Forecaster Training—A Review and Analysis

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Abstract

Several key events in the history of modern meteorology are reviewed and analyzed in light of the current state of forecasting. A common thread in much of the material reviewed is the need for greater interaction between research meteorologists and forecasters. Greatly hindering this desirable goal is the inadequate training system for forecast meteorologists. Some possible means for altering the structures within which forecaster training takes place are examined. Responses and commitment to improve the current situation are solicited.

1. Introduction

The history of science reveals that science and technology (the application of science to practical problems) have been most productive when they interact. Numerous examples can be found (see Wightman, 1964) where the results of "pure" research have been the source for whole new technologies. However, there are equally numerous examples where the interaction has gone the other way; e.g., the science of thermodynamics was pioneered by Carnot, Watt, and others in the early 19th century in response to the need for a systematic way to improve the steam engine.

Meteorology has a relatively brief history of practical application compared with other sciences. Although forecasting began on an organized basis early in the 20th century, we have already seen a polarization of the profession of meteorology into two areas considered by many to be nearly mutually exclusive: forecasting and research. This dichotomy has not been total, as we shall see, and, consistent with the general history of science, occasional periods of significant interaction have resulted in large gains for both operational application and theory.

Nevertheless, weather forecasting remains a process that is neither wholly science nor wholly art. It is known that persons with little or no formal training can develop considerable forecasting skill. For example, farmers often are quite capable of making their own short-range forecasts of those meteorological factors that directly influence their livelihood, and a similar statement can be made about pilots, fishermen, mountain climbers, etc. Weather phenomena, often of a complex nature, have a direct impact on the safety and/or economic stability of such persons. Further, it has been documented recently (Gedzelman, 1978; Sanders, 1973) that scores in a forecasting contest are not clearly related to one's level of formal meteorological education.

Is it reasonable, then, to propose that forecasting is such an arcane process that training in meteorology is useless and not worthy of any substantial commitment? In order to consider this question, we propose to review some salient events and documents of the past and to examine the current state of forecaster training. Some suggestions are made in light of that analysis.

2. Historical perspectives

The foundations of modern meteorology generally are recognized to lie in the pioneering efforts of the so-called Bergen School. In the period from 1918 to 1930, this group developed the techniques of air mass analysis and the polar front theory, both of which have endured to this day. Bergeron (1959) has documented much of the history of modern meteorology, and has stated that progress in meteorology has resulted from the improvement of three factors: observations, tools, and models. Whenever all three factors are advancing simultaneously, the most rapid and enduring progress is made. Bergeron also described the next major focal point for advances in weather forecasting, the so-called Chicago School. This era, extending roughly from 1939 to 1948, laid the conceptual basis for quasi-geostrophic theory and numerical weather prediction, which began shortly thereafter.

Bergeron concluded that the lack of contact between theory and empiricism is the major factor blocking progress. The various "schools" he described made their contributions precisely because at those times and in those places the interaction and mutual respect between theoreticians and forecast-

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ers was substantial. He finished his analysis on an interesting note:

> Moreover, Man is after all a lazy creature. Thanks to these innovations Weather Service may become more and more mechanized, i.e. convenient to handle. We would not be human if we could resist this temptation. And why should we? In fact, it is there to be yielded to, provided that we utilize the new O[bservations], T[ools], M[odels] for all that they can give, without giving up or forgetting to use older methods for what they can give—things that may after all lie outside the scope of the newest facilities.

Additional insight into past views of the problem can be found in the 1953 Advisory Committee on Weather Services's report (George *et al.*, 1953), written as the prospect of numerical weather analysis and prediction was just beginning to excite those involved in operational forecasting. This committee saw one of the functions of the "National Weather Service"[2] to be "to promote and foster research in meteorology by the use of private and governmental research facilities and to support and encourage the dissemination of the results of such research." The committee touched on a wide variety of topics, including the statement that "We view with considerable concern the steady whittling away of the observation network. . . ."[3] They further commented that:

> The Committee is keenly aware of the many difficulties and problems which have beset the Weather Bureau during the last two decades. Over and above the routine difficulties experienced in the administration of Civil Service procedures by all government agencies, the Weather Bureau has had to adjust its course to conform to an extremely rapid growth in the science of meteorology, as well as the emergence of a private practice in meteorology. Due to these unusually rapid developments the Weather Bureau has had to do its best to train the existing personnel and at the same time recruit new personnel [who have] received formal training in the universities. This change has created a certain amount of personnel difficulties and has made it hard for them to develop the scientific stature which the organization should have.

About the same time as this committee was making its report, Neiburger (1953) commented on formal university training. Specifically, Neiburger was concerned with an apparent dilemma: if synoptic meteorology is ". . . merely [an] illustration and application of the principles of dynamic meteorology, . . . [it is] thus no longer a subject in its own right." On the other hand, if the universities are to yield to the ". . . pressure of the student's desires for training in the phases of the subject which they visualize as fitting them for a job (as a weather forecaster) . . .", then there is a need for more, not less, synoptic meteorology. Neiburger resolved the issue by suggesting a balance:

> To the present author it seems that both the broad educational objectives and the practical issues involved require an intermediate procedure. The methods and subject matter of synoptic meteorology are sufficiently extensive and advanced to be deserving of separate and comprehensive treatment, but the laboratory work associated with the courses should not be permitted to dominate the students' attention nor to degenerate into repetitious practicing of routine procedures.

However, his analysis indicated that the realization of that ideal in the universities was (in 1953) far from complete:

> In the dynamics courses we proceed as far as we can toward the real phenomena, but so far unfortunately we can attain only skeletal idealizations at best. In the synoptic courses we are frequently similarly blocked from getting back to first principles, but having dealt from the start with the real phenomena, we have information, however limited, which is of immediate practical use. Unquestionably, the topics of classification, explanation, and development of forecasting methods require a synoptic approach as well as the dynamic one.

3. Current state

Considerable debate continues over the state of weather forecasting in the United States. Ramage (1976, 1978) maintains that the quality of weather forecasts has not improved substantially since the inception of numerical weather prediction. He has detailed several reasons for this and has proposed an alternative (Ramage, 1978):

> We should contemplate a drastic restructuring of our public weather service to capitalize on local skills and talents, to ensure local accountability, and to reflect local priorities. It would be a partnership between NWS [National Weather Service], NESS [National Earth Satellite Service], and NCC [National Climatic Center] at the federal level and universities and industrial meteorologists at the local level.

Ramage has echoed the recommendations of the committee report (George *et al.*, 1953) published 25 years earlier. That is, Ramage and the committee have identified the need for a cooperative program among all elements, public and private, of our profession in order to advance our understanding and improve forecast services.

In general, communication and interaction between academicians and forecasters have probably decreased, despite continuing statements about the need to enhance them. In a recent panel discussion (Golden *et al.*, 1978) on short-range weather forecasting, a basic element in the problem was given substantial attention. The issue was what constitutes

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[2] At the time, it was named the "Weather Bureau," so this was a good forecast.

[3] In 1953 upper-level wind observations were taken four times daily at 130 rawinsonde sites over North America and at 195 United States pilot balloon stations, with complete soundings taken twice per day at the rawinsonde sites. Currently, we have twice-daily rawinsondes at about 110 sites over North America and pilot balloon soundings are no longer available!

the appropriate "man-machine mix," which Droessler (1980) suggests ". . . is probably the principal issue of today . . . ." The most obvious "machine" in use within the forecast arena is the computer model-produced guidance forecast. Other "machines" include remote sensors (radar and satellites), which, while being relatively "old" technological tools, are still poorly understood and utilized in the operational environment (e.g., Lemon, 1979). Nevertheless, computer model guidance generally is seen as the main problem, since, in the words of Murphy (Golden *et al.,* 1978):

> The current system, as it has evolved, makes it difficult if not impossible for the forecaster to assimilate and weight the available guidance information properly (particularly the guidance forecasts) and discourages him from using his training and experience to depart from this guidance.

This situation has led directly to the "meteorological cancer" described by Snellman (1977), whereby:

> . . . today's forecaster can, if he chooses, and many do, come to work, accept Numerical Weather Prognoses (NWP) and [Model Output Statistics] MOS guidance, put this into words, and go home. Not once does he have to use his meteorological knowledge and experience. This type of practice is taking place more and more across the United States, and it will be made easier to do with Automation of Field Operations and Services (AFOS). . . .

It certainly can be argued that meteorological cancer is largely a motivation problem. However, in speaking of his own experience as a Meteorologist-in-Charge (MIC) of a forecast office, Augulis (1978) felt that young forecasters are "short on experience but long on job motivation and enthusiasm." In his view:

> With little analytic and diagnostic experience, it is only natural that he accept the centrally prepared product more often than not. . . . When a new forecaster comes on duty the emphasis on training too often is making a station routine and forecast deadline. When the person is able to attain this goal, the training aspect is de-emphasized. . . . All too often the MIC and PA [Principal Assistant] stay in the background and do not give the technical leadership they should.

In order to provide technical leadership, there must exist an enthusiastic local management staff that is well versed in both theoretical and operational environments. As Augulis stated:

> Some general guidelines might come from NWSH [National Weather Service Headquarters] and the Regional Office, but it is up to each MIC to develop a basic structured approach to the forecast problem in his area of responsibilities.

It is probably fair to assert that the ideal balance of theoretical and operational expertise rarely is achieved at the local forecast office level.

4. Discussion

In such an environment, it is not difficult to foresee an erosion of whatever skills the forecaster had originally. At no time in the past has the need for expanded contact between theorists and practitioners been so important. The National Weather Association has arisen, in part, as a protest because the research community, the theoretical forecast modelers, and, regrettably, the AMS did not seem to be very interested in addressing forecasting *per se.* Many forecasters feel left out of their own field, and that their skills and talents are regarded as somehow inferior and less worthwhile than those of the basic researchers. The issues of the "man-machine mix" and "meteorological cancer" merely reflect the larger conflict inherent in our profession's schism.

Since many operational meteorologists have not been adequately trained in the basic physical concepts that are available today, it seems unlikely that new concepts can be transferred very easily to the forecast arena in the future. Forecasters are not generally trained or encouraged to read the current meteorological literature, so typically they can't even try to ferret out those articles that actually have a bearing on their job. Rotating shift work makes it difficult for forecasters to participate actively in any but the most brief of training programs, much less maintain currency in their profession. (Having experienced the rigors of shift work, we can only admire those rare individuals who can conduct applied research and/or stay up-to-date under the handicap of rotating shifts.) Many have dropped out of the AMS, so they will probably continue to fall farther and farther behind the researcher's level of understanding.

At the universities, the student seeking a career in forecasting generally is regarded as one who should terminate his or her education at the bachelor's degree level. In effect, this is an admission by the universities that they have nothing more to offer to a prospective forecaster beyond the B.S. degree. For these students, the topics of dynamic meteorology are something to be endured until the end of the degree program. Therefore, such a student becomes a forecaster who is convinced that dynamics has nothing to offer, and is unwilling and unable to evaluate research results in light of their applicability to "real world" problems. The all too common separation of synoptics from dynamics does not allow the undergraduate student an opportunity to understand and appreciate the profound connections between the two. As Neiburger indicated, this may result from a lack of academic interest and expertise in operational problems and their connections to problems of basic research.

Most existing training programs within the operational community currently are directed toward nondegreed technicians, rather than "meteorologists" (i.e., those with a B.S. degree). However, these programs generally are seriously outdated (Lemon, 1979). What little training that is available to meteorologist/forecasters generally is outdated also, often consisting of "cookbook" exercises that have only incidental basis in physical principles. Neither is there a program that allows all meteorologist/forecasters to participate in the process of continuing professional education. Of course, there are correspondence courses from various sources, but these share the same difficulties already described. The medium of videotape is being developed for forecaster training, but it is hard to envision a videotape program capable of giving the broad-based training required.

In discussing this issue, Chappell (Golden *et al.*, 1978) has proposed that:

> The educational requirements for a weather forecaster should be raised. As a minimum, he should have a master's degree in meteorology or atmospheric science, preferably more. He should be carefully prepared for the job through appropriate screening, training, and experience. His name should appear on every forecast and warning that leaves the office and, like a doctor, he should be held accountable by the public for his work.

Chappell's analogy to the medical profession is worth some examination. Although the analogy is not entirely fair, the medical profession does indeed contain many features that we feel would be desirable in meteorology. In medicine virtually no "field practitioner" is without a high-level degree. During the academic part of their education, medical doctors are required to train and perform in the actual working environment. Further, much research in medicine is accomplished by those who are involved actively on the operational level. Standards of performance are set and vigorously enforced. Continuing postdoctoral education is actively encouraged, if not required. Structured approaches to operational problems are mandatory and are the subjects of continuing reevaluation, research, and revision. Perhaps of greatest relevance here is the notion that in medicine an operationally oriented person is held in high professional esteem and is training actively throughout his or her professional career.

If we have made a fair statement of things as they really are, then what can we conclude about the desirability of educating our forecasters? We have seen that both forecasting and basic research have made substantial gains when a mutual understanding has existed between forecasters and researchers. Some of the most important contributors to our profession have been quoted in support of this idea. It appears that training has received relatively little attention because it has been assumed that forecasters are trained adequately in the universities. However, it seems that universities are not providing the necessary linkage between theory and practice. We are inclined to believe that the failure to improve weather forecasting skill so that it is commensurate with our improved dynamical understanding is related largely to the absence of that linkage, via inadequate training. Thus, there ought to be no doubt that a properly educated forecaster (i.e., one receiving a balanced educational program of theory and operational experience) is bound to be more effective than an uneducated one, all other factors being equal (which, of course, they never are).

On the basis of some of the material quoted here, it appears that the burden for the training failures lies with the universities. However, we feel that it is not plausible to put all the responsibility on any one side of the issue. What does seem clear is that Bergeron's, and the others', statements remain as true today as they were when they were made. If real and enduring progress is to be made, it must involve both the theoretical and empirical sides of our profession. This split, which meteorology shares with many professions, must be minimized by some means if forecasters are to be brought up-to-date and given the sort of basic physical understanding that permits both forecasting and research advances to be made.

Merely bringing the forecast community up-to-date is not the entire issue. We cannot afford to omit the process of continuing forecaster education. No matter how thoroughly we educate the operational community about today's concepts, in 10 years we will have to do it all over again and once again overcome substantial inertia in the process. Whatever solutions we may propose should be lasting ones operating on an ongoing basis. Along the way, we are bound to inject new ideas and new enthusiasms into the research side of our profession, thereby enriching it as well.

Further, it is not enough to call for training without specifying where the emphasis should be. We need a quantitative estimate of where the state of the art in forecasting is in order to develop applied research programs and to determine the areas in which the training is most needed. This estimate should involve both operational and research personnel in a combined effort to determine quantitatively where our forecast strengths and weaknesses lie. These are basic questions that will need answers in a continuing program.

Although our emphasis in this article is on programs for the operational side, we see the need for expanded programs of applied research to relate the concepts developed in basic research facilities to the "real world." The present situation permits many research meteorologists to pursue an entire career without ever having to analyze a real weather map! It is not hard to see how such a condition hinders communication between theorists and forecasters. If most research meteorologists currently are not interested in forecast problems, the history of science suggests that they should consider developing the interest.

5. Suggestions

If we are to provide continuing education, then we can reject the training document approach as the sole means of this education, since any written document tends to reflect the author's biases. Also, any publication necessarily reveals the state of the art only as seen by the author prior to the actual date of publication and certainly well before its use in training. Although training guides have considerable value in providing material for study, it should be obvious that they cannot stand alone. This is especially pertinent when shift work does not encourage a thorough study of the documents. No doubt we could propose a scheme to send all forecasters back to some academic program, but there are two problems with that suggestion. First, it is obviously impractical. Second, we have indicated already that the universities still, in general, do not have advanced programs geared toward the synthesis of dynamics and synoptics. If a change in the current situation is to have a reasonable chance of being accomplished, we feel that there must be a change in the forecaster training structures.

One option is to establish some sort of "Forecaster's Postgraduate School," in which advanced study programs would be offered, some perhaps leading to advanced degrees or certification of some sort. Naturally, the faculty's level of professionalism would have to be equivalent to a university's, but be combined with demonstrated operational expertise. While such an approach is attractive, it probably represents an unrealistic commitment level for funding and staffing. Also, it is hard to see how NWS forecasters could be spared for the lengthy study period that would be necessary, and their travel expenses would be substantial.

Another alternative is to enhance the program of the NWS Technical Training Center (NWSTTC). The current pay scale at the NWSTTC could be increased as an incentive to attract high-professional-level individuals from the research and operational arenas. This is desirable in any event, but to attain an appropriate level of professionalism this alternative basically would consist only of the postgraduate school described previously. While an upgrading of NWSTTC is long overdue, it can represent only part of any overall solution.

We recognize that there are university faculty members who already have demonstrated a commitment to giving students a unified view of theory and empiricism. Thus, another possible course of action would be to foster further contact with these educators through "short courses" at their universities and through a program of sabbatical leaves so that these faculty members could visit operational centers and provide extended seminars. A related concept would provide a "traveling workshop" with a mixture of academic, research, and operational meteorologists drawn from those with demonstrated expertise in the interface between theory and operations.

Yet another possibility would be the establishment of a "laboratory" for forecasting within the structure of the NOAA Environmental Research Laboratories (ERL). Presumably, such a group would be expected to have substantial contact with field forecasters. Indeed, ERL's PROFS (Prototype Regional Observing and Forecasting Service) may be an initial step in this direction (Beran and Little, 1979). Although it is likely that a major area of concern would be mesoscale convective phenomena, the subjects under study should by no means be limited to that; that is, a significant effort could be devoted profitably to winter weather phenomena, aviation weather forecasting problems (including turbulence), or the training problem itself (including strategies for technology transfer). An ERL thrust into forecasting could be an important contact point for communication between forecasters and researchers. By creating a "Cooperative Institute" (akin to the Cooperative Institute for Research in Environmental Sciences in Boulder, Colo.; or the Cooperative Institute for Mesoscale Meteorological Studies in Norman, Okla.), an involved university could provide academic input and develop a curriculum in advanced forecasting methods for those with or without advanced degrees.

Further, by the creation of additional Techniques Development Units (in the general pattern of the National Severe Storms Forecast Center's (NSSFC) or the National Hurricane Center's) in local forecast centers, interested and qualified personnel from the research and operational camps could function to infuse research results directly into operations. The lessons of the past suggest that this is profitable for both sides, and we feel that the NSSFC unit has managed to operate successfully "on the interface." Since the members of such units are expected to perform operational duties as well as to accomplish applied research, a unique and valuable dual perspective is obtained.

6. A call for action

As Ramage (1978) says, "There are no villains." The problem continues, but not because of the failings of any one person or any small group of persons. Nevertheless, the paths of researchers and forecasters are still widely divergent, a condition that has developed in spite of many written and spoken warnings in the past and the continuing expression of concern by seemingly isolated spokesmen on either side of the research/operations fence. How can this be? It seems to result from the lack of a firm commitment to establish structures in which the necessary cross-fertilization can occur. Without such structures, it seems clear that no substantial interaction can develop spontaneously. The NWS is understaffed and underfunded to accomplish even the current set of tasks at the current level of skill. Most universities and research facilities have difficulty maintaining core programs of basic research and are not really familiar with, or interested in, "real-world" forecast problems. Private meteorology does not have the resources or the motivation to pursue lines of research that would be beneficial to all segments of our profession. The situation is exacerbated by the reality that research and forecast meteorologists literally do not speak the same language—the formalisms of dynamic meteorology are too often virtually unknown at the operational level, and forecasters have their own jargon (Augulis, 1978).

In light of the historical review we have outlined, we are concerned that this article will not elicit any response and that no real activity will result. First and foremost, we urge our readers to respond in *some* way, positive or negative. Have we stated the situation fairly? What other suggestions for altering the situation can be explored? Is the profession in general agreement that a split exists that needs to be healed?

Basically, we wish to motivate to action those who want to reestablish the ties that have existed in the past between theorists and practitioners. Action and commitment are needed, rather than lip service, but in order to take action, we need to identify at least a core group of persons committed to some positive plan. In a sense, we are asking, "Is there anyone out there who shares our concerns and wants to do something to alter the situation?" If so, we urge such persons to respond to this article.

We have made some long-range suggestions for improving forecaster training and stimulating exchange between the two aspects of our profession. No doubt other possibilities exist. We have already indicated the need for some sort of working group before steps can be taken to implement *any* plan. This group could be drawn from existing structures (AMS, the University Corporation for Atmospheric Research (UCAR), the National Academy of Sciences (NAS), etc.) and should be prepared to explore possible strategies and to establish some priorities. Private meteorologists and military forecast organizations will surely see the advantages of enhanced theory/operations interaction, and they should be urged to participate in planning a program to enhance such interaction.

Given the current economic woes, it behooves us to consider ways in which our profession can perform more effectively. Indeed, the relevance of some of our activities already has been questioned. During periods of fiscal austerity, it should be self-evident that it will be more difficult to support "pure" research unless it can be related to more practical problems. Therefore, we should take this economic situation as an opportunity to reunite the diverging elements of our profession. In fact, the history of science and the advice of our own pioneers (like Bergeron) suggest that this is the most productive strategy.

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U.S. scientific cooperation with the Federal Republic of Germany

U.S. investigators may request supplemental funding from the National Science Foundation (NSF) to expand domestic research into cooperative projects with scientists of the Federal Republic of Germany, who are supported by the German Research Association, the Max Planck Society, or the Fraunhofer Society. A German counterpart proposal must be submitted to one of these three organizations.

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Nuclear and Chemical Waste Management — new journal

Nuclear and Chemical Waste Management, an "international journal of hazardous waste technology," began publication in 1980. The quarterly publication is intended to serve as a forum for the presentation of information encompassing the entire field of hazardous waste, including high- and low-level radioactive waste, chemical waste, and transuranic waste. Among areas of concern for the journal are sources and production rate of hazardous waste; management of gaseous, liquid, and solid waste; technology for detoxification of hazardous waste; laws, regulations, and norms; and information contributing to improvement of waste management technology and/or protection of environment from deleterious effects of hazardous waste. The journal, which serves a multidisciplinary audience, is not aimed primarily at the meteorologist. However, effective nuclear and chemical waste management necessarily must involve the atmospheric sciences in some phases, and so the journal may be of interest to some BULLETIN readers.

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