Design and Test of a "Hands-On" Applied Climate Course in an Undergraduate Meteorology Program

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ABSTRACT

Job opportunities for undergraduate meteorology students are decreasing. An innovative course in applied climatology has been designed and tested to help prepare such students for the career options developing in the private sector. Students are trained to use their meteorological knowledge and analytical skills to work interactively with weather-sensitive users in utilities, agribusinesses, water-resource agencies, recreation firms, and transportation companies. The students develop and test climate relationship-decision models in a real-world environment for these organizations. The models they develop bridge existing information "gaps" between climatologists and weather-sensitive managers who 1) do not understand climate information, and/or 2) do not know how to apply it to their environmental or economic decisions. As a result, students receive applied research experience and important "education-to-career" opportunities; that is, students can apply what is learned through direct and often beneficial interactions with decision makers. These efforts address problems similar to those they likely will encounter after employment. Other long-term objectives of this course are to develop a more effective information flow between climatologists and weather-sensitive users and to assist climatologists by identifying the types of needs for climate information.

1. Introduction

Each year in the United States approximately 500 students complete an undergraduate degree in meteorology (AMS and UCAR 1992). The meteorology program at Northern Illinois University (NIU) graduates between 10 and 15 students a year. In the past, these students have found employment in one of many career paths or gone on to graduate school. Those NIU graduates who have found jobs where they apply their meteorology education have typically been involved with short-term weather forecasting, that is, with the National Weather Service (NWS), private consulting firms, a branch of the armed services, or in some aspect of the media (newspapers, radio, and television).

From the late 1980s through the mid-1990s, the single largest employer of NIU students was the NWS. However, now that the "modernization" and restructuring process is nearing completion, students are finding that entry to this career path has been effectively closed (Smith and Snow 1997). This is not the first time there has been a freeze on NWS hiring; however, because those who were brought in to "spin-up" new NWS offices and to replace retiring forecasters have generally been new graduates, it means that the median age of the NWS work force has lowered. Thus, it may be 20 years or more before a significant number of these new employees retire and are replaced. How can atmospheric scientists tell students and their parents that they should invest in a 4-year education (now costing approximately $30,000 at NIU) to be trained in meteorology when there is a slim chance of an NWS job opportunity existing after they have completed their education?

Does this decreased demand for meteorologists in the NWS indicate a need to reduce the number of U.S. meteorology programs? Should atmospheric scientists and educators point high school students interested in meteorology toward different fields? The answer should be "no" to both questions, as the atmospheric sciences still have many research questions yet to be answered. However, the research career path, typically...
through a Ph.D., is not meant for everyone, and the situation leaves many educators with a dilemma.

Given these concerns, it appears that atmospheric scientists should consider not only educating their students in the important physical processes and concepts associated with meteorology and climatology, but also providing educational experiences where students are taught how to apply knowledge of atmospheric sciences in fields other than forecasting (Croft and Binkley 1997; Smith and Snow 1997).

Several assessments of existing and potential uses of climate data, information, and forecasts have revealed that the weather-impacted decision makers were not effectively using weather–climate information or were using antiquated data (e.g., Changnon 1992; Sonka et al. 1992; Changnon et al. 1995). Potential users in areas such as agriculture, water resources, and power utilities often did not understand weather–climate information, how to get what they could use, or did not know how to integrate that information into their decisions and operational models (Brown et al. 1986; Glantz 1987; Brown and Murphy 1987). A key reason for the lack of usage cited in these assessments is the lack of models that can relate climate conditions and weather–climate forecasts quantitatively either to physical conditions (soil moisture, streamflow, crop yields, etc.) or to economic outcomes (sales, retention of seed surpluses, construction plans, advertising schedules, purchases, etc.). Historical climate information, often used in conjunction with quasi–real-time weather data, can provide a quantitative means to aid short- and long-term decisions. Decision makers in weather-sensitive entities not only require relevant climate information, but they also require interaction with those who understand the information and can interpret it, thus assisting in developing and implementing decision models.

One solution to these problems has been designing and implementing a new “education-to-career” opportunity that incorporates upper-level undergraduate students in an activity that combines applied research and education. They learn in the course how to examine and interpret climate data and information in trial efforts to solve existing economic and environmental issues for various weather-sensitive users. The idea of further developing applied research efforts that are specifically focused at examining and answering concerns of society have been described recently by Stokes (1995), Croft and Binkley (1997), and Pielke (1997). The aim is to better prepare B.S.-level students for careers in firms and government agencies.

This article describes how these needs and ideas were brought to actual practice, as part of an NSF CAREER grant, by developing an interactive research laboratory where students develop computer-based relationship models to assist public and private sector managers who make weather-sensitive computer-based relationship models to assist public and private sector managers who make weather-sensitive decisions (Fig. 1). Through frequent interactions (lines with arrows on figure) between climatologists, students, faculty, and users, these faculty-directed student projects are designed to bridge existing information “gaps.” These gaps are bridged between climatologists who develop and use climate information and forecasts, and weather-sensitive users who need help in understanding how to apply climate information to their decisions through interpreting and enhancing existing information for specific weather-related problems (Changnon et al. 1995). Furthermore, these projects will provide students and professional applied climatologists—meteorologists, located in academia and government agencies, with an excellent opportunity to see how organizations function, understand better the difficulties

![Fig. 1. A schematic illustrating how information can flow between applied climatologists–meteorologists and weather-sensitive users. The arrows represent paths of interactions between climatologists, students, faculty, and the users. The information “gap” is filled by the faculty-directed student research projects that interpret and enhance climate information for decision makers faced with a weather-related problem.](image-url)
that many groups have in incorporating climate information, and identify what types of models are necessary to help nonmeteorologists make timely and economic decisions.

2. Development of an applied climate course

Although approximately 30% of U.S. academic meteorology programs offer an applied climatology or applied meteorology course, most provide a textbook view of applied climate problems in a lecture setting (AMS and UCAR 1992). This generally provides the theoretical background for the students but generally does not incorporate instruction about online use of climate data and products. Further, students do not deal directly with potential weather-sensitive users of atmospheric information.

A new course has been developed for the Meteorology Program at NIU, “Applications in Climatology,” designed to aid students interested in working on applied problems. The objectives of this course are to: 1) develop an enriching educational environment that will interest students and provide them with the opportunities to learn about analyses in applied climatology, and 2) develop climate relationship models as joint endeavors with students and potential users, thus providing “job training” for students and eliciting user involvement in actual applications. Course prerequisites include senior standing in the meteorology program and successful completion of junior level climatology and statistics courses. The approach is designed to have students work in two- or three-person teams to simulate an employment situation where each individual on the team learns the importance of communication, shared responsibility, and trust if their project will provide useful results.

This course was first taught during the spring 1997 semester. Prior to the start of the course, the author identified potential weather-sensitive organizations, interviewed various managers in those sectors who needed weather-sensitive information (and models), and with the aid of these managers, developed a detailed problem description. These descriptions were the focus of the student teams’ projects. Although the outreach process was time consuming, it set the framework for developing the desired educational experience. Three team projects were undertaken: 1) developing a corn earworm prediction model with an agribusiness, 2) assessing spatial variability in temperature and precipitation for use in precision agriculture, and 3) developing peak electrical load forecast models with a regional utility.

3. Student research projects

a. Model to predict corn earworm outbreaks in sweet corn

Two students, working with managers in a regional agribusiness, examined weather conditions linked to the airborne infestation of corn earworms into sweet corn fields. Corn earworms can significantly reduce yields, but spraying insecticides at key periods can minimize losses. The hypothesis developed by the students, after discussions with a company expert, was that corn earworms were carried by the wind into local (northern Illinois) corn fields from areas south of the region on days late in the summer when the surface synoptic pattern was characterized by an area of high pressure east of Illinois and an advancing front to the west of Illinois. Surface weather characteristics associated with this synoptic pattern (i.e., air mass) included increasing temperatures and dewpoints, decreasing surface pressure, and wind directions from 135° to 225°. The students objectively tested this hypothesis (corn earworm forecast model) using available surface weather observations from nearby first-order weather stations. This analysis revealed that nearly 75% of all serious corn earworm events, when 25 or more corn earworms were detected in a field, began when two or more of these surface weather conditions were met between the day prior to the event and the day of the event. The strongest model relationships were found for the dewpoint and wind direction values. Results from this forecast model could help the agribusiness decision maker determine when to begin spraying insecticides to 1) reduce the number of corn earworms and 2) limit the duration of a particular infestation.

Interestingly, analysis revealed one of the reasons the model failed to predict corn earworm events in nearly 25% of the cases. Most of those events occurred after the front had arrived, when surface weather conditions were nearly opposite those hypothesized, that is, decreasing temperatures and dewpoints, increasing surface pressure, and winds from the north. These northerly events indicated that the corn earworms were migrating southward following atmospheric conditions in which they could survive. This finding further suggested that when predicting corn earworm infestations, this agribusiness needed to monitor where corn
earworms were located at any time and to consider the various conditions which would move them.

When used as a pest management tool, the final model will aid in forecasting changes in corn earworm populations and assist in dispersal monitoring. Through these advance warnings, the agribusiness can reduce costs associated with spraying when not needed and minimize losses to their sweet corn harvest each year by timely spraying as an infestation begins. The model was put to use in field tests in 1997.

b. Model to estimate critical weather conditions for use in precision agriculture

An agribusiness interested in providing information for use in precision agriculture agreed to have a team of students develop a model that could estimate daily weather conditions at farms. The team analyzed data on daily temperatures (maximum and minimum) and precipitation amounts for locations (farms) between existing cooperative weather stations to define how well values were estimated. Three Illinois Climate Network (ICN) automated weather stations were used as the "unobserved" farm sites, each located at various distances away from existing NWS stations, to examine estimated (interpolated) values versus the observed ICN station values.

Initially, all daily precipitation amounts for three NWS stations were ranked for 5 years and then the mean and median event frequency was determined for each of five different precipitation ranges (0.01–0.25, 0.26–0.50, 0.51–1.00, 1.01–2.00, and > 2.00 in.). This analysis indicated that, depending on station and season, between 70% and 85% of all precipitation events produced ≤ 0.50 in. This indicated that correct prediction of smaller events within the NWS station grid was of greatest importance.

Two statistical methods—inverse distance weighting and nearest neighbor—were applied to determine the interpolated values for all rain events. To assess the interpolation accuracy, the team used the root mean square error (rmse), coefficient of determination, and absolute errors determined for the five different precipitation ranges. Results based on rmse indicated that, when interpolating a precipitation event, the error can be quite large (between 0.17 and 0.42 in. for events in the 0.01–0.50-in. precipitation range), suggesting that interpolation from NWS stations to the ICN locations (i.e., predicted farm) is not recommended. A partial explanation for the large rmse were differences in the observation times among the ICN and NWS stations and the knowledge that summer showers exhibit great spatial variability. However, when considering predicted minus observed absolute errors for the three ICN stations, between 67% and 83% of all differences were less than 0.10 in. Because the results based on absolute error tended to differ with those derived from interpolation methods, the team had concern about whether they had applied appropriate methods to address this problem. Since accuracy requirements vary depending on the application, the utility of these findings for use in crop modeling at the field level is for the user to decide.

During the 1997 summer, all three students involved with this project were hired by the agribusiness to establish and collect data from a dense network of rain gauges and automated weather stations (Fig. 2) to further examine precipitation and temperature variability at the field level in two northern Illinois areas. Their findings will assist the agribusiness in decisions related to monitoring surface climate parameters.

c. Model relating climate factors to peak electrical load

A midwestern utility asked three students to investigate the relationship between climate parameters and daily peak electrical loads. The utility manager involved with this project wanted a climate relationship decision model developed that could help him determine when his company may need to make spot purchases of electricity off the regional utility market, ranging from days to weeks in advance of a forecasted extreme high-heat period.

After obtaining both the hourly and daily electric load data from the utility and climate data from the
Midwestern Climate Center, the student team investigated the relationship between load and maximum temperature and dewpoint for each day from 1 June through 31 August. Cumulative frequency distributions or ogives were developed for daily maximum temperature and daily mean dewpoint for each summer day based on 30 years of climate data. The overall variability in these two climate parameters decreased from early June through early August before increasing again in late August. These graphs could be used by the utility manager to determine where in the distribution (above or below the average or median value) a given day’s forecasted maximum temperature and/or dewpoint would be located in relation to historical observations. This then could be used to help the utility manager estimate whether electric loads would be above or below average for a given day.

Using regression analysis, the daily peak electric load was then related to maximum temperature, dewpoint, and a “load” index (based on the combination of daily maximum temperature and mean dewpoint). Due to varying average temperatures over the summer (warmest in late July), peak electric load prediction models were developed for six 2-week periods during the summer. Because differences in peak electrical loads were found on weekend days and weekdays, these days were separated into two groups when developing the models. Results indicated that 1) maximum temperature was better correlated to peak electric loads than mean dewpoint; 2) the slope term of the “best fit” line changed dramatically throughout the summer (revealing that different regression models should be used in different periods); and 3) when used over the entire summer, the load index is the best predictor of peak electrical load. The team concluded that several factors hurt the model’s performance including a small sample size (only three summers of load data were available), shifting societal influences on daily peak electrical loads, and the electrical utility’s altering the load due to system capacity limitations. During the 1997 summer, the utility tested the climate information and models developed by the team and will compare results to those determined using previously developed techniques.

4. Summary

Career opportunities in atmospheric sciences have changed and will continue to change. Hence, it is critically important that educators in the atmospheric sciences examine and expand the ways to prepare undergraduate students in meteorology for new, nontraditional careers. Traditional educational approaches, which are rooted in lectures with limited student involvement with weather-sensitive issues, do not provide students with all the essential tools necessary for achieving successful careers in applied climatology–meteorology. To address these recent changes in employment opportunities and needs for interpreted climate information by various weather-sensitive users, NIU’s Meteorology Program developed a new course, “Applications in Climatology.” Undergraduate students, with the assistance of the faculty, develop climate relationship-decision models to address real problems faced by companies or agencies. In these models, climate information is examined, interpreted, enhanced, and used to examine environmental and economic issues.

The educational endeavors associated with such a course provide important technology transfer to government (those who develop climate information) and private sector partners (users). Furthermore, it provides students with a hands-on “education-to-career” opportunity where they can help public–private sector managers incorporate “enhanced” climate information into timely economic decisions. Also, applied climatologists–meteorologists in universities and government agencies should benefit because the projects will reveal new information about the types of climate information a variety of users require. Finally, this education plan has potential for transferability to other meteorology programs across the country.

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