What Does It Take to Get into Graduate School? A Survey of Atmospheric Science Programs

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Undergraduate students planning to attend graduate school in the atmospheric sciences deserve quantitative information that allows them to assess their likelihood of admission and, ultimately, success in graduate school. Faculty members at undergraduate or graduate institutions can speak from personal experience, but their information is inherently anecdotal or limited to individual schools. In addition, graduate schools themselves may be interested in how their admission policies, selectivity, and student profiles compare to those of other schools.

In order to provide objective information regarding these and other issues, the AMS's Board on Higher Education (AMS BHE) undertook a survey of atmospheric science graduate programs in the United States and Canada during the fall and winter of 2007–08. The survey was performed with assistance from AMS headquarters and in cooperation with the University Corporation for Atmospheric Research (UCAR).

Survey responses were solicited with an e-mail to all UCAR members and academic affiliates. Usable responses were received from 29 schools, representing a broad array of programs: some large and some small, some exclusively atmospheric science and some interdisciplinary. Other responses were received but discarded because they did not include admission data or did not provide comparative information on criteria for admission.

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Among all 71 UCAR members at the time, the usable response rate was 39%. Among the 41 UCAR members that include any variation of the words meteorology, atmosphere, or climate in their school, department, or center names, the response rate was 54%; among other UCAR members, the response rate was 20%. One response was received from an M.S.-granting UCAR affiliate. Seven of the responding institutions offer a nonthesis option.

All survey responses consist of self-reported information. Answers to subjective questions partly reflect the respondents' perceptions of the admission process at their own institutions. The actual admission considerations may be different than those reported, as unarticulated or unconscious factors are possible. Our analysis of the survey assumes that the responses are correct, except for three that were numerically inconsistent and were replaced by the apparent consistent responses.

SIZES AND ADMISSION RATES. Applications, admissions, offers, and enrollments are shown in Fig. 1 for all usable responses. The individual programs are plotted from smallest to largest according to typical incoming graduate class size, which ranges from 1 to 24. For purposes of later comparative analysis, the programs are grouped as small (1–5), medium (6–14), and large (15–24). The 29 schools reported a total of 258 students as beginning their graduate studies in a typical year.

Although direct comparison is difficult, these numbers may be compared to the results of a previous UCAR survey by Vali et al. of graduate programs covering the school years 1995–96 to 1999–2000, which appeared in the January 2002 *BAMS*. In the earlier survey, the average class size was 10.8, compared to the present 9.2 among UCAR members. The three largest responding schools averaged a class size of 31, while the largest incoming class in the present survey is 24. The decline in graduate enrollments per institution is partially offset by an increase in UCAR member institutions from 63 to 71.

The responding programs receive between 6 and 140 applications per year. This represents an average

SCHOOLS PROVIDING USABLE SURVEY RESPONSES

The University of Alaska at Fairbanks
The University of Arizona
The University of California at Davis
The University of California at Irvine
The University of California at San Diego
The University of Chicago
Colorado State University
Cornell University
The Florida State University
The University of Houston
The University of Maryland
McGill University
The University of Miami
The University of Nebraska at Lincoln
The University of Nevada at Reno

The University of New Hampshire
North Carolina State University
Oregon State University
The University of Oklahoma
The Pennsylvania State University
Princeton University
Purdue University
Rutgers University
San Francisco State University
Stanford University
The State University of New York at Stony Brook
Texas A&M University
Texas Tech University
The University of Washington

of 51 applications for each UCAR member, compared to about 70 applications a few years ago when a downward trend was already evident. About 69% of all applications are from domestic (United States or Canada) students; at individual schools this percentage ranges from 39% domestic to 93% domestic. Actual new graduate student enrollment is 76% domestic. Many of the programs with the smallest percentage of domestic students are at private schools.

The meaning of "admitted" may vary from program to program. For some, admission may happen in the course of evaluating applications, while for others, admission may only occur when students receive offers, or even later in the process. Thus, it is not possible to compute a meaningful yield rate.

Graduate school in the atmospheric sciences generally involves considerable financial support in the form of research assistantships, teaching assistantships, or fellowships. The definition of full support may vary slightly among the programs (e.g., tuition remission, size of stipend, etc.). At 16 out of 29 schools, no students were admitted without an offer of full financial support. Only the two largest programs and the smallest program offered partial (rather than full) support to a substantial fraction of applicants.

Roughly 18% of those applying to a particular school, on average, end up attending that school. This percentage ranges from a low of 5% to a high of 50%, but does not vary systematically with program size.

Sixteen programs characterize themselves and their student pool as highly competitive, while eleven characterize themselves as moderately competitive and two as somewhat competitive. Larger programs are more likely to self-characterize as highly competitive. The percentage of those applying who eventually attend is almost identical for highly competitive (18%) and moderately competitive schools (17%). The fraction of applicants who go on to attend the two somewhat competitive schools (32%) is almost twice as high as the fraction attending the others.

STUDENT CHARACTERISTICS AND ADMISSION CRITERIA. The academic characteristics of the students entering graduate school were assessed objectively (using GRE scores) and semiobjectively (using reported undergraduate grade point averages, or GPAs).

GRE scores. The GRE scores varied somewhat depending on the size of the program (Fig. 2), but there was considerable variation among programs of similar size, so very few differences were statistically significant. There was a general tendency for students in larger programs to have lower GRE verbal scores and higher GRE quantitative scores.

According to the Educational Testing Service (ETS), the typical student entering graduate school in the atmospheric sciences has a verbal score of 560 and a quantitative score of 740, corresponding to the 77th and 81st percentiles among GRE test-takers. The gap between verbal and quantitative scores is present among both foreign and domestic students. If GRE scores were used as predictors of graduate
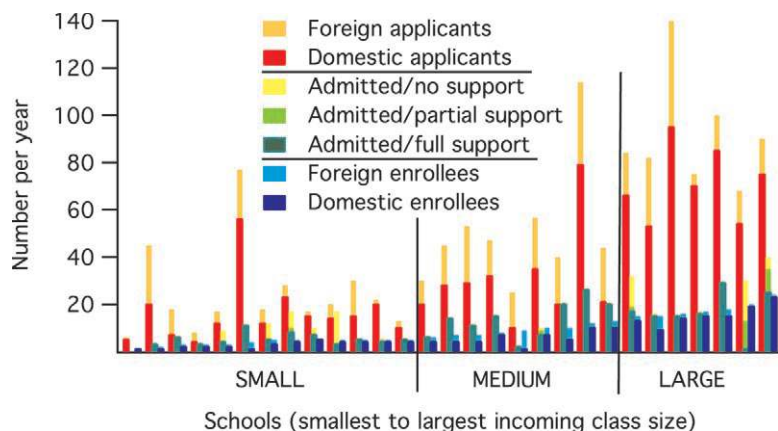
Fig. 1: Application and admission profiles of all schools with usable responses. Schools are ordered left to right from smallest total number of enrollees to largest total number of enrollees. Three bars are plotted for each school. The first (orange-red) bar gives the total number of applicants, broken down by domestic vs. foreign. The second (yellow-green) bar gives the number of students admitted, broken down by the amount of support provided to the student. The third (cyan-blue) bar gives the total number of enrollees, also broken down by domestic vs. foreign.

school performance, a student with such a GRE score (combined 1,300), while well above average in terms of the applicant pool, would be expected to become an average graduate student.

In their 2002 paper, Vali et al. expressed concern that the ongoing decline in applications and an increase in the percentage of students accepted and enrolled per application would lead to a decline in student quality, as measured by GRE scores. This has apparently not happened, although the numbers are not directly comparable. In the earlier survey, the average GRE scores for those admitted were 548 verbal and 717 quantitative, slightly lower than the median scores for enrollees in the present survey.

The minimum GRE verbal score averaged about 460 at the small and medium programs, with a range of 380–600. Only two large programs reported minimum GRE verbal scores (of 300 and 320). The minimum GRE quantitative score ranged from 550 to the maximum possible 800 (!), with a typical value being 640. Thus, a student with a GRE combined score as low as 1100 is likely to have difficulty gaining admission at most schools,

even if other aspects of the application package partially compensate for the low GRE scores. According to the ETS, such a score is slightly below the average of all GRE test-takers intending to major in Earth, atmospheric, and marine sciences. Such a score is also well below the average for intended majors in physics, chemistry, mathematics, and all fields of engineering, but above the average for intended majors in most other fields.

Undergraduate GPAs. Schools were also asked what undergraduate GPA was needed for a student to be strongly considered for admission. Responses were requested for a variety of undergraduate majors: meteorology, mathematics, physics, chemistry, Earth sciences (including oceanography and geology), and nonscience majors. Meteorology degrees were subdivided into those from "strong" and "lesser" programs, with interpretation of those terms left to the respondents. Also requested was the undergraduate GPA in math and science courses that would be needed for strong consideration for admission.

Median responses were 3.3–3.4 for majors in mathematics, physics, chemistry, and meteorology from a strong program, 3.5 for majors in meteorology from a lesser program or majors in other Earth sciences, and 3.7 for nonscience majors. There was consider-
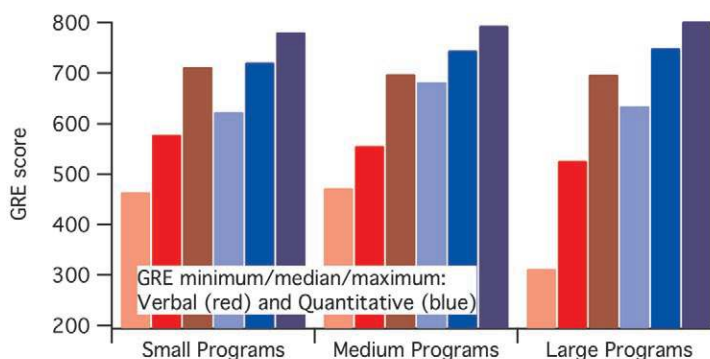

Fig. 2: GRE verbal (reddish hues) and quantitative (blueish hues) scores, subdivided by size of graduate program. For each score category, the bars represent, from left to right, the average value of the minimum, median, and maximum score among incoming graduate students at the various schools.

able variability among schools regarding the specific GPA value needed (responses for mathematics majors ranged from 2.7 to 3.7, for example). Schools were generally consistent about which majors needed a higher GPA. A nonscience degree required a higher GPA than most other listed majors in 19 of 27 schools that provided a response to this question. The 19 include 7 schools that provided GPAs for most other majors but left this major blank, which we interpret as meaning that a nonscience major would generally not receive strong consideration for admission at those schools, even with a 4.0 GPA.

Most schools looked for similar GPAs from meteorology majors from strong programs as they did from mathematics or physics majors. Three expected a higher GPA from meteorology majors, four wanted a higher GPA from math or physics majors, and one school accepted lower GPAs from physics majors but required higher GPAs from mathematics majors.

Fifteen of 27 schools consider the strength of undergraduate meteorology programs in their admission process, requiring a higher GPA for students from a lesser program than from a strong program.

Other requirements for admission. Schools were asked to identify which application characteristics (from a specified list) are needed for admission to their graduate program. Responses are shown in Table 1. There was little difference among responses from small, medium, and large schools.

For admission, almost all programs required that a student's GPA in math and science, letters of recommendation, overall GPA, and GRE score for admission all be reasonably good. Many required a reasonably good match between student and faculty research interests or a reasonably good application essay.

Three programs (10%) attach particular significance to an undergraduate meteorology degree. They require an undergraduate degree in meteorology or atmospheric sciences for a student to be admitted to their program, except in very unusual cases. No program generally requires that a student be self-supporting.

Some students gain admission even though they do not satisfy a particular school's stated requirements. Overall, 8% of admitted students fall into this category.

IDENTIFYING THE MOST DESIRABLE APPLICANTS.
Schools were asked to estimate the importance of various considerations to their recruiting and financial support decisions (Fig. 3). The importance was rated on a seven-point absolute scale, with 1 being extremely important, 4 being somewhat important, and 7 described as "doesn't matter."

The most important considerations were a strong grade point average in mathematics and science and strong letters of recommendation. Each was rated extremely important by more than half of the schools.

At the next level of importance were a strong overall grade point average, a good correspondence between interests and faculty research programs, and a strong GRE score. Each of these was rated 1 or 2 in importance by the majority of schools. At one school, the GRE is not required and the score therefore doesn't matter there.

Somewhat important, on average, were self-support for graduate school, an undergraduate degree from one of the leading undergraduate programs, and undergraduate research or internship experience. Self-support for graduate school drew a wide range of responses. While five schools said that self-support doesn't matter, five others regarded it as extremely

TABLE 1. Percentage of schools requiring particular characteristics, in response to the question: "What must students show in their application just to be admitted to a graduate atmospheric sciences program?"	
Characteristic	**%**
Reasonably good letters of recommendation	97
A reasonably good overall grade-point average	97
A reasonably good grade-point average in mathematics and science	97
A reasonably good GRE score	93
A reasonably good correspondence between interests and faculty research programs	62
A reasonably good application essay	59
An undergraduate degree in meteorology or atmospheric sciences	10
An undergraduate degree from one of the leading undergraduate programs	3
Undergraduate research or internship experience	3
Accomplishments with volunteer or student organizations	0
An undergraduate scholarship, fellowship, or other form of competitive award	0
Self-support for graduate school (graduate fellowship, etc.)	0

important. Perhaps, when filling out the survey, some schools interpreted self-support as a mere financial matter, while others interpreted it in the context of winners of nationally-competitive graduate fellowships.

Of less importance was an undergraduate scholarship or an undergraduate degree in meteorology. Even so, both characteristics were rated as extremely important by two schools and more than somewhat important by nine schools. On the other hand, seven schools regarded having an undergraduate degree in meteorology or atmospheric sciences as irrelevant for the purpose of evaluation of graduate applications.

Least important of all the provided options were accomplishments with volunteer or student organizations. While such activities can matter a great deal for undergraduate admissions, over half of the responding graduate atmospheric science programs considered them to be of little or no importance for evaluating prospective graduate students. This is distinctly different from what prospective employers look for. In a 2006 study by Norwood and Henneberry in the *American Journal of Agricultural Economics*, prospective employers regarded existence of a student volunteer leadership position as only moderately determinative, but more important than a high GPA.

Some statistically significant differences (at the 95% level) emerged when programs were grouped by size. Larger programs tended to value letters of recommendation and math/science grades more highly than did smaller programs. Conversely, smaller programs valued more highly than larger programs the correspondence between interests and faculty research programs, undergraduate research or internship experience, undergraduate scholarships or fellowships, and self-support for graduate school. Much of this difference in emphasis may be due to the typically more limited resources of smaller programs.

In a separate open-ended question, schools were asked what GRE scores "really let an applicant stand out above the crowd." In response, nine schools
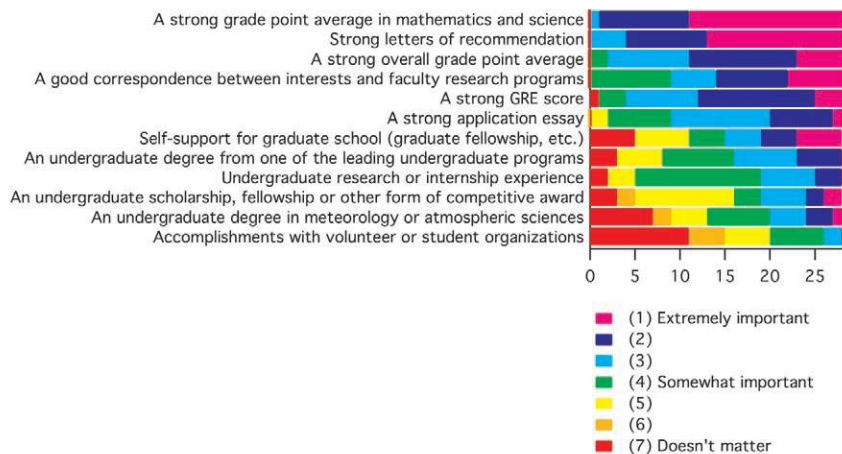

Fɪɢ. 3: The importance of various considerations to graduate schools' recruiting and financial support decisions. The length of each colored bar denotes the number of schools attributing the corresponding level of importance to that characteristic. For example, 18 schools rated a strong grade-point average in mathematics and science as extremely important, 10 rated it one notch below extremely important, and 1 rated it one notch above somewhat important.

provided a combined GRE score, the average value of which was 1,375. Eleven schools listed individual verbal and quantitative scores, which averaged 640 and 750 respectively, for a total of 1,390. Two schools mentioned quantitative scores only, while one mentioned (and another emphasized) verbal scores only. Four of the schools that listed individual verbal and quantitative scores also listed analytical writing scores, identifying minimum standout scores as 5.0–5.5.

Other application considerations. Does submitting a very early application improve a student's chances of being admitted and offered financial support? In most cases, no. Only six programs report improved chances for admission and support, including four of the eight largest responding programs.

Many students finish their undergraduate work in December or otherwise are ready for graduate work in the spring rather than the fall. The fate of student applicants who wish to begin work in the spring is shown in Table 2. There is a wide variation in policies among programs in this area. Most larger programs tend to consider such students for spring admission, while most smaller programs rarely do so.

Schools noting "rare circumstances" for spring admission were asked to identify the circumstances. These circumstances included a faculty member willing to support the student (5 schools), a student entering with an M.S. (2 schools), an open teaching assistant

position (1 school), or an undergraduate meteorology degree (1 school). Some schools noted that students would have difficulty with course sequences, or that support was much less available than in the fall.

COMMENTS FOR SCHOOLS. Schools may be able to use the results of this survey to assess their competitiveness overall and in relation to similarly-sized schools. For example, a program that considers itself highly competitive and treats GRE scores as extremely important can verify this by comparing its median GRE scores to the average from the survey.

The survey and its results also provide an opportunity for self-reflection. Schools may ask themselves why they value some characteristics over others, or why their value system differs from that of their peers.

Diversity of application criteria is good, because no school has a magic formula for predicting graduate student success, and diverse students are best served by diverse options. To the extent that a graduate school's admission criteria differ from that of other schools, it is in the school's interest to make that fact known to potential applicants, so that it may attract a pool that best fits its admission criteria. With the information gathered from this survey, schools now have the ability to differentiate themselves from other schools regarding their admission criteria.

COMMENTS FOR STUDENTS. To some extent, students can estimate their chances of entering graduate school on the basis of this survey. However, there is considerable variability among programs regarding minimum criteria for admission. Students with marginal grades and GRE scores should contact schools directly to find out whether their overall application has a chance for success. They are likely to find that their chances of admission to some schools are much better than their chances of admission to others.

Undergraduate degree and grades. For the most part, students do not need an undergraduate meteorology degree, although some sort of science degree is generally helpful. Whether or not they have a meteorology degree, it is important to demonstrate strong academic ability in undergraduate mathematics and science courses. Most programs regard grades in these courses as extremely important.

Letters of recommendation. One other component of an application is extremely important: the letters of recommendation. The letters are more important than the overall GPA at 16 schools, while only 4 schools regard the GPA as more important. Therefore, prospective graduate students should devote considerable effort to obtaining good letters of recommendation.

There are three prerequisites to a good letter. First, the letter writer must be perceived by the graduate school as a reliable source of information about a student's potential for graduate school. Generally, this means the writer must have attended graduate school and preferably received a Ph.D. Faculty members are ideal, as are those who have supervised research in an academic or laboratory setting. The writers may supervise their own graduate students, or they may have experience with students who have gone on to be successful in graduate school.

Second, the letter writer must know the student well. It is not helpful to a graduate school if a letter writer merely summarizes the student's academic performance, because that information is already available to the graduate school. The letter writer should be able to identify from experience attributes of the student (such as creativity, maturity, meticulousness, and curiosity) that suggest future success in a difficult academic setting and in research. Ideally, such attributes will be associated with specific events or experiences rather than simply listed as qualities. In the classroom, students should make sure that potential letter writers know who they are and can recognize them early on as potential graduate student material.

Except for nonthesis programs, graduate school is not a place for students who do not like research. Research aptitude and compatibility are difficult to judge in a regular classroom setting. For both these reasons, it is important to gain research experience while an undergraduate, either through summer programs or during the regular semesters for course

TABLE 2. Responses to the question: "Qualified students who wish to begin graduate work in spring rather than fall are:"			
Response by program size	**Large**	**Medium**	**Small**
Not considered for admission	0	0	1
Considered for admission in spring in rare circumstances	2	3	4
Considered for admission in spring in most or all circumstances	8	2	2
Considered for admission to the following fall semester/quarter	2	4	0

credit or pay. The students may find out (before it's too late) whether they will like graduate school, and the faculty members will be able to give detailed, reliable assessments of students' research potential.

Third, and most obvious, the letter writer must be able to say good things about the student.

Research interests. Dozens of books are available for those wishing to improve their GRE scores, but precious little information is available on an equally important application attribute: a good match between student and faculty research interests. Of the 29 programs, 10 regarded GRE scores as more important than research match, but 8 regarded research match as more important and the remaining 11 regarded the two as equally important.

Students might think that expressing the broadest possible interest in atmospheric sciences maximizes their chances of being accepted into a program, but many faculty are on the lookout for students who want to work with them in particular and will only latch on to general students if those students have superior credentials or if no closer fits are available.

In a typical undergraduate meteorology curriculum, few students are exposed to a broad spectrum of atmospheric science research issues in a way that allows them to identify topics of potential interest. This is even more the case for nonmeteorology majors. Yet, students are expected to state their preferred area of research by the middle of their senior year. Most students end up listing the topic that originally got them excited about meteorology (such as severe storms or hurricanes) or the topic they worked on over the summer in a research project.

There are many ways to find out about different research areas. Students can work on two or three separate research topics during different semesters. Students can read articles in publications such as *BAMS* or *Eos, Transactions, American Geophysical Union*. Students should also take advantage of atmospheric science seminars offered at their school. They may be difficult to follow at first, but they provide a flavor for some of the important research questions and how they are tackled.

Once students have identified one or two research areas of potential interest, they should talk to a researcher to find out what research in those areas entails. Some research involves lots of field work, some involves mostly laboratory work, and some involves working mostly with computers and model output. Students should consider what sort of work

suits them, and also should consider what sort of research experiences will be valuable for their desired future employment. They may find people to talk to at their own institution or elsewhere; faculty members are generally quite responsive to potential students contacting them and asking about research.

After settling on research interests, students should look for schools where faculty members conduct that sort of research. For a student's research experience and future career, it may be more valuable to work with an outstanding researcher at an ordinary program than to work with an ordinary or worse researcher at an outstanding program. Students should identify particular faculty members with whom they might wish to work, and contact them expressing their interests. The most effective way of accomplishing this is to visit campuses and talk with faculty during the application period. All other things being equal, faculty members are more likely to make an offer to a potential student they know than one they don't know.

Graduate fellowships. While most institutions offer full support to incoming students, having a graduate fellowship can still be a strong advantage. Having a fellowship means the student has come out near the top of a competitive review process. A fellowship also means that less financial support is required from the faculty member. This broadens the opportunities for the student, because a faculty member may not have a fully funded research opening available to coincide with the start of the academic year.

Students should familiarize themselves with graduate fellowship opportunities available from the AMS and elsewhere. Also, some graduate schools offer a limited number of fellowships. If students think they would be competitive for a fellowship, they should find out about any relevant application deadlines.

ADVICE FROM SCHOOLS TO STUDENTS.
The final survey question asked graduate schools, "What else would you like students to know about the graduate admissions process?" Of the 17 responses, 11 were department-specific. These will not be repeated here, but their existence illustrates the importance of contacting graduate schools prior to submitting an application. Prospective students should find out about particular admissions processes, including such aspects as expected meteorology background (if any), the timing of funding offer decisions, the possibility of campus visits, and the types of support typically available to incoming students.

The other six responses were more generally applicable, and we close this article with them.

"Students should identify faculty members and explore whether they have research interests in common with them."

"Rather than thinking about the school, it is important to find individual professors with active research programs in your area of interest."

"Please contact (school name) professors directly, this improves your chances. If possible, consider a campus visit."

"Discuss application with faculty adviser. There are often strengths that are not measured by GRE scores that can trip the process from one borderline on admission to admission based upon e-mail or phone contact with the graduate faculty adviser."

"[Be aware of the] depth of the research on research assistantship positions, future job opportunities after the graduation, available student fellowships, award competitions, possibilities to attend conferences, [and] field programs worldwide."

"In a way the bottom line is simple: somehow, and in some way, you must get a faculty member some-where excited about you. And there are an infinite number of ways of doing this as long as you bring something intriguing (some interesting talent) to the table in an objective fashion."

FOR FURTHER READING

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