Recent and Future Trends in U.S. Undergraduate Meteorology Enrollments, Degree Recipients, and Employment Opportunities

BY JOHN A. KNOX

The U.S. undergraduate meteorology population is at a 40-yr high and growing rapidly. Is this too much of a good thing? What should we do?

It has been over a decade since the last study of undergraduate meteorology[1] enrollments and degree recipients was published. Using degree data through 1993, Mass (1996) posed the question, "Are we graduating too many atmospheric scientists?" Since that time, numerous developments have profoundly altered the meteorological world and significantly raised its visibility with the general public, requiring a reexamination of Mass's question. Examples include the following:

- The May 1996 release of the film *Twister,* a popularization of stormchasing that grossed nearly a quarter-billion dollars at the U.S. box office (http://imdb.com/boxoffice/alltimegross);
- The development of the World Wide Web, creating new industries and leading to instant worldwide access to meteorological information;
- The evolution of mainstream media into niche markets, including the expansion of weather-related vendors (e.g., The Weather Channel) and nature-related cable networks offering weather entertainment as a staple of their programming; and
- The rise of weather and climate topics to prominence in national and world affairs, from global warming and the 1997/98 El Niño to Hurricane Katrina in 2005 and the coawarding of the 2007 Nobel Peace Prize to the Intergovernmental Panel on Climate Change (IPCC).

During this same period, anecdotal reports surfaced of rapidly growing undergraduate meteorology programs. Without an update to Mass (1996), however, no definite nationwide conclusions can be drawn from these scattered reports.

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[1] In this article, "meteorology" will be construed as including not only meteorology but also atmospheric physics and the atmospheric sciences, including climate.

Therefore, it seems timely to ask: What have been the trends since 1993 in U.S. meteorology enrollments, in particular the number of degree recipients and their employment prospects in our field? This article seeks to quantify the trends using two independent sources of data: the U.S. Department of Education's National Center for Education Statistics (NCES; http://nces.ed.gov/programs/digest/) and the American Meteorological Society–University Corporation for Atmospheric Research (AMS–UCAR) online database (http://ametsoc.org/amsucar_curricula/index.cfm). I also speculate on what these numbers and trends imply about the future for our students and our profession.

THE CONTEXT: U.S. DEGREE TRENDS SINCE 1968. Before making sense of recent trends in meteorology student numbers, we must first place them in the broader context of long- and short-term trends in higher education. As shown in Table 1, from 1968 to 2004 the number of annual bachelor's degree recipients in the United States more than doubled. During the same period, the number of physical science majors of all types declined 7%. As a result, the percentage of all bachelor's recipients with a degree in the physical sciences plummeted from 3.1% in 1968 to approximately 1.3% in 2004. In the geosciences, a category that includes meteorology but whose degree recipient trends are dominated by the solid Earth sciences (e.g., geology), the number of bachelor's degree recipients increased 83% between 1968 and 2004. This trend, however, masks a rollercoaster of soaring gains until the mid-1980s, followed by a precipitous decline in geology and then a slow recovery. The discipline of geography, which includes a meteorological component in the specialty of physical geography, has experienced trends similar to the solid Earth sciences (though with less volatility). Meteorology's sister science of oceanography swelled its ranks 164% from 1968 to 2004, but dropped 31% from 1994 to 2004 to near 35-yr lows.

TABLE 1. Changes in the number of U.S. bachelor's degree recipients by selected fields of study. The totals for all degree recipients, the physical sciences, and geography are based on NCES data for academic years ending in the calendar years cited (e.g., 1994 = academic year of 1993–94). The totals for the geosciences, meteorology, and oceanography are based on 2-yr averages from AIP (e.g., 1968 = average of values from academic years of 1967–68 and 1968–69). The totals for geography are based on yearly statistics from the Association of American Geographers compiled from NCES data. Red numbers denote declines.

U.S. college degree recipients in	Long-term change 1968–2004	Recent change 1994–2004
All fields	+122%	+20%
Physical sciences	–7%	–2%
Geosciences	+83%	+9%
Geography	+74%	+3%
Oceanography	+164%	–31%
Meteorology	**+161%**	**+47%**

DEGREE RECIPIENT TRENDS IN METEOROLOGY. *NCES data.* To quantify the number of meteorology degree recipients, we turn first to NCES data as analyzed by the American Institute of Physics (AIP) Statistical Research Center. According to Roman Czujko of AIP (R. Czujko 2006, personal communication),

> the degree data have taxonomy issues which, for a comparatively small field, could represent a significant error bar. However, I have found no reason to believe that the definitions used for the atmospheric science and meteorology data have changed over time. In short, I have moderate confidence in the levels reported in any one year and high confidence in the rate of change over time.

Two-year-averaged data from NCES as analyzed by AIP (Fig. 1) reveal that the number of atmospheric science bachelor's degree recipients (which includes meteorology and atmospheric physics and is equivalent to meteorology in this article) has increased 161% from 1968 to 2004 and 47% from 1994 to 2004. The change between 2002 and 2004 is nearly 16%, the largest 2-yr rise in meteorology degree recipients in this dataset since the mid-1970s. The total number of bachelor's degree recipients in meteorology in the most recent 2-yr-averaged yearly estimate, 567, is the highest since at least 1963–64 [based on data from NCES and from Orville (1978) as republished in Mass (1996)]. This combination of unprecedented numbers and rapid growth is not mirrored in the graduation statistics of any other related science, nor in the U.S. college graduate population as a whole.

AMS–UCAR Curricula *data.* A pertinent independent dataset is the AMS–UCAR *Curricula in the Atmospheric, Oceanic, Hydrologic, and Related Sciences,* better known simply as the *Curricula*. The *Curricula*

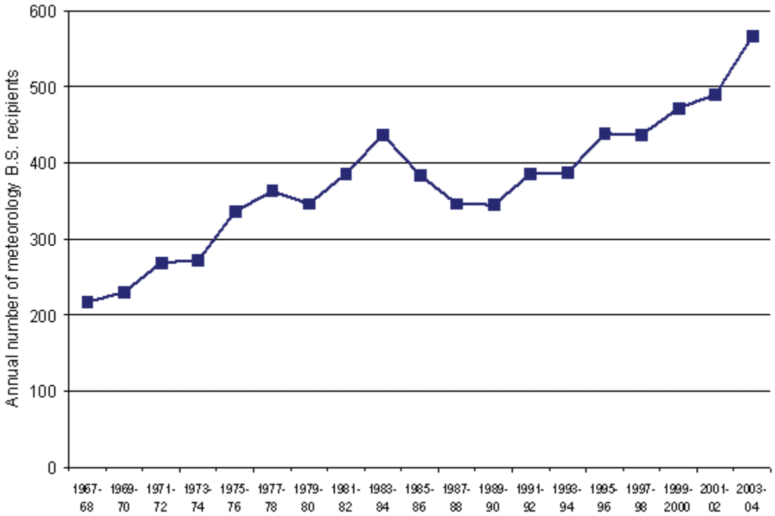

Fig. 1. Annual number of U.S. bachelor's degree recipients in the atmospheric sciences based on 2-yr averages for the academic years 1967–68 to 2003–04. Figure adapted from data provided by Roman Czujko, AIP Statistical Research Center, compiled from data collected by the NCES.

was published biannually in hardcopy format through 2000 and now is in an undated, continuously updatable online format (http://ametsoc.org/amsucar_curricula/index.cfm) that currently contains data beginning with the 2003–04 academic year. In both the hardcopy and online editions, *Curricula* data include the number of bachelor's degree recipients, projected number of bachelor's degree recipients, the number of majors at U.S. colleges and universities offering degrees in these fields, and information regarding graduates' career choices.

Past studies (e.g., Mass 1996; Vali et al. 2002) have more often relied on *Curricula* data than on U.S. Department of Education statistics to quantify numbers and trends in degreed meteorologists. The advantages of *Curricula* versus NCES data include timeliness and breadth of information; relevant disadvantages include lack of reporting/misreporting from a number of institutions and the inclusion of non-U.S. and nonmeteorology programs.[2]

In the following discussion of online *Curricula* data, I have chosen to omit information provided by Canadian institutions and programs that are overwhelmingly oceanographic in nature (the U.S. Naval Academy, Old Dominion University, the Department of Oceanography at the University of Washington) to focus tightly on U.S. meteorology programs. A total of 75 such institutions are included in the online *Curricula* database (not including some new meteorology programs and, inexplicably, Saint Louis University).

As of 15 April 2007, however, only 34 institutions (45%) had reported the number of bachelor's degree recipients during the academic years 2003–04 and 2004–05, compared to 59 institutions reporting in the 1994 *Curricula* (Fig. 6a in Mass 1996), 53 in the 1998 *Curricula*, and 45 in the 2000 *Curricula* (Vali et al. 2002).

Given the relatively sparse reporting to the online *Curricula*, analysis of the data must be made with some caution. Figure 2 provides a direct, though imperfect, comparison to Mass's 1991–93 data by tabulating the number of degree recipients per institution for the 2-yr period of 2003–05. Despite 25 fewer institutions reporting online than in the 1994

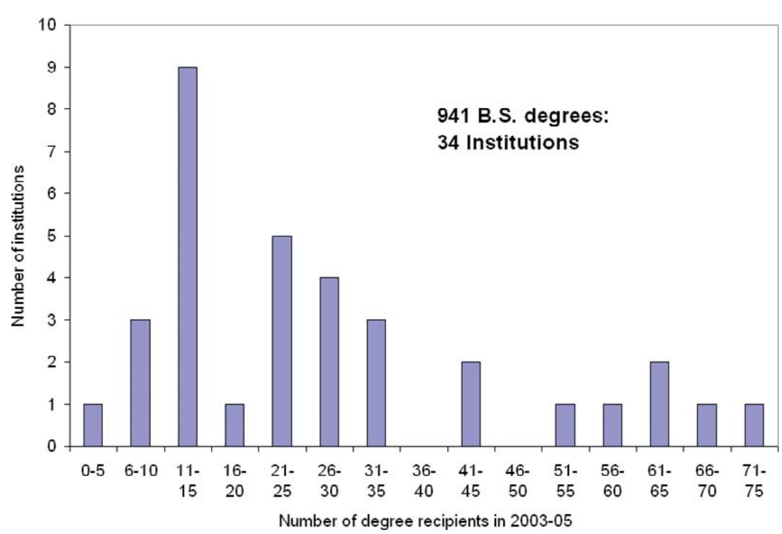

Fig. 2. Histogram of the 2-yr sum of bachelor's degree recipients in meteorology from the 34 institutions reporting to the AMS–UCAR online *Curricula* as of 15 Apr 2007.

[2] The results discussed below differ with those tabulated at www.ametsoc.org/amsucar_curricula/appendices_statistical.cfm. The statistics found in this appendix on the AMS Web site do not appear to be continuously updated and apparently omit some institutions' data. The more complete tabulations presented in this paper are accurate as of 15 April 2007.

Curricula, the total number of degree recipients is greater: 941 in 2003–05 versus 901 in 1991–93.[3]

A trend toward larger numbers and larger programs seems evident. According to Mass (1996, his Fig. 6a), during 1991–93 only six institutions graduated more than 30 meteorologists. As seen in Fig. 2, during 2003–05 eleven institutions conferred more than 30 meteorology degrees. Thus, *Curricula* data generally support the conclusion drawn from NCES data that there has been a notable rise in the number of meteorology bachelor's degree recipients since the early 1990s.

We next compare 2003–04 graduation numbers with 2004–05 graduation numbers from the *Curricula*. In the academic year 2003–04, the 34 institutions providing data reported 446 bachelor's degree recipients; in 2004–05, 495 bachelor's degree recipients were reported from these same institutions, for a 1-yr increase of 11%. (Note that the absolute numbers are lower than in NCES data because of the comparatively spotty reporting in the *Curricula* database.) This growth is somewhat larger, but not incompatible, with the 2-yr rise of nearly 16% determined from NCES data ending in 2004.

In summary, both NCES and *Curricula* data indicate that from 2001 through 2005 the number of meteorology bachelor's degree recipients increased at an annual rate of approximately 8%–11%.

RECENT ENROLLMENT TRENDS IN METEOROLOGY. A mostly untapped source of demographic information on undergraduate meteorology is the data collected on current undergraduate majors in the *Curricula*. Though labeled "Ethnicity/Gender Profiles," the totals also allow for calculation of the number of meteorology majors enrolled nationally. The number of majors is a less reliable statistic than bachelor's degree recipients because of sparser reporting, differences in the definition of a meteorology major between different institutions, and errors in reporting (e.g., some institutions report the same number of majors as degree recipients, an unlikely situation). Nevertheless, trends in this statistic may anticipate future trends in meteorology degree recipients.

Despite the absence of many of the largest meteorology programs in the nation from this statistic, the number of majors reported for fall 2005 by 22 institutions is 2,154, or an average of 98 majors per institution. This represents a 69% increase (just over 9% per year) in majors per institution since the 2000 *Curricula,* in which 36 institutions reported 2,091 meteorology majors for fall 1999. However, this trend is probably a bit of an overestimate due to a relative absence of smaller programs in the online database versus the 2000 *Curricula.*

The online *Curricula* also contains data on the number of meteorology majors for the 2003–04 and 2004–05 academic years. This data can be used to calculate per year changes in majors. Unfortunately, only 17 institutions appear to have reported accurate majors numbers for all three time periods of 2003–04, 2004–05, and fall 2005. The 1-yr upward change in undergraduate meteorology majors based on these 17 institutions was 2%, but the quasi-two-year rise (from the 2003–04 academic year to fall 2005) was nearly 21%, for an increase of almost 10% per year. This rate of increase, too, may be an overestimate because of attrition during the 2005–06 school year, but it is consistent with the trends found above in degree recipient data. However, this analysis does not include some new and rapidly growing programs, a point addressed below.

PROJECTED DEGREE RECIPIENT TRENDS IN METEOROLOGY. The projected degree information in the *Curricula* provides another untapped data source regarding future degree trends. Institutions reporting to the *Curricula* estimate their future graduation totals for up to 6 yr into the future. In the aggregate, this data may provide a glimpse, however imperfect, of future graduation trends. As with any forecasts, the shortest-term projections are probably the most accurate.

Forty institutions reported projected degree recipient information 3 yr beyond the fall 2005 reporting deadline (i.e., 2005–06, 2006–07, and 2007–08). However, only 23 institutions projected graduation numbers all the way out to 2010–11, limiting confidence in the longest-term projections.

The 1-yr increase in projected degrees (from 2005–06 to 2006–07) obtained from the 40 institutions is 12%, similar to the rates in actual degree recipients discussed above. The 2-yr change in projected degrees obtained from the 40 institutions approaches 15%, or 7% per year. Using just the 23 institutions who reported projections out to 2010–11 the 5-yr rise in projected degrees is 28%, or an increase of about 5% per year. Taken together, these results imply a 5%–12% per year increase in projected bachelor's degree recipients through 2011.[4]

[3] For comparison, Table 3a in Vali et al. (2002) lists 2-yr totals of 1,157 degree recipients from 53 institutions in 1995–97 based on 1998 *Curricula* data, and 816 degree recipients from 45 institutions during 1997–99 based on 2000 *Curricula* data.

The agreement between the upward trends across independent datasets and different statistical categories (see Fig. 3) provides compelling evidence that meteorology has grown rapidly at the undergraduate level in the United States since Mass's (1996) study. To the extent that the projections discussed here are accurate, this growth—anomalous with respect to the trends in other related sciences and with respect to the previous history of meteorology in the United States—will continue for at least the next several years.

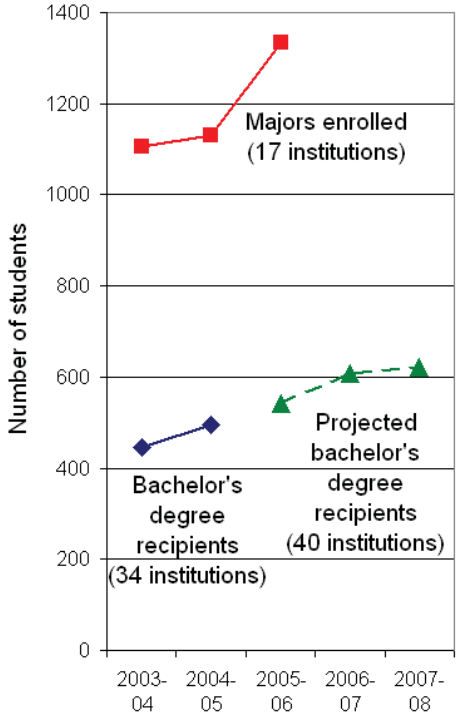

Fig. 3. The total number of bachelor's degree recipients in meteorology (solid line with diamonds; 34 institutions reporting both time periods), the projected number of bachelor's degree recipients (dashed line with triangles; 40 institutions reporting all three time periods), and the number of meteorology majors enrolled (solid line with squares; 17 institutions reporting all three time periods) from the AMS–UCAR online *Curricula* as of 15 Apr 2007.

RECENT AND FUTURE EMPLOYMENT TRENDS IN METEOROLOGY.

Is this growth sustainable? To answer this question, we must estimate the demand for meteorologists, and the future growth of that demand.

Approximately 7,400 people in the United States were employed in 2004 as meteorologists, according to the U.S. Department of Labor's Bureau of Labor Statistics (BLS) *Occupational Outlook Handbook* (*OOH*; http://stats.bls.gov/oco/ocos051.htm#outlook). During 1994–2004, 1.2% annual growth in meteorology employment took place, spanning a period of sizable growth in the late 1990s and downsizing from 1998 to 2000 (Table 2). The 12% total growth during this period should be compared to the 47% growth in meteorology bachelor's degree recipients during virtually the same period in NCES data (Table 1). In other words, *during 1994–2004 the growth in demand for meteorologists was approximately 4 times slower than the growth in the supply of new meteorologists.*[5]

During the same period, AMS *Curricula* data capture a change in the career choices of recent graduates. Table 3 lists the percentages of career choices by bachelor's degree recipients in meteorology in 1997–99 (from the 2000 *Curricula*) versus 2003–05 (from the online *Curricula*). In 2003–05, over 29% of new bachelor's degree recipients pursued additional education, as compared to under 20% in 1997–99. Conversely, fewer than 19% of new graduates obtained private sector employment in 2003–05, as compared to nearly 29% in 1997–99. (It should be noted that these are changes in percentages, not absolute numbers. NCES data indicate that the total number of meteorology graduates increased 30% from 1998 to 2004.) The civilian government, once the primary employer of new meteorology graduates, employed fewer than 8% of new graduates in 2003–05, down from 10%

Table 2. U.S. BLS estimates of the number of meteorologists employed in the United States, from successive editions of the *OOH*. Military meteorologists and college meteorology faculty are omitted from these BLS statistics.

Year	No. of employed U.S. meteorologists
1994	6,600
1996	7,300
1998	8,400
2000	6,900
2002	7,700
2004	7,400

[4] The lower bound of this estimate range is the less accurate figure, because of the extended range of the projection and the lack of institutions reporting projections out to 2011.

[5] This statement compares demand for all meteorologists with production of B.S. meteorologists; however, since a majority of employment announcements stipulate no more than a bachelor's degree (see Table 4), trends in the hiring of B.S. meteorologists should dominate the hiring trends for all meteorologists.

Table 3. Career choices of bachelor's degree recipients in meteorology from the 2000 *Curricula* and the current online *Curricula*. Boldfaced numbers indicate the largest single career choice for each time period.

Period of record	No. of graduates included	Civilian government	Military service	Private sector	Further university education	University employment	Other	Unknown
1997–99	711	9.99%	9.85%	**28.69%**	19.83%	0.56%	4.36%	26.72%
2003–05	624	7.69%	10.10%	18.59%	**29.33%**	0.48%	6.09%	27.72%

in the late 1990s and 50% or more in the early 1970s (Horn et al. 1974).

Did a larger percentage of recent graduates turn to graduate school instead of the private sector in the early to mid-2000s because of a lack of employment opportunities? The answer likely depends on the number of jobs relative to the number of degreed meteorologists.

To assess job numbers, we use the 2006 listings of the *Meteorological Employment Journal,* an online service containing a much more comprehensive list of private sector and university employment than other sources, with a total of 759 U.S. meteorology positions advertised during 2006. (However, civilian and military government meteorology positions are not generally included in this database and will be discussed separately.) This total is 51% greater than the 500 new job openings found by Mass (1996, his Fig. 13) for 1993, which *did* include civilian and military positions as well as academic faculty positions. Since the total number of meteorology jobs has risen much less than 51% since 1993 (Table 2), this suggests that the *Meteorology Employment Journal* database is more comprehensive than Mass's analysis.

Table 4 summarizes the *Meteorological Employment Journal* listings for 2006 in terms of the number of jobs advertised and the educational and professional requirements for each job. At most, 167 positions were determined to be "entry-level," that is, requiring no experience beyond a bachelor's degree in meteorology.

How many entry-level government meteorology positions open up each year? The listings in the *National Weather Service* (*NWS*) *Focus* publication (www.nws.noaa.gov/com/nwsfocus) for 2005–06 show that 105 meteorological interns and technicians have been hired, for an average of 53 new positions per year. These positions may not always be entry-level in practice, given the intense competition for NWS employment.

Turning to military employment, Mass (1996) stated that 65 Department of Defense meteorologist positions were available per annum during the early 1990s. This is roughly equal to the number of students reporting "military service" in the online *Curricula* for 2003–05, a 2-yr sum. Given the underreporting to the *Curricula,* 65 military positions per year appears to be a reasonable estimate.

Summing these statistics, *it appears that currently there are approximately 285 entry-level meteorology positions available in the United States on an annual basis.* This estimate is consistent with the results of Hanson (1993) but is lower than Mass's (1996, his Fig. 13) estimate of 500 new job openings per year during the early 1990s. The lower number determined in this paper reflects more careful elimination of nonentry-level positions from the calculation than in Mass (1996). Most importantly, the estimate of 285 entry-level jobs per year is only half of the 567 meteorology bachelor's degree recipients per year identified in NCES data.

With regard to job growth, we return to the *Occupational Outlook Handbook*. The *OOH* also provides projections of future employment trends (http://stats.bls.gov/oco/ocos051.htm#outlook), although these projections are not particularly reliable (R. Czujko 2007, personal communication). With that large caveat, the *OOH* predicts that from 2004 to 2014 the employment of atmospheric scientists will increase about as fast as the average for all U.S. occupations. The *OOH* definition of "about as fast as average" equals an increase of 9%–17% over that 10-yr period, translating to a growth rate of no more than about 1.6% per year.

Comparing this 1.2%–1.6% per year actual and projected growth rates in employment to the 5%–12% per year actual and

Table 4. Summary of job listings in the *Meteorological Employment Journal* for the calendar year 2006. The number of entry-level positions was determined by analyzing all advertisements requiring a bachelor's degree or less and eliminating those requiring additional experience.

Period of record	Total U.S. meteorology job listings	Jobs requiring B.S. degree	Jobs without degree requirement	Entry-level positions
2006	759	303	132	**167**

projected growth rates in graduates through 2011, the following conclusion seems inescapable, if the projections are accurate: *the number of undergraduate meteorology degree recipients will increasingly exceed the number of meteorology employment opportunities into the next decade.*

Thus, given recent trends and future projections, the growth of the U.S. undergraduate meteorology population is potentially unsustainable in terms of bachelor's degree–level employment within meteorology.

DISCUSSION. The subject of undergraduate degree and enrollment trends has the potential to generate contentious responses. The previous sections have intentionally focused on quantifiable trends to establish a factual basis for further discussion. In this section, I discuss relevant but less provable assertions regarding the topics of degree recipients, enrollments, and salary information.

Student undercounts. The large absolute numbers in meteorology bachelor's degree recipients in the NCES dataset are an underestimate. The winter 1998 *UCAR Quarterly* (www.ucar.edu/communications/quarterly/winter98/employment.html), in coverage of the biannual AMS Heads and Chairs Meeting in October 1998, stated, "Colleges and universities are now awarding 600–700 bachelor's degrees in meteorology annually." For this same time period, NCES data placed the number of meteorology bachelor's degree recipients at 437, a 37%–60% underestimate versus the *UCAR Quarterly* figures. Adjusting the latter for the 30% growth rate in bachelor's degree recipients between 1998 and 2004 in NCES data, this would imply 780–910 meteorology graduates per year by 2003–04. Furthermore, the high end of this estimate, combined with the 11% climb from 2004 to 2005 documented in "The context: U.S. degree trends since 1968" section, would imply that by 2006 the nation's universities were graduating up to 1,000 meteorologists per year in the United States—numbers unheard of in the post–World War II era.

How accurate is this estimate? No one knows; the NCES dataset is incomplete, and the online *Curricula* data are even less comprehensive. It is best used as an inexact upper bound. Thus, based on reasonable extrapolations of the data at hand, *the best guess is that there are now between 600 and possibly 1,000 new bachelor's degree recipients in meteorology each year.* Assuming that the estimate of 285 entry-level jobs per year is accurate, this implies that currently there are entry-level positions available for only 28.5%–47.5% of new bachelor's degree recipients in meteorology (assuming that no jobs are filled by nonmeteorologists).

Over and above these numbers, however, is the growth of meteorology at "under-the-radar" colleges and universities. To cite one unusually well-documented example, in April 2004 a request was made by the University of North Carolina (UNC) at Charlotte to the Office of the President of the UNC system to create a new B.S. degree in meteorology. This request officially projected slow growth, predicting 7 majors during the 2004–05 academic year, 9 majors by 2005–06, 11 majors by 2006–07, and 12 majors by 2007–08 (www.provost.uncc.edu/planning/rte/meteorology-RTE.pdf, p. 7). Instead, UNC Charlotte had attracted 40 majors by September 2005 and 75 majors by April 2007 (www.charlotte.com/274/story/103334.html)! At this rate of growth, UNC Charlotte will soon have one of the top 10 largest meteorology programs in the nation. Yet this program's enrollment statistics are not included in the online *Curricula*. It is therefore entirely possible that under-the-radar growth in meteorology at the undergraduate level will soon make a significant contribution to the total pool of bachelor's degree recipients in our field and will further intensify the competition for jobs.

Starting salaries. In the May 2002 *AMS Newsletter* summary of the *OOH* (www.ametsoc.org/NEWsltr/nl_05_02.html#departmentoflabor), it was stated that "prospective atmospheric scientists may face competition if the number of degrees awarded in atmospheric science and meteorology remain near current levels." As we have seen, instead of remaining near current levels the number of degrees awarded has been increasing rapidly since 2002.

One measure of an oversupply of labor is depressed salaries. The AMS Web site apparently does not provide current information on salaries; AMS's *A Career Guide for the Atmospheric Sciences* (http://ametsoc.org/atmoscareers/index.html) contains salary data from 1993 with some updated estimates for 1998. Therefore, we must turn elsewhere for more timely information.

Table 5 compares starting annual salary data for new bachelor's degree recipients in a variety of selected majors, from the National Association of Colleges and Employers (NACE) database published in fall 2006 (available in piecemeal form at www.ncsu.edu/majors-careers/do_with_major_in/index.php). Meteorology graduates' salaries in this national database are much closer to those in the traditionally glutted and underpaid humanities fields than to

Table 5. Summary of starting salaries for newly hired class of 2006 bachelor's degree recipients in a range of disciplines, from NACE.

U.S. college degree recipients in	Class of 2006 average starting salary
Computer science	$50,744
Physics	$45,120
Geology	$45,091
Mathematics	$44,672
Chemistry	$39,804
Meteorology	**$35,211**
Environmental science	$34,219
Secondary education	$33,089
History	$33,071
Philosophy	$31,774
Marine science	$31,643
English	$31,385

salaries for graduates with computer science, physics, geology, or mathematics degrees.

Moreover, the NACE salary data may be overly optimistic. Widespread anecdotal evidence pegs most starting annual salaries in meteorology at between $20,000 and $35,000. On the high end, entry-level National Weather Service employees currently begin at annual salaries ranging between approximately $26,000 and $32,000, not including the locality pay factor. However, it cannot be overemphasized that the civilian government is no longer the dominant employer of new bachelor's degree recipients, hiring fewer than 8% of graduates in 2005 and fewer than 10% as far back as 1999 (Table 3). Instead, starting annual salary levels across the discipline are dictated by private sector employment, where typical entry-level annual pay is currently between $20,000 and $26,000 (see also the winter 1998 *UCAR Quarterly* for specific late-1990s salary information for the private sector). Therefore, the NACE *average* nationwide starting annual salary for just-graduated meteorologists of $35,211 is difficult to reconcile with the available anecdotal evidence—except in cases where graduates have abandoned meteorology for other forms of employment. AIP statistics expert R. Czujko (2007, personal communication) concurs, stating, "I would not be surprised to discover that atmospheric scientists who work outside of the discipline earn higher salaries than those who find employment in the discipline."

The overall situation for meteorology bachelor's degree recipients may therefore be worse than official statistics indicate. There are probably more meteorology students than we are aware of, and anecdotal information regarding salaries for new degreed meteorologists is generally lower than publicly stated figures suggest.

WHAT SHOULD BE OUR RESPONSE? Given the recent and likely future growth in meteorology bachelor's degree recipient and enrollment numbers compared to employment possibilities, what should be done by students, faculty, departments, and leaders in our field?

Mass (1996) responded to the "deterioration in job availability" in the mid-1990s by calling for a broadening of the meteorology curriculum, honesty on the part of the departments regarding the job market, and for an organized effort, perhaps by AMS and/or UCAR, to create an employment database.

These three suggestions are as timely today as in 1996. I discuss them in turn below.

A broadened curriculum? In 1999 the AMS took considerable strides in this regard with its broadened recommendations for a bachelor's degree in atmospheric science (www.ametsoc.org/policy/bachelor99.html). The new AMS strategic plan goal 5 (AMS 2007) includes the statement that "the Society is also committed to . . . supporting efforts to develop meaningful curriculum options." Nevertheless, many departments and students alike remain focused on curricula that satisfy federal civil service requirements, despite the small and shrinking possibilities for civilian government employment.

One possible response is for meteorology programs to make a definitive break with the civil service requirements and tailor their majors to other modes of employment. One appealing possibility would be to train meteorologists for careers in precollege science education, which would satisfy AMS strategic goal 4 (to create a more scientifically literate population). Given the similarity in NACE starting salaries for meteorologists and secondary school educators (Table 5) and the large market for the latter, an emphasis on training meteorologists as precollege science teachers would appear to be a win–win–win situation for the discipline of meteorology, undergraduate meteorology majors, and for precollege education in the United States.

As another alternative, a meteorology major could be reconstituted as a scientific version of a liberal arts degree, in keeping with the first objective listed in the 1999 AMS recommendations (see Kidder et al. 2002 for a related perspective). For example, at the

University of Georgia we offer a multidepartmental atmospheric science certificate that satisfies both civil service requirements and AMS recommendations but can also be combined with any major. Most of our atmospheric science students choose to major in geography, thereby completing a liberal arts degree while also obtaining a solid education in meteorology. In addition, some of our students simultaneously pursue certificate work in the highly employable area of geographic information systems (GIS). It would seem that current and future trends in our field call for similar creative educational approaches that emphasize breadth of training and experience.

Straight talk about jobs and careers? No one wants to be a "party pooper" when it comes to discussing the possible negative consequences of growth in meteorology. College students enthused about the weather want to major in meteorology. Their parents want them to pursue their career dreams. Faculty members want to recruit more students to their classes and departments. Administrators want more credit-hour production and tuition dollars. Professional organizations want to grow the next generation of scientists. The AMS strategic goal 5 regarding recruitment of students calls for increases in effort, activities, funding, and additional development efforts.

The risk of unsustainable growth is real, however. A confluence of events led to a boom in solid Earth science majors into the early 1980s, and then a bust by the late 1980s, with only slow recovery thereafter. Meteorology may now face a similar situation. The absence of up-to-date, comprehensive enrollment and employment data from the AMS falls well short of Mass's call for honesty regarding employment opportunities. Discussion and debate of the recent record growth and nearly stagnant employment trends demonstrated in this paper are needed as well.

Also with regard to candor, a common response to the topic of meteorology enrollment and employment is, "There's no guarantee of a job with a meteorology degree! Why should meteorology be any different than, say, English in this regard?" The difference is that unlike a liberal arts degree, for decades a bachelor's degree in meteorology usually *was* a ticket to employment in meteorology, particularly in the National Weather Service (Horn et al. 1974). The message that this is no longer the case does not appear to have been universally disseminated. Instead, meteorology students have attended recent national meetings where talks entitled "Challenging Careers with Opportunities Available: Top Students Like You Needed!" have been presented. The difference between the perception and reality of job prospects appears to be greater in meteorology than in the humanities. If meteorology is to be reconfigured as a liberal arts degree, this restructuring and the implications for employment must be broadcast widely in professional and academic settings.

One other common rebuttal to concern regarding meteorology enrollment and employment is to claim that a meteorology degree is a fine preparation for a wide range of careers (e.g., Mass 1996). These claims must be supported by quantitative evidence that an education in meteorology is as beneficial as undergraduate training in other disciplines, for example, physics or mathematics. Math and physics bachelor's degree recipients receive much higher starting salaries than do meteorologists (Table 5) and are often preferentially recruited by the best atmospheric science graduate departments—both of which suggest that even if meteorology is a beneficial training ground, majoring in another field may be even more beneficial. Assuming that the "good ol' days" of abundant B.S.-level meteorology job opportunities versus the number of meteorology graduates are past, meteorology as a discipline must be able to answer convincingly the following question from students: "Why major in meteorology instead of something else, if I'm less and less likely to pursue a career in meteorology with this degree?"

Grassroots database efforts? The results of this article confirm that a comprehensive national database not only of meteorology employment (demand) but also of meteorology enrollments and degree recipients (supply) is desperately needed (see also Pielke 2003). Mass's (1996) recommendation that AMS and/or UCAR create an employment database has apparently gone unheeded for a decade. Worse yet, the *Curricula* has declined markedly in comprehensiveness at exactly the moment of greatest growth in meteorology and the greatest need for reliable statistics.

Rather than wait another decade for institutional action, perhaps the swiftest course of action would be for meteorology students nationwide to assemble and update their own "open-source" employment databases. A grassroots effort of this type could also collect information on starting salaries and confirm or reject some of the speculations in this paper regarding pay. Any such database creation needs to be comprehensive, consistent, and ongoing, however, so that reliable long-term data can be accessed. Sporadic, nonstandardized individual efforts such as Hanson (1993), Mass (1996), and this paper are inadequate.

Meteorological "birth control"? A more polarizing possible response is "birth control," that is, the intentional limitation of the number of students in a discipline, as in physics at the graduate level during the mid-1990s (www.aps.org/publications/apsnews/199506/letters.cfm). Mass (1996) rejected the possibility for meteorology, stating that "one can argue persuasively that there is no need to limit the number of atmospheric sciences/meteorology majors," given that it is a "good base for a variety of careers." Vali and Anthes (2003) were even more emphatic in a response to Pielke (2003):

> the most responsible position is to look ahead with optimism and to encourage and motivate young people to embark on careers in the sciences, regardless of somebody's prediction of future job opportunities in these fields . . . the future for atmospheric scientists, although not quantifiable, appears to be very bright indeed.

In contrast, the quantitative results of this article can be construed to indicate that we have entered a period of chronic oversupply of undergraduate meteorologists. This oversupply has arguably come about because the mechanisms that generate interest in our field (e.g., unprecedented media emphasis on weather) are mostly uncoupled to the mechanisms of demand. Media coverage of weather and climate topics can inspire throngs of students to pursue meteorology as a career; it is specifically cited by UNC Charlotte meteorologists as a reason for their program's spectacular growth (www.charlotte.com/274/story/103334.html). But widespread media attention does not magically create future employment opportunities for these students within meteorology. If, in turn, this situation translates into a future boom in graduate school enrollments and Ph.D. production, the current parlous state of "grantsmanship" in our science as described by the critiques of Carlson (2006) and Roulston (2006) would seem tame by comparison. For those students choosing "out" instead of "up" in meteorology, the sanguine assessment of Mass (1996) regarding the transferability of skills gained from meteorological training would be put to a stringent test.

In the context of this scenario, overt or passive attempts at "birth control" could be a reasonable response to the unprecedented and rapidly growing ranks of undergraduate meteorologists. However, such attempts run counter to the academic rewards system of increased credit-hour production. Any attempt at departmental "birth control," that is, the limitation of the number of meteorology programs nationwide, would violate the ingrained decentralization of American higher education. Thus, "birth control" appears to be impracticable regardless of one's views on the subject.

CONCLUDING REMARKS. Based on the results of this article, *if current trends in undergraduate meteorology enrollment and employment in the United States continue,* there will be far more degreed meteorologists than jobs in meteorology during the next decade.

It is true, however, that "short-term trends and projections into the future are highly risky" (Vali et al. 2002). The academic and career choices of students are notoriously fluid and unpredictable. Changed political and scientific realities could create professional opportunities unimaginable at present. Predictions of shortfalls and gluts in employment are easily made but are more rarely verified.

Moreover, some of the possible responses detailed in this article, from broadened majors to straight talk about the employment challenges ahead, could go a long way toward preventing nightmare scenarios and creating unforeseen long-term benefits to meteorology, but only if they are implemented. The track record since Mass (1996) is not particularly encouraging in this regard.

It is said (www.nsf.gov/geo/adgeo/geo2000/geo_2000_tools.jsp) that we are living in a "Golden Age" of discovery about the Earth's system, including the atmosphere. In a Golden Age, the Golden Rule must apply: the leaders in meteorology must care for their students as they expect their own sons and daughters to be cared for by the leaders of their chosen professions.

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former students who are unemployed, underemployed, or who have left the field of meteorology.

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