NWS-CR-TA-90-37

CRH SSD
NOVEMBER 1990

CENTRAL REGION TECHNICAL ATTACHMENT 90-37

CREATING INSTANT EXPERIENCE...OR, HOW TO MAKE A FORECAST STUDY[1]

Major Gregory D. Nastrom
U.S. Air Force, Air Weather Service
Scott AFB, Illinois

1. Introduction

So you're thinking of doing a forecast study? That's exciting, because a forecast study is the way to increase your knowledge of meteorology; on your own, just you and the atmosphere! This will be original, new knowledge--your personal contribution--not just some facts you read in a book or heard from someone else. What's more, when you're done you'll be sure of what you learned because you can demonstrate it with maps or charts from the data. Last, but not least, you'll be able to share your new knowledge with others by writing it down; this is the way the field of meteorology move forward, by people adding new knowledge to the reference base so that those who come later can use it. As one famous scientist said, "If I have seen farther than others, it is because I stood on the shoulders of giants." Besides helping the person doing a study organize their thoughts, forecast studies provide a means of passing on instant experience to others. Each of us has the chance to provide "shoulders" for others to stand on. The purpose of this memo is to describe the steps in a forecast study that help lead to a successful completion.

Maybe you're not planning a "giant" study, maybe all you had in mind was a review of an exceptionally successful (or exceptionally bad) forecast. That's okay, the same ideas apply, regardless of the class of study you make. In fact, the first thing you have to do is decide what class of forecast study you're going to make. This will depend on three things: your motivation, your objectives, and the time you have available.

Forecast studies are usually grouped into three categories:

a. Forecast review: Post-analysis of a particular forecast to see what went right (or wrong) and why.

b. Case study: This is an in-depth review of a classic situation representing a general forecast problem for your location.

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[1] *This is a slightly edited version of USAF Air Weather Service Forecaster Memo AWS/FM-86-001, May 1986.*

c. Objective forecast study: A melding of data from a large number of cases, by applying statistical methods, to arrive at an objective procedure to forecast a variable or event from available data.

The category of study you undertake depends on your motivation (that is, why you're doing a study), and your objectives or goals. For example, if your goal is to get a handle on something to help forecast freezing rain (versus snow or plain rain), you probably need to do an objective forecast study. However, the motivation for this goal may arise from a forecast review you just completed (of a freezing rain episode) and in which you concluded that the "textbook" synoptic models just don't provide enough knowledge to forecast freezing rain at your location because of local effects. Further, to help decide which variables should be considered in the objective forecast study, you may want to do one or more detailed case studies of freezing rain episodes so that you know which variables appear most relevant. Clearly, the classes of forecast studies are not mutually exclusive, and one class may lead to another class. On the other hand, as the result of doing a case study or two, you may decide that the classical synoptic model is adequate, even at your location, and that you merely misunderstood how to apply it. In that case, you still need to write up your results for future reference so that you, or a future forecaster, clearly understand how to apply the classical model learned in school to this situation. Thus, one class of forecast study, if done properly, may short-circuit the need for another class of study. Finally, keep in mind that a properly completed forecast review or case study can be more valuable than a hastily done or incomplete objective forecast study, which is why you have to consider the amount of time available. The MIC/OIC or the Science Focal Point at the WSFO can help you decide how much time is available, and it is best for you to discuss your ideas and plans before going too far. You can also refer to A Guide for Operational Meteorological Research, available at each WSFO (National Weather Service, 1988).

The decision to make a study, and the steps followed in making one, are not arbitrary. There are time-tested procedures to follow which help to reap the greatest benefit with the least amount of effort. This does not mean work is not required, but rather that there will be less wasted effort if the proper steps are followed. These steps are outlined below and discussed in further detail.

2. Outline of the Steps to Follow in Developing a Forecast Study

Six steps are listed here, but we should note that the number of steps, their exact names, and event the exact order in which they are completed are not unique. For example, as your study progresses you may be able to cover one step very quickly, or you may spend so much time on different aspects of a single step that you would prefer to split it into two separate steps. Also, there is a certain amount of feedback between steps so they seem to proceed simultaneously (or, like the chicken and the egg, you really can't tell which one comes first). Also, don't be surprised if this list differs slightly from ones given by other authors (see, for example, Petterssen (1956) or National Weather Service (1988)). The important idea here is not the precise makeup of the list of steps, but rather the method of approach and logic that it represents. The

steps here represent what is called the scientific method, which has been found to be the best way of tackling a study, whether it's a forecast review, a case study, or an objective forecast study.

a. State the forecast problem in precise terms.

b. Do background research on the problem.

c. Propose a solution(s) to the problem.

d. Collect and analyze data.

e. Test solutions to the problem.

f. Present results in a simple manner.

Notice that collecting and analyzing data is the fourth step, not the first step of a forecast study! If you would have though data came first, then read on; you may save some work and a lot of time. Also, a couple of pointers on things to do that can save time and short-circuit misunderstandings should be noted: first, discuss your study with the MIC/OIC and/or WSFO Science Focal Point. There usually isn't time to study every interesting problem, and by checking you can be sure that your work is consistent with what has already been done. Second, keep a notebook or logbook to document your steps as you proceed with the study and to keep track of ideas for other studies, etc. More will be said about the logbook later.

3. Discussion of the Steps of a Forecast Study

a. State the forecast problem in precise terms. This may seem self-evident, but you'd be surprised how many studies are launched without a clear statement of the forecast problem. For example, instead of asking "Will there be fog in the morning?" try to ask "Can we forecast visibility below 1/4 mile at 0500-0900 due to radiation fog using data available at 1800 the previous day!" Notice the second question clearly defines the forecast variable (radiation fog, visibility below 1/4 mile), the forecast window (0500-0900), and the forecast preparation period (up to and including 1800). Don't worry if you have to change the statement after the study starts; this is part of the feedback process. In our example, it could turn out there is not enough data with visibility below 1/4 mile, but that there is plenty with visibility below 1/2 mile.

Of course, some meteorological principles depend on season, time-of-day, wind direction, etc. If possible, try to work such stratification into your question by using phrases like "during autumn." Otherwise, you'll have to be sure to look for possible stratifications during your analysis phase discussed later.

b. Do background research on the problem. Once you've formed your question, the first thing to do is find out if someone else has already answered it (or at least tackled the same question). If you're doing a case study or forecast review and find that others have looked at similar situations, you can add

a new dimension to your work by comparing the synoptic features, conclusions, etc., of their study and yours. If you're thinking of an objective forecast study and find someone tried one before but did not find a useful predictor, you can save a lot of time by reviewing their work--maybe new data or a new approach will lead to a very useful predictor. By the way, note that there is no such thing as an unsuccessful study, because even studies that don't find immediate application should be written up and filed for later reference so that others, perhaps using new insight, can stand on the shoulders of those who went before.

In-station or local reading files are obvious places to look for information. Other sources of information which may be available are a local university, old-timers on station, the Science Focal Point, and don't forget the Scientific Services Division (SSD) of your Region.

If all this check reveals that you've got a question that needs attention, the next part of your background research is to bone up on the meteorology of the question. For example, if your question has to do with snowfall, go back and review the material in your textbooks or meteorology courses on winter cyclones or upslope flow or whatever. With some handle on the principles of the meteorology involved, you're ready to move on to the next step.

c. Propose a solution to the problem. If you're making an objective forecast study, this step could also be called "selection of likely predictors;" more on that a little later. If you're making a forecast review or a case study, you might be tempted to skip this step; please don't! Even for the latter types of studies, it is important to go into the data with an idea in mind that you are trying to prove or disprove. For example, if you're making a case study of a heavy rain-flash flood event, your data (your hypothesis) might be something like "even though the morning sounding showed less than one inch of precipitable water over our area, strong advection increased this to over three inches by mid-afternoon." Having a hypothesis helps you organize your thoughts, and points the way for analyzing the data in a systematic manner.

Returning to the selection of likely predictors for an objective forecast study, Petterssen (1956) states "this is the most difficult part of the work and the results depend largely upon the choice." The predictors chosen should be known to have a physical coupling with the predictand (the variable to be predicted). For example, upwind dew point levels might be used in a study of radiation fog. However, other predictors might also be chosen, based on forecasting experience, for which the physical coupling is not well understood; i.e., position of the surface ridge, etc. This is where feedback between steps becomes very important: based on experience, a local rule-of-thumb, or a case study or two, you may suggest a predictor; but before completing an objective forecast study using that predictor, it is recommended that you first make a pilot study to test it. Based on the pilot study you may accept, revise, or reject that predictor.

The important point here is that the predictors should be chosen on the basis of physics or experience. For predictors based on experience, you might save some time and work by discussing them with your peers, and MIC/OIC and/or

WSFO Science Focal Point, even before making a pilot study. They may see some physical basis for your experience, and may have suggestions to help you revise or hone the predictor before you enter the data analysis phase.

d. Collect and analyze data. The hypothesis you formed, or predictors you selected, will dictate the type of data needed to complete the study. For a forecast review or a case study, all of the needed data are usually available in the station at the time of the event. Thus, the important feature for these studies is that you act quickly to save the data (maps, charts, bulletins, metsat data, etc.) for in-depth study later. Save the whole package! If you need other data, contact SSD.

Objective forecast studies, on the other hand, usually require larger quantities of data collected over a long period. An important point here is that you use enough data to ensure that your results are statistically significant. Also, to demonstrate the skill of your predictors; it will be necessary to save some of the data for independent tests of the predictors. Thus, depending on the frequency of occurrence, variability of attendant conditions, and the number of predictors used; it may not be practical to save and collect the required data locally. Historical data can be obtained through SSD.

Once the data are on hand, you're ready to begin the analysis phase. During the analysis, be ready to apply feedback; i.e., if your statement of the problem from the first step clearly needs modification, then modify it and document your change of approach in your logbook. If you notice patterns in the data that suggest another predictor should be added, then add it and document. Finally, don't get distracted by interesting features seen in the data which have no relation to the topic under study. If you have ideas for other studies, jot them down for later use but try to keep your focus on the question at hand.

Objective forecast studies use statistical tests of predictors. Important points to keep in mind are that the data used for the tests must be independent and they must be homogeneous; that is, they must represent the same conditions as the data used for the analysis phase. Don't mix apples and oranges! For example, it would make no sense to develop predictors for cases of radiation fog and then test them using cases of post-frontal fog.

f. Present results in a simple manner. This is the trip report for your excursion into the mysteries of the atmosphere. It will clearly state the conclusions reached for a forecast review or a case study, and will contain enough material (data, analysis) to support the conclusions, together with an introductory paragraph explaining what question you set out to answer.

The report for an objective forecast study will probably be in two parts. One part will be the working summary. It will contain a brief, concise statement of the forecast problem for which the study is designed; a step-by-step explanation of how to use the study, the charts and diagrams used by the study; and a brief statement of the skill level achieved by the study in the tests with independent data described earlier. If a useful forecast technique results from

your research, you should make sure it's simple to use, takes little time to apply, and is presented in a straight forward manner; e.g., a flow chart or menu.

The second part of the report will be a fairly thorough discussion of all the steps you went through while completing the study. It should contain enough detail that later forecasters can see how you did the study, why the study was begun, the questions asked, the predictors considered and why, the predictors selected, the data used, the working charts and diagrams (even those that didn't give encouraging results), and the steps of the tests with independent data. This part of the report is why it is essential that you keep a logbook of your activities. The main reason for the second part of the report is to show the road you followed on your quest so that those who follow you won't have to travel it again, and with your armchair travelogue to help them they will be able to spend their time attacking new questions. Careful, accurate documentation also lends credibility to the study. Finally, an objective forecast study is not cut into stone, but rather has to be a dynamic tool. Thus, it will always be in a state of verification, and as new data accumulate it may become clear that the study can be improved by fine-tuning a predictor, or adding a new predictor, etc. By having your notes, a later forecaster will be able to work with the study as time goes on; always keeping it up-to-date and useful.

The physical format used in writing your report should follow closely that used in the American Meteorological Society (AMS) journals from introduction to references. This ensures not only that the paper is well organized, structured, and referenced, but it is also in the proper form in case you desire to submit it for a more formal review by your fellow scientists.

4. Summary

Forecast studies provide a means to organize, demonstrate, and preserve our experience. They help the person making the study because he/she can prove to himself/herself that patterns and signatures in the atmosphere noticed by experience are real. Perhaps more important, forecast studies are a way to pass along "instant experience" to other forecasters new to the station.

There are three general categories of forecast studies: the forecast review, the case study, and the objective forecast study. Each category serves a different purpose, and the category selected depends on your motivation, objectives, and the time available. The basic steps followed while completing a study are the same regardless of the category selected and represent the scientific method. This has been found to be the most efficient approach for effectively completing a study. When these steps are followed, the final product is sure to be significant (even if it's a negative result) and will be produced with minimum effort and frustration.

Although a forecast study may take time and effort, it can be an adventure into the exciting world of the unknown; a chance for you to create new knowledge of the atmosphere. In brief: Try it, you'll like it!

5. References

National Weather Service, 1988: A Guide for Operational Meteorological Research, G. K. Grice and K. W. Howard, Eds.

Petterssen, S., 1956: Weather Analysis and Forecasting, Volume II, Chapter 27, Local Forecast Studies, Second Edition, McGraw-Hill, New York, NY.