A Forecasting/Nowcasting System for Remote Field Locations

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ABSTRACT

Vast quantities of frequently updated weather data for both forecasting and nowcasting are generally required in meteorological field programs. The continuing synthesis of this data to suit specific operations is best accomplished using computers. Recent advances in telecommunications and computer hardware have allowed improved assimilation and presentation of weather data at remote field sites at significantly reduced costs. This paper describes a forecasting/nowcasting system designed and assembled to support a weather modification field project in Illinois. With minor modifications, this system can be located anywhere that has access to electrical power and standard telephone lines. The use of new technology with on-site computer capabilities allows rapid generation of products specifically tailored to meet the requirements of individual field projects, both for forecasting the operations and nowcasting during operations.

1. Introduction

Meteorological field programs generally require the frequent acquisition and synthesis of vast quantities of weather data for forecasting and operational purposes. In the past, forecasting often relied solely on facsimile maps accompanied by hand plotted, analyzed, or raw teletype data. Examples include surface analyses and thermodynamic diagrams. Radar was the chief means of nowcasting, although hard copy satellite images were sometimes available in recent years. In some field programs, however, these are not sufficient nor timely. In a weather modification experiment, it is often necessary to anticipate where new cloud development will take place and to launch and guide aircraft to these locations while clouds are in their early stages of development. This requires rapid and frequent access to a variety of analyzed real-time meteorological data. For example, maps of moisture distribution and moisture and velocity convergence as well as remapped satellite imagery at half-hour or hour intervals are particularly valuable for operational decisions.

The synthesis of large amounts of meteorological data at a field location is best accomplished using computers. Some forecasting products can only be constructed using computers, either because of the high volume of data to be manipulated or the computational complexity in producing an analysis. Some examples are the display of digital satellite images and the computation of divergence fields. Recent advances in computer hardware have allowed improved assimilation and presentation of meteorological data at remote field sites at significantly reduced costs. Personal computers, high speed modems, high resolution color image display systems, and multicolor pen plotters have all undergone significant recent improvements. It is now possible to assemble, at relatively low cost, a portable forecasting/nowcasting system that meets the needs of the most demanding meteorological field programs.

This paper describes a forecasting/nowcasting system, which we assembled to support a weather modification program in Illinois (the Precipitation Augmentation for Crops Experiment or PACE; Changnon 1986). In addition we will discuss alternatives and refinements to our system which may prove helpful for application to different circumstances.

2. System overview

We developed a forecasting/nowcasting system to support an exploratory weather modification field program. The system was required to support three main functions: 1) forecasting, 2) nowcasting, and 3) severe weather monitoring. Early morning forecasts of the likelihood of convection during the afternoon and evening were used to plan operations. The forecasting system utilized facsimile maps, plotted soundings, sounding-derived static stability indices, one-dimensional cloud model predictions, and 4-km resolution satellite images of the central United States. Nowcasting of the time and location of cumulus development on time scales of 0–3 hours was used to direct aircraft to cloud areas during the afternoon and early evening. The nowcasting system utilized high resolution satellite im-

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ages of Illinois, radar displays, hourly weather observations, and hourly analyses of surface streamlines and divergence. Severe weather indicators were continuously monitored utilizing radar-derived parameters and National Weather Service (NWS) weather watches and warnings, to assure that dangerous systems would be avoided during the experiment. Figure 1 shows a block diagram of the system and is the basis for the discussions in the following sections.

3. Weather data acquisition and storage

A Zephyr system for receiving weather data via satellite was installed at the Water Survey Research Center (WSRC) in central Illinois. The system consisted of an ordinary satellite TV dish antenna and a Zephyr-supplied receiver/decoder. A variety of weather data services are available with this system including FAA604 data, NWS DIFAX, NAFAX, Domestic Data, International Data, and Public Products. We chose NAFAX, FAA604 and Public Products to meet the needs of the project.

The FAA604 and Public Products data were monitored and selectively stored by a VAX 11/750 computer at the WSRC. This choice was made, in part, to support post-experiment data requirements. A personal computer such as an IBM PC/AT with a hard disk could also be used for data acquisition and storage.

4. Weather data products

For forecasting purposes, data were analyzed and displayed in several ways. NAFAX maps were simply displayed on a facsimile machine. A leased telephone line connected the WSRC to the facsimile machine at the field program headquarters at the University of Illinois Willard Airport (approximately 6 km distant).

Sounding data were routinely plotted using a Hewlett-Packard 7475A multicolor pen plotter connected by an error-correcting modem to the WSRC VAX. Error-correcting modems are essential for remote plotting since any transmission error will render a plot useless. We used 1200 baud modems; however, new, low cost, 9600 baud modems would significantly improve plotter performance. Analyses of surface streamlines and divergence were plotted hourly. In addition, we had the capability to plot constant pressure upper air maps as a backup to the facsimile machine products.

A one-dimensional cloud model (Hirsch 1971) was modified to run on an IBM PC/AT and used each morning with the Peoria and Salem, Illinois soundings. The model was run for twelve cloud radii in 0.5 km steps from 0.5 to 6 km. Model-estimated cloud heights were used to indicate the likelihood of afternoon convection. Both seeded and nonseeded cases were simulated by altering the freezing temperatures for hydrometeors, and the difference in predicted cloud tops was used as an index of seedability.

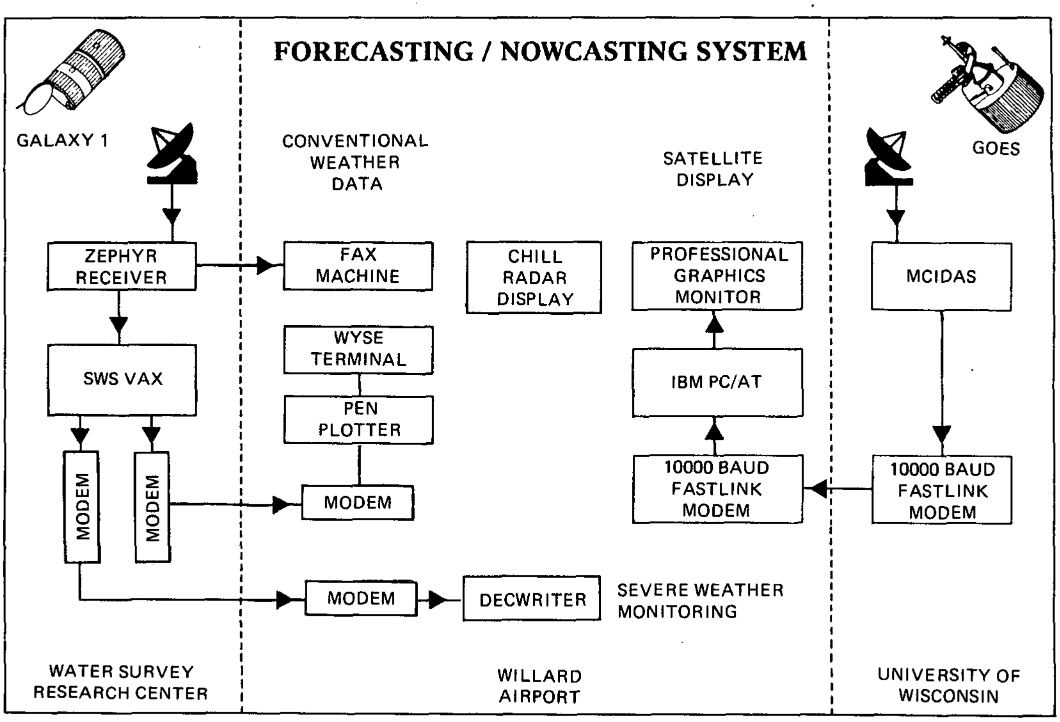

FIG. 1. Overview diagram of forecasting/nowcasting system.

A system was developed to use the FAA604 information as an on-line database which could be quickly searched by computer for pertinent information, such as hourly surface observations at a station, or precipitation occurrences in an area. All of the previous and current day's data were available on-line and older data was stored on tape.

Weather watches and warnings from the NWS Public Products line were continuously monitored by the WSRC VAX. Watches and warnings for Illinois and surrounding states were automatically transmitted and printed at field headquarters. In addition, an audible alarm was sounded for all weather warnings. On one occasion a tornado warning was issued during a seeding flight. Seeding operations were suspended within one minute of receipt of the warning. This system was also used to print current area weather forecasts from the Public Products line.

5. Satellite imagery

Hard copy GOES images have long been used to support meteorological field programs. A digital system allows the satellite images to be manipulated and displayed in a format which best meets the needs of a particular field program. For example, satellite images can be remapped into map projections which allow direct, undistorted comparison with other meteorological data. In addition, images can be color enhanced to emphasize details important to the project. Also, visible and infrared images can be combined in useful ways, or satellite images can be overlaid with conventional meteorological data. Using new technology and newly available services from the Space Science and Engineering Center of the University of Wisconsin, we developed an inexpensive, high quality system for the display of digital GOES images. Frequent, highly detailed cloud images were needed to direct aircraft operations involving sampling and modification of newly developing cumulus congestus clouds.

Satellite image data were obtained from the University of Wisconsin using a Fastlink modem from Digital Communications Associates. This modem provides error-free data transfer over ordinary dial-up voice-quality telephone lines at speeds up to 10 000 baud. It was installed in an IBM PC/AT equipped with a math coprocessor, a monochrome display, and an IBM Professional Graphics Controller (PGC) and Display. The PGC system has a resolution of 640 by 480 pixels and can display 256 simultaneous colors out of a palette of 4096 possible colors. The PGC employs a color look-up table to assign a color to a data value. This permits the instant enhancement of images.

GOES satellite data are ingested in real time by the McIdas computer system at the University of Wisconsin. For a small fee, images sectors were extracted, compressed, and placed in a file server system for access

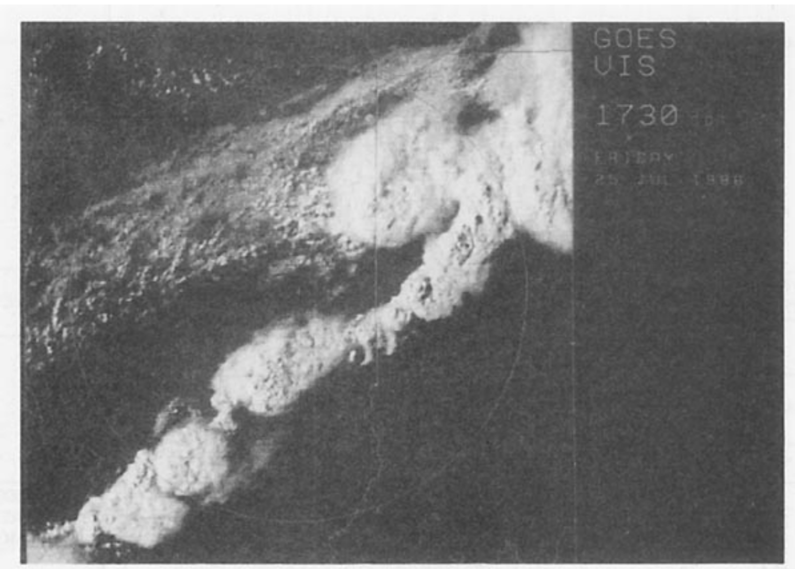

FIG. 2. Photograph of a personal computer display of a GOES image, which shows a squall line developing over Missouri, Illinois and Indiana. The image data has been remapped into an azimuthal-equidistant map projection. The circle shows the extent of the field research area and the plus sign at the center is located over operational headquarters at the University of Illinois Willard Airport. The actual screen image is brighter with a greater contrast range than can be shown in the photograph. The photograph was taken of the cloud images rendered using an enhanced contrast grey scale. The state outlines are red and the lettering is in green. Each pixel in the 640 by 480 image represents about 1 square km of surface area.

by dial-up telephone lines. We received a 1-km resolution visible image centered on Illinois each 30 min (Fig. 2), and a 4-km resolution visible image of the central United States each 2 h (See Kidder and Ochs 1987, for an example). Data at 1-km resolution were remapped into an azimuthal-equidistant map projection for undistorted comparison with radar displays. Approximately 7 min were necessary to acquire and display GOES images. As the image was being displayed, a histogram of the pixels was constructed. At the completion of the display process, the histogram could be used to enhance the image. The total elapsed time between the acquisition of the raw data by the University of Wisconsin and the display of the data at field project headquarters was less than 15 min.

A separate program was used to locate a marker at a selected range and azimuth from a reference point in a remapped image. Conversely, the range and azimuth of a point in the image could be determined by positioning a cross hair cursor. This program was also used to compensate for errors in the supplied GOES navigation data.

6. Radar display

The forecasting/nowcasting system was physically located in the User Van of the CHILL radar, a national research radar facility funded by the National Science Foundation. The CHILL color displays of both PPI and RHI rainfall patterns and cloud heights were available (Mueller and Silha 1978). These data were automatically recorded on a video tape recorded allowing review of echo development and motion for any time period. This greatly facilitated objective monitoring of cloud condition changes during convective rain periods. Direct comparisons of the radar echo conditions with satellite images and weather conditions as depicted by the system products was extremely useful in developing operational strategy.

7. Alternatives

If a VAX system is not available or located prohibitively far from a field headquarters to be of operational use, the satellite dish and Zephyr receiving system can be located at the remote field site. An IBM PC/AT-class personal computer is capable of monitoring and storing the incoming weather data as well as monitoring and printing severe weather bulletins. A second PC/AT-class computer could be networked with the first and used to produce all of the products discussed above. In this configuration, the multicolor pen plotter would be attached to the second PC/AT. This alternative has the advantage of allowing the forecasting system to be located anywhere that there is access to electrical power and standard telephone lines.

8. Summary and conclusions

We developed a high quality forecasting/nowcasting system for use in remote meteorological field operations. The system provides up-to-date integrated, analyzed products for forecasting, nowcasting and severe weather monitoring. It proved extremely useful and reliable in the 1986 PACE field program. Minor modifications would make the system independent of off-site computing capabilities. The use of new technology with on site computer capabilities allows forecasting/nowcasting products to be specifically tailored and coherently presented to meet the requirements of individual field projects.

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