbook.

C5. Data: Evaluating the Student Experience and Accountability for Progress

As we aim to communicate effectively and make informed decisions, we need to continue to invest in the collection, aggregation, and distribution of data about our programs. This directly follows guidance of a recently published anti-racism plan for geoscience organizations (Ali et al. 2021) which highlights the importance of translating data collection into informed action, following tenets of both transparency and accountability. Some of these are data already collected by Rackham or LSA, but they must be aggregated in ways relevant to our department, specifically in regard to student activities (e.g., fellowships, grants, internships, outreach, teaching, publications). These data must be connected to information about MS and PhD students' experiences, while in the program and after they leave. We recommend that the faculty working group charged with communication in the section above leads this effort, using frameworks for program evaluation available through Rackham and Wolverine Wellness.



D. Diversity, Equity and Inclusion: Plan for Systemic Change

In Fall 2017, the department created a Diversity, Equity, and Inclusion (DEI) committee of tenure-track faculty that was subsequently expanded to include graduate students, and administrative and technical staff. Going forward, we recommend expansion of the committee to include postdoctoral fellow, undergraduate student, research scientist, and lecturer representatives so that various constituents within the department all have a voice. During the 2020-2021 academic year, a subset of the department community participated in the Unlearning Racism in Geosciences (URGE) program, which offered us an opportunity to critically evaluate our current structures. The following proposed actions, in combination with the recommendations in Section V-E, are seen as the highest priority to have a positive impact on the department as we seek to identify and combat structural and implicit biases within the department.

1. **Hire a Wellness and Inclusion Advocate (WIA)** to provide critical support for our goals related to DEI and wellness. This WIA should have training in social work/mental health and advocacy for equity and inclusion. The WIA will support developing codes of conduct and field safety plans that support diverse students; help with resolving and reporting conflict and climate issues; provide mental health support; coordinate and plan DEI, mental health, and mentoring trainings; and set up structures and codify new systems needed for positive change in department culture. This expert will coordinate recurring trainings, partnering with campus wellness and community resources, to educate students, faculty, and staff, and maintain an up-to-date database of campus resources. We propose to draft an anti-racism and anti-discrimination statement to be publicly displayed, with departmental input and faculty vote. Precedents exist in other programs at UM (Andrea Hill, Epidemiology and Biostatistics Dept., SPH) as well as Harvard Dept. of Earth & Planetary Sciences (several DEI staff members), University of Washington (advisor for graduate and undergraduate students), and the Scripps School of Oceanography (DEI coordinator).
2. **Collection, analysis, and dissemination of demographic data** will be overseen by the WIA, including working with existing University data (e.g., via Rackham, Tableau) and making data publicly available whenever possible. With university guidance, department members and invited guests will be asked to self-report data on intersectional identity to be reported in broad, anonymized groupings. Students, faculty, and staff will be asked to complete new surveys every 3 years to assess diversity and success of recruiting and support programs.
3. **Ensure the curriculum is inclusive** at both the graduate and undergraduate levels. An interdisciplinary seminar on the history of geoscience, including colonialism and pervasive racism, hosted by an EARTH faculty member in collaboration with a colleague in another department, should be created for graduate students. Supported by the Curriculum Chair, faculty should build anti-racism and justice into teaching through incorporating acknowledgement of wrongdoings of colonialism and racism, disproportionate impacts of environmental hazards, differential access to resources by various communities, and effects of climate change on communities of color.
4. **Field experiences** will transform into inclusive, accessible, and anti-racist spaces through the development, led by the WIA, of a Field Safety Guide "Best Practices for Inclusive Fieldwork and Engaging with Local Communities". The guide should include wellness and safety information for students from communities underrepresented either/both in Earth and environmental sciences and fieldwork, including international students, students with disabilities, students from racial/ethnic minority groups, among others. The field guide should also detail ways to perform fieldwork in collaboration with local communities with historical expertise. Graduate students will be exposed to the guide in the required ethics course. In addition, GeoClub will be supported with facilitating low-pressure camping trips for undergraduate and graduate students to gain experience with camping, working with the UM Adventure Leadership program. Geoclub leaders will also be encouraged to expand the Gear Reuse program and ensure it is advertised to undergraduate and graduate students.
5. **A Research Group Code of Conduct and Policies** should be developed and provided by the WIA, a step that would improve equity and inclusivity in labs and research groups. This would be distributed to all PIs to adapt for their research groups and posting in their research spaces.

E. Department Climate: Advance Review

In January 2020, the UM ADVANCE team prepared a series of surveys in collaboration with the Strategic Planning Committee and department leadership to evaluate the department cultural climate. These surveys were completed in early March 2020 by five constitutive groups (Graduate Students; Tenure-Track Faculty; Postdoctoral Fellows; Research Scientists and Lecturers; and Administrative and Technical Staff). Due to the pandemic interruption, results were delivered in late summer 2020 and further discussed with the department in Fall 2020. The following term (Winter 2021), department leadership, the DEI committee, and the Associate Chair of Graduate Studies held a series of town hall meetings with the constitutive groups to discuss the survey outcomes, as well as any changes that may have occurred in the light of the pandemic. Group-specific recommendations for responding to these surveys and discussions are below.

E1. Graduate Students

1. **Professional Development and Communication:** Some students reported a lack of opportunities for professional training (e.g., giving interview/job talks), communication of departmental policies, unrealistic workloads, and unavailability or unawareness of resources. We recommend promoting increased disciplinary group interactions, strengthening support of international students, and improving communication and transparency about policies and expectations (Section V-C4).
2. **Mentorship and Faculty-Student interactions:** Student concerns, especially for those from underrepresented backgrounds/identities, include: experiences or witnessing of negative interactions by, or with, members of the department; a lack of transparency over reporting; and the feeling that students are "on their own" with respect to issues of mentorship, mental health, and DEI. In addition to changes in mentoring and committee structures (Section V-C4), we recommend that the WIA develop the codes of conduct described above; help with resolving and reporting conflict and climate issues; provide mental health support; coordinate and plan DEI, mental health, and mentoring trainings; and set up structures and codify new systems needed for positive change in the department.
3. **Transparency and Reporting:** The Grad Chair and the WIA should jointly create a clear "decision tree" for situations when any member of the department has a grievance or concern with another member of the department (e.g., bullying, harassment, discrimination). The current reporting form should be revised to clarify the limits of anonymity of the report, add other recipients beyond the Department Chair, and provide other courses for redress (e.g., grievance policy, SAPAC). Adding a physical dropbox to the main office, checked weekly, would help to alleviate concerns about the anonymity of digital reporting.

E2. Tenure-Track Faculty

1. **Collegiality and Inclusivity**: Some international and/or lower-income-background faculty feel excluded from informal networks in the department and also report more stress, feeling more surveilled, and perceive they have less influence over department matters; they report having to work harder to be perceived as legitimate. Women faculty feel more stress and that some department members have a condescending attitude toward them. We suggest that department leadership institute a Code of Conduct, build awareness and education on marginalization of women and minorities, select leadership to represent diverse perspectives (but not overburdening URM individuals), and assign mentors to new faculty even if hired with tenure. We also recommend organizing an informal, intradepartmental seminar series, inclusive events to promote social connections, and a department-level faculty handbook.
2. **Diversity:** Faculty agree that a diverse faculty is important, yet there is a lack of diversity within their ranks. We recommend adding a standing committee as a departmental service assignment to scout for, and encourage applications from, historically underrepresented candidates via programs such as the LSA Collegiate Fellowship and Presidential Postdoctoral Fellowship Program, as well as identifying potential senior candidates. Starting in 2021, the department will solicit DEI and service statements from faculty applying for tenure, in compliance with college policy.

3. **Resources and Workload:** Some faculty feel there should be more time available for scholarly work and more support for securing grants. To help faculty with grant writing, we suggest hiring a staff member to assist with developing broader impacts and/or with writing large grants. To strategically alleviate the workload on the faculty, we should hire Lecturer III positions that can also serve as a lab/field coordinator and/or undergraduate advisor(s). We suggest moving and/or shortening faculty meetings to end by 4.30 pm in order to accommodate family responsibilities.

E3. Postdoctoral Fellows

1. **Mentorship and Career Support:** Postdoctoral fellows reported a need for additional guidance outside their immediate sphere of research, anxiety revolving around funding issues, and the desire for more support on career advancement. We suggest that current postdocs and administrative staff engage in adapting the LSA handbook for postdoctoral fellows to include department-specific information and resources to help with professional development such as CRLT. To improve and create a baseline standard for mentoring practices, we suggest requiring an annual performance evaluation and review that includes a funding plan for transparency purposes, similar to the IDP for graduate students, be done by the EC. We also recommend that postdoctoral fellows be invited and encouraged to organize and give talks at a proposed intradepartmental seminar series (see above), as well as initiating and organizing with graduate students a "Future Faculty workshop series" that includes training for being a PI for interested postdoctoral fellows and graduate students.
2. **Inclusivity:** Postdoctoral fellows reported a lack of interactions and connections across the department outside of their primary research groups. To improve community-building and networking within the department, we suggest that each new postdoctoral fellow will receive an introductory meeting with the CA, be encouraged to attend research group meetings outside their principal lab, and be invited to an annual Welcome Lunch hosted and organized by each subdisciplinary group in the fall, with support from the administrative staff.
3. **Work-Life Balance:** Postdoctoral fellows reported a lack of work-life balance and a sense of unreasonable expectations. The postdoctoral fellow handbook should include information about expectations and vacation/leave policies. Research and performance expectations will be discussed between postdocs and their advisors upon arrival and during the annual performance evaluation.

E4. Research Faculty and Lecturers

1. **Inclusivity and Community**: Research faculty and lecturers reported feeling isolated and excluded from the department network, not respected by tenure-track faculty, and unwelcome in department functions. We suggest supporting lecturers and research faculty by arranging semesterly meetings with their respective groups, with a point person designated to communicate any community concerns with department leadership. We also suggest that the Curriculum Chair organize annual meetings with instructors to discuss best teaching practices. We recommend that PIs encourage research faculty affiliated with their labs to participate in the proposed informal seminar series.
2. **Mentorship Structure:** Research faculty and lecturers reported receiving inadequate mentoring from the department. In addition to annual meetings with the Department Chair, we recommend the Department Chair establish mentoring teams comprised of tenured faculty member(s) and a lecturer or research faculty.
3. **Communication:** Research faculty and lecturers reported that department procedures are not transparent, open, or well-communicated, and that they do not feel like they have a voice in decision making. Department leadership has recently begun to invite research faculty and lecturers to faculty and departmental meetings when appropriate, and this type of communication should be continued and formalized. Going forward, the Department Chair should unequivocally invite research faculty and lecturers to faculty meetings where relevant information will be shared or input from research faculty or lecturers would be valued, and it should be made clear in the invitational emails when these groups are able to speak up or vote (as applicable). Additionally, lecturers and research faculty should work with the WIA to develop separate policy booklets and guides to assist with onboarding new lecturers and research faculty (including contact info for relevant mentors, HR contacts, and staff roles) and to clearly articulate their rights and requirements.

E5. Administrative and Technical Staff

1. **Collegiality and Mutual Respect:** Staff members reported feeling like "second class citizens" and some staff, particularly women and those from low-income-backgrounds, experienced condescension from faculty. We recommend increasing departmental offerings of workshops and learning opportunities about implicit bias, particularly with an intersectionality lens. Staff will be explicitly invited to all-department gatherings. Additionally, impartial channels need to be built out by the WIA in collaboration with the DEI committee for staff to report instances of bias, unreasonable expectations, and workplace difficulties.
2. **Supervisory Relationships:** Staff identified a need for more reasonable expectations from supervisors for deliverables. PIs should be encouraged by department leadership to engage the university's opportunities for management training to improve communication, interpersonal relationships, and help set realistic expectations for deliverables, timelines, and performance.
3. **Work-Life Balance:** More than half of staff reported intrusions into their personal time by work obligations, such as working during vacation time. These concerns should be addressed by adhering to LSA guidelines for communication outside of work hours and developing agreed-upon guidelines for what constitutes an emergency requiring immediate response. Explicit guidance should be provided to faculty on what constitutes an emergency. Leadership should provide support to staff in declining to respond to outside work hours.
4. **Pathways for Advancement:** Many staff indicated dissatisfaction with promotion opportunities and pay. Clear advancement pathways from lab technician to other technical or administrative positions should be created. PIs should be encouraged to openly discuss any financial issues that may arise with their technical staff and work toward acceptable solutions.

F. Administrative and Technical Staff

EARTH has 22 staff, both administrative and technical. The administrative staff is overseen by the CA who, in concert with the Department Chair, manages the financial, human resources, student services, facilities, and faculty affairs domains. Each of these areas is supported by at least one dedicated administrative staff person, including a student services manager, student services assistant, executive coordinator, building manager, communications coordinator, Earth Camp coordinator, and Camp Davis project coordinator.

The technical staff consists of fifteen lab technicians and lab managers working in sponsored and recharge labs. They are supervised by both the CA and individual PIs, with the CA providing administrative supervision and the PI functional supervision.

As in other units, EARTH staff experienced great challenges during the 2019-2020 and 2020-2021 academic years. While our move to remote operations was difficult, it was handled with grace and creativity. As in many other cases, the pandemic did underline the importance of issues that had long been present, namely the need for a more robust and engaged online presence, clearer communication channels, better outreach to external constituencies, and increased support to students.

We have reassessed the duties of the executive coordinator (previously executive secretary), emphasizing this as a role equally engaged with project management as with administrative support. This has allowed for the building out of a "Chair's Office" that is responsible for leadership and core administrative operations, and better differentiation of the other administrative domains. While the staff leans heavily on each other for collaboration and problem solving, this reorganization aims to eliminate some of the role confusion that existed in the past. By charging the executive coordinator with a scope of work that is done in collaboration with but not necessarily at the direction of the CA and Chair, the position has fostered greater independence, creativity, and problem solving both for the coordinator and the team as a whole.

The department is in the process of reviewing its communications strategy, examining whether it reaches its target audiences. We plan to make communication more regularized and predictable, increasing the communication coordinator's time dedicated to social media, advancement, and alumni correspondence.

Staff turnover on the administrative side is low, with 11.7 as the mean number of years of service in the department. Turnover on the technical side has been relatively high, primarily driven by early-career technicians leaving to pursue more education and occasionally, other career opportunities. As discussed in previous sections, we are addressing this by better defining pathways for career advancement for technicians within the unit and/or UM, while also acknowledging this is common for both the field and those in early stages of their careers.

Staff satisfaction is generally high, as reflected by recent surveys by UM's ADVANCE program. There were a few opportunities for improvement noted in the surveys, much of which is addressed in previous portions of this plan. Outside of what has been previously discussed, the most significant opportunity for growth in staff satisfaction is for increased transparency and information sharing with staff, both administrative and technical. For administrative staff, this has meant increased participation in strategic planning, as well as frequent, clear communication about future directions. For technical staff, faculty PIs will be encouraged to develop their skills as supervisors through management training and other opportunities (publications and newsletters, small group discussions, etc.). The unit will also provide more regular meetings with lab PIs and their staff to review administrative aspects (staffing, budget, long-term planning) to better reflect lab staff's significance as stakeholders.

G. Department Management and Organization

EARTH is one of fourteen units in LSA's Natural Sciences division. Each unit reports to a divisional associate dean, who sits under the college's dean.

The department consists of 33 tenured and tenure-track faculty members. Of these, three have curatorial appointments with the UM Museum of Paleontology and five have joint appointments in Program in the Environment (PitE), ranging from 25-50% effort. EARTH has five research faculty, spanning ranks from assistant research scientist to research professor. We currently have seven lecturers, some of whom also hold appointments as research faculty; they teach both in Ann Arbor and at Camp Davis. EARTH has fifteen postdoctoral fellows.

As is typical of similar academic units, the Chair oversees the research and academic programs. EARTH differs from some of its peer units in also charging its Associate Chairs, EC, and CA with oversight of various aspects of these enterprises, sometimes in partnership with, and sometimes independent of, the Chair. This structure adds breadth to leadership of the unit, with a wide range of decision-makers charged with representing the interests of all stakeholders.

EARTH's EC is composed of four tenured faculty members, elected by the full faculty for a term of two years. After serving, an EC member is ineligible to serve again for a period of two years. Those faculty holding other leadership positions in the unit (i.e., Associate Chairs, field station director) are ineligible. The EC is responsible for evaluating faculty as part of their annual reviews, considering certain requests from faculty and students, codifying practice into formal policy, and advising the Chair on sensitive matters. By electing rather than appointing its EC, EARTH aims to represent the diverse voices of faculty in its decision-making.

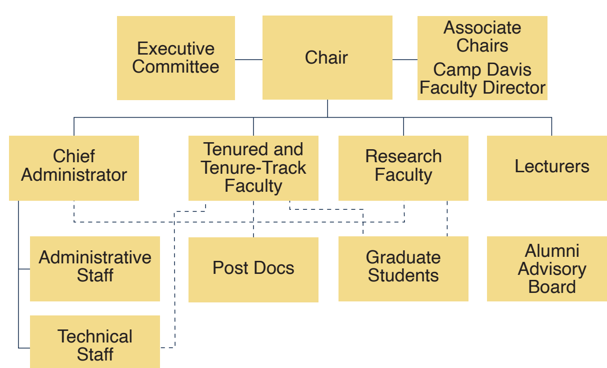


Fig. V-G.1 *Department of Earth and Environmental Sciences organizational chart.*

H. Space and Infrastructure

H1. Analytical and Computational Facilities in EARTH

Our faculty, staff, and students operate 34 chemistry and experimental labs and six computational facilities, all housed in the North University Building. Since our last strategic plan, we have newly launched or renovated more than a third of the labs, as indicated below, while a few have been decommissioned due to retirements. Faculty with joint appointments with the Museum of Paleontology and their students use eight shared laboratories (including preparation facilities and areas for hosting visiting researchers), two computational labs, and eight collections areas distributed between the Biological Sciences Building and two sites off of central campus: the Research Museums Center and the Kipke Building.

Table H1.1: Analytical Facilities in Earth and Environmental Sciences

Aquatic Geochemistry Laboratory*	PI: Rose Cory; Lab Manager: Catherine Polik
Biogeochemistry & Environmental Isotope Geochemistry Laboratory*	PI: Joel Blum; Lab Manager: Marcus Johnson
Biogeochemistry & Micropaleontology Lab	PI: Ingrid Hendy
Continental Environments Research Lab	PI: Nathan Sheldon
Earth Systems Clean Lab	PIs: Ingrid Hendy, Nathan Shedon
Earth Systems Science--General Lab	PIs: Ingrid Hendy, Nathan Sheldon
Economic Geology Lab*	PI: Adam Simon
Electron Microbeam Analysis Lab (EMAL)	PI: Becky Lange; Lab Manager: Owen Neill
Experimental Igneous Petrology Lab (EPL)	PI: Becky Lange
Extreme Environment Research Laboratory	PI: Jackie Li
Geochronology Lab*	PI: Robert Holder
Geomicrobiology Lab	PI: Greg Dick; Lab Manager: Catherine Polik
Helium Thermochronology Lab*	PIs: Marin Clark, Nathan Niemi
High Pressure Laboratory	PIs: Jackie Li, Youxue Zhang, Becky Lange
Isotopologue Paleosciences Lab*	PIs: Ben Passey and Naomi Levin
Computed Tomography in Earth & Environmental Sciences (CTEES)*	PIs: Selena Smith, Matt Friedman
Michigan Elemental Analysis Lab (MEAL)*	PI: Ingrid Hendy; Lab Manager: Angela Dial
Microbe-Mineral Lab*	PI: Jena Johnson
Mineral Chemistry	PI: Udo Becker
Mineral Physics Research Laboratory	PI: Jackie Li
Mineral Separations Lab*	PI: Nathan Niemi
NanoGeoRadio Materials Labs A and B	PI: Udo Becker
Noble Gas Lab*	PI: Clara Castro
Plant Evolution, Paleobotany, and Paleoecology Research (PEP-PR)*	PI: Selena Smith
Radiogenic Isotope Geochemistry Lab (RIGL)	PI: Joel Blum
Rock Cutting Room	PI: Jeff Alt
Sample Prep & Rock Crushing Room*	PI: Nathan Niemi
Stable Isotope Facility*	PIs: Julia Cole, Kyger Lohmann, Sierra Petersen
Structure Lab-Chemistry	PI: Ben van der Pluijm
TEM & X-Ray Diffraction Sample Prep Lab	PI: Udo Becker
X-Ray Diffraction Lab	PI: Udo Becker

* Renovated since 2011

Table H1.2: Computational Facilities in Earth and Environmental Sciences

Climate Change Research Lab	PI: Chris Poulsen
Computational mineralogy	PI: Udo Becker
Genomics	PI: Greg Dick
Geophysics*	PIs: Eric Hetland, Yihe Huang, Zack Spica, Jeroen Ritsema
Geospatial	PIs: Marin Clark and Nathan Niemi

* Renovated since 2011

H2. Camp Davis Rocky Mountain Field Station

The Camp Davis Rocky Mountain Field Station is a seasonal facility located near Jackson, WY that is operated by the EARTH for the primary purpose of experiential field learning. Camp Davis is open from May to September, and offers 7 month-long courses each summer, including three courses in introductory Earth or environmental sciences, an upper-level non-major course in energy and the environment, and three upper-level major-oriented field courses in geology and ecosystem science. The courses are primarily taught by tenure-track faculty, and provide field-based teaching experiences for ~14 GSIs each summer. Enrollment across all courses is around 140 students, with all classes limited to 24 students. Camp Davis is also used for workshops, meetings, short courses, graduate summer schools, and alumni events.

The field station sits on 129 acres adjacent to the Bridger-Teton National Forest, spanning the Hoback Wild and Scenic River. Physical facilities include 20 faculty cabins and 30 student cabins (all with heat and restrooms; renovated in 2009 and 2019, respectively), three instructional buildings (constructed in ~1930, 1970 and 1990), a recreation building (2019), dining hall and commercial kitchen (1930–1980), and various support buildings (most dating to the 1930s). Fiber optic ethernet service was extended to Camp Davis in 2019.

At the time of the last strategic plan, a major renovation of faculty cabins had just been completed, and we were anticipating renovating the student cabins. The student cabin renovation project was completed in 2019, and, at ~$6M, is the largest capital project in Camp Davis history. 30 new student cabins (including 2 ADA cabins) were constructed, with heat, insulation, and en suite bathrooms, increasing Camp Davis student occupancy to 116 students. This renovation also included the construction of a new recreation building (to replace an older recreation building that was damaged by tree fall during an ice storm mid-renovation planning). In addition to the new structures, significant upgrades were made to sewer, septic, power, and water utilities, and a fire and life safety system was installed in the student cabins, a first for Camp Davis. Strategically, renovation of the dining facility is the most pressing remaining infrastructure need for Camp Davis. Segments of the dining hall and commercial kitchen are approaching 90 years old with minimal upgrades or retrofits since original construction. Scaling up life and fire safety systems at Camp Davis to serve a building the size of the dining hall will be the most significant (and costly) challenge in achieving this renovation, but dining services are essential to continued Camp operations, and so planning for this renovation must be a priority.

Student cabin renovation 2019

Rec Hall renovation 2019

I. Alumni Advisory Board and Advancement Objectives

In 1982, the department was amongst the first in the college to organize an AAB, comprising eight successful alumni representatives from the natural resource extraction industries. The impetus for creating the board was to rekindle contacts with former students to provide insights in current trends in industry. Such insights were used as we revised our curricular offerings to better prepare our students for future careers, and to provide strategic guidance for future hiring of faculty. Additionally as a byproduct, this also created a venue for soliciting philanthropic donations to our burgeoning departmental endowment. Donations made through the early 1990s emphasized the opportunities provided by flexible departmental endowment funds. For example, the Turner Fund sponsored seed research funds to both students and faculty to undertake new and exploratory research projects, an initiative that greatly expanded our success in obtaining research grants from external sources. Combined with this, the establishment of the Turner Lecture Series created the opportunity to provide weekly seminars exposing our faculty and students to exciting emerging research by national and international experts. The AAB continues to serve as an critical component of the department's fundraising efforts, providing resources that have enhanced teaching and research opportunities available to members of the department.

Over the years, participation on the AAB has increased to a current membership of 24 active alumni who represent diverse fields. Though initially composed of members derived from only the petroleum and mining industries, the current board also includes members representing academia, government, non-profit environmental groups, and financial services. This diversification is representative of the changes in career opportunities available to Earth scientists that have evolved in response to changing societal needs, and the diversity of AAB members offers an essential perspective to students when considering their future career options.

In 2019, the AAB re-evaluated and affirmed its role in supporting the department during a facilitated meeting to assess the Board's role in the future department. As a result, a new Statement of Purpose was created, codifying the primary areas that serve as the AAB's goals and responsibilities. While fundraising remains a component of their role, mentorship of students and promotion of underrepresented groups has become an important focus of their interaction with the department. The AAB has taken an active role in sponsoring Earth Camp (Section V-B2.2), and they organize numerous career panels each year. Alumni panel members meet with our graduate and undergraduate students to discuss aspects unique to their chosen careers and highlight the challenges and opportunities that lie ahead. Furthermore, student-alumni mentoring relationships have been established as an unexpected outcome of these panels. All of these interactions have been tremendously successful and will continue as a key future role of the Board and its members.

The 2019 Revised Statement of Purpose outlined below exemplifies the future role of the Alumni Advisory and its primary focus on guiding and aiding in the success of our students in their academic and future lives.

- To provide a vehicle for communication among the department alumni, faculty and students;
- To provide insight into economic and employment trends in public and private sectors affecting the department in parallel with career information on our website;
- To serve as a resource to students with regard to career counseling, academic guidance, and mentorship;
- To provide guidance to the department on employable skill sets
- To provide financial support and assist the department in the identification and solicitation of financial and other resources;
- To serve as an external advocate of the department to the college and central university administration;
- To assist with special projects or other department initiatives as needed.

Fig. V-I.1. *AAB members meeting with students.*