

STATISTICS OF TURBULENCE RESEARCH

K.R. Sreenivasan
Yale University

I. PREAMBLE

This note adds nothing to the knowledge of turbulence. Instead, it presents some statistics of turbulence research. If it amuses you even for a brief moment, I would consider the exercise (begun totally out of idle curiosity) amply rewarded.

II. THE SIZE AND TRENDS OF TURBULENCE LITERATURE

Turbulence literature is bulging in size. Figure 1 shows the number of papers* on turbulence that appeared annually since 1969. Interestingly, the number has not changed substantially over the last decade or so**, unlike a

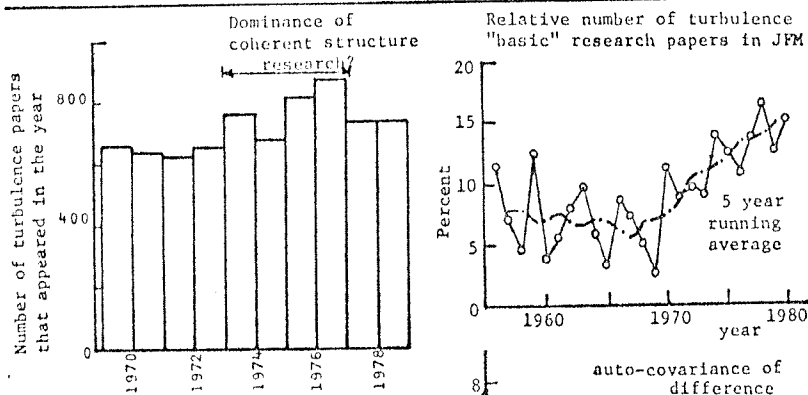


Figure 1

few other topics in fluid mechanics which faded rather abruptly or picked up dramatically over the same period of time. There is thus not much chance of "turbulence people" running out of business altogether in the near future. On the average, about two papers a day appear in print, and just reading them all (assuming that some one would want to do it) could be a full-time occupation!

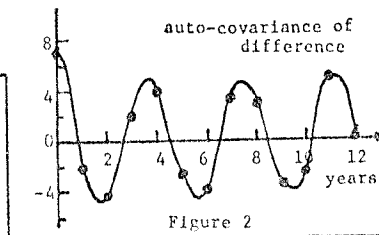


Figure 2

The upper part of figure 2 (lifted, with his permission, from Professor Stanley Corrsin's treasure-house of memorabilia) shows that the number of

* The data were obtained from counting the Subject Index of the Science Citation Index, making sure that all duplication were avoided. They include atmospheric and oceanic turbulence as well, and exclude Chinese, Japanese, and East European literature, as well as Russian publications not translated into English.

** The slight surge in the mid-1970's may or may not be significant.

papers on basic turbulence research that appeared in the Journal of Fluid Mechanics forms a sizeable fraction of the total number, and has been on a slight increase since the early 1970's. The figure also shows a five-year running average. The lower diagram shows that the auto-covariance of the difference between the "instantaneous" and the "average" is periodic*, with a mean period around 3½ years or so. Professor Corrsin muses that coherent structures occur not only in turbulent flows but also in turbulence research!

III. CITATION STATISTICS

On occasion, I have encountered statements (explicit and implied) that the Citation Index can serve as a useful indicator of the impact that an individual has had on the growth of his chosen field of research. Whether this is true or not, it certainly seemed interesting to look at the citation statistics in turbulence research. There are probably a few hundred living scientists who have contributed something or the other to the turbulence literature; there are fewer of them whose attention has been focused nearly exclusively on turbulence. I chose to do statistics on the "best" 100 of the latter category. The choice of the "best" 100 is to some extent necessarily arbitrary, but not nearly as much as one would be inclined to think. More than about half the people on the list will not be disputed by many, although some choices — especially among the younger people — may be. But all of them (chosen from all over the world) have been active in research, have been publishing currently at a steady rate or have made a name for themselves in the past; all or nearly all their research has been in turbulence.** Their distribution according to age is as follows: about 27 or 28 each in age groups 35-45, 45-55 and 55-65, with the rest of them coming from the younger breed in the range of 25-35.

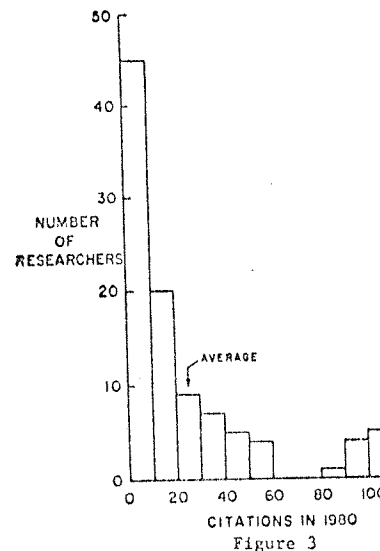


Figure 3 is a histogram of the number of researchers cited a given number of times (actually, in groups of 10) in the year 1980. For example, 45 of them were cited less than 10 times in 1980, 20

* One possible explanation of this periodicity is that some of the papers otherwise targeted for JFM get siphoned off by the proceedings of conferences exclusively devoted to turbulence.

** By this criterion, Kolmogorov, Heisenberg, or (closer to home) Liepmann would not be on this list in spite of their unquestioned contributions to turbulence.

of them between 10 and 20 times, and so on. Assuming 1980 to be a typical year, the "average"* number of citations for such a group would be about 25, with only 30 people cited more often. There is a break in the range of 60-80 citations/year (in other years too this range is thinly populated), but some people do get cited more often. At first it seemed strange that there should be no continuous and monotonic distribution, but a closer examination quickly revealed the pattern: those occupying the upper levels are invariably the authors and editors of books on turbulence, or have further become visible by writing *several* reviews on varying topics in turbulence. Most of the very well-known people whose contributions to turbulence are long-standing, but have authored no books or did extensive reviews, invariably fall in the range of 40-60 citations/year. The conclusion appears fairly clear. If one has reached this 40-60 range and wants to be cited much more often, it is more efficient to write books or reviews: a good book or a review, authored by a competent person, does not seem to go a waste! Finally, it may be relevant to recall the view held at least by some people that Nobel laureates on the eve of winning the prize get cited about 100 times or more.

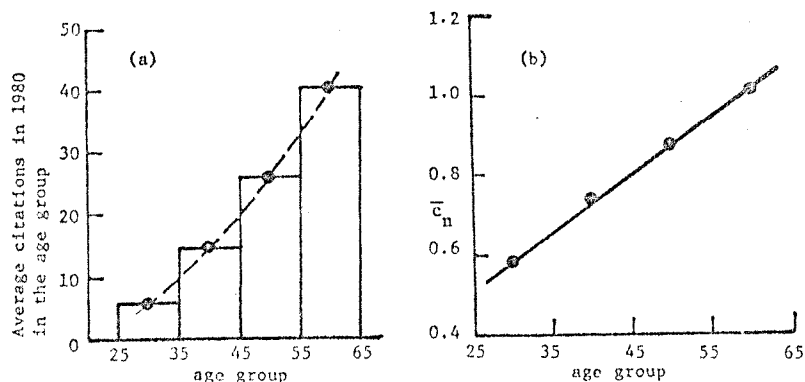


Figure 4

A similar analysis for each age-group would no doubt be worthwhile, but the sample size is inadequate for computing the detailed distributions. However, the "average" citations/year can be computed fairly reliably for each of the four age-groups mentioned earlier, and is shown in figure 4a. Perhaps a more appropriate way of plotting the data is in the form of the quantity \bar{c}_n , which is the average citations/year in a given age-group normalized by the number of years the people belonging to the group have been actively engaged in research. This way, one removes the bias of "seniority". The fact that \bar{c}_n increases with age (figure 4b) is indicative of how cumulative the process is; instant stars seem rare in this business!

* Since our example is skewed towards the "best", this is really a qualified average for the "best" 100.

A straight line fit adequate for the data in figure 4b is given by:

$$\bar{c}_n = 0.58 + (A-30)/70, \quad 30 \leq A \leq 65, \quad (1)$$

where A is the age in years. For the most visible people in each group, the coefficient \bar{c}_n is about three times as high as that given by (1).

IV THE CITATION SCALE

Some very brilliant people visited turbulence for a while, made some contributions to the field, and went on to other areas and conquests for which they are better known. Did these people somehow sense that a full-time pre-occupation with turbulence was less rewarding (quite apart from the limited progress possible) in the eyes of their peers? Figure 5 shows a citation scale which may throw some light on the question. On this scale, 25 is the "average" number we have already discussed with reference to figure 3. At about 55 is the largest citation in turbulence if book writers are excluded. The largest number in turbulence is around 100, which is also the region populated by some Nobel laureates and other well-known people in mechanics. Many of them however (including some of the leaders in mechanics - living and dead) occupy even higher levels. Some of the best known physicists of our time move even higher up. For a variety of reasons, the citation frequency of scientists in life sciences seems to be quite a bit higher. For example, one scientist averaged 1000 citations/year, only from his papers (*excluding* books) written in the period 1965-1975! (It should be clear that the numbers of figure 5 are the citations in 1980 of *all* books ever written by the authors mentioned.)

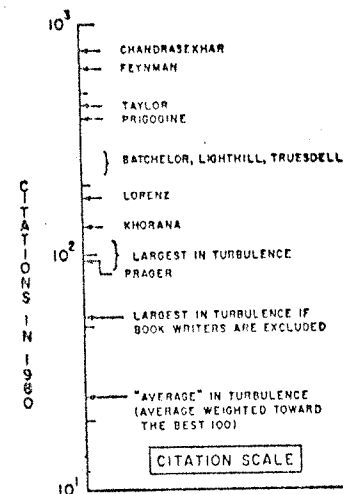


Figure 5

V CONCLUDING REMARKS

Even the most cited authors in turbulence are cited nearly an order of magnitude fewer times than the most-cited physicists (for example), and even fewer times than the most-cited life-scientists. Absolute numbers thus make no sense. Even when restricted to turbulence, the significance of the citation number needs some interpretation. Building a reputation in turbulence is in general a slow process; one has very little hope of reaching the pinnacle of the "local" glory before one is about 40 or so! Much work is thus perspiration!