Trends in Atmospheric Science Journals: A Reader's Perspective

Bart Geerts
Goddard Space Flight Center, Greenbelt, Maryland

ABSTRACT

A survey of 22 atmospheric science journals shows that the number of published articles tripled in 30 years during 1965–95, so that it has become increasingly difficult to keep abreast of the literature. A total of 1642 peer-reviewed articles in the journals were categorized numerically in terms of features of the abstracts and the conclusions. Consistent differences were found between journals. Most journals are mediocre in terms of their reader-friendliness, with little or no improvement over recent decades. The abstract and/or the conclusions in many papers have become too long and too discursive, preventing the reader from making a rapid assessment of the papers' usefulness. These trends may retard atmospheric research. Therefore journal editors are urged to insist on some easy improvements.

1. Introduction

In view of the rapidly growing number of articles in atmospheric science journals, readers are more interested than ever in easier access and readability, yet increases in length, complexity, and scope of articles have yielded the opposite. That is the topic of this paper.

The number of scientific journals worldwide grew exponentially since the beginning of modern science around 1700 until 1960 (de Solla Price 1961). For instance, C.-G. Rossby started four new journals about the atmosphere and/or the ocean in the 1930s and 1940s (Phillips 1998). More scientific papers were published between 1960 and 1980 than had been throughout previous time (Batchelor 1981). The prolific growth of papers in geosciences since 1960 is less due to the creation of new journals than to the expansion of the journals themselves. And the publication rate of peer-reviewed journal articles in the sciences has continued to grow, with a concomitant increase in the average number of pages per article. The *Journal of Geophysical Research* (*JGR*), for instance, produced a slowly rising number of about 500–700 pages per year before the International Geophysical Year of 1958 (Fig. 1). The annual page count then rose to around 6000 in just a few years, and a second spurt of growth starting in the late 1970s appears unabated. The 1996 page count of 29 720 is equivalent to about 47 000 pages in the pre-1974 format of *JGR*, which used a larger font on a smaller page. This represents a nearly exponential growth with a doubling time of seven years.

Few atmospheric science journals have grown as fast as *JGR*, yet the trends shown in Fig. 1 underestimate the overall growth, because the number of journals and the number of words per page have increased as well. Some of the older "parent" journals, such as *Beiträge zur Physik der Atmosphäre* (*BPA*) and *Theoretical and Applied Climatology* (*TAC*), have grown little, because of the emergence of new, more specialized journals, such as the *Journal of Atmospheric and Oceanic Technology* (*JAOT*). But even established journals such as the *Monthly Weather Review* (*MWR*) and the *Quarterly Journal of the Royal Meteorological Society* (*QJRMS*) have seen a phenomenal and unprecedented growth since the early 1970s. In particular journals dealing with climate dynamics (such as *Journal of Climate* and *Climatic Change*) have mush-

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Corresponding author address: Dr. Bart Geerts, Science Systems and Applications, Inc., NASA/GSFC, Mail Code 912, Greenbelt, MD 20771.
E-mail: geerts@agnes.gsfc.nasa.gov
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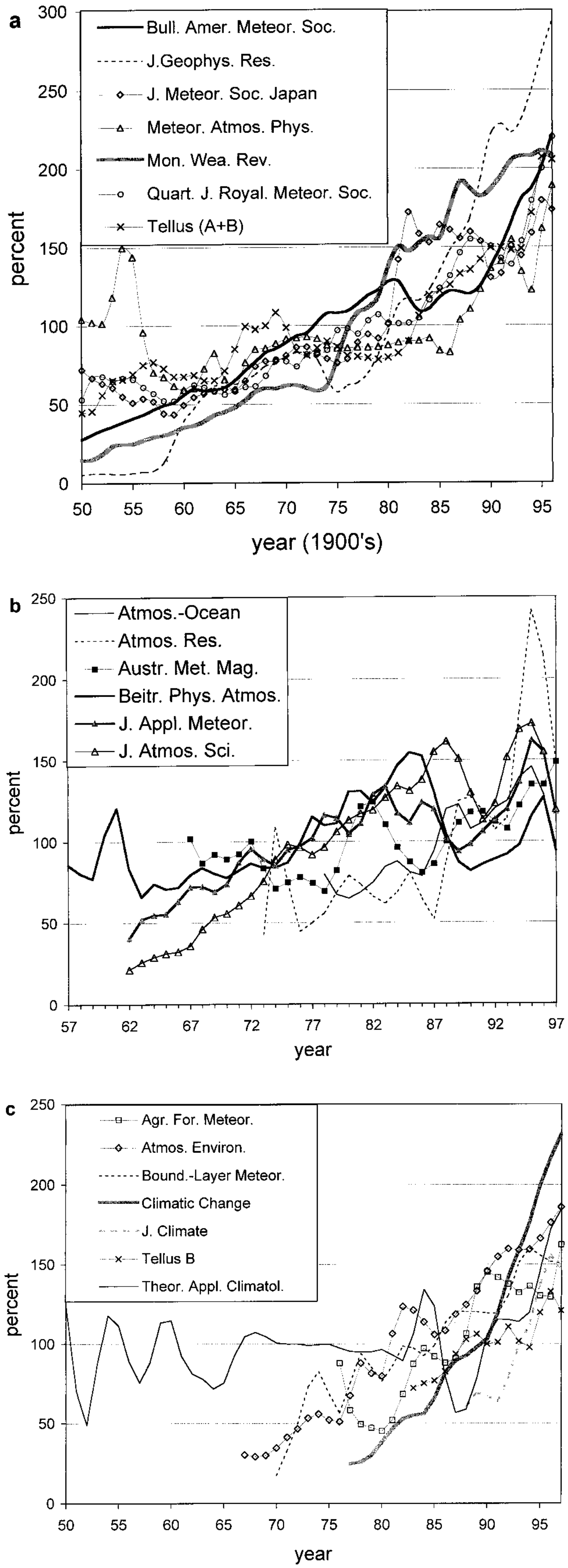


roomed. The growth rate of atmospheric science journals, in terms of the combined number of pages, was small in the 1950s, explosive in the 1960s, but slowly declining thereafter. All the journals in Fig. 1, except *JGR*, collectively show the following trend: an increase of 18% during the 1950s, 130% during the 1960s, 95% during the 1970s, 58% during the 1980s, and 44% during 1990–95.

The expansion of atmospheric science journals is not only because more articles are accepted, but also because articles have become longer, on average. For instance, the mean length of a paper in the *Journal of the Atmospheric Sciences* (*JAS*) nearly doubled between 1968 and 1987 (Johnson and Schubert 1989). In 1970 nearly half of the *JAS* papers were eight pages or less; such short papers were a rarity in 1986–87 (< 10%). Both the number of figures and the amount of text contribute equally to the increase in mean length of *JAS* papers (Johnson and Schubert 1989). The growth in the number of pages per paper, and the number of papers, makes it increasingly difficult to keep abreast of developments in atmospheric sciences. An incidental observation seems to confirm this challenge. It relates to the number of comment and reply exchanges of letters to the editor in *JAS*. Not all comments are followed by a single reply, so exchanges are counted individually. *JAS* counted 22 such exchanges per year, on average, in 1971–80 (Johnson and Schubert 1989), but only 11 in 1981–90, and 9 in 1991–97. Effectively this means that the probability of public scrutiny of a paper in *JAS* fell from about 8% in the 1970s to less than 4% in the 1990s.

It is difficult to conceive that the growth observed during the last few decades will continue during the next few decades. In fact the number of pages in all journals listed in Fig. 1 (excluding *JGR*) *decreased* by 8% between 1995 and 1997. Several factors suggest a stabilization at least in the number of articles published. In the 1970s at least six major atmospheric science journals were launched, at least three in the 1980s, but none so far in the 1990s. Second, funding in support of atmospheric research has grown less than the

FIG. 1. Trend of the number of pages published annually by a selection of journals in atmospheric sciences and *JGR*. The journal abbreviations are those used by the American Meteorological Society in the references of its journal articles. The numbers are expressed as a percentage of the average for the publication period shown in the graph. The average ranges from 9761 pages for *JGR* to less than 500 pages for several journals (Table 1).

overall publication volume; in fact, U.S. federal funding to academic research, adjusted for inflation, has been in decline since 1988 (National Science Board 1998) (Fig. 2). The relation between project funding and publication frequency is obvious, although the latter may lag by a few years. And third, the rapid growth of numbers of fresh Ph.D. graduates in earth, atmosphere, and oceanic sciences ceased around 1977, at a time when the number of pages published in these sciences started to grow more rapidly (Fig. 2). The number of Ph.D.s in sciences in general has almost stagnated since the 1970s in the United States (Goodstein 1997; National Science Board 1991). It is assumed that most Ph.D. graduates publish the bulk of their work within about 20 years of graduating.

The present survey explores changes in the effort required to keep abreast of atmospheric research in peer-reviewed publications. It seems useful to examine the ease with which a reader can scan a paper to decide whether or not to devote precious time to reading it carefully. That decision is likely to be made on the basis of the title, the abstract, and the conclusions of the paper. It is those formal aspects of atmospheric science journal papers that are the concern and will be the focus of the following discussion. This survey does not address the more fundamental questions of scientific merit and editorial quality (White 1998). Clearly it is the role of the formal review process to evaluate these aspects, and to the reader they are important only after a decision to read the paper.

To assess the reader-friendliness of a paper, we use generally accepted criteria. The abstract should cover three topics concisely: what is the problem, how is it tackled, and what is the solution (e.g., Becker 1975). The paper should be closed with a conclusion, which should briefly summarize what advance has been made. The findings are preferably listed discretely, so that the reader can absorb or skip them rapidly. The concluding section (referred to in the rest of this study as the "conclusions," although it may have a different title) should not be a mere summary of the paper, because then it repeats the abstract. Neither should it be confused with the discussion, which is a free-ranging consideration of matters such as the agreement with earlier work, confirmation of theory, possible implications or applications, weaknesses in the method, further work that is needed, etc. Rather, the conclusions should be a bald statement of the outcome of the research. Limitations of the work may be mentioned in the conclusions, but only as a distinct finding. The same applies to ideas resulting from a previous discussion.

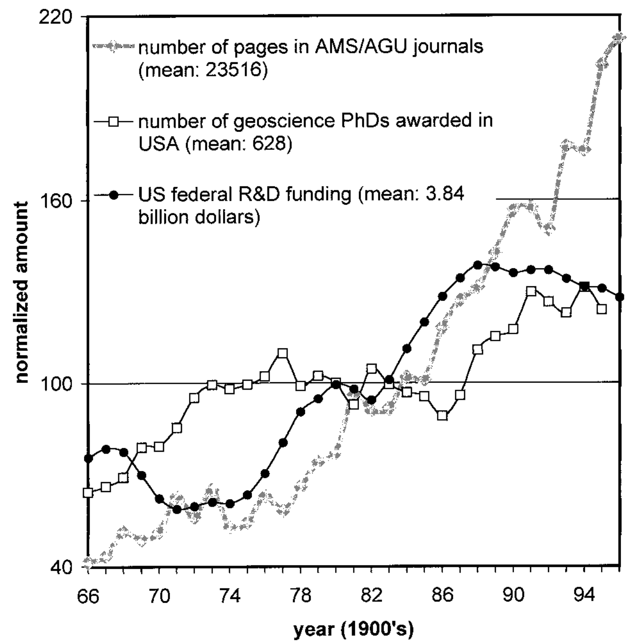


FIG. 2. A comparison of the annual number of pages in *JGR* and all journals by the AMS, to the number of doctorates in earth, atmosphere, and oceanic studies awarded in the United States (Hill 1997) and to the federal funding to universities, colleges, and federally funded research and development centers in the United States in constant 1992 dollars (National Science Board 1998), between 1966 and 1995.

The proposed constraints on the content of the conclusions are widely accepted in theory but widely ignored in practice. In fact, many writers nowadays do leave it to the reader to work out what is the point of their paper, assuming that the reader is willing to undertake such labor. Some writers blend discussion and conclusions, others merely conclude with discussion material, and some papers close with a section entitled "concluding remarks" or "final comments" or something similar. These approaches blur the papers' true contributions. By contrast, a small but increasing number of articles include a schematic cartoon or flow chart in their conclusions (e.g., Locatelli et al. 1994), which makes the new ideas more succinct, vivid, and accessible to a larger readership.

Universities and publicly funded institutions have become increasingly aware of the key role of clear and simple scientific communication. For instance, the National Aeronautics and Space Administration encourages the writing of a "popular summary" as a supplement to any paper prepared for submission. Yet clear and simple writing within the established structure of scientific writing, in particular within abstracts and conclusions, has not been stimulated. Few studies have evaluated clarity in abstracts and conclusions, which is surprising in view of their importance in scientific communication (Batchelor 1981). One notes a paper by Lowry (1965), who laments that many abstracts are of "billboard style:" they intentionally omit aspects, to arouse the readers' curiosity, with closing sentences such as, "The results lead to several intriguing conclusions, the implications of which are discussed."

The extent to which a paper matches the criteria for satisfactory abstract and conclusions can be quantified. A way to do this is outlined in the next section. The aims are (i) to categorize papers in peer-reviewed atmospheric science journals according to "clarity," (ii) to discover trends and differences between journals and to explain these in terms of other journal attributes, and (iii) to make some easy-to-implement suggestions resulting in easier reading, for use by writers and journal editors.

2. Method

About 90 articles were examined for each of the journals surveyed. Only refereed, contributed papers are selected, including memoirs [e.g., in the *Journal of the Meteorological Society of Japan* (*JMSJ*) and *Atmospheric Research* (*AR*)]. But discussion papers, shorter contributions, notes, letters to the editor, book reviews, pictures-of-the-month, climate summaries, conference proceedings, and other information and correspondence are not included. Twenty-two journals are surveyed, all of which now use English as the main or exclusive language. Seven of these are North American, seven European, four Australasian, and four are truly international from inception. This is not a complete list, but it represents the large majority of atmospheric research in the world.

The North American journals are the *Bulletin of the American Meteorological Society* (*BAMS*), the *Journal of Applied Meteorology* (*JAM*, called *Journal of Climate and Applied Meteorology* from 1983 to 1987), *JAS*, and *MWR*, all published by the American Meteorological Society (AMS); *National Weather Digest* (*NWD*), a publication of the National Weather Association of the United States; *Atmosphere–Ocean* (*AO*, called *Atmosphere* until 1977) by the Canadian Meteorological and Oceanographic Society; and the *Journal of the Air and Waste Management Association* (*Journal of the Air Pollution Control Association* until 1989), from the U.S. Air and Waste Management Association.

The European journals are *AR* (*Journal de Récherches Atmosphériques* until 1985), which is French in origin and now published by an international publisher; *BPA* (Contributions to Atmospheric Physics), by the Deutsche Meteorologische Gesellschaft; *Meteorology and Atmospheric Physics* (*MAP*, *Archives for Meteorology, Geophysics, and Bioclimatology. Series A: Meteorology and Geophysics* until 1985), as well as *TAC* (*Archives for Meteorology, Geophysics, and Bioclimatology. Series B: Climatology, Environmental Meteorology, and Radiation Research* until 1985), both international now but originally Austrian; the *QJRMS*, by the Royal Meteorological Society of the United Kingdom; *Tellus*, by the Swedish Geophysical Society; and *Zeitschrift für Meteorologie* (*ZM*) by the Meteorologische Gesellschaft der Deutsche Demokratische Republik.

The Australasian journals are the *Australian Meteorological Magazine* (*AMM*) by the Australian Meteorological and Oceanographic Society (originally by the Australian Bureau of Meteorology), the *JMSJ* by the Japanese Meteorological Society, *Mausam* (*Indian Journal of Meteorology and Geophysics* until 1982) by the India Meteorological Department, and *Advances in Atmospheric Sciences*, a recent journal (since 1984) published by China Ocean Press. Four journals are not associated with any organization and are produced by an international publisher: *Agricultural and Forest Meteorology* (*Agricultural Meteorology* until 1984), *Atmospheric Environment*, *Boundary-Layer Meteorology* (*BLM*) (since 1970), and *Climatic Change* (since 1977).

Some basic statistics were collected for each of the sampled papers, such as the number of authors, the author's country of affiliation, the number of pages, figures, tables, and equations; and the abstract and conclusions were scanned. A summary of these statistical data is given in Table 1. The first 30 papers were selected for each of three years (1965, 1980, and 1995); however, some journals were also sampled in 1950, some journals were founded after 1965, and some journals published less than 30 articles in some years. Only 19 of the 22 journals are listed in Table 1. One of the three missing (*NWD*) did not have enough refereed, contributed articles, and some issues of the other two (*MAP* and *ZM*) were not available to the author.

Each article was numerically categorized by an "equation index" and by a "clarity rating."

a. *Equation index*

The equation index is calculated as follows: one point for papers without equations, two points for papers with 1–5 equations, three points for papers with 6–20 equations, and four points for the heavily mathematical papers (> 20 equations).

b. Clarity rating

The clarity rating of a paper is a measure of the readability of the abstract and conclusions and is based on these criteria: an abstract that is brief and that covers the basic aspects of the paper, that is, the topic, the approach, and the outcome; and the existence of nondiscursive, distinct, and brief conclusions. A paper was given one point (+1) for each of the first four conditions (a–d below) and a penalty (−1) for the last condition (e).

(a) The length of the abstract (L_a) is less than 200 words. This seems ample, but long papers may need more space. The following formula is used for papers whose number of pages (L_p) exceeds 20:

$$L_a < 200 + 10(L_p - 20).$$

(b) There is a closing section (referred to here as the conclusions whose title contains the word conclusion(s) or summary or concluding or summarizing or epilogue.
(c) The concluding section is brief, at most 5% of the length of the paper. Practically, the number of pages or fraction thereof is counted. An illustration first mentioned in the conclusions is counted as part of the conclusions.
(d) The various conclusions are listed briefly, clearly, and distinctly, either in a numbered list, or by means of bullets, or in the form of short paragraphs.
(e) The conclusions actually contain discussion material and/or introduce new facts not mentioned in previous sections.

Both conditions (c) and (d) can be satisfied when formal conclusions are absent [i.e., (b) is not satisfied], but (b) is usually satisfied when either (c) or (d) is obtained. According to this scheme, the clarity rating has the same range as the equation index, that is, between 0 and 4. It cannot be negative, because a penalty (e) can be given only to papers with conclusions (b).

The question may arise: how subjective a measure of clear abstracts and conclusions is this rating? The arguments for the clarity rating are broadly accepted as objective measures of clear scientific communication (e.g., Becker 1975; Batchelor 1981). But the numerical threshold values used in criteria (a) and (c) are arbitrary; they are not intended as specific constraints that should be adopted by journal editors. The proposed maximum size of an abstract allows direct use by abstracting journals, such as the *Meteorological and Geoastrophysical Abstracts* (*MGA*), without a second process of abstraction. And the proposed limit for the length of the conclusions is consistent with the need for distinct crisp statements in this section of the paper, without detailed repetition of earlier material. How objective is the assignment of a clarity rating? The first three conditions of the rating can be assessed mechanically. However, the last two conditions do involve some judgment. Nevertheless, clarity ratings given by two different people to the same 150 articles, sampled from the *QJRMS* (1965, 1980, and 1995) and the *JMSJ* (1980 and 1995), were almost identical. The average difference between the ratings of the two assessors for the first journal was 0.13, out of the possible rating of 4.0. The average absolute difference for the second journal was only 0.05. Such differences are insignificant compared to the standard deviations of values for articles from a single journal for one year. In short, the clarity rating is reproducible and therefore useful. In any case, the present ratings are used here only in a relative sense. Any systematic bias is canceled by the subtraction inherent in examining differences or trends.

3. Results

The number of authors per article has increased significantly, from an average of 1.2 in 1950 (for all journals listed in Table 1), to 1.5 in 1965, to 2.0 in 1980, and 2.9 in 1995. The first authors of the AMS journals are generally affiliated with U.S. institutions, but AMS journals are becoming more international, notwithstanding the large contribution of authors to the publication costs. An estimated 90% of the first authors in *BAMS*, *JAM*, *JAS*, and *MWR* were U.S. affiliated in 1965, but only 71% were in 1995. The four Australasian journals listed in Table 1 are and remain self-sufficient: at least 80% of the contributing authors are from the country of affiliation. This applies also to the Canadian *AO*. Australia is well represented in atmospheric research for the size of its population, whereas contributions from Third World countries continue to be sparse.

The international tradition of the European journals has strengthened, as seen in Table 1, where five European journals are listed: *QJRMS*, *Tellus*, *AR*, *BPA*,

TABLE 1. Summary of the journal survey. The parameters are listed in the top row. The values shown are the averages for all samples. The average number of pages published annually between 1950 (or the year of inception, whichever is later) and 1997 is shown in the first column in parentheses, for most journals. In some cases a journal is not available in a key year (1965, 1980, 1995), and in some years some journals published less than 30 papers.

			Number of...[b]					Number of equations[c]				
Journal	Year	Authors' country[a]	Samples	Authors	Pages	Figures	Tables	0	1–5	6–20	> 20	Clarity rating
Quart. J. Roy. Meteor. Soc. (965)	1950	UK (88%)	26	1.1	14.0	4.8	3.0	14	7	6	3	1.6
	1965	UK (43%), US (35%), Oz (15%)	46	1.4	9.8	5.4	1.3	13	4	9	4	1.8
	1980	UK (48%), US (20%), Oz (14%)	50	2.0	17.4	7.1	1.7	2	7	11	10	1.8
	1995	UK (40%), EU (24%), US (22%)	50	2.5	23.6	12.7	1.4	6	5	9	10	1.8
	1998	UK (43%), EU (30%), US (17%)	30	2.6	22.6	10.5	1.9	3	4	13	10	2.0
Mon. Wea. Rev. (1554)	1950	US (100%)	30	1.3	5.6	6.8	1.4	26	4	0	0	0.8
	1964	US (97%)	30	1.5	9.6	9.3	2.0	22	1	3	4	2.2
	1980	US (87%)	30	2.0	13.8	11.1	2.8	14	8	6	2	2.1
	1995	US (60%), Ca (17%), Oz (8%)	30	2.9	17.3	13.9	1.0	9	7	5	9	1.7
	1998	US (77%), EU (10%), Ca (7%)	30	2.5	19.8	17.0	1.9	13	6	6	5	1.9
J. Atmos. Sci. (2433)	1965	US (80%), Oz (10%)	30	1.4	9.6	6.8	2.0	12	5	8	5	1.6
	1980	US (77%), Oz (13%)	30	2.0	14.7	10.2	1.5	5	6	9	10	1.8
	1995	US (70%), EU (17%)	30	2.5	16.8	14.3	1.1	7	4	6	13	1.6
J. Appl. Meteor. (1479)	1965	US (83%), EU (7%)	30	1.6	8.1	8.1	2.3	16	6	5	3	2.5
	1980	US (80%), EU (10%)	30	2.3	9.5	7.8	1.7	11	4	12	3	2.4
	1995	US (57%), EU (17%), CA (13%)	30	3.3	15.0	11.2	2.7	12	7	8	3	2.1
Bull. Amer. Meteor. Soc. (1340)	1965	US (100%)	30	1.4	6.5	2.9	0.4	28	2	0	0	0.8
	1980	US (97%)	30	1.7	7.7	5.4	1.7	27	2	1	0	2.1
	1995	US (97%)	30	4.1	12.8	9.6	1.7	18	8	4	0	2.0
Tellus A and *B* (725)	1965	US (53%), Sc (23%), EU (17%)	30	1.3	11.7	6.1	1.9	3	5	8	14	1.4
	1980	US (33%), Sc (23%), EU (20%)	30	1.9	10.6	6.2	1.8	10	5	9	6	1.8
	1995	EU (53%), Ca (20%), US (17%)	30[d]	2.8	15.0	9.2	2.7	10	6	10	4	1.7
Aust. Meteor. Mag. (235)	1966	Oz (92%)	12	1.2	13.4	5.3	2.1	17	7	3	3	2.3
	1980	Oz (92%)	13	1.4	13.5	4.2	4.0	21	5	2	2	1.8
	1995	Oz (100%)	25	2.2	12.7	12.9	1.6	23	4	3	0	2.0

TABLE 1. *(continued).*

Journal	Year	Authors' country[a]	Number of...[b]					Number of equations[c]				Clarity rating
			Samples	Authors	Pages	Figures	Tables	0	1–5	6–20	> 20	
Atmos.–Ocean	1980	Ca (76%), US (14%)	21	1.6	14.9	6.7	2.3	9	9	11	1	1.8
(543)	1995	Ca (83%), US (17%)	29	4.0	26.0	10.8	2.3	16	7	4	3	1.8
Atmos. Res.	1965	US (29%), Fr (23%), UK (13%)	11	1.4	10.3	4.9	2.1	17	2	11	0	2.0
(565)	1980	US (47%), Fr (23%), It (10%)	30	2.2	14.5	6.9	0.8	14	6	8	2	2.4
	1995	US (30%), Eu (30%), Ca (20%)	30	2.5	12.6	6.2	1.6	16	8	2	4	2.4
Beitr. Phys.	1965	De (87%)	15	1.1	16.1	5.9	3.9	4	0	12	14	2.1
Atmos.	1980	De (73%), other EU (20%)	30	1.7	16.9	7.7	2.1	10	2	7	11	2.2
(376)	1995	De (76%), other EU (10%)	29	2.9	12.3	8.7	1.1	8	0	16	6	1.9
Theor. Appl.	1965	EU (37%), US (17%), Oz (13%)	30	1.3	10.2	5.2	2.9	10	12	4	4	0.9
Climatol.	1980	EU (53%), US (20%), Oz (13%)	30	1.5	12.0	4.0	2.7	12	10	6	2	2.0
(415)	1995	EU (60%), As (23%)	30	2.5	10.7	7.1	3.3	15	10	5	0	2.6
Climate Change	1980	US (55%), EU (20%), UK (15%)	16	1.8	17.0	4.8	1.7	20	6	4	0	1.6
(772)	1995	US (43%), EU (23%), Oz (10%)	30	2.3	20.2	5.3	3.4	23	3	4	0	1.8
Mausam	1965	In (95%)	20	1.7	10.9	8.1	3.3	21	6	2	1	2.3
	1983	In (100%)	10	2.5	10.2	6.0	3.7	15	3	6	6	3.1
	1995	In (87%)	15	2.0	10.1	5.3	1.8	14	8	6	2	2.7
J. Meteor. Soc.	1965	Jp (97%)	29	1.4	11.7	9.1	0.6	10	2	5	13	2.3
Japan (648)	1980	Jp (80%), US (13%)	35	1.7	13.1	11.1	1.2	7	5	7	11	1.8
	1995	Jp (83%), US (8%)	50	3.5	16.1	11.6	1.0	19	4	6	1	2.2
Adv. Atmos. Sci.	1985	Ch (97%), US (3%)	30	1.9	10.2	5.6	1.0	4	3	15	8	2.2
	1995	Ch (80%), In (13%)	30	2.4	10.4	6.0	1.3	10	4	11	5	2.2
Bound.-Layer	'70-'71	US (50%), Ca (33%), EU (17%)	30	1.7	14.6	7.7	1.3	3	2	14	11	2.3
Meteor.	1980	US (50%), Oz (20%), EU (20%)	30	2.1	16.1	7.7	2.4	10	6	8	6	1.4
(1387)	1995	EU (30%), US (20%), UK (20%)	30	2.6	23.2	8.8	2.2	1	4	12	13	2.4

TABLE 1. *(continued).*

Journal	Year	Authors' country[a]	Number of...[b]					Number of equations[c]				Clarity rating
			Samples	Authors	Pages	Figures	Tables	0	1–5	6–20	> 20	
Agric. For.	1965	US (20%), EU (20%), Af (17%)	30	1.4	12.0	4.6	2.1	18	6	5	1	1.9
Meteor. (1083)	1980	US (27%), Oz (20%), UK (20%)	30	2.4	12.4	5.6	1.8	15	10	4	1	1.6
	1995	EU (40%), UK (20%), US (17%)	30	2.8	16.1	6.7	2.1	12	8	9	1	1.5
Atmos. Environ.	1967	US (60%), UK (20%), Ca (7%)	30	2.0	10.6[e]	4.3	2.7	21	6	2	1	1.9
(2291)	1980	US (60%), EU (13%), UK (8%)	30	2.2	8.0	5.2	3.1	14	8	7	1	2.3
	1995	EU (30%), US (27%), UK (13%)	30	3.4	12.6	6.3	2.9	11	6	10	3	2.4
J. Air Waste	1980	US (87%)	30	2.8	6.0	5.2	3.6	10	7	12	1	2.4
Manage. Assoc.	1995	US (75%), EU (10%)	30	3.0	7.8	5.4	3.0	18	6	6	0	1.7

[a]This is the country (or group of countries) of affiliation of the *first* author, for the sampled articles only: Af = Africa; As = Asia; Ca = Canada; Ch = China; De = (West) Germany; EU = continental Europe (excludes the British Isles and Scandinavia, includes the former east block countries); Fr = France, In = India, Bangladesh, Pakistan; It = Italy; Jp = Japan; Oz = Australia and New Zealand; Sc = Scandinavia; UK = United Kingdom and Ireland; US = United States. The regions are ranked, and if there is no clear dominance, only the top three regions are listed.

[b]The number of pages, figures, tables, and equations are counted in the article as well as any appendices and are averaged for all samples. The paper's original counting or labeling system is used. For instance, a Fig. 5 in a paper is counted as one only, even though it may consist of four graphs, 5a–5d. With regard to the number of authors, a few of the early papers were written by the "staff" of an institute. In this case, the number of authors is arbitrarily set to 3.

[c]If the number of samples is less than 30, the numbers are prorated to be out of 30.

[d]Fifteen samples from Series A and 15 from Series B.

[e]Compared to the 1980 and 1995 issues, the 1967 issue has a page size that is about 30% smaller and a font size that is about 20% larger. So in comparable units, the average number of pages in 1967 is only 6.0.

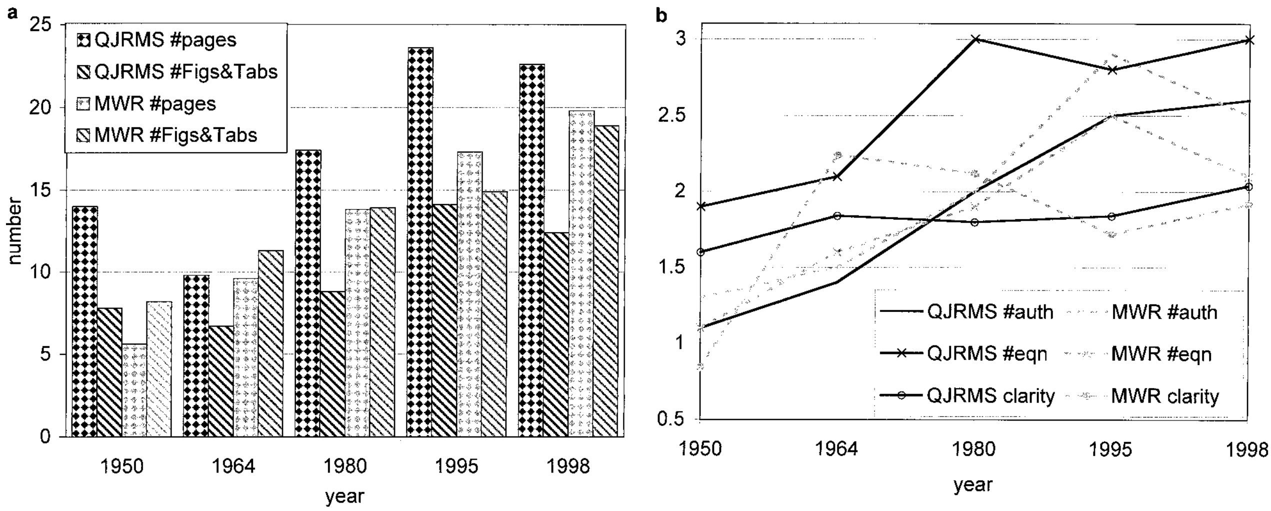


FIG. 3. A comparison between *QJRMS* and *MWR.* (a) The average number of pages and the number of figures and tables. (b) The average number of authors (#auth), the equation index (#eqn), and the clarity rating (clarity).

and *TAC.* The U.S. contribution to these journals has dropped from about 28% in 1965 to 17% in 1995, while that from European countries other than the journal's country of origin has grown. This reflects the increasing collaboration among European forecasting and atmospheric research centers, and the adoption of a single main language (English) in European journals. The U.S. decline is consistent with a reduction of the American portion of all peer-reviewed publications in natural sciences and engineering, from 36% to 33% between 1981 and 1995 (National Science Board 1998).

A comparison between *QJRMS* and *MWR,* which also were sampled in 1950 and 1998, shows that both journals have increasingly contained more bulky papers (Fig. 3a). There are some traditional differences between the two journals; *MWR* is more observational (hence more figures), whereas *QJRMS* tends to be more theoretical (hence more equations). These differences shrank until 1995.

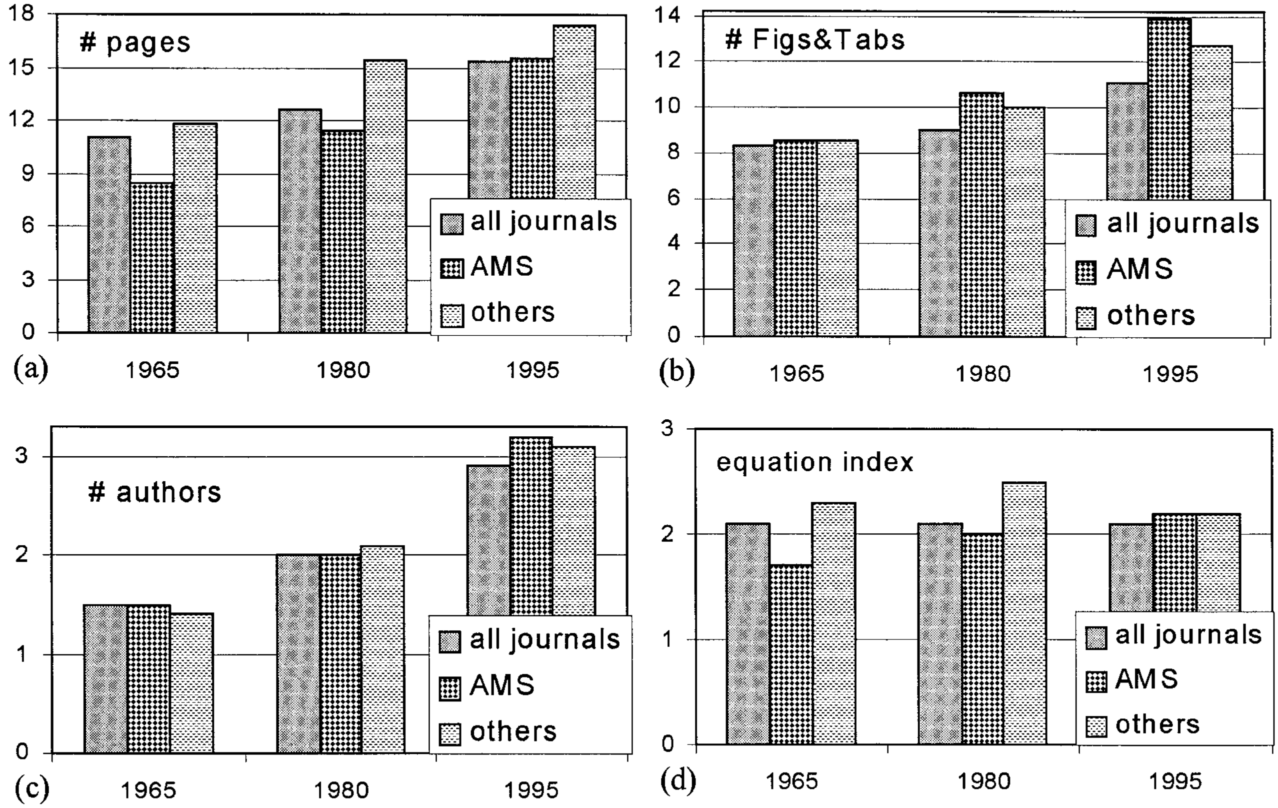
a. Clarity rating: Trends

The clarity rating (defined in section 2) was generally low in 1950, when the Euclidean format, now universally used in peer-reviewed articles (with an abstract, introduction, method, results, discussion, concusion, acknowledgments, and references), had not yet become standard. Many papers in those days lacked a conclusions section altogether. Specifically, *MWR*'s rating increased rapidly between 1950 and 1980 (Fig. 3b) as the journal's vision changed and the editorial desk was transferred from the U.S. Weather Bureau to the AMS.

The clarity rating continued to improve slightly from 1965 to 1980 among most journals. From 1980 to 1995, many journals, in particular some AMS journals, weakened in their clarity rating (Fig. 4).

A dissection of the clarity rating (Fig. 5) shows why this trend of improving readability and easier access to papers reversed. On the one hand, there was the general adoption of the Euclidean format, so that abstracts and conclusions became more common, even though 32% of papers were still without conclusions even in 1995. The closing section was typically longer in 1995 than in 1965, but because during this period the average length of a paper increased by 40%, the conclusions actually became proportionally shorter, and this slightly improved the clarity rating.

These improvements were more than offset by the increasing lengths of abstracts (a) and the increasing presence of discursive discussion material in the conclusions (e). The abstracts were too long in 43% of the 1995 papers, versus 22% in 1965. (Abstracts seem to have become more directed at experts, so less attention is paid nowadays to stating the problem and more is given to the methodology and the results. Also, the results seem increasingly often clouded by long and obscure text. As the clarity of the abstract was not assessed, these apparent trends cannot be quantified.) Seventeen percent of the 1965 papers combined a brief abstract with itemized, concise conclusions free of discussion material. In 1980 this perfect clarity rating had become slightly more common (19%), but it fell again in 1995 (16%). Condition (d) is least commonly satisfied in any journal and does



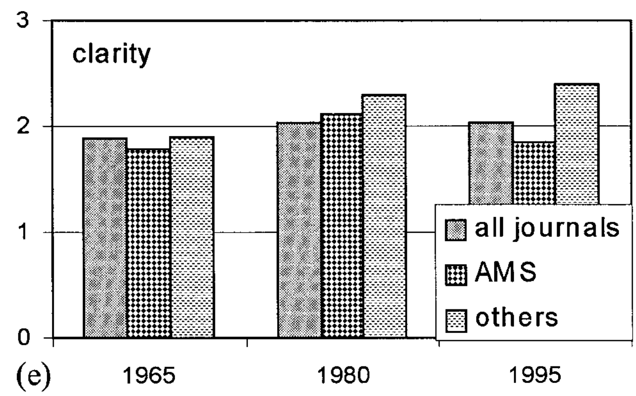


FIG. 4. A comparison between AMS journals (*BAMS, JAM, JAS, MWR*) and "other" journals (*AO, AR, AMM, BPA, JMSJ, Mausam, QJRMS, Tellus, TAC*). The latter category represents the bulk of non-AMS atmospheric research, excluding the journals that are more interdisciplinary in nature. The reference column "all journals" refers to the 19 journals listed in Table 1. Shown are (a) the average number of pages, (b) number of figures and tables, (c) number of authors, (d) equation index, and (e) clarity rating.

not show a consistent trend (Fig. 5). In other words, the most room for improvement lies in a discrete listing of conclusions.

Perhaps the downward trend in clarity is related to the increasing number of authors per paper. Papers with three or more authors have a 93% higher chance of failing clarity criteria (a) and (c) (regarding the lengths of abstract and conclusions) than papers written by one or two authors, for all journals and years listed in Table 1. A speculative explanation is that in many team-written papers each author adds to the opening and closing sections, whereas core sections are divided among the authorship. More careful editorial supervision may be needed for multiauthor papers.

b. Clarity rating: Journal comparison

The AMS journals have lost some clarity between 1980 and 1995, whereas other atmospheric science journals have continued to improve in clarity, on average. Among the AMS journals, only *JAM* scores high in terms of clarity (Table 2). Incidentally, the average size of a paper in an AMS journal, in terms of either the number of pages or the number of figures and tables, has expanded more than that of a typical paper in other journals. So AMS journal papers have become more time-consuming to assess in a preliminary way, and then harder to read thoroughly, compared with papers in the other journals. *BAMS* rates lowest of all journals, which is unfortunate because it has the largest readership. The low rating is due in part to the common presence of discursive material in the concluding section (e), though its improvement over the years is due the inclusion of conclusions (b). Other AMS journals, especially *JAS*, rate low mainly because of lengthy abstracts and conclusions [(a) and (c)].

The three Asian journals in this survey are among the top six. Of the *Mausam* papers 43% have a perfect clarity rating of 4, compared to 7% in *BAMS*. The high rating in *Mausam* is explained by the common use of a clearly structured, compact summary that avoids discussion material [criteria (b)–(e)].

Any comparison of journals or years (as in Figs. 3–5 and in Table 1) must be judged in the context of large standard deviations bracketing the mean, for each sample of about 30 papers. For instance, the standard deviations for the clarity ratings (not shown) are about 1.0, ranging between 0.3 and 1.4. While the sample sizes are sufficient to establish general patterns, data for a particular journal or year cannot be extended to all papers in that journal/year. Also, the assessment of a trend based on just three sampling years does not account for interannual variability. This weakness has been compensated for somewhat by the broad selection of journals.

The average standard deviation of clarity rating increased between 1965 and 1995 from 1.0 to 1.1. This trend is surprising in view of more detailed and explicit editorial policies, a more stringent review, and a gradual standardization of article format. Also, the variability of article lengths decreased: the index of variation of the article length fell from 0.48 to 0.39 between 1965 and 1995. The wider range of clarity indicates that journal editors are becoming unduly tolerant of writers' idiosyncrasies.

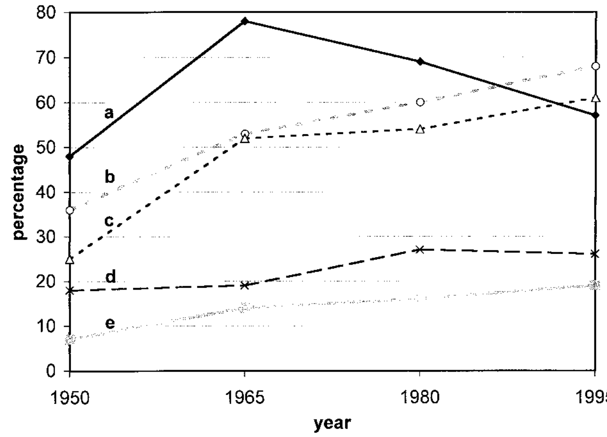


FIG. 5. Trends of the components of the clarity rating, for all journals listed in Table 1. Shown is the percentage of papers that (a) have a brief abstract; (b) have conclusions; (c) have a brief conclusion; (d) list their findings; and (e), in their conclusions, digress into a discussion. These criteria are detailed in section 2.

4. Discussion

The average clarity rating for atmospheric science journal articles was and still is quite low. There is plenty of room for improvements, which are easy to make, as shown by the example of the better journals. The suggested improvements cannot be gainsaid by quibbling about the criteria adopted here to measure easy readability. Readers are unnecessarily burdened by verbose abstracts and fuzzy, lengthy, or missing conclusions. The conclusions to many papers become excessively lengthy because they discuss unresolved questions, limitations of the present work, and plans for future work. There is some logic to including these aspects after the summary of the results. It is suggested that they be listed in a separate section following the conclusions [as in Wang and Holland (1995)] or, preferably, since they are discussion items, that they are moved to the discussion (e.g., Edwards and Mobbs 1997).

The increasing number, complexity, and vagueness of atmospheric science journal articles have a number of consequences, whose effects on scientific progress may offset the benefits gained from the gradual worldwide assumption of one common language (English) in these and other journals (Spurgeon 1987).

TABLE 2. Journal ranking based on the clarity rating (in brackets) in 1965, 1980, and 1995. Only two years are used for some journals, as detailed in Table 1.

1) *Mausam* (2.7)	7) *Beitr. Phys. Atmos.* (2.1)	13) *Atmos.–Ocean* (1.8)
2) *J. Appl. Meteor.* (2.4)	8) *Aust. Meteor. Mag.* (2.0)	14) *Climate Change* (1.7)
3) *Atmos. Res.* (2.2)	9) *Bound.-Layer Meteor.* (2.0)	15) *Agric. For. Meteor.* (1.7)
4) *Adv. Atmos. Sci.* (2.2)	10) *Mon. Wea. Rev.* (2.0)	16) *J. Atmos. Sci.* (1.7)
5) *Atmos. Environ.* (2.2)	11) *Quart. J. Roy. Meteor. Soc.* (1.8)	17) *Tellus* (1.6)
6) *J. Meteor. Soc. Japan* (2.1)	12) *Theor. Appl. Climatol.* (1.8)	18) *Bull. Amer. Meteor. Soc.* (1.6)

First, it has diminished the ability of atmospheric scientists to keep up with advances in their science or even their own subdiscipline (Johnson and Schubert 1989). Certainly this problem is not unique to atmospheric sciences—it is probably worse in physics (Mermin 1988), for instance. As papers become more numerous, less time can be spent per paper, and as they become longer, fewer can be read. As abstracts become more verbose and their content fuzzier, abstracting journals, in particular *MGA*, become less useful. This evolution is unfortunate, since the atmosphere is a complex but single entity, coupled to its underlying surface. A cloud physicist should understand synoptic processes and radiative transfer, for instance. And great scientific advances come especially from applying discoveries in one field to another field entirely. In short, cross-fertilization may suffer and community-wide amnesia may increase.

Second, it has broadened the gap between the atmospheric science community and the public (Diamond 1997). Science journalists generally understand little of atmospheric processes and less of the research methods we use. For lack of more balanced information, and because journalists are pressured to put substance into mass-media science writings (Dunwoody 1987), they will either ignore or else dramatize research results. Public awareness is important, in the least because the potential benefits of atmospheric research to society often are not obvious. Increasing public indifference may result in cuts in government spending on atmospheric research.

Third, it may hurt education, mainly at the undergraduate level. Faculty, unable to keep abreast of atmospheric research through journals, may resort to more accessible media, such as books and nonrefereed online materials. And for the pregraduate student population, journal articles are, at best, of little use in their learning process, and at worst they will repel good students from a career in sciences.

These three possible consequences have in common one outcome: they slow progress in atmospheric sciences. Therefore the ease with which readers can gain access to at least the main gateways of a paper should be a major concern of contributing authors. Journal editors should pay more attention to the clarity of submissions, in addition to other factors such as paper length.

5. Conclusions

A survey of the size and clarity of peer-reviewed papers in a large selection of journals in atmospheric sciences was conducted, and these are the key findings.

- The number of words and illustrations published per year more than quadrupled between 1965 and 1995.
- The size of a typical paper in these journals increased by about 40% during the same period, and its mean number of authors doubled to about three.
- The abstract to a typical paper has grown even more, thereby reducing reader-friendliness.
- In many papers the conclusions have become excessively lengthy, because authors digress into discussion items such as unresolved questions and comparisons to other work.
- The typical clarity, as defined by characteristics of the opening and closing sections of a paper, is poor and has not improved since 1980; for some journals it has declined, notably for some AMS journals.
- Improvements can easily be made; to start, journal editors should insist on brief abstracts and discrete, concise conclusions.

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