The AWIPS Forecast Preparation System

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Preface

This is a concepts document. It describes how forecasts will be prepared in the AWIPS era, and how the NWS will develop a system to accomplish this. Not everything is explained in great detail. Many concepts described here may change throughout the development cycle.

The forecast preparation system described in this document is intended to become an integral part of AWIPS. Although it is logical that this work has come to be known as AFPS as a convenient means of identification, a successful realization of the intent stated above will result in its components fading from the user's view as distinct entities. A forecaster at his or her AWIPS workstation should not be required to enter and exit "forecast mode." There should be no buttons or menu items labelled "AFPS." Our use of AFPS herein is merely a convenience.

Boulder, Colorado
20 November 1992

Please direct comments or questions to Joseph S. Wakefield

Executive Summary

The National Weather Service (NWS) has been modernizing its observing systems, data processing and communications, and forecast tools and procedures for several years. This work will culminate in the mid-1990s in the deployment of the Advanced Weather Interactive Processing System (AWIPS).

A key element in the NWS modernization is the reorganization of forecast responsibility, both in geographic terms and in individual forecaster assignments. Part of the intraoffice job redistribution is predicated on the availability of new forecasting tools that will automate parts of the forecaster's job, providing increased opportunity for examining and forecasting the state of the atmosphere.

Described in this document is a system for forecast visualization and graphical editing, which will be developed within the NOAA Forecast Systems Laboratory (FSL). Also described are automated techniques for preparing text products, similar to those typed by today's forecasters. These product generators are being developed in the NWS Techniques Development Laboratory (TDL). Taken together, these parts constitute a system that will become an integral part of AWIPS approximately two years after initial system deployment. This system will be referred to in this document as AFPS.

At the heart of this system is a forecast database, containing weather elements that support forecast preparation, quality control, monitoring, and verification. Starting with first-guess fields "rolled over" from previous forecasts or based on numerical models, and drawing on their experience and training, forecasters will maintain this database, from which forecasts will be generated.

FSL will spend the initial two years in investigative work, examining techniques and building prototypes of the graphical depiction and editing system. Each prototype system will be tested by NWS forecasters, whose suggestions will be incorporated in the design of the next. During this period, TDL will continue developing product generators.

Once AWIPS equipment is delivered and familiarization is complete, a functional prototype system will be built to be used in Risk-Reduction (operational) tests at WFO Denver and a to-be-named marine WFO. Finally, an operations-ready system will be handed off to the NOAA Systems Program Office (SPO), for operational implementation by the AWIPS contractor.

Several significant assumptions have been made in planning this work, including the following:

- a close working relationship will be established between the FSL/TDL development team and the AWIPS contractor;
- software and documentation will be given to the AWIPS contractor for final integration;
- AWIPS configuration controls may need to be relaxed at the Risk-Reduction WFOs; and
- forecasters will forecast both general and service-specific weather elements, which will be kept as few in number as possible, consistent with final product quality.

1 The Project

1.1 Background

1.1.1 National Weather Service Modernization

For several years, the National Weather Service (NWS) has been engaged in activities directed toward modernizing and restructuring its operations. The activities include as major components the development of a new radar system (NEXRAD; the individual hardware units are known as WSR-88D), a new automated surface observing system (ASOS), and a new communications and forecaster workstation system, the Advanced Weather Interactive Processing System (AWIPS).

In order to make more effective use of the talents of its staff of professional meteorologists, the NWS plans to reorganize its operations. Currently, 52 Weather Service Forecast Offices (WSFOs) perform the bulk of the forecasting functions for statewide areas, and 180 Weather Service Offices (WSOs) and other small offices provide local adaptive forecasts. Both WSFOs and WSOs issue severe weather warnings, though many WSOs operate on a less-than-24-hour schedule and must be backed up by their parent WSFO at night.

In the restructured Weather Service, there will be 115 Weather Forecast Offices (WFOs), roughly collocated with WSR-88Ds. AWIPS will provide the communications and forecast support functions for these offices.

1.1.2 Acquisition of AWIPS

An AWIPS Requirements Task Team (ARTT) was formed in the early 1980s, comprising representatives of NWS administrative, development, and field offices, plus what is now the Forecast Systems Laboratory (FSL). The work of the ARTT was used to refine and validate AWIPS requirements prepared by the NWS Office of Meteorology. These requirements form the basis of the functional requirements included in the AWIPS Request for Proposal (RFP) and the AWIPS Development Phase contract.

The AWIPS requirements include several hydrometeorological techniques. The functions of these techniques range from decoding, analyzing, and displaying observations to formatting official forecasts. Detailed specifications for these techniques have been prepared by the NWS Techniques Development Laboratory (TDL), working closely with other NOAA elements, in the form of Technique Specification Packages (TSPs).

In preparation for the development and deployment of AWIPS, the NWS has asked FSL to participate in several risk reduction activities. The primary activity has been developing and testing a series of forecaster workstations at the Denver and Norman WSFOs. Currently, systems known as DARE (Denver AWIPS-90 Risk Reduction and Requirements Evaluation) in Denver and Pre-AWIPS in Norman are being used by the WSFO staffs. These systems have provided valuable insight into modernized operations; experience gained in Denver over the past five years has been used to refine the specifications that are being used by the AWIPS contractor.

The AWIPS Extended Definition Phase, wherein two competing contractors developed detailed plans and proposals for the system and forecaster workstations, has just been completed.

The AWIPS Development Phase contract was awarded to Planning and Research Corporation (PRC) on 29 December 1992. Contractor software is to be delivered in several "builds," with the first due approximately one and one-half years after contract award; the second, known as the First Article Capability (FAC), to be completed approximately two years after contract award; and the third, known as the Initial Deployment Baseline (IDB), scheduled for delivery three years after contract award.(1)

Of the many techniques included in the AWIPS requirements, several will not be developed by the AWIPS contractor but will be furnished by the government. The government will furnish software to the contractors in two Pre-Planned Product Improvements (P3I), which will take place after the IDB delivery. Two of the major software developments by the government are a grid-based forecast system and a full suite of product generators. Collectively, these constitute the AWIPS Forecast Preparation System.(2) The software and documentation described in this document will be delivered to the contractor as part of the second P3I.

1.2 Objective

The specific objective of this project is to develop a set of techniques that will allow the forecaster to efficiently issue a full suite of products. Improving the efficiency of the forecast generation process will permit forecasters to focus more on hydrometeorology and allow for more timely updates of forecast products to improve the quality of the forecasts. Further, the use of product generators will improve product consistency.

1.3 NWS Requirements and Assumptions

In Appendix A of the AWIPS System Requirements Specification, Volume I (part of the AWIPS-90 Request for Proposal, dated 22 August 1990), the grid-based forecast system is outlined as follows:

The WFO will maintain an up-to-date official set of digital forecasts, usually in gridded form, over this [750 kilometers by 750 kilometers] area. From this set of forecasts, routine forecast products shall be automatically formatted for release after forecaster review and, if necessary, modification. (RFP p. SRSI-A-10).

1.3.1 Requirements

The AWIPS IDB will include many of the basic hydrometeorological techniques required to support forecast operations at WFOs. These include improved observation decoders, improved quality control techniques, and improved analysis and display techniques. Graphical techniques will be used to enter and edit Watch/Warning/Advisory information and to format these products automatically. Also included will be interactive techniques to enter information for selected forecasts as well as techniques to format selected public, agricultural, and hydrologic observations and forecasts such as today's weather roundup. Techniques to assist in the preparation of additional products, including aviation, marine, and fire weather programs, will be deferred until the two P3I upgrades of AWIPS.

At the heart of these upgrades is a forecast database, containing gridded and geographically located weather elements that support forecast preparation, quality control, monitoring, and verification. Forecasters will maintain this database, starting with first-guess fields "rolled over" from previous forecasts or based on one or more centrally- or locally-run numerical or statistical models, and drawing on their experience and training. This project will develop prototype techniques to refine the concept and integrate the resulting system into the AWIPS workstation.

The NWS requires techniques to assist the forecaster in preparing most, if not all, routine forecasts as well as watches, warnings, and advisories. These techniques must facilitate the maintenance of a forecast database which supports all program areas. The database must have appropriate time resolution to allow the creation of all forecast and data products, it must contain quantitative and qualitative variables needed by the products, and it must support related programs such as forecast monitoring and verification.

The interactive techniques used by the forecaster must allow specification and control of the weather elements necessary to generate products and perform other forecast functions. The number of elements should be kept low to minimize the amount of information the forecaster must enter. Information should have to be entered or edited only once, not multiple times for each program area or forecast function. In addition to the general forecast, the techniques must permit the entry of local forecast information to define the effects of terrain and bodies of water on the forecasts.

AWIPS will automatically generate as many forecast and warning products as is reasonable and partially format those that will still require considerable manual entry. The system must be capable of producing text, graphics, and gridded forecast products, as well as broadcast-ready text products for NOAA Weather Radio (NWR). Taken as a whole, these techniques must streamline the forecast process when compared with today's operations, and they should improve the consistency of the forecasts. They should enhance interoffice coordination and optimize the use of central and local guidance. The system of preparing forecasts and generating products should allow for the rapid changes that are sure to take place in the future as additional high-resolution guidance information becomes available.

1.3.2 Basic Assumptions

Several basic but critical assumptions have been made in this plan. If any of these assumptions is incorrect or cannot be realized, the implementation schedule and/or the breadth of the final project will be affected.

1.3.2.1 Timely Delivery of AWIPS Equipment

To meet the goal of transferring forecast preparation software to the AWIPS contractor for integration into the system by the second P3I, both FSL and TDL must receive standard-configuration WFO AWIPS systems (Government Development Platforms, or GDPs) soon after contract award. The basic COTS (commercial off-the-shelf) hardware and software platform are scheduled to be received 12 weeks after contract award,(3) with FAC software and documentation delivered at the second scheduled software build (approximately two years after contract award).

1.3.2.2 AWIPS Contractor Assistance

During the Prototype Stage of FSL's development (see Chapter 9 for schedule information), we will be developing generic code using UNIX, C++, OI (Object Interface, a C++ Graphical User Interface library), and XGL (Sun's version of GL, an industry-standard graphics system incorporating parts of and compatible with X) on a network of Sun computers. Once AWIPS hardware and System Software are available, we will build our first integrated system on AWIPS.

Due to the short time allowed to build the first integrated operational prototype on AWIPS, we must have direct contact with the AWIPS contractor. Our schedule includes approximately one year between receipt of AWIPS System Software and the commencement of WFO risk-reduction activities. During this period, we will need to "come up to speed" on the internals of AWIPS and integrate perhaps 250,000 lines of code into AWIPS. FSL's Advanced Development Facility (ADF) group has been involved with AWIPS proposal evaluations, and will attend design reviews and study the internals of AWIPS. They will serve as consultants in this work. Direct contact with the AWIPS contractor will also be essential.

The assistance needed takes several forms. We would like to make a formal presentation and demonstration of our plans to the AWIPS contractor so they can gain an appreciation of the magnitude of the task. Once they are familiar with our goals, they can offer guidance on the preferred method of integrating this system into AWIPS. Once we start integrating code, the contractor could serve as a consultant. Ideally, we would work daily with the contractor and have one or two members of the contractor team on site in Boulder.

1.3.2.3 FSL/TDL Will Port to AWIPS

FSL will port the visualization and editing software into AWIPS for the Risk Reduction Stage tests. Our software will be visually integrated into AWIPS at this time but may not actually use all of the AWIPS System Software (i.e., it may use some parallel implementations of system functions). "Visually integrated" means that the user will not perceive any separation between our software and the rest of AWIPS, although the code will not be truly integrated. Actual integration will be performed by the AWIPS contractor, since modifications to the AWIPS System Software could be required.

TDL will port product generators to the AWIPS platform (GDP) to make them available during the Risk Reduction Stage tests. Some will be supplied to the AWIPS contractor for the IDB; others will be prepared for the first P3I.

1.3.2.4 Risk-Reduction WFOs are Unique Sites

We assume that the Risk-Reduction WFOs (Denver and a to-be-determined marine office) will be unique sites in that their AWIPS will not be under strict configuration management by the AWIPS contractor.

We will need to load our prototype software at these sites for risk reduction testing. While it is imperative to keep the contractor informed of configuration changes, we must not be restricted from making such changes. This issue will be coordinated with the AWIPS Program Office.

1.3.2.5 Static AWIPS Architecture

AFPS will eventually become an integrated part of AWIPS. It will utilize many of the sophisticated graphic processing features of the AWIPS hardware. As a result, we will be making design decisions based on information obtained from the AWIPS contractor. We assume that the basic hardware and software configuration of AWIPS, e.g., operating system, windowing system, graphical bit plane allocation, will remain static during our development.

1.3.2.6 Forecasters Will Work with Weather Elements

Forecasters will be asked to forecast general and service-specific weather elements, not all product parameters, once this system is deployed. General weather elements are a few observable items such as temperature, winds, and clouds, and service-specific elements include such fields as wave heights and dew intensity. In contrast, product-specific items such as heat index/wind chill, hours of sunshine, and maximum temperature may not need to be edited by the forecaster. To minimize forecaster workload, the number of edited weather elements must be kept to a minimum.

1.3.2.7 Techniques Not Designed for RFCs and NMC

We are developing a software package to meet the needs of the WFO forecaster to produce routine forecast products. It is not intended to satisfy all interactive drawing requirements of River Forecast Centers (RFCs) or the National Meteorological Center (NMC).**(4)**

Although there may be technical common ground among various government groups writing AWIPS code, AFPS is being designed to support WFO operations, and thus the list of weather elements, support data (e.g., background maps), and grid/time resolutions will be built from a WFO perspective, and by itself will not support NMC or RFC operations. We expect that a GDP technical forum comprising NMC, the NWS Office of Hydrology (OH), the NWS Office of Systems Development (OSD), and FSL will be formed by OSD's Advanced Development and Demonstration Laboratory to discuss GDP development issues. This group would meet periodically to discuss new ideas and problems.

NMC is preparing a document which will present plans for development within NMC to provide forecast products required to support an operational AFPS at WFOs. Specifically, NMC must be able to provide a set of gridded products to WFOs sufficient to initialize the AFPS forecast database.(5)

1.3.2.8 Common Product Formats

The NWS issues many different types of products. Many of those products today, such as agricultural and public forecasts, contain similar types of information; however, their formats differ. If common formats can be specified for various products, then the required number of discrete product generators will be reduced. For example, if the zone forecast (or its successor) uses the periods today, tonight*,* and tomorrow*,* and the agricultural forecast uses the same format, common code can be developed for both.

It is assumed that the NWS will examine the products in the AWIPS environment and determine which products can be formatted similarly. If the products continue to have different formats, then more product generator code will have to be developed.

1.3.2.9 Forecast Database Will be Used by Related Programs

As noted above, forecasters will edit general and service-specific weather elements. Algorithms will sample the database and create additional product parameters. Forecast monitoring and quality control programs will refer to this database.

Eventually, verification should also be based on the forecast database. For now, the verification program will remain as is, using such products as the CCF (coded cities forecast). The National Verification Committee is responsible for planning any changes in this program.

1.3.2.10 Forecasters are Allowed to Edit Text Products

NWS forecasters will be allowed to edit the text produced by product generators using standard AWIPS capabilities. This principle is enunciated here because it has the potential to compromise the effectiveness of the forecast database concept. In Chapter 10, we propose solutions to the problem of uncontrolled text editing.

1.3.3 Integration with AWIPS

FSL procured development hardware and began investigative work before the AWIPS platform became available. Although this forecast preparation system eventually will become a fully integrated part of the AWIPS System Software, we will take a step-wise integration approach. The software will first be installed as an AWIPS application program while we start risk reduction exercises and are gaining knowledge of AWIPS. Later, the AWIPS contractor will integrate it into the AWIPS System Software.

We must be cognizant of the integration process from the outset of the project. The effort required to integrate existing software must be weighed against the effort required to "start from scratch" and develop new routines that would serve the same functions.

A final issue to be considered in integration is forecaster training. Depending on AWIPS deployment schedules, AFPS could be released to all 115 WFOs simultaneously. The forecasters will have become familiar with AWIPS by that time; however, this new system will introduce novel capabilities that will change the way forecasts are prepared. Thus, substantial training requirements should be anticipated.

1.4 The Digital Forecast System

The AWIPS grid-based forecast system requirement is intended to streamline forecast generation. By itself, the system is not intended to improve the accuracy of forecasts, though it may incidentally contribute to that goal by freeing the forecaster from routine chores and allowing more time to study the weather.

Simplified, forecasting comprises three steps (which overlap in practice): examination of data, models, numerical and statistical forecasts, analogs, climatology, yesterday's successes and failures, etc.; mental formulation of a forecast; and (text) composition. Although this new system will not change this process, it will reduce the mechanical and repetitive composition phase, giving the forecaster relatively more time to apply his or her knowledge and expertise to forecasting.

The central component of this system is the forecast database of weather elements, describing the present and future state of the atmosphere in the forecast area. Values in this database are initialized and/or updated with observations and forecast values derived from national and local models, including forecast grids produced manually at NMC. The forecaster modifies and maintains the forecast database to create the best representation of the future state of the weather in the forecast area according to his or her experience and judgement, based on the complete set of weather and model information available through the AWIPS workstation. Interactive graphic tools allow the forecaster to maintain and modify the database. Automatic consistency checkers examine the internal consistency of the values in the database, and monitors compare the forecasts represented by the database with adjacent WFO forecasts for boundary consistency, with new observations and guidance, and with the current forecast. Significant deviations are brought to the forecaster's attention for consideration and action where needed.

All required text products are generated when appropriate (by forecaster request or on a schedule) by automatic text generators which compose English-language or coded text products from the information in the database. The forecaster has the option of editing the text products, but will generally do so only to improve clarity or description of weather and not to revise the forecast; doing otherwise would compromise the validity of verification based on the forecast database.(6) One goal of the NWS modernization is to provide a set of products that will routinely require no editing by the forecaster.

The details of how this system will be built will be understood only after investigative development and risk reduction evaluations. Given their experience, FSL and TDL are well qualified to do this work.

1.4.1 Project Scope

An essential factor for successful completion of this project is an understanding of the scope of the project from the beginning.

In the modernized National Weather Service, the forecaster will have three techniques to assist in creating forecast and warning products (Figure 1 on page 8):

- Warning Generation permits the forecaster to draw a watch, warning, or advisory, which is used to create a text product;
- Graphical Forecast Editor (GFE) allows forecasters to create and modify graphical forecasts and store them in the forecast database;

- Product Preparation takes data from the forecast database and generates products for final review and dissemination. (Note that dissemination is outside the scope of this project.)

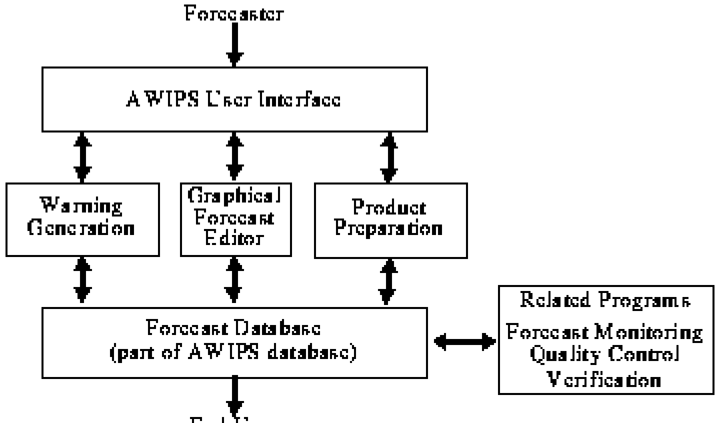


Figure 1 - AWIPS Forecast Generation Support

This project encompasses development of the Graphical Forecast Editor and interactions with/development of the AWIPS user interface, Warning Generation, Product Preparation, and the forecast database.

Creating forecast products supported by the GFE involves three steps: creating first-guess forecast weather elements (from, e.g., a previous forecast, climatology, numerical and statistical guidance), editing these elements, and generating products. The forecaster will import selected guidance and/or previous forecasts into a graphical worksheet and then will use interactive editing tools to modify the depictions until the desired forecast solution is created. This solution will be stored in the database as the official forecast. Products will be generated on command of the user.

The concept of manipulating a forecast database and automatically producing formatted products is not new. The Interactive Computer Worded Forecast System (ICWF) has been under development at TDL since 1985. Using Model Output Statistics (MOS) and Local AWIPS MOS Program (LAMP) output as a first guess, ICWF produces a limited set of forecast products. Depending on the outcome of current operational evaluations, it will become part of the AWIPS IDB or first P3I. AFPS will build on the ICWF concepts and provide even more capabilities to the forecaster.

The primary difference between the ICWF and AFPS, other than differences in scope, is the method of editing forecasts. With the ICWF, the forecaster manipulates a matrix of zone forecast numbers and symbols to specify forecast elements; with AFPS, the forecaster will graphically manipulate a picture to specify weather elements.

1.4.2 Overview of the System

The following five components constitute the AWIPS Forecast Preparation System:

- algorithms to derive weather elements from guidance, interpolating to grids where necessary;
- interactive tools for manipulating the weather elements;

- a forecast database;
- product parameter derivation functions, which prepare data for input to the generators; and
- product generators to create the products.

Figure 2 describes the system data flow. The process begins by retrieving guidance and observations from the AWIPS database(7) and generating general weather elements. These elements may be derived from model output or observations, or simply copied from a previous forecast. The forecaster will manipulate these fields using graphical editing tools. Interpolator tools will fill in snapshots that were never initialized. Service-specific elements are computed from the general elements and other information in the AWIPS database. Any changes made to these elements cannot be reflected back to the general elements. At the forecaster's request, the weather elements are checked for inconsistencies, and the forecaster may resolve them. Next, samplers extract point, area, and route forecasts from the database and convert them into specific product parameters. Finally, a product generator uses the product parameters to generate a forecast in text form. The forecaster reviews the product with the AWIPS word processor and makes any necessary wording changes. The product is then stored and disseminated to users.

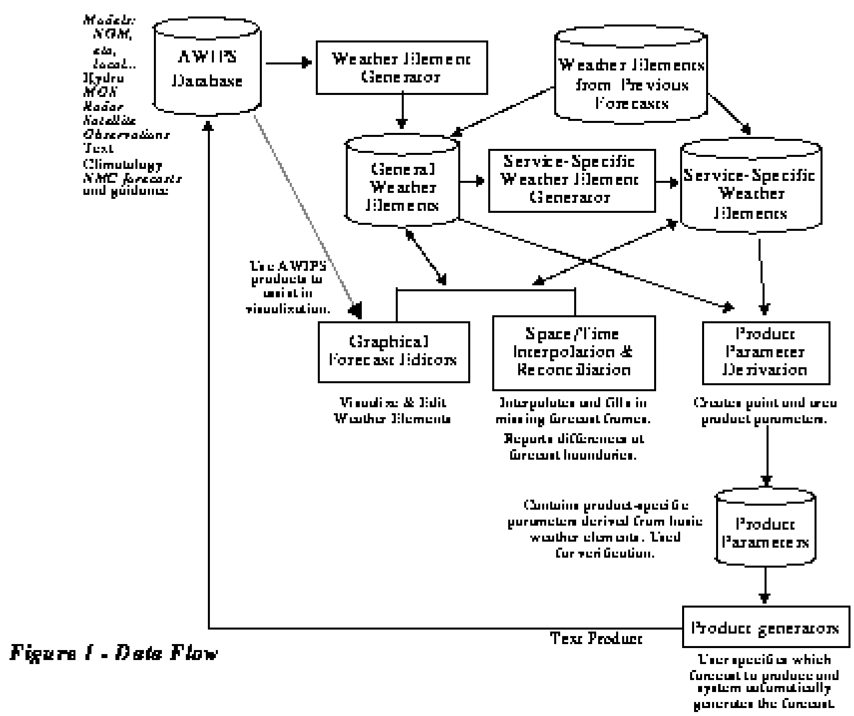


Figure 1 - Data Flow

1.4.3 Definition of Tasks

The goal of this effort is to produce a system via which a forecaster can produce a full suite of forecast products by visualizing and modifying a representation of atmospheric weather elements. To achieve this goal, the following tasks have been defined.

1.4.3.1 Phase I Tasks

The work described in this plan will focus on the development of a basic system, to be deployed two to three years after the AWIPS IDB, and will include development of the five components listed above.

In the initial work, the database will be in essence a two-dimensional, ground-based representation of the atmosphere.(8) The limitation to two dimensions is imposed to reduce the scope of the near-term work.

A full suite of product generators will be developed during Phase I. These generators will initially work with the ICWF database, but later will be modified to work with the weather elements in the database.

1.4.3.2 Phase II Tasks

Work necessary to make the forecast system fully functional includes the following:

- integration of the watch/warning program;
- improved derivation of weather elements;
- development of three-dimensional visualization and manipulation tools;
- implementation of a four-dimensional forecast database;
- interoffice coordination and boundary reconciliation;
- graphical and gridded forecast products;
- enhancement of related programs, such as forecast monitoring and verification, to use the forecast database;
- restriction of text product editing;
- editing model output; and
- editing model input.

These longer-term tasks are further addressed in Chapter 10.

1.4.4 Related Projects

A few government organizations have been involved with projects that are similar to AFPS. We are examining these projects in order to take advantage of others' expertise in this work. Other NWS groups also have experience with modern computer networks and computer graphics, notably OH, which has been working on RFC-related systems, and the NWS Alaska Region, where forecaster-programmers have developed a number of UNIX/X applications to support forecast operations.

We have examined the experience of the NWS with the Aviation Route Forecast project of the early 1980s. Two current projects are the ICWF developed by TDL and the Forecast Production Assistant (FPA) developed by the Canadian Atmospheric Environment Service (AES). Since the latter two are in many ways similar to AFPS, we describe some details of them below.

1.4.4.1 ICWF Project

In the early 1970s, TDL began development of an automated computer worded forecast system (CWF). It initially produced city forecasts from MOS guidance. In the early 1980s, the program was expanded to include zone forecasts and terminal forecasts. The forecaster was presented with the end product, a text forecast, for editing.

The ICWF program began in 1985 to develop a text generator for AFOS. It presented the forecaster with a zone-based basic weather matrix. The forecaster could interactively view and modify the matrix before the text forecast was generated. This version of the ICWF was limited to the forecast projections available from MOS guidance. A demonstration of ICWF began at several WSFOs in June 1986. WSFO Charleston still actively uses the ICWF, and much of its operation is built around the ICWF digital database.

The Forecast Entry and Formatting System (FEFS) program started in the summer of 1987. FEFS was based on a grid of digital weather elements, with higher temporal and spatial resolutions than the zone-based ICWF. It provided both zone-based and grid-based viewing and modification tools. The grids were initialized from LAMP, MOS, and Perfect Prog techniques. Before it could be implemented, the FEFS project was suspended in 1989 by the NWS in favor of porting ICWF to the Norman, Oklahoma, Pre-AWIPS demonstration system. What was learned in FEFS is being considered in the design of AFPS.

In 1990 and 1991, the ICWF program was enhanced to take advantage of many things that TDL learned from the FEFS development. The current version of ICWF uses a new set of weather elements that makes it easier for a forecaster to depict the desired weather. The Pre-AWIPS version of ICWF has become a part of the Norman risk reduction exercises. If the evaluation is favorable, ICWF will be ported to AWIPS as part of the IDB or the first P3I.

Many of the concepts developed for ICWF will be incorporated into AFPS, such as point and area forecast extraction from a grid and the station model plot depiction.

1.4.4.2 FPA Project

The FPA is the Canadians' approach to the automatic creation of forecasts from a digital weather element database. It allows forecasters to draw a series of weather depiction forecasts and to produce a set of computer-generated forecasts. When the FPA project is complete, it will produce all public, aviation, marine, and forestry products. It will also produce graphical products for specialized users.

The FPA concept began in 1985 when a student of computational linguistics took a series of hourly temperatures and created a statement of the temperature trends and abnormal situations. In 1988, the FPA project was funded and development began.

The first goal was to produce a marine forecast from weather depictions of five sensible weather elements. The elements used were surface temperature, surface pressure, clouds and weather areas, wind deviation from geostrophic, and wave height. AES conducted several risk reduction exercises in Halifax, Gander, and Toronto. Version 1.0 of the FPA became operational in the spring of 1991 at Gander, Halifax, and the Arctic Weather Centre. One interesting requirement of the product generators for the FPA is that they produce forecasts in both English and French.

FPA development continues. It was determined that a Forecast Bulletin Editor was required to accurately create the forecast since the weather depiction charts could not always be made to properly represent the weather. The Bulletin Editor provides a time series depiction of the forecast at a point, allowing the forecaster to fine-tune the forecast after the weather depiction charts have been drawn. The Canadians do not permit editing of the text product.

AES plans to expand the FPA to include public forecasts in 1993, and forestry, agriculture, and aviation forecasts by 1996. Local models will help create these products starting in 1996.

AFPS will draw on many of the concepts developed for the FPA. Its weather depiction capabilities and interactive graphical editing tools provide a working example of how a forecast production system might operate. However, there are three important conceptual differences between the FPA and AFPS. The set of weather elements with which the forecaster works will differ, the value of computational linguistics for text generation compared to the ICWF approach is unclear, and whether the FPA graphical techniques are applicable to mesoscale forecasting is unknown.

Footnotes

(1)

An overview of the AWIPS development schedule and its relationship to the work described in this document is found in Section 9.3.

(2)

Since this system will be an integral part of AWIPS, it need not be singled out by name; however, for convenience we will refer to it throughout this document as .

(3)

FSL's GDP equipment was delivered on 29 March 1993; TDL's (NWS HQ) on 5 April.

(4)

NMC is in the process of reorganizing and modernizing its service operations. NMC will become the National Institutes for Environmental Prediction (NIEP) and the national centers will be restructured to become the Aviation Weather Institute, the Marine Prediction Institute, the Tropical Weather Institute, the Storm Prediction Institute, the Climate Prediction Institute, and the Weather Prediction Institute.

(5)

The forecasts provided by NMC will generally be for projections beyond six hours. Local information (e.g., observations and short-range forecasts) will have to be integrated with these fields.

(6)

This is a future concept only. As noted in Section 1.3.2.9, verification will remain text-forecast-based until NWS policy directs otherwise.

(7)

Although it appears in Figure2 that there are several databases, all are part of the AWIPS database.

(8)

Requirements for 3-d data (in particular, for aviation terminal forecasts) can be met in our 2-d representation by including height information in the data (e.g., 50SCT).

1.1 Background

1.1.1 National Weather Service Modernization

For several years, the National Weather Service (NWS) has been engaged in activities directed toward modernizing and restructuring its operations. The activities include as major components the development of a new radar system (NEXRAD; the individual hardware units are known as WSR-88D), a new automated surface observing system (ASOS), and a new communications and forecaster workstation system, the Advanced Weather Interactive Processing System (AWIPS).

In order to make more effective use of the talents of its staff of professional meteorologists, the NWS plans to reorganize its operations. Currently, 52 Weather Service Forecast Offices (WSFOs) perform the bulk of the forecasting functions for statewide areas, and 180 Weather Service Offices (WSOs) and other small offices provide local adaptive forecasts. Both WSFOs and WSOs issue severe weather warnings, though many WSOs operate on a less-than-24-hour schedule and must be backed up by their parent WSFO at night.

In the restructured Weather Service, there will be 115 Weather Forecast Offices (WFOs), roughly collocated with WSR-88Ds. AWIPS will provide the communications and forecast support functions for these offices.

1.1.2 Acquisition of AWIPS

An AWIPS Requirements Task Team (ARTT) was formed in the early 1980s, comprising representatives of NWS administrative, development, and field offices, plus what is now the Forecast Systems Laboratory (FSL). The work of the ARTT was used to refine and validate AWIPS requirements prepared by the NWS Office of Meteorology. These requirements form the basis of the functional requirements included in the AWIPS Request for Proposal (RFP) and the AWIPS Development Phase contract.

The AWIPS requirements include several hydrometeorological techniques. The functions of these techniques range from decoding, analyzing, and displaying observations to formatting official forecasts. Detailed specifications for these techniques have been prepared by the NWS Techniques Development Laboratory (TDL), working closely with other NOAA elements, in the form of Technique Specification Packages (TSPs).

In preparation for the development and deployment of AWIPS, the NWS has asked FSL to participate in several risk reduction activities. The primary activity has been developing and testing a series of forecaster workstations at the Denver and Norman WSFOs. Currently, systems known as DARE (Denver AWIPS-90 Risk Reduction and Requirements Evaluation) in Denver and Pre-AWIPS in Norman are being used by the WSFO staffs. These systems have provided valuable insight into modernized operations; experience gained in Denver over the past five years has been used to refine the specifications that are being used by the AWIPS contractor.

The AWIPS Extended Definition Phase, wherein two competing contractors developed detailed plans and proposals for the system and forecaster workstations, has just been completed.

The AWIPS Development Phase contract was awarded to Planning and Research Corporation (PRC) on 29 December 1992. Contractor software is to be delivered in several "builds," with the first due approximately one and one-half years after contract award; the second, known as the First Article Capability (FAC), to be completed approximately two years after contract award; and the third, known as the Initial Deployment Baseline (IDB), scheduled for delivery three years after contract award.(1)

Of the many techniques included in the AWIPS requirements, several will not be developed by the AWIPS contractor but will be furnished by the government. The government will furnish software to the contractors in two Pre-Planned Product Improvements (P3I), which will take place after the IDB delivery. Two of the major software developments by the government are a grid-based forecast system and a full suite of product generators. Collectively, these constitute the AWIPS Forecast Preparation System.(2) The software and documentation described in this document will be delivered to the contractor as part of the second P3I.

1.2 Objective

The specific objective of this project is to develop a set of techniques that will allow the forecaster to efficiently issue a full suite of products. Improving the efficiency of the forecast generation process will permit forecasters to focus more on hydrometeorology and allow for more timely updates of forecast products to improve the quality of the forecasts. Further, the use of product generators will improve product consistency.

1.3 NWS Requirements and Assumptions

In Appendix A of the AWIPS System Requirements Specification, Volume I (part of the AWIPS-90 Request for Proposal, dated 22 August 1990), the grid-based forecast system is outlined as follows:

The WFO will maintain an up-to-date official set of digital forecasts, usually in gridded form, over this [750 kilometers by 750 kilometers] area. From this set of forecasts, routine forecast products shall be automatically formatted for release after forecaster review and, if necessary, modification. (RFP p. SRSI-A-10).

1.3.1 Requirements

The AWIPS IDB will include many of the basic hydrometeorological techniques required to support forecast operations at WFOs. These include improved observation decoders, improved quality control techniques, and improved analysis and display techniques. Graphical techniques will be used to enter and edit Watch/Warning/Advisory information and to format these products automatically. Also included will be interactive techniques to enter information for selected forecasts as well as techniques to format selected public, agricultural, and hydrologic observations and forecasts such as today's weather roundup. Techniques to assist in the preparation of additional products, including aviation, marine, and fire weather programs, will be deferred until the two P3I upgrades of AWIPS.

At the heart of these upgrades is a forecast database, containing gridded and geographically located weather elements that support forecast preparation, quality control, monitoring, and verification. Forecasters will maintain this database, starting with first-guess fields "rolled over" from previous forecasts or based on one or more centrally- or locally-run numerical or statistical models, and drawing on their experience and training. This project will develop prototype techniques to refine the concept and integrate the resulting system into the AWIPS workstation.

The NWS requires techniques to assist the forecaster in preparing most, if not all, routine forecasts as well as watches, warnings, and advisories. These techniques must facilitate the maintenance of a forecast database which supports all program areas. The database must have appropriate time resolution to allow the creation of all forecast and data products, it must contain quantitative and qualitative variables needed by the products, and it must support related programs such as forecast monitoring and verification.

The interactive techniques used by the forecaster must allow specification and control of the weather elements necessary to generate products and perform other forecast functions. The number of elements should be kept low to minimize the amount of information the forecaster must enter. Information should have to be entered or edited only once, not multiple times for each program area or forecast function. In addition to the general forecast, the techniques must permit the entry of local forecast information to define the effects of terrain and bodies of water on the forecasts.

AWIPS will automatically generate as many forecast and warning products as is reasonable and partially format those that will still require considerable manual entry. The system must be capable of producing text, graphics, and gridded forecast products, as well as broadcast-ready text products for NOAA Weather Radio (NWR). Taken as a whole, these techniques must streamline the forecast process when compared with today's operations, and they should improve the consistency of the forecasts. They should enhance interoffice coordination and optimize the use of central and local guidance. The system of preparing forecasts and generating products should allow for the rapid changes that are sure to take place in the future as additional high-resolution guidance information becomes available.

1.3.2 Basic Assumptions

Several basic but critical assumptions have been made in this plan. If any of these assumptions is incorrect or cannot be realized, the implementation schedule and/or the breadth of the final project will be affected.

1.3.2.1 Timely Delivery of AWIPS Equipment

To meet the goal of transferring forecast preparation software to the AWIPS contractor for integration into the system by the second P3I, both FSL and TDL must receive standard-configuration WFO AWIPS systems (Government Development Platforms, or GDPs) soon after contract award. The basic COTS (commercial off-the-shelf) hardware and software platform are scheduled to be received 12 weeks after contract award,(3) with FAC software and documentation delivered at the second scheduled software build (approximately two years after contract award).

1.3.2.2 AWIPS Contractor Assistance

During the Prototype Stage of FSL's development (see Chapter 9 for schedule information), we will be developing generic code using UNIX, C++, OI (Object Interface, a C++ Graphical User Interface library), and XGL (Sun's version of GL, an industry-standard graphics system incorporating parts of and compatible with X) on a network of Sun computers. Once AWIPS hardware and System Software are available, we will build our first integrated system on AWIPS.

Due to the short time allowed to build the first integrated operational prototype on AWIPS, we must have direct contact with the AWIPS contractor. Our schedule includes approximately one year between receipt of AWIPS System Software and the commencement of WFO risk-reduction activities. During this period, we will need to "come up to speed" on the internals of AWIPS and integrate perhaps 250,000 lines of code into AWIPS. FSL's Advanced Development Facility (ADF) group has been involved with AWIPS proposal evaluations, and will attend design reviews and study the internals of AWIPS. They will serve as consultants in this work. Direct contact with the AWIPS contractor will also be essential.

The assistance needed takes several forms. We would like to make a formal presentation and demonstration of our plans to the AWIPS contractor so they can gain an appreciation of the magnitude of the task. Once they are familiar with our goals, they can offer guidance on the preferred method of integrating this system into AWIPS. Once we start integrating code, the contractor could serve as a consultant. Ideally, we would work daily with the contractor and have one or two members of the contractor team on site in Boulder.

1.3.2.3 FSL/TDL Will Port to AWIPS

FSL will port the visualization and editing software into AWIPS for the Risk Reduction Stage tests. Our software will be visually integrated into AWIPS at this time but may not actually use all of the AWIPS System Software (i.e., it may use some parallel implementations of system functions). "Visually integrated" means that the user will not perceive any separation between our software and the rest of AWIPS, although the code will not be truly integrated. Actual integration will be performed by the AWIPS contractor, since modifications to the AWIPS System Software could be required.

TDL will port product generators to the AWIPS platform (GDP) to make them available during the Risk Reduction Stage tests. Some will be supplied to the AWIPS contractor for the IDB; others will be prepared for the first P3I.

1.3.2.4 Risk-Reduction WFOs are Unique Sites

We assume that the Risk-Reduction WFOs (Denver and a to-be-determined marine office) will be unique sites in that their AWIPS will not be under strict configuration management by the AWIPS contractor.

We will need to load our prototype software at these sites for risk reduction testing. While it is imperative to keep the contractor informed of configuration changes, we must not be restricted from making such changes. This issue will be coordinated with the AWIPS Program Office.

1.3.2.5 Static AWIPS Architecture

AFPS will eventually become an integrated part of AWIPS. It will utilize many of the sophisticated graphic processing features of the AWIPS hardware. As a result, we will be making design decisions based on information obtained from the AWIPS contractor. We assume that the basic hardware and software configuration of AWIPS, e.g., operating system, windowing system, graphical bit plane allocation, will remain static during our development.

1.3.2.6 Forecasters Will Work with Weather Elements

Forecasters will be asked to forecast general and service-specific weather elements, not all product parameters, once this system is deployed. General weather elements are a few observable items such as temperature, winds, and clouds, and service-specific elements include such fields as wave heights and dew intensity. In contrast, product-specific items such as heat index/wind chill, hours of sunshine, and maximum temperature may not need to be edited by the forecaster. To minimize forecaster workload, the number of edited weather elements must be kept to a minimum.

1.3.2.7 Techniques Not Designed for RFCs and NMC

We are developing a software package to meet the needs of the WFO forecaster to produce routine forecast products. It is not intended to satisfy all interactive drawing requirements of River Forecast Centers (RFCs) or the National Meteorological Center (NMC).**(4)**

Although there may be technical common ground among various government groups writing AWIPS code, AFPS is being designed to support WFO operations, and thus the list of weather elements, support data (e.g., background maps), and grid/time resolutions will be built from a WFO perspective, and by itself will not support NMC or RFC operations. We expect that a GDP technical forum comprising NMC, the NWS Office of Hydrology (OH), the NWS Office of Systems Development (OSD), and FSL will be formed by OSD's Advanced Development and Demonstration Laboratory to discuss GDP development issues. This group would meet periodically to discuss new ideas and problems.

NMC is preparing a document which will present plans for development within NMC to provide forecast products required to support an operational AFPS at WFOs. Specifically, NMC must be able to provide a set of gridded products to WFOs sufficient to initialize the AFPS forecast database.(5)

1.3.2.8 Common Product Formats

The NWS issues many different types of products. Many of those products today, such as agricultural and public forecasts, contain similar types of information; however, their formats differ. If common formats can be specified for various products, then the required number of discrete product generators will be reduced. For example, if the zone forecast (or its successor) uses the periods today, tonight*,* and tomorrow*,* and the agricultural forecast uses the same format, common code can be developed for both.

It is assumed that the NWS will examine the products in the AWIPS environment and determine which products can be formatted similarly. If the products continue to have different formats, then more product generator code will have to be developed.

1.3.2.9 Forecast Database Will be Used by Related Programs

As noted above, forecasters will edit general and service-specific weather elements. Algorithms will sample the database and create additional product parameters. Forecast monitoring and quality control programs will refer to this database.

Eventually, verification should also be based on the forecast database. For now, the verification program will remain as is, using such products as the CCF (coded cities forecast). The National Verification Committee is responsible for planning any changes in this program.

1.3.2.10 Forecasters are Allowed to Edit Text Products

NWS forecasters will be allowed to edit the text produced by product generators using standard AWIPS capabilities. This principle is enunciated here because it has the potential to compromise the effectiveness of the forecast database concept. In Chapter 10, we propose solutions to the problem of uncontrolled text editing.

1.3.3 Integration with AWIPS

FSL procured development hardware and began investigative work before the AWIPS platform became available. Although this forecast preparation system eventually will become a fully integrated part of the AWIPS System Software, we will take a step-wise integration approach. The software will first be installed as an AWIPS application program while we start risk reduction exercises and are gaining knowledge of AWIPS. Later, the AWIPS contractor will integrate it into the AWIPS System Software.

We must be cognizant of the integration process from the outset of the project. The effort required to integrate existing software must be weighed against the effort required to "start from scratch" and develop new routines that would serve the same functions.

A final issue to be considered in integration is forecaster training. Depending on AWIPS deployment schedules, AFPS could be released to all 115 WFOs simultaneously. The forecasters will have become familiar with AWIPS by that time; however, this new system will introduce novel capabilities that will change the way forecasts are prepared. Thus, substantial training requirements should be anticipated.

1.4 The Digital Forecast System

The AWIPS grid-based forecast system requirement is intended to streamline forecast generation. By itself, the system is not intended to improve the accuracy of forecasts, though it may incidentally contribute to that goal by freeing the forecaster from routine chores and allowing more time to study the weather.

Simplified, forecasting comprises three steps (which overlap in practice): examination of data, models, numerical and statistical forecasts, analogs, climatology, yesterday's successes and failures, etc.; mental formulation of a forecast; and (text) composition. Although this new system will not change this process, it will reduce the mechanical and repetitive composition phase, giving the forecaster relatively more time to apply his or her knowledge and expertise to forecasting.

The central component of this system is the forecast database of weather elements, describing the present and future state of the atmosphere in the forecast area. Values in this database are initialized and/or updated with observations and forecast values derived from national and local models, including forecast grids produced manually at NMC. The forecaster modifies and maintains the forecast database to create the best representation of the future state of the weather in the forecast area according to his or her experience and judgement, based on the complete set of weather and model information available through the AWIPS workstation. Interactive graphic tools allow the forecaster to maintain and modify the database. Automatic consistency checkers examine the internal consistency of the values in the database, and monitors compare the forecasts represented by the database with adjacent WFO forecasts for boundary consistency, with new observations and guidance, and with the current forecast. Significant deviations are brought to the forecaster's attention for consideration and action where needed.

All required text products are generated when appropriate (by forecaster request or on a schedule) by automatic text generators which compose English-language or coded text products from the information in the database. The forecaster has the option of editing the text products, but will generally do so only to improve clarity or description of weather and not to revise the forecast; doing otherwise would compromise the validity of verification based on the forecast database.(6) One goal of the NWS modernization is to provide a set of products that will routinely require no editing by the forecaster.

The details of how this system will be built will be understood only after investigative development and risk reduction evaluations. Given their experience, FSL and TDL are well qualified to do this work.

1.4.1 Project Scope

An essential factor for successful completion of this project is an understanding of the scope of the project from the beginning.

In the modernized National Weather Service, the forecaster will have three techniques to assist in creating forecast and warning products (Figure 1 on page 8):

- Warning Generation permits the forecaster to draw a watch, warning, or advisory, which is used to create a text product;
- Graphical Forecast Editor (GFE) allows forecasters to create and modify graphical forecasts and store them in the forecast database;

- Product Preparation takes data from the forecast database and generates products for final review and dissemination. (Note that dissemination is outside the scope of this project.)

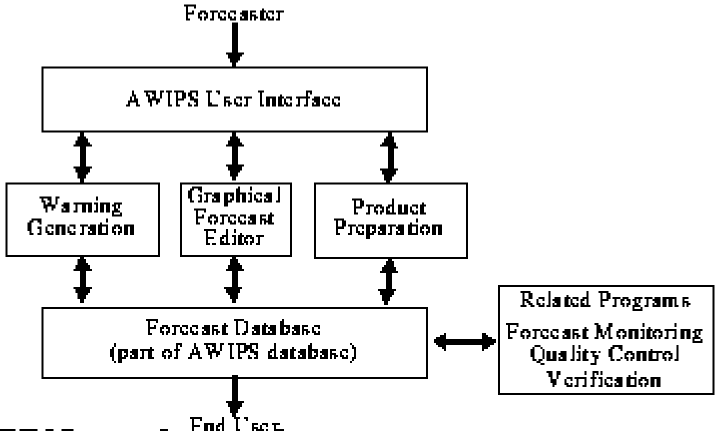


Figure 1 - AWIPS Forecast Generation Support

This project encompasses development of the Graphical Forecast Editor and interactions with/development of the AWIPS user interface, Warning Generation, Product Preparation, and the forecast database.

Creating forecast products supported by the GFE involves three steps: creating first-guess forecast weather elements (from, e.g., a previous forecast, climatology, numerical and statistical guidance), editing these elements, and generating products. The forecaster will import selected guidance and/or previous forecasts into a graphical worksheet and then will use interactive editing tools to modify the depictions until the desired forecast solution is created. This solution will be stored in the database as the official forecast. Products will be generated on command of the user.

The concept of manipulating a forecast database and automatically producing formatted products is not new. The Interactive Computer Worded Forecast System (ICWF) has been under development at TDL since 1985. Using Model Output Statistics (MOS) and Local AWIPS MOS Program (LAMP) output as a first guess, ICWF produces a limited set of forecast products. Depending on the outcome of current operational evaluations, it will become part of the AWIPS IDB or first P3I. AFPS will build on the ICWF concepts and provide even more capabilities to the forecaster.

The primary difference between the ICWF and AFPS, other than differences in scope, is the method of editing forecasts. With the ICWF, the forecaster manipulates a matrix of zone forecast numbers and symbols to specify forecast elements; with AFPS, the forecaster will graphically manipulate a picture to specify weather elements.

1.4.2 Overview of the System

The following five components constitute the AWIPS Forecast Preparation System:

- algorithms to derive weather elements from guidance, interpolating to grids where necessary;
- interactive tools for manipulating the weather elements;

- a forecast database;
- product parameter derivation functions, which prepare data for input to the generators; and
- product generators to create the products.

Figure 2 describes the system data flow. The process begins by retrieving guidance and observations from the AWIPS database(7) and generating general weather elements. These elements may be derived from model output or observations, or simply copied from a previous forecast. The forecaster will manipulate these fields using graphical editing tools. Interpolator tools will fill in snapshots that were never initialized. Service-specific elements are computed from the general elements and other information in the AWIPS database. Any changes made to these elements cannot be reflected back to the general elements. At the forecaster's request, the weather elements are checked for inconsistencies, and the forecaster may resolve them. Next, samplers extract point, area, and route forecasts from the database and convert them into specific product parameters. Finally, a product generator uses the product parameters to generate a forecast in text form. The forecaster reviews the product with the AWIPS word processor and makes any necessary wording changes. The product is then stored and disseminated to users.

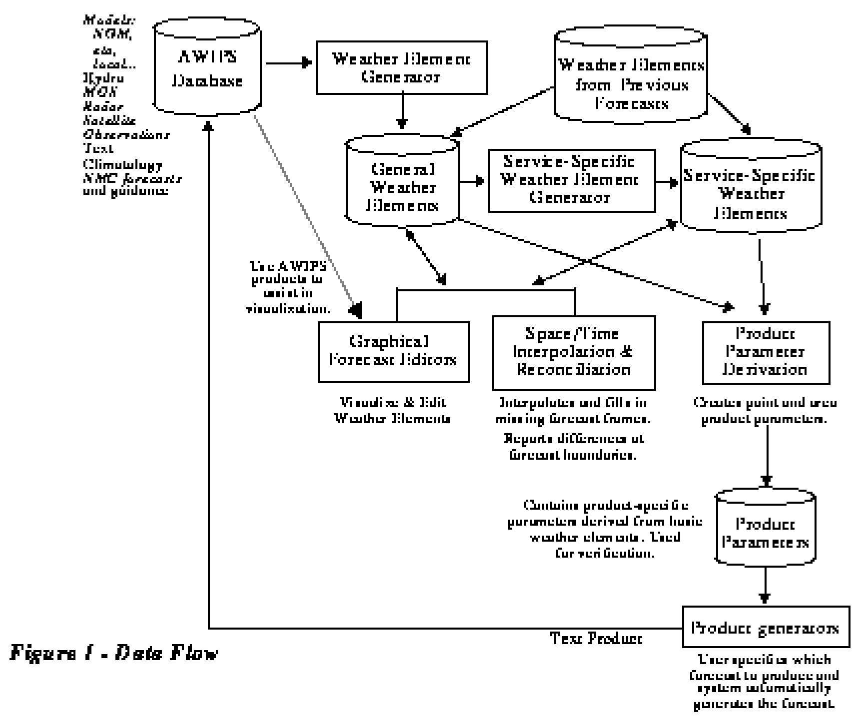


Figure I - Data Flow

1.4.3 Definition of Tasks

The goal of this effort is to produce a system via which a forecaster can produce a full suite of forecast products by visualizing and modifying a representation of atmospheric weather elements. To achieve this goal, the following tasks have been defined.

1.4.3.1 Phase I Tasks

The work described in this plan will focus on the development of a basic system, to be deployed two to three years after the AWIPS IDB, and will include development of the five components listed above.

In the initial work, the database will be in essence a two-dimensional, ground-based representation of the atmosphere.(8) The limitation to two dimensions is imposed to reduce the scope of the near-term work.

A full suite of product generators will be developed during Phase I. These generators will initially work with the ICWF database, but later will be modified to work with the weather elements in the database.

1.4.3.2 Phase II Tasks

Work necessary to make the forecast system fully functional includes the following:

- integration of the watch/warning program;
- improved derivation of weather elements;
- development of three-dimensional visualization and manipulation tools;
- implementation of a four-dimensional forecast database;
- interoffice coordination and boundary reconciliation;
- graphical and gridded forecast products;
- enhancement of related programs, such as forecast monitoring and verification, to use the forecast database;
- restriction of text product editing;
- editing model output; and
- editing model input.

These longer-term tasks are further addressed in Chapter 10.

1.4.4 Related Projects

A few government organizations have been involved with projects that are similar to AFPS. We are examining these projects in order to take advantage of others' expertise in this work. Other NWS groups also have experience with modern computer networks and computer graphics, notably OH, which has been working on RFC-related systems, and the NWS Alaska Region, where forecaster-programmers have developed a number of UNIX/X applications to support forecast operations.

We have examined the experience of the NWS with the Aviation Route Forecast project of the early 1980s. Two current projects are the ICWF developed by TDL and the Forecast Production Assistant (FPA) developed by the Canadian Atmospheric Environment Service (AES). Since the latter two are in many ways similar to AFPS, we describe some details of them below.

1.4.4.1 ICWF Project

In the early 1970s, TDL began development of an automated computer worded forecast system (CWF). It initially produced city forecasts from MOS guidance. In the early 1980s, the program was expanded to include zone forecasts and terminal forecasts. The forecaster was presented with the end product, a text forecast, for editing.

The ICWF program began in 1985 to develop a text generator for AFOS. It presented the forecaster with a zone-based basic weather matrix. The forecaster could interactively view and modify the matrix before the text forecast was generated. This version of the ICWF was limited to the forecast projections available from MOS guidance. A demonstration of ICWF began at several WSFOs in June 1986. WSFO Charleston still actively uses the ICWF, and much of its operation is built around the ICWF digital database.

The Forecast Entry and Formatting System (FEFS) program started in the summer of 1987. FEFS was based on a grid of digital weather elements, with higher temporal and spatial resolutions than the zone-based ICWF. It provided both zone-based and grid-based viewing and modification tools. The grids were initialized from LAMP, MOS, and Perfect Prog techniques. Before it could be implemented, the FEFS project was suspended in 1989 by the NWS in favor of porting ICWF to the Norman, Oklahoma, Pre-AWIPS demonstration system. What was learned in FEFS is being considered in the design of AFPS.

In 1990 and 1991, the ICWF program was enhanced to take advantage of many things that TDL learned from the FEFS development. The current version of ICWF uses a new set of weather elements that makes it easier for a forecaster to depict the desired weather. The Pre-AWIPS version of ICWF has become a part of the Norman risk reduction exercises. If the evaluation is favorable, ICWF will be ported to AWIPS as part of the IDB or the first P3I.

Many of the concepts developed for ICWF will be incorporated into AFPS, such as point and area forecast extraction from a grid and the station model plot depiction.

1.4.4.2 FPA Project

The FPA is the Canadians' approach to the automatic creation of forecasts from a digital weather element database. It allows forecasters to draw a series of weather depiction forecasts and to produce a set of computer-generated forecasts. When the FPA project is complete, it will produce all public, aviation, marine, and forestry products. It will also produce graphical products for specialized users.

The FPA concept began in 1985 when a student of computational linguistics took a series of hourly temperatures and created a statement of the temperature trends and abnormal situations. In 1988, the FPA project was funded and development began.

The first goal was to produce a marine forecast from weather depictions of five sensible weather elements. The elements used were surface temperature, surface pressure, clouds and weather areas, wind deviation from geostrophic, and wave height. AES conducted several risk reduction exercises in Halifax, Gander, and Toronto. Version 1.0 of the FPA became operational in the spring of 1991 at Gander, Halifax, and the Arctic Weather Centre. One interesting requirement of the product generators for the FPA is that they produce forecasts in both English and French.

FPA development continues. It was determined that a Forecast Bulletin Editor was required to accurately create the forecast since the weather depiction charts could not always be made to properly represent the weather. The Bulletin Editor provides a time series depiction of the forecast at a point, allowing the forecaster to fine-tune the forecast after the weather depiction charts have been drawn. The Canadians do not permit editing of the text product.

AES plans to expand the FPA to include public forecasts in 1993, and forestry, agriculture, and aviation forecasts by 1996. Local models will help create these products starting in 1996.

AFPS will draw on many of the concepts developed for the FPA. Its weather depiction capabilities and interactive graphical editing tools provide a working example of how a forecast production system might operate. However, there are three important conceptual differences between the FPA and AFPS. The set of weather elements with which the forecaster works will differ, the value of computational linguistics for text generation compared to the ICWF approach is unclear, and whether the FPA graphical techniques are applicable to mesoscale forecasting is unknown.

Footnotes

(1)

An overview of the AWIPS development schedule and its relationship to the work described in this document is found in Section 9.3.

(2)

Since this system will be an integral part of AWIPS, it need not be singled out by name; however, for convenience we will refer to it throughout this document as .

(3)

FSL's GDP equipment was delivered on 29 March 1993; TDL's (NWS HQ) on 5 April.

(4)

NMC is in the process of reorganizing and modernizing its service operations. NMC will become the National Institutes for Environmental Prediction (NIEP) and the national centers will be restructured to become the Aviation Weather Institute, the Marine Prediction Institute, the Tropical Weather Institute, the Storm Prediction Institute, the Climate Prediction Institute, and the Weather Prediction Institute.

(5)

The forecasts provided by NMC will generally be for projections beyond six hours. Local information (e.g., observations and short-range forecasts) will have to be integrated with these fields.

(6)

This is a future concept only. As noted in Section 1.3.2.9, verification will remain text-forecast-based until NWS policy directs otherwise.

(7)

Although it appears in Figure2 that there are several databases, all are part of the AWIPS database.

(8)

Requirements for 3-d data (in particular, for aviation terminal forecasts) can be met in our 2-d representation by including height information in the data (e.g., 50SCT).

2 Operations in the Modernized NWS

2.1 New Operations Concept

Forecasters coming on duty in the AWIPS era will perform many of the same functions as today but in a considerably different manner. Aside from the wealth of new observations from direct and remote sensors, NMC guidance(1) in gridded and graphical form, and new applications to manipulate these data, one of the more significant differences will be in the way the forecasters prepare forecasts and warnings.

Similar to today, the forecaster will start the shift with a briefing by the departing forecaster using a variety of techniques to display time sections, cross sections, and plan views. These techniques will include computation and display of weather elements as static charts, tables, and animated graphics.

The departing forecaster will have spent much of the previous shift maintaining a forecast and warning database. This will include reviewing incoming observations and central guidance, graphically preparing forecasts and warnings, reviewing machine-generated graphics, text, and broadcast-ready text, and then releasing the products to the end user. This database will support all NWS forecast programs including public, aviation, marine, hydrology, agriculture, and fire weather. Because a common database will support all forecast and long-term warning programs, inconsistencies from one forecast product to another will be minimized.

Forecast responsibilities will no longer be divided along product lines. The forecasters will work as a team to maintain the forecast database from the current time through the extended outlook. They will concentrate their efforts on the initial 24 to 48 hours, with special emphasis on 0- to 6-hour mesoscale events. As in the recently restructured public forecasts, text forecasts will include both short- and long-range predictions. It may be difficult for forecasters to improve on either numerical or NMC guidance at longer projections. Typically, longer-range (beyond 48 hours) guidance will be reviewed; occasionally, as time permits, the forecaster will modify this guidance.

During severe weather, it will be difficult for the forecaster to maintain (update) the routine forecast database to the same level as in fair periods. This may necessitate greater reliance on guidance and centrally-produced forecast grids for routine products so that the focus can remain on watches and warnings. NMC intends to prepare a full suite of gridded forecasts, which will be sufficient to generate all forecast products for projections of 6 hours and beyond. The forecast system is designed to run on "autopilot" if necessary; i.e., it will be possible for text forecasts to be generated from existing or updated information in the database that has not been edited by the forecaster. Such forecasts still will be reviewed and released by a forecaster. Certainly, the quality of these forecasts may not be as high as those issued under normal circumstances, especially in the first periods.

Most forecasts will be issued at scheduled times with updates as required by the meteorological situation. Guidance and observations will arrive continuously, and local applications will produce additional short-range statistical and dynamic forecasts. Automatic monitoring programs will compare incoming information with the current forecast database and advise the forecaster of significant differences.

The forecaster will have the option of using new guidance to update the current forecast in the database or staying with the current forecast. He/she will select forecast projections and weather elements from the various sources of incoming guidance. Whenever the database is updated, the forecaster, with the assistance of automated tools, will ensure that the forecast is internally consistent.

Whether a forecaster updates the forecast database will depend on several things:

- how rapidly the weather is changing,
- how significant the differences between the current forecast and new thinking are, and
- the forecast projections.

Similar considerations will govern whether new text products are generated to reflect the revised database. Depending on the nature and significance of changes, one or more text products may need to be reissued. Initially, such decisions will be made by the forecasters; it may be possible eventually to develop automated methods to suggest update necessity.

Other issues of this nature may arise in the future, when graphical and gridded forecasts are in use, and particularly were the NWS to adopt a "dial-in" facility for users to retrieve forecasts directly from a WFO database.

2.2 The Forecast Process

Forecasters will have access to observations, NMC manual forecasts, and model output in the AWIPS database. Models will include those run at National Centers as well as those run locally. In addition, forecasters will draw on conceptual models, rules of thumb, climatology, analogs, and their own experience and training.

Figure 3 is a processing flow diagram illustrating how forecasts will be prepared.(2) Observations will arrive continuously at the WFO, as will central guidance from direct model output, from statistical models, and from the human/machine mix at NMC; all will be ingested by AWIPS. Some guidance parameters will be converted to weather elements before the forecaster views them.

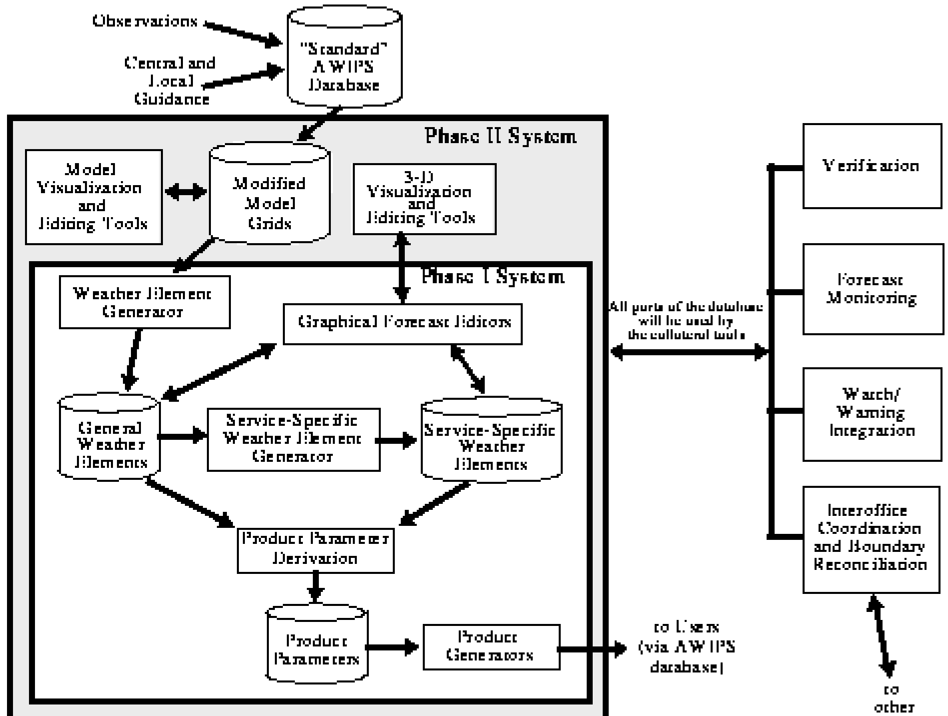


Figure 1 - Components and Evolution

The forecaster will be able to retrieve and review this guidance and graphically adapt it to the forecast of the day. For example, the guidance temperatures for 2200 UTC may be depicted as analyzed contours over the local forecast area. Precipitation areas may be depicted as enclosed areas with labels. The forecaster will manipulate contours and enclosed areas to construct forecasts. The greatest attention will be given to the forecast for the first 24 hours, with progressively less out to six days. If multiple sources of guidance are used, the forecaster may have to smooth the transitions from one model to another at their time boundaries.

When the forecast database does not provide adequate spatial resolution to represent significant features (local effects), the forecaster will have access to a set of reference areas. Local phenomena may be specified (e.g., canyon winds or lake-effect snows); these will be inserted in forecasts by the text generators, as appropriate.

Once the general forecast depictions are prepared, service-specific weather elements will be computed. For example, drying conditions will be computed for the agricultural forecast, and chance of wetting rain and lightning activity level will be computed for fire weather forecasts. These fields will be available for forecaster review and editing. Changes made to these elements do not reflect back to the general weather elements, so usually the forecaster will finish working on the general weather elements before starting work on service-specific elements.

Some NWS products are issued as combinations of forecast areas (zones, counties). Once the forecast has been created over the area of responsibility, appropriate combinations will automatically be chosen. Also, numerous forecast-specific product parameters (e.g., wind chill, heavy surf) will be computed.

Aviation terminal forecasts are issued for specific points. Aviation-specific weather elements will be derived from the general elements and will be modified independently of the general forecast.

When all forecast elements and computed parameters are complete, individual products will be generated.

This entire forecast process will be ongoing because new guidance will arrive periodically, forecast product release times will occur throughout the day, and forecasts will need to be updated because of changing weather.

Forecasters are responsible for approving each product for release. They may decide to enhance the wording of the text products to better describe the meteorological situation or to elaborate on how the forecast will vary in the local area of responsibility. This may also be the case for broadcast-ready products for NWR. However, if the forecaster manually edits an NWR product, the edited broadcast-ready text will also require checking to ensure that the words will be recognized by the NWR text-to-voice software.

The option to edit text products is advantageous due to the flexibility it gives the forecaster. The forecaster may edit the product to add details that the product generators are not programmed to include, to improve clarity, to incorporate local idioms, etc., but the text generators will be designed to produce an acceptable text product without human intervention. By choosing to edit the products, the forecaster spends extra time and becomes less efficient. He/she also sacrifices the consistency built into an automated method of producing text products: not only are the text products potentially inconsistent with one another, but also any product whose technical content has been changed will be inconsistent with the database. If so, the ability to use the database for monitoring and verification purposes is compromised.

Editing of graphic or gridded final products should not be necessary because the forecaster will be working with these products when the forecasts are created.

Operations Scenario

A typical scenario illustrates the forecast process using AFPS. After reviewing both observational and model data, the forecaster decides that a particular model best represents the atmosphere in the local domain. The forecaster instructs the system to initialize a reference worksheet(3) using this model (including the statistical guidance created from it). Since local effects beyond the scope of the model generally remain constant from day to day, and the current forecast is in good shape, the forecaster starts with the current forecasts (reflecting the previous numerical forecast cycle). Using the graphical forecast editors, he/she adjusts various fields to account for the differences reflected in today's model run.

Later, output arrives from a model that often is better initialized because it has a more accurate and complete database of observations on which to draw. After reviewing these data, the forecaster decides that this model better handles the upper-level wave that is forecast for tomorrow morning. The forecaster generates a new set of general weather elements (stored in a new reference worksheet), then selects several hours of the wind forecast and includes them as part of the forecast worksheet.

With editing complete, the forecaster invokes the space/time interpolation and consistency checker. Informed by the latter that the dew point forecast is slightly inconsistent with the temperature,(4) the forecaster adjusts the dew point forecast, then stores the worksheet in the database, whereby it becomes the official forecast.

The text generators are then invoked using this forecast, and one or more text products are created and placed in a text editor. The forecaster reviews the text and, if required, makes a few changes to improve the wording, then stores and disseminates the product.

Later in the morning, extended forecast grids arrive from NMC. The forecast monitor program alerts the forecaster that the new guidance differs significantly from the current forecast. The forecaster reviews the guidance using standard AWIPS techniques and determines that the only significant difference is in the fourth and fifth days. The forecaster initializes another reference worksheet with this new guidance and then copies the fourth and fifth days, thereby replacing the old forecast.

By early afternoon, it is apparent that the atmosphere is less stable than forecast. Thunderstorms are becoming widespread instead of isolated. They are also appearing several hours ahead of schedule. Deciding to update the forecasts, the forecaster redraws some of the weather depictions to denote the widespread coverage of thunderstorms and copies (moves) later depictions to earlier in the day to adjust for the earlier thunderstorm appearance.

The forecaster then stores the revised official forecast and invokes the space/time interpolation and consistency checker. The system indicates that everything is consistent and the desired products can be generated. Selected products are then created, stored, reviewed, and disseminated.

2.3 Preparing Watches/Warnings/Advisories

Watch, warning, and advisory (W/W/A) products will be generated much as warnings are generated today on the DARE and Pre-AWIPS workstations. The forecaster selects the product to be issued, defines the affected area and time period, selects the phenomena, and enters the basis where appropriate. Marine and fire weather watches and warnings are currently part of regular forecast products, though that may change in the future. Severe thunderstorm and tornado watches are currently issued by the National Severe Storms Forecast Center (NSSFC). Regardless of who generates watches in the future, local offices will at least be responsible for tailoring them to their areas of responsibility.

W/W/As will be issued in text, voice, and graphical forms, and will be reviewed and, if necessary, edited by the forecaster before release. Products destined for NWR will be quality-controlled to ensure proper text-to-voice conversion.

The issuance of W/W/As will affect routine forecasts in at least two ways. Many of today's forecasts (e.g., zone, coastal marine) carry headlines or banners alerting users to severe weather. Further, if a severe thunderstorm watch or warning is issued, all appropriate products should reflect the severe weather. For these reasons, when the forecaster selects severe weather phenomena, AWIPS techniques must update the database to allow the product generators to include the new W/W/A banners in the products.

2.4 Support for Other Functions

The forecast database must support other important forecast-related functions, including quality control, monitoring, coordination, and verification.

2.4.1 Quality Control

Two kinds of forecast quality control will be available to assist the forecaster. The first will ensure that the forecasts are temporally, spatially, and collaterally consistent. These techniques will review the forecaster-entered or -modified forecast fields, alerting the forecaster when predefined relationships are violated. For example, the forecaster will be alerted if forecast weather is inconsistent with cloud amount and types or if the forecast temperature change from one hour to the next is too abrupt. Site- and season-specific quality control thresholds will be tailored by forecast offices for their needs and preferences. For example, larger temperature changes might be permissible in mountainous regions than in Southeast coastal locations.

The second class of quality control routines will check the final text products before they are transmitted. These routines will be devoted to finding errors or problems in portions of the products that the forecaster manually edits. These checks can include spelling checks or, for NWR products, checks to ensure the forecasts can be converted from text to voice. These latter routines are not part of this project.

2.4.2 Monitoring

The volume of data and guidance available to the forecaster in the AWIPS era would overwhelm today's forecaster using AFOS. Sophisticated monitoring routines will be in place to help the forecaster stay on top of the incoming data, guidance, and forecasts. At least three types of monitoring will be required:

- observations versus forecasts,
- guidance versus forecasts, and
- current forecasts versus revised forecasts.

Observations-versus-forecast monitoring compares incoming observations to the forecast, ensuring the validity of the current forecasts. For example, aviation terminal forecasts (i.e., the database behind the forecasts) will be compared with incoming surface observations on a continuing basis.

Guidance-versus-forecasts monitoring compares new guidance to the current forecast. This includes guidance from central sources as well as locally produced guidance. These techniques will compare appropriate product parameters and projections and alert the forecaster if the new guidance indicates a substantial change from the current forecast.

As the forecaster maintains the forecast database and makes changes, a monitor will compare the changed values with the current forecast and alert the forecaster if it is necessary to issue a revised forecast product. These techniques will make it easier to maintain current forecasts in each program area.

2.4.3 Coordination

To minimize differences in the forecasts between adjacent forecast offices, future WFOs will exchange gridded forecasts.(5) Each office will compare these forecasts with its own and, if necessary, discuss discrepancies with the adjacent office. Because of the volume of data to be exchanged, manual review of all forecast fields will be impossible. AWIPS techniques will perform this operation automatically and will alert the forecaster to significant discrepancies. Thresholds used to determine significant discrepancies will be under the control of the forecast office (probably within limits prescribed by the NWS) and will be tailored for each forecast element and season.

NMC may create the position of Chief Forecaster, part of whose job would be to perform some coordination activities. Clearly, this will be a significant and difficult task, for machine or human.

2.4.4 Verification

Incoming observations and guidance and locally produced forecasts will be continually collected to produce a forecast verification database. This database will contain point, area, and gridded forecasts created by the techniques described in this plan. The data will be used to create daily, weekly, monthly, and seasonal verification information.

Although some aspects of verification may be tested during the development of AFPS, specification of verification techniques and procedures is not part of this project.

Footnotes

(1)

Throughout this chapter, we will use the term "guidance" in a rather broad sense, encompassing direct-from-model grids or weather elements prepared from same, NMC human-prepared forecasts, and statistical aids (e.g., MOS).

(2)

Note that Figure3 includes Phase II goals. In contrast, Figure2 includes only functions planned for the initial implementation.

(3)

Worksheets, the forecaster's "window" into the forecast database, are described in Chapter 3.

(4)

Forecast consistency checking will be rudimentary. For example, we don't want precipitation without clouds, or snow with temperatures in the 70s. No model will be running to fully adjust the atmosphere. Our weather elements are a surface-based view of the atmosphere, and thus do not require extensive consistency checks.

(5)

The requirement for such forecast exchange is outlined in the AWIPS RFP, page SRSI-N-19.

3 The Forecast Database

Forecast fields will be stored for later retrieval by various modules, including the interactive editing tools, the product generator, and interpolation tools. During the early stages of development, this project will use an interim storage system to house the weather elements; later, they will be integrated with the AWIPS database.

The forecast database contains both general and service-specific weather elements. In addition to these forecaster-edited elements, some forecast-specific product parameters are needed by the text generators. Derivation of these product parameters from the weather elements is described in Chapter 7. All of these are part of the AWIPS database.

3.1 Database Structure

The physical structure of the forecast database will be defined by AWIPS; no details are included here. The logical structure of the database will incorporate a worksheet concept (Figure 4 on page 22). A worksheet consists of a matrix of weather elements versus time, and each element of the matrix is a two-dimensional forecast of a single element at a particular time covering the entire forecast area. Multiple matrix elements may be edited simultaneously by the forecaster. The forecast worksheet represents a complete forecast for the area and time covered.

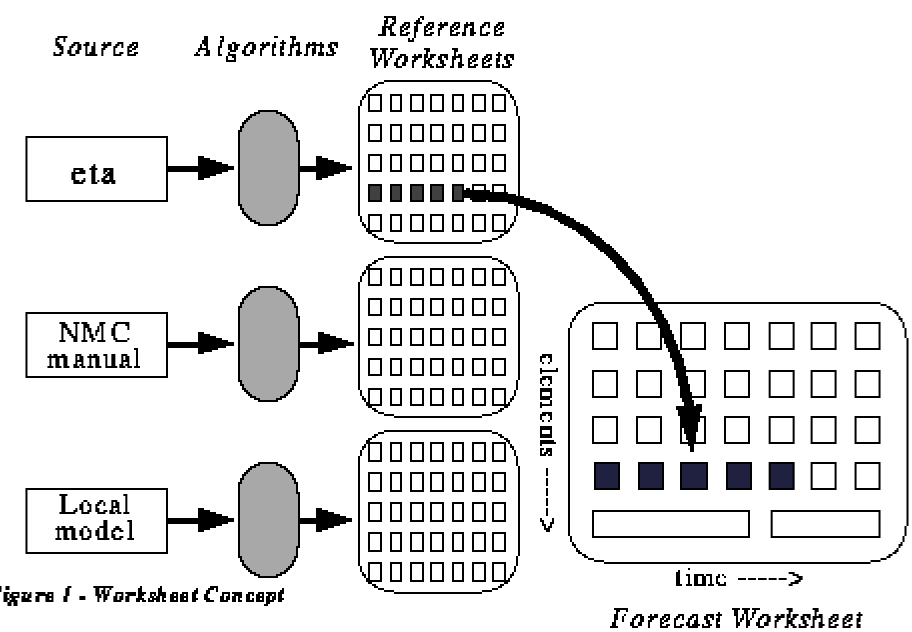


Figure 1 - Worksheet Concept

The worksheet concept provides the forecaster great flexibility by allowing the forecast to be generated with input from a wide variety of data sources. Typically, forecasters will use several reference worksheets. One can be constructed, using predefined algorithms, from the output of each numerical model. Another will contain the forecast grids manually prepared at NMC. The forecaster will be able to refer to these fields and copy them as desired into the forecast worksheet. For example, a forecaster could generate two reference worksheets, each based on a different model, then choose the features that are handled best by each model and build a composite worksheet that utilizes each model's strengths. The graphical editors are used to modify these first-guess fields. Interpolation tools will be provided to fill in missing times so the forecaster is not required to edit every matrix element.

The final worksheet containing the desired forecast solution is saved in the database as the official forecast. All text forecasts are generated from this database.

3.2 Relationship to AWIPS Database

Since AWIPS is not yet available, an interim forecast database will be created so that work may begin immediately. This forecast database will be integrated with the AWIPS database when feasible. Since performance is critical, success in integrating the database into AWIPS will depend heavily on the performance of the AWIPS database.

3.3 Weather Elements

The weather elements to be stored in the forecast database will be derived from the contents of the AWIPS database. The AWIPS database will contain forecast fields from NMC (manually prepared) and from national- and local-scale models. It will also include surface observations, upper air observations, radar data, and satellite imagery. Methods using these data sources will be developed for initializing a predefined set of weather elements, which will be available for viewing and editing by the forecaster.

General weather elements (those applying to multiple services) will be created directly from guidance. After forecaster editing, other general elements may be derived. For example, maximum relative humidity, used in agricultural and fire weather forecasts, is derived from dew point and temperature. Service-specific elements will be derived from the general elements and, in many cases, other data.

The general/specific weather element concept is aimed at reducing forecaster workload, while allowing him or her to work in a logical progression through the forecast process. The design is a trade-off between conflicting requirements to automate an inherently hands-on process.

The weather element sets may undergo revision as work on this project progresses. The lists will be reviewed by NWS management and the AFPS Forecaster Working Group (AFWG)(1) to ensure that they are adequate for all products to be generated.

3.3.1 General Weather Elements

An initial set of general weather elements is defined in Table 1. This set contains elements that

- are intuitively familiar to forecasters;

- can be derived from information in the AWIPS database (observations, model fields, and central guidance and forecasts);
- can be used to derive other, more specialized, weather elements; and
- are required for standard NWS products.

Table 1 - General Weather Elements

Weather Element	**Descriptors**	**Data Type(a)**	**Spatial Representation(b)**
Temperature		Numerical	Continuous
Dew Point		Numerical	Continuous
Wind	Speed, Direction. Gust	Numerical	Continuous
	Amount, Type, Probability(c)	Categorical	Bounded Area
Clouds			
	Base, Top*c*	Numerical	Bounded Area
Weather	Type, Intensity, Coverage	Categorical	Bounded Area
Sky Condition		Categorical	Bounded Area
Probability of Precipitation		Step-Numerical	Continuous
QPF		Step-Numerical	Continuous
Visibility		Step-Numerical	Bounded Area
Snow Accumulation		Numerical	Continuous
Freezing Level		Numerical	Continuous
Inversion	Type, Top, Base	Categorical	Bounded Area

(a)

Numerical refers to floating-point or integer numbers, categorical to one of a set of categories (e.g., CLR, SCT, BKN, OVC), and step-numerical to quanta (e.g., PoP is in 10% increments).

(b)

Data representations are further described in Section 6.2.1.

(c)

Type, probability, base, and top of clouds are needed only for aviation-oriented forecasts.

Note that we have excluded pressure from the list of general elements. Although pressure is a commonly viewed element (and will be available for reference), it is not used in forecast products. Pressure could be edited and used to derive winds, but wind forecasts are available both directly from models and from statistical guidance.

As discussed in Chapter 4, considerable QPF guidance will be provided to WFO forecasters. It would be desirable to relate QPF to precipitation intensity and duration (part of the "weather" weather element); this will be difficult, at best. Further, the relationship between QPF and probability of precipitation (PoP) is complex.

QPF grids will be sent from WFOs to RFCs with three probabilities for each accumulation period. Though these have yet to be determined, suppose that they are chosen as 20%, 50%, and 80%. Consider, for example, an area specified at 80% chance of 0.50 inch accumulation. The 50% map might show 0.75 in and the 20% map 1.00 in. In addition, the 50% map might show 0.25 in and the 20% map 0.10 in. That is, there is a 50% chance that between 0.25 in and 0.75 in will occur.

PoP, of course, is the probability of any measurable precipitation. How this relates to QPF probabilities, and how all of these various precipitation elements will work together, will require much study.

Derived General Weather Elements

Table 2 includes those general weather elements that are derived from the "basic" general elements. The derivation techniques will be transparent to the forecaster. Temperature and relative humidity extremes are straightforward, given a time series. Sky condition will be determined from cloud fields.

Table 2 - Derived General Weather Elements

Weather Element	Data Type	Spatial Representation
Maximum Temperature	Numerical	Continuous
Minimum Temperature	Numerical	Continuous
Maximum Relative Humidity	Numerical	Continuous
Minimum Relative Humidity	Numerical	Continuous
Sky Condition	Categorical	Bounded Area

3.3.2 Service-Specific Weather Elements

The product generators require many specialized parameters that are not in the above lists of general weather elements. As with the derived elements listed above, these are derived from the general weather elements, plus whatever other information may be required from the AWIPS database. For example, the agriculture forecast requires hours of sunshine, which can be derived from cloud cover and sunrise/sunset information. These elements differ from the derived elements only in that they apply to just one service. Tables 3 - 7 list these elements by service. Aviation-specific weather elements are of two types, supporting terminal and route forecasts, described Tables 3 and 4.

To-be-developed high-quality derivation techniques will minimize forecasters' need to edit these fields.

Table 3 - Aviation-Specific Weather Elements -- Terminal Forecasts

Weather Element(a)	**Descriptors**	**Data Type**	**Temporal(b) Representation**
Wind	Speed, Direction, Gust	Numerical	Continuous
Cloud	Type, Amount	Categorical	Stepped(c)
	Base	Numerical	Continuous
Weather	Type, Intensity	Categorical	Stepped
Visibility		Step-Numerical	Continuous

(a)

All apply to Prevailing, Occasional, and Chance conditions.

(b)

Since terminals are point forecasts, there is no spatial representation to consider.

(c)

"Stepped" refers to categorical changes with time.

Table 4 - Aviation-Specific Weather Elements -- Route Forecasts

Weather Element(a)	**Descriptors**	**Data Type**	**Spatial Representation**
Cloud	Base, Top	Numerical	Continuous
	Amount	Categorical	Stepped**(b)**
Weather	Type, Intensity	Categorical	Stepped
Surface Visibility		Step-Numerical	Continuous
Hazards		Categorical	Stepped

(a)

All apply to Isolated, Local, Areas, and Widespread conditions.

(b)

A route forecast is essentially a line; thus, "stepped" applies as above.

Table 5 - Fire-Weather-Specific Weather Elements

Weather Element	Descriptors	Data Type	Spatial Representation
	Transport Speed/Direction		
Wind	Free Air Speed/Direction	Numerical	Continuous
10-Hour Fuel Moisture		Numerical	Continuous
Precipitation Duration		Step-Numerical	Continuous
Haines Index		Step-Numerical	Continuous
Mixing Depth		Numerical	Continuous
Stability		Categorical	Bounded Area
Lightning Activity Level		Categorical	Bounded Area
Chance of Wetting Rain		Step-Numerical	Continuous

Table 6 - Agriculture-Specific Weather Elements

Weather Element	Data Type	Spatial Representation
Dew Intensity	Categorical	Bounded Area
Dew Dry-off Time	Step-Numerical	Continuous
Drying Conditions	Categorical	Bounded Area
Hours of Sunshine	Numerical	Continuous
Minimum Dew Point	Numerical	Continuous

Table 7 - Marine-Specific Weather Elements

Weather Element	Descriptors	Data Type	Spatial Representation
Waves	Height	Numerical	Continuous
Swells	Height and Direction	Numerical	Continuous
Superstructure Icing		Categorical	Bounded Area

3.4 Domain and Resolution

The domain and resolution in both space and time must be sufficient to accurately detect any approaching phenomena that could influence the forecast.

3.4.1 Spatial

Although forecasts will be issued for just the WFO's area of responsibility, the domain must be large enough to view upstream phenomena that could affect the forecast. We also must accommodate aviation route forecasts (Transcribed Weather Broadcasts, or TWEBs), some of which extend beyond WFO boundaries. The forecast database will store data on the AWIPS Local scale. Resolution must be fine enough to define local effects sufficiently. Our initial plans specify a 10-km horizontal resolution; whether this is appropriate will be determined through investigation.

Occasionally, forecasters will need to define forecasts in higher spatial resolution than supported by the standard forecast grid. To support this requirement, the forecaster will be able to define, store, and reuse special local-effects areas.

There will also be a terminal forecast tool. Suppose a forecaster has forecast responsibility for two airports that are separated by only several kilometers. One lies at the bottom of a valley, and the other is much higher in elevation. Fog has enveloped the entire area, and it is the forecaster's job to predict when the fog will lift, allowing for normal aircraft operations. Expecting the fog to burn off early in the day at the higher airport, while the valley airport remains in fog most of the day, the forecaster creates a general forecast that shows the fog slowly dissipating with time, then uses the terminal forecast tool to define a specific forecast for the valley site that shows fog and low visibility remaining throughout the day.

3.4.2 Temporal

The time domain of the forecast database will generally be 0 to 6 days, reflecting current forecast requirements. Aviation-specific elements are limited to 24 hours (terminal forecasts) and 18 hours (route forecasts). Time resolution for most elements is one hour, though several require less (e.g., fire weather winds are all forecast with 12-hour resolution). Further, time resolution will generally be finer for shorter forecast projections and somewhat more coarse for longer projections. This approach will give us flexibility for expansion and customization and will provide an added benefit of saving storage space and time for performing interpolations.

The choice of resolution will affect the wording in the forecast. For example, if we were to limit ourselves to maximum and minimum temperature, we would not be able to produce rush-hour forecasts or create phrases such as "sharply colder in the afternoon." On the other hand, retaining a 1-hour resolution in later periods may be inappropriate since the guidance will not have that resolution and the forecaster cannot accurately distinguish between one hour and the next after several days, e.g., between hours 95 and 96.

Time in the database will be reckoned from the current hour, rolling forward each hour. Users will work in terms of valid time, so this should not result in any confusion.

In the future, when W/W/A functions are integrated with AFPS, it will be necessary to increase time resolution to 1 minute.

Footnotes

(1)

The AFWG met for the first time in February 1993. This group, comprising representatives of each NWS Region, the Office of Meteorology (OM), OH, NMC, the AWIPS Program Office, and FSL and TDL, will help ensure that NWS operational needs are properly considered during development.

4 Forecast Guidance

The development of AFPS entails creation of techniques for defining the product parameters used in the forecasts, as well as techniques by which a forecaster will enter and edit forecasts. Interactive manipulation of the forecast is described in Chapter 6. The elements to be manipulated are the weather elements defined in Section 3.3.

At the start of a forecast session, the forecaster will initialize a worksheet using either weather elements from earlier forecasts or new guidance from central or local models. This guidance may be direct model output (possibly interpreted by algorithms), it may be enhanced by a forecast team at NMC, or it may be statistical guidance based on numerical models. The quality of this information is critical to the automated product preparation process. The better it is, the less a forecaster will have to change or update it to produce a forecast. It is expected that centrally produced forecast grids will be of sufficient scope and quality to support preparation of all routine forecast products (for 6 hours and beyond) without forecaster intervention, if necessary (e.g., during severe weather).

Table 8 lists expected sources of guidance. Numerical guidance will be based on NMC's Nested Grid Model (NGM), Global Spectral Model (GSM), eta model, and Rapid Update Cycle (RUC), plus any local models that may be implemented. The National Hurricane Center (NHC) and NSSFC will also generate graphics and grids.(1) Further, RFCs will be producing soil moisture accounting information, and precipitation, river, and flood guidance.

Table 8 - Weather Elements Sources

Source	Statistical Techniques	Projections	Availability
NGM	MOS	6 - 60 hours	AWIPS IDB
GSM	MOS	6 - 60 hours	Partial set at IDB; complete set at first P3I
	calibrated MOS/ Perfect Prog	greater than 60 hours	AWIPS IDB
eta	to be determined	to be determined	to be determined
RUC	none	to be determined	to be determined
NMC manual	none	6 hours - 7 days	First P3I
NSSFC	to be determined	6 - 24 hours	First P3I
NHC	to be determined	6 hours - 5 days	First P3I
RFC	none	to be determined	AWIPS IDB
LAMP		1 - 20 hours	AWIPS IDB
Local models	to be determined	to be determined	Second P3I

Additional manual guidance is available from NMC. Currently, this guidance is in graphical form, but NMC is in the process of upgrading its procedures, and plans to issue forecast grids in the AWIPS era.

4.1 Numerical Model Guidance

NMC model output will be available at AWIPS initial deployment in the form of graphics and gridded fields. Guidance will be available from several models. In some cases, rather sophisticated techniques will be necessary to help forecasters sort out complementary and conflicting information. An example is shown in Table 9, which lists gridded QPF guidance that will be provided to future WFOs from NMC numerical models. (In addition to those shown in the table, short-term forecast grids will be derived from WSR-88D data, 0-18 hour forecasts will be produced by TDL techniques, and manual guidance will be received from NMC. Locally run models will also generate QPF fields.) Each WFO will send QPF grids to its associated RFC with 1-hour (0-6 hours), 3-hour (6-18 hours), and 6-hour (18-72 hours) durations.

Table 9 - NMC Model-Output QPF Guidance for WFOs

Projection (hours)	Summation (hours)	Resolution (km)	Source	Update Frequency (hours)
0 - 18	2	20	eta	6
18 - 36	3 to 4	20	eta	6
0 - 48	6	40	RAFS	12
0 - 24	2	40	MRF (Aviation Run)	12
24 - 48	6	40	MRF (Aviation Run)	12
48 - 72	12	40	MRF (Aviation Run)	12

4.2 Statistical Guidance

One of the WFO forecasters' primary guidance sources will be interpretations provided by the statistical techniques of MOS, LAMP, and calibrated Perfect Prog.

Table 10 lists the statistical guidance planned to be produced from the NGM, GSM, and LAMP. The guidance will be produced centrally and transmitted to WFOs. The schedule for development of these techniques is given in Section 9.3.2.2.

Table 10 - Statistical Weather Forecasts Produced by MOS and Calibrated PerfectProg

	NGM MOS	GSM MOS	GSM PP	LAMP

Maximum Temperature (MAX TEMP)	x	x	x	x
Minimum Temperature (MIN TEMP)	x	x	x	x
Surface Temperature (TEMP)	x	x		x
Surface Dew Point (DP)	x	x		x
Wind Direction and Speed (WIND)	x	x		x
Probability of Precipitation (POP)	x	x	x	x
Probability of Quantitative Precipitation (categories) (QPF)	x	x		x
Probability of Thunderstorms (TSTM)	x	x		
Probability of Severe Weather (SVR WX)	x	x		
Probability of Precipitation Type (categories) (POPT)	x	x		x
Probability of Ceiling Height (categories) (CIG)	x	x		x
Probability of Cloud-Cover (categories) (CLD)	x	x		x
Sunshine (hours, percent of total possible) (SUN)	x	x		
Probability of Visibility (categories) (VIS)	x	x		x
Probability of Obstructions to Vision (categories) (OBVIS)	x	x		x
Probability of Snow Amount (categories) (POSA)	x	x		
Probability of Precipitating Conditions (categories) (POPC)	x	x		
Probability of Frozen Precipitation (POF)		x		x

Statistical forecasts will be produced from the NGM and GSM using MOS for projections ranging from 6 to 60 hours. The MOS technique involves derivation of statistical relationships between desired predictands and numerical weather prediction model output. Separate linear regression equations must be developed for each predictand and for each forecast projection. To produce meaningful relationships, the numerical models must not undergo substantial changes when the outputs are collected for the equation derivation and during the time when the resulting equations are used to produce forecasts. The MOS method produces some of the most accurate forecasts of the statistical forecast methods. The disadvantage of this method is that it is slow to follow the evolution of the numerical model.

LAMP is a local MOS updating technique designed to improve short-range MOS guidance. The program uses relationships between the predictands in Table 10 and central MOS guidance, simple advective models, and current surface observations. The technique is designed to update central MOS guidance at any hour of the day and to produce forecasts from 1 to 20 hours. LAMP will update guidance from both the NGM and GSM MOS output.

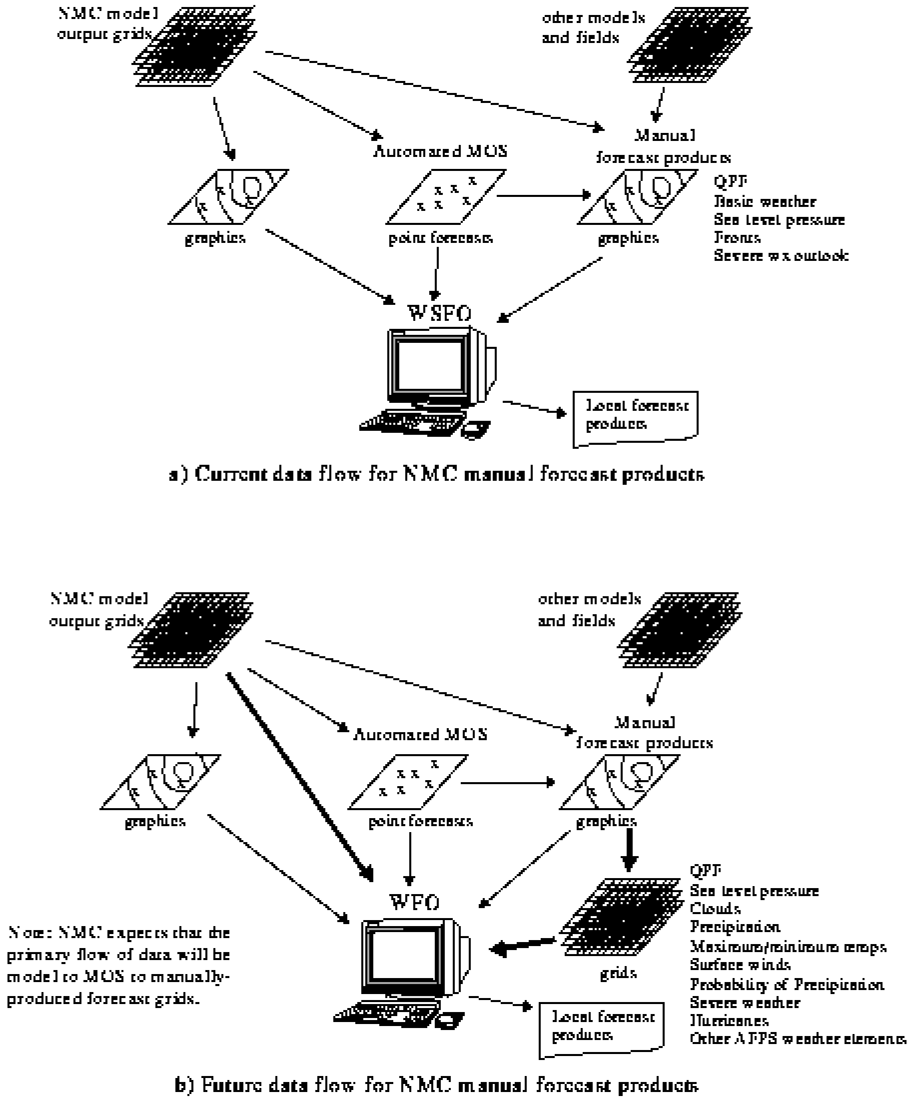
Statistical forecasts based on GSM projections from 60 hours out to 8 or 10 days will be produced using the Perfect Prog technique, a modified version of it, or a modified MOS approach. Parameters forecast by this technique are designated in Table 10. Perfect Prog equations are prepared by developing concurrent regression relationships between observations of the element to be predicted and observed predictors. These relationships are then applied to direct model output at any forecast projection to produce the statistical forecasts. Perfect Prog assumes that the numerical model output is perfect, hence the name. Some modification of the forecasts produced by "pure" Perfect Prog is usually necessary to assure sufficient accuracy, particularly with longer forecast projections; this modification is usually called "calibration."

The advantage of the pure Perfect Prog approach is that the regression relationships can be applied to any numerical model. Forecasts should improve as the quality of the numerical model improves. The disadvantage of Perfect Prog when compared with MOS is accuracy. Glahn (1991)(2) discusses the advantages and disadvantages of these approaches in detail.

4.3 Manual Guidance and Forecasts

Guidance and forecast grids will be produced by NMC. Forecasters at NMC will use gridded output from the models, apply appropriate bias corrections and judgement, and "draw" an optimum solution.

NMC's MOD is in the early stages of a system upgrade which includes automation of the manual forecast preparation system; i.e., they will be replacing the traditional acetate-and-grease-pencil system with a computerized graphical editing system. Included with this upgrade will be a change in the data flow from NMC to each forecast office. The concept is illustrated in Figure 5.(3) Currently, WSFOs receive graphics based on NMC models, point forecasts from MOS and other statistical guidance, and manually produced graphics from NMC. In the future, NMC model grids and a collection of manually produced grids will also be sent to WFOs; indeed, NMC expects that the primary flow of data will be model to MOS to manually produced forecast grids.



(new data flow arrows are highlighted)

Figure 1 - Modernization of NMC Manual Guidance Procedures

It is a goal of NWS that, for 6 hours and beyond, these manually produced grids will be used, in unedited form, to produce a full suite of routine forecast products, when WFO resources are demanded by the watch/warning function during severe weather situations. As such, all general weather elements and many of the service-specific weather elements described in Section 3.3 will be supplied by NMC for use by AFPS.

Footnotes

(1)

In the future, these tasks will be handled by the new Tropical Weather and Storm Prediction Institutes, respectively. The Weather Prediction Institute will produce what is referred to as "NMC manual" forecasts in Table8.

(2)

Glahn, H.R., 1991: On MOS and Perfect Prog for interpretive guidance. TDL Office Note 91-3, NOAA/NWS/OSD/TDL, Silver Spring, MD, July 1991.

(3)

Original figure provided by Dr. Lou Uccellini, NMC

5 Deriving Weather Elements

Whether a forecaster chooses to initialize forecast fields from the current forecast or based on a numerical model, it will be necessary to generate grids of weather elements. These grids will at least be used for reference.

A difficult problem that must be addressed when initializing weather elements is related to the representativeness of the basis data. Neither grids nor points can be expected to adequately represent small-scale topographic and geographic features, which may produce significant localized changes in weather. We will provide means for forecasters to include such local effects in the forecasts (see Section 6.2.6), but a much better solution would be to incorporate such techniques in the initialization.

5.1 Direct from Model Grids

As a rule, numerical models do not directly produce weather elements. The obvious solution is to generate the elements directly from a model's output variables. Such algorithms are being developed. Examples include work at FSL using the Local Analysis and Prediction System (LAPS), Mesoscale Analysis and Prediction System (MAPS, soon to become operational as NMC's RUC), and NMC's eta model. Much of the present work is directed at aviation-specific weather elements, in support of the FSL/FAA Aviation Gridded Forecast System. Similar algorithms could be developed for other NMC models and weather elements.

Currently, most weather elements must be derived using statistical or interpretive approaches. Regardless of the success of developing direct-from-model fields, it is likely that statistical methods will always produce better first-guess forecasts at stations, since they are tied to station climatological records.

5.2 Using Statistical Methods

NMC model output will be interpreted in terms of probability and best-category forecasts by statistical techniques. These statistical forecasts will then be used to derive forecasts for weather elements which constitute the hydrometeorological fields required for the official forecast. Some elements, such as temperature, dew point, and wind speed and direction, can be obtained directly from statistical guidance.

The ICWF's transformation of MOS point data into grids of "explicit weather" elements is a multistep process:

1. MOS station guidance, as updated by the most recent LAMP output, is mapped to a grid. For continuous MOS elements (those for which an average is meaningful), the forecasts for one or more stations contribute to the value assigned to a grid point. For categorical elements, each grid point is assigned data from a single station.
2. If any grid points remain undefined due to missing MOS data, they take on the value of the

nearest data-bearing grid point.

3. Selected continuous elements are spatially smoothed.
4. Weather elements are derived from the guidance at each grid point.
5. Areas of precipitation and cloud layers are identified and mapped.

The early versions of AFPS will rely primarily on statistical guidance and thus will use a similar scheme. The increased number of stations available in the future will improve this scheme, but any statistical approach is likely to have difficulty in complex terrain.

Even though the inherent accuracy of Perfect Prog is less than MOS, the results achieved from calibrated Perfect Prog forecasts are expected to be sufficiently accurate for grid initialization.

5.3 Using Interpretive Algorithms

Since present NWS statistical techniques do not directly produce forecasts of certain weather elements, algorithms will be used to translate probability and categorical forecasts for various weather elements into forecasts of other weather elements.

As an example, consider the determination of precipitation type and intensity. The ICWF employs a three-step process, using currently available MOS parameters. First, the phase of precipitation (liquid, freezing, or frozen) is determined by analyzing the probabilities of each phase, the best category forecast of precipitation type, and 3-hour temperature forecasts. The nature of the precipitation (general, showery, or drizzle) is then determined by analyzing probabilities of rain, rain showers, and drizzle. Finally, precipitation intensity is determined from an analysis of quantitative precipitation forecasts. In the 1- to 20-hour time frame, LAMP forecasts can be used in basically the same manner.

6 Interactive Techniques

Interactive techniques are used in three main areas of this project:

- worksheet initialization,
- viewing and modifying weather elements (tool kit), and
- product generation selection.

This section provides a description of our initial thoughts about these techniques. Through exploratory development, and in consultation with operational forecasters (including the AFWG), these ideas are expected to evolve.

6.1 Worksheet Initialization

The worksheet concept, through which the forecaster will work with the data, was outlined in Section 3.1. AFPS will provide the tools and user interface required to

- select the guidance source,
- copy all or selected parts of a reference worksheet to the forecast worksheet, and
- copy selected portions of the forecast worksheet to itself.

A potential user interface for worksheet initialization is shown in Figure 6 on page 38. Assume that the forecaster has been "drawing" the forecast using the tools described in the next section. New output from the 12Z eta model arrives, and the forecaster examines model fields such as 500 hPa heights and vorticity using standard AWIPS product display techniques. Liking the solution and believing that the model run has some merit, the forecaster decides to include the guidance into the forecast worksheet. The forecaster initializes a reference worksheet containing the general weather elements derived from this guidance.

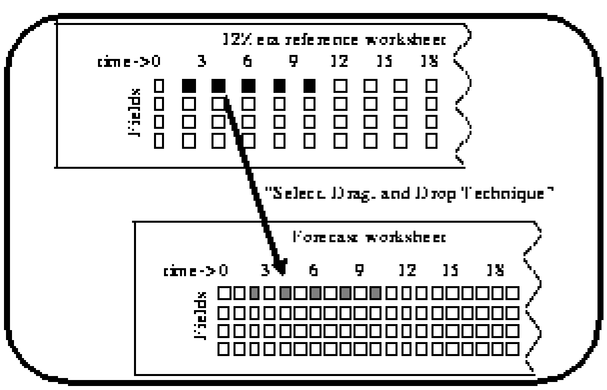


Figure 1 - Forecaster selects elements to transfer from the 12Z eta reference worksheet to the forecast worksheet. Select, drag, and drop

Figure 1 - Conceptual Worksheet Initialization Interface

The forecaster then examines the derived weather elements on the 12Z eta worksheet and decides that its solution for the surface temperature from hours 2 through 10 is better than the current forecast. Using an interface depicted in Figure 6, the forecaster selects the 2- through 10-hour temperature forecasts and drags them over the forecast worksheet. The selected 12Z eta model guidance replaces the data currently in the worksheet. The forecaster can then examine and edit the worksheet until the desired solution is shown,(1) and then save it in the database as the official forecast.

6.2 Viewing and Modifying Weather Elements

The user interacts with data in the forecast database through a tool kit. The tool kit (Figure 7) comprises a series of related routines to display and edit the various weather elements, either singularly or grouped in several formats. It also will be possible to display (overlay) standard AWIPS products (graphics or images) with any of the spatial depictions.

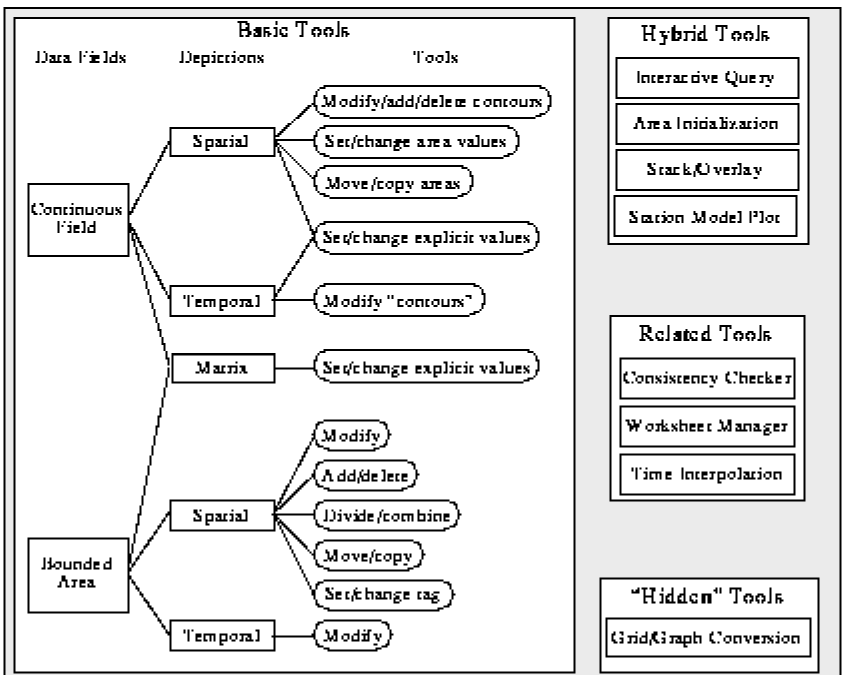


Figure 7 - Tool Kit Structure

The tool kit will be designed initially to support only two dimensions plus time. The structure of the tool kit, graphical depictions, and tools is such that the concepts can be applied to three-dimensional fields plus time when appropriate.

The tool kit will contain tools that work with all general weather elements. It will not contain forecast-product-specific tools, such as zone combinations. One of the principal purposes of AFPS is to have all products come from the same source, i.e., the forecast database. Forecasters will not have time to concentrate on individual products, nor should they be forced to do so.

6.2.1 Field Type

The field type defines the way in which the data are stored in the forecast database, as well as the available viewing and editing tools. Two types of fields are used:

- continuous fields,
- bounded areas.

Each weather element is represented by one of the field types, illustrated in Figure 8.

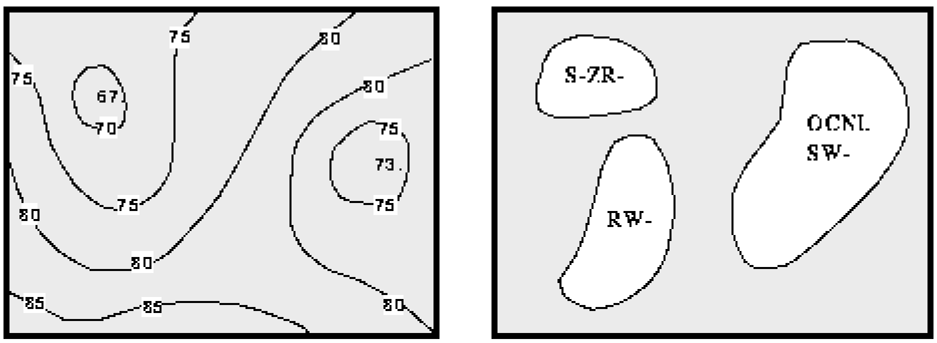


Figure / - Field Types

A continuous field is used to represent those weather elements whose values are defined over the entire domain. A contour representation can be used to depict a one-dimensional field (e.g., temperature), while vectors or barbs can be used for a two-dimensional field (e.g., wind).

Each bounded area has an associated value, represented by a series of tags that can be interpreted by the product generators. For example, a bounded area with a value of 3R- would be interpreted as 3 miles visibility and light rain.

6.2.2 Graphical Depictions

Three graphical depictions will be available (Figure 9). The spatial depiction shows a geographic area at a single time for a single weather element. The temporal depiction shows a single element versus time for a single point (or area). The matrix depiction, showing an element at a particular time and place, permits the forecaster to view data that are not in gridded form.

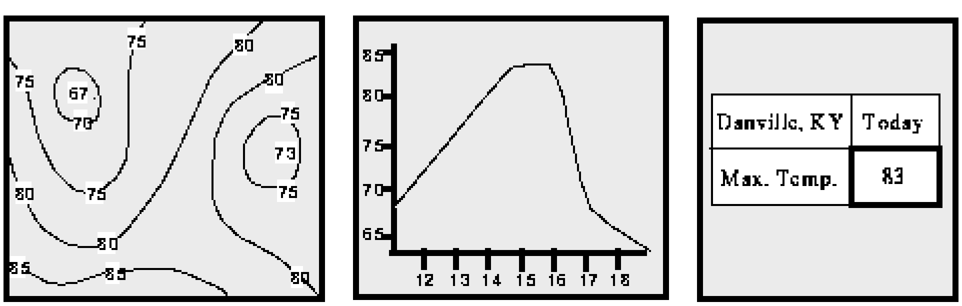


Figure / - Graphical Depictions

6.2.3 Drawing and Modification Tools

As Figure 7 illustrates, a set of tools is available for working with each field type and graphical depiction. Sampling and labeling tools will also exist for both field types. The sampling function allows the forecaster to interrogate and label fields anywhere on the display. The label function allows the forecaster to label continuous field contours, maximum/minimum points, and bounded area tag values.

During all edit operations, the changes made to the field are displayed immediately along with their original unchanged values. Once the edited changes are saved, the contours and lines representing the original unchanged value are removed from the display.

Examples of the spatial depiction tools are shown in Figure 10. Forecasters will be able to draw new contours, delete contours, and modify existing contours. The last will probably be the most used of this set. In like fashion, it will be possible to add or delete bounded areas, and reshape existing areas. Bounded areas may also be divided or combined.

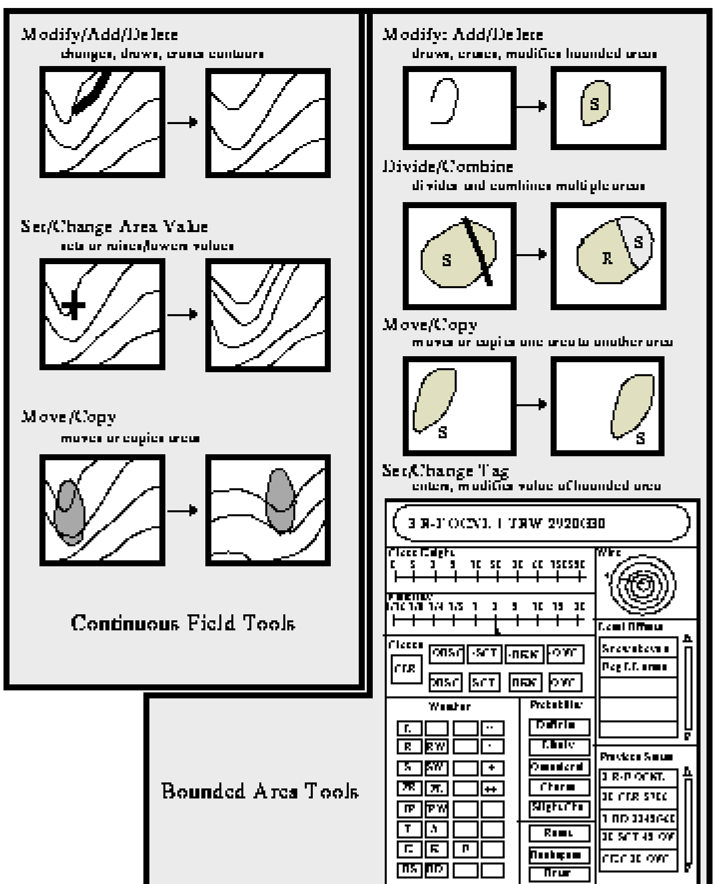


Figure 7 - Edit Tools for Spatial Depictions

A forecaster may select an area of continuous field and apply a new value to that area or specify a change to be made. A user-selected weighting function will determine how the modified data blend with surrounding points.

The move/copy tools allow the forecaster to identify a bounded area or to outline an area on a continuous field and move it to another area of the screen. The associated field values are moved to the new location and the hole left behind is filled in using interpolation or extrapolation.

A weather entry calculator may be used to enter or edit the value of a bounded area.

Time series lines (for continuous fields) will be edited in the same way as contours. Appropriate tools for bounded area tags will also be developed.

It will be possible to set or change selected gridpoint values explicitly. The same technique will be used for data presented in matrix form.

6.2.4 Hidden and Related Tools

A small set of "hidden" tools underlies the graphical presentation and modification tools. These tools are called hidden because they are transparent to the user, and will include routines that convert between grids and contours.

Several related tools that the user controls but does not use for depiction editing are contained within the tool kit. These tools perform time interpolation and linking, consistency checks, and worksheet management.

6.2.5 Hybrid Tools

The simplest application of the tool kit allows the user to view just one weather element at a time in just one graphical depiction. Typically, the user will wish to work with several weather elements simultaneously, thus requiring a set of hybrid tools.

Forecasters are familiar with viewing many elements simultaneously using a station model plot. Although not quite a "tool" (it will be for viewing only), this way of viewing data will be useful in many circumstances. A common way of using this will be in time-series form (Figure 11).

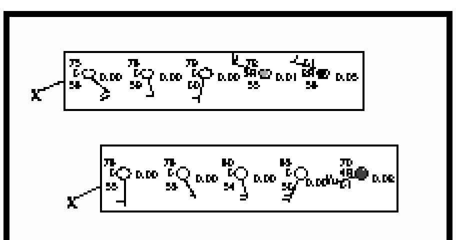


Figure 1 - Station Model Plot

Combining the various depictions provides an additional set of tools, such as the interactive query and bounded area initialization hybrid tools. One such interactive query tool will allow the forecaster to move and click the mouse over the spatial depiction and view the time series or station model plot for the selected point (Figure 12). The bounded area initialization tool (Figure 13 on page 44) will allow the forecaster to vary the value of a bounded area over time.

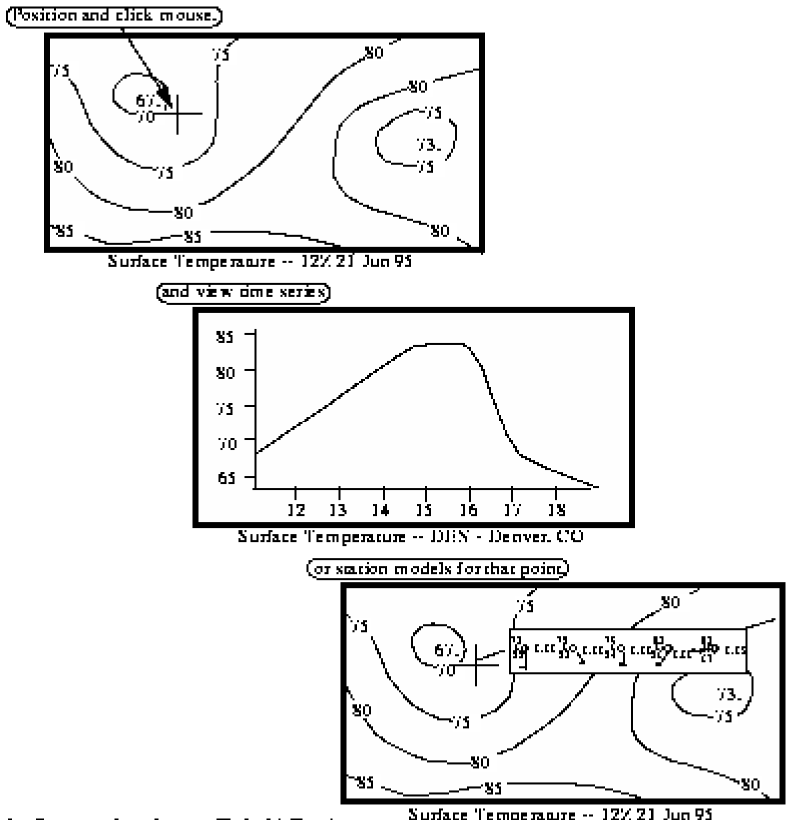


Figure 1 - Interactive Query Hybrid Tool

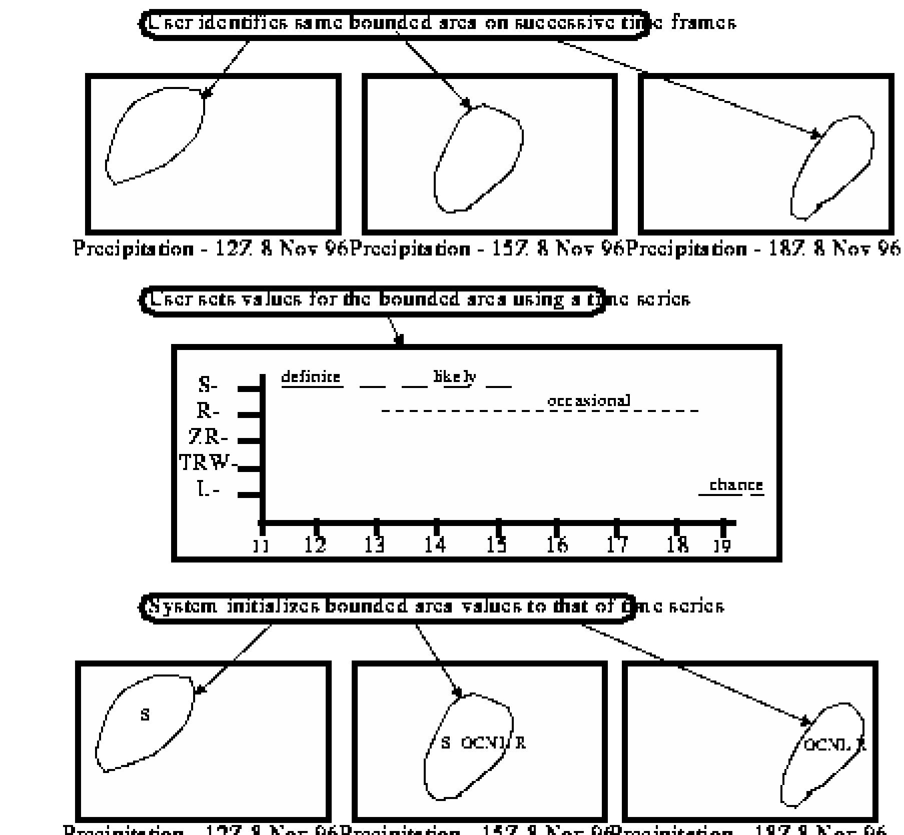


Figure 1 - Bounded Area Initialization Hybrid Tool

The capability of overlaying depictions also provides an additional set of tools. Multiple weather elements valid for the same time on the spatial depiction or for the same location on a time series can be stacked or overlaid. An example is shown in Figure 14 on page 45, a possible aviation terminal forecast tool including both observed and forecast time periods for temperature/dew point, winds, clouds, and precipitation. The temperature and dew point are overlaid, while the others are stacked. Similarly, multiple locations can be presented on a time series.

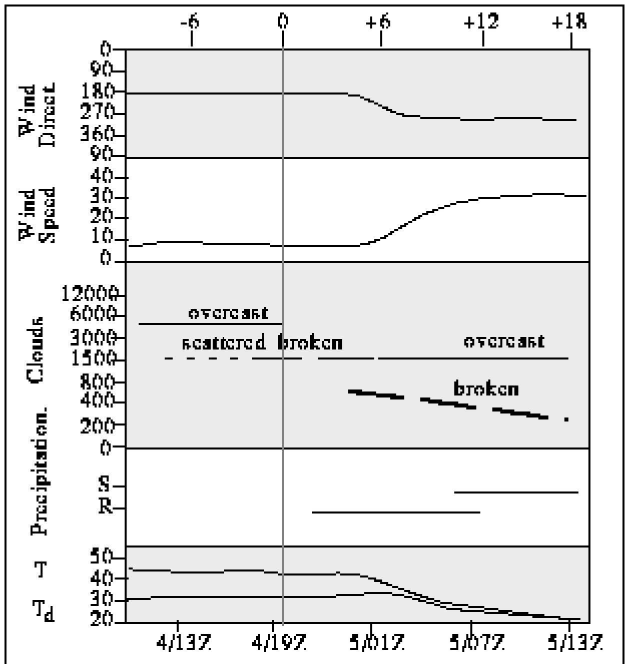


Figure I - Multiple Elements Hybrid Tool

Forecasters will wish to view the change from time period to time period; AWIPS animation capabilities may be used for this purpose. Multiple times can also be presented on the spatial depiction to allow a forecaster to view such changes. For example, bounded area depictions of the precipitation pattern at multiple times may be simultaneously displayed and edited, as illustrated in Figure 15 on page 45. Adjusting the arrows on the time bar will display the corresponding depiction.

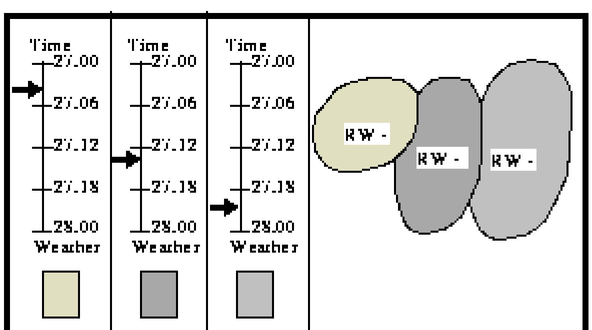


Figure I - Overlay of Multiple Fields from Multiple Times

6.2.6 Interactions Between Depictions

The spatial and temporal depictions can be used together to view and modify the data in three dimensions (x, y, time). However, the interaction between the temporal and spatial tools is not clearly defined and is a candidate for exploratory work. A spatial area of influence and temporal range of influence will exist when the forecaster is modifying data. It may be desired to allow the forecaster to vary the area of influence from a single point for local effects to the entire screen for major effects, depending on the specific task at hand. It is expected that changes made on time series will affect the values of all associated spatial depictions over the area of influence. Similarly, modifications made to a spatial depiction will affect corresponding time series.

A forecaster may have several windows open on the display, each containing one or more depictions. Modifications made on one depiction will result in changes in any related windows, allowing the forecaster to interleave operation sequences as appropriate.

All forecasters are confronted with areas that consistently experience conditions different from surrounding areas. Examples include lake-effect snow areas and fog-prone valleys. Means will be provided for forecasters to define and store special areas of influence to assist with forecasting in these regions.

6.2.7 User Interface

Most of the user interaction with the tool kit is directly with graphical objects (e.g., contour lines), rather than through traditional menus. The user can select, draw, and label by using the mouse directly on the depictions. Other functions, such as selection of fields to edit and status of time interpolation, will be presented as menus.

The user interface necessary to operate the tool kit will be determined through investigative work including prototype testing and risk reduction exercises. A conceptual example is shown in Figure 16.

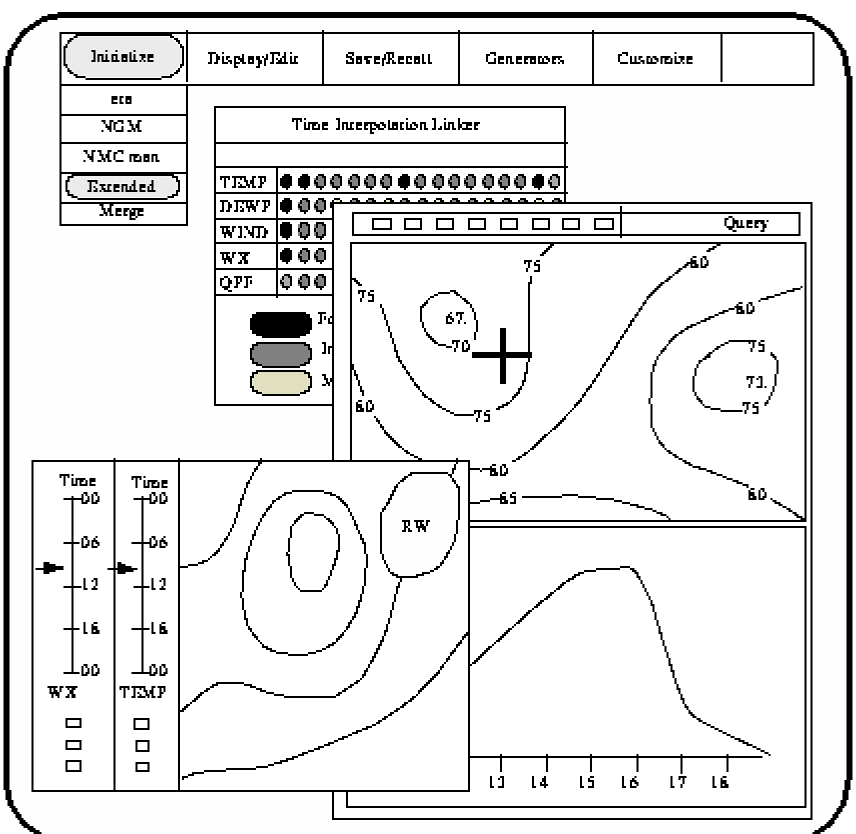


Figure I - Conceptual Graphical Forecast Editor Screen Display

6.2.8 Forecaster Use of the Tool Kit

This section provides an operational scenario of how the tools may be used. Please keep in mind that the tools will be designed to allow virtually any combination and presentation method. This operational scenario attempts only a cursory look at use of the tools.

Once the forecaster has initialized the forecast worksheet as discussed in Section 6.1, she will use the various tools in the tool kit to modify the forecast until it accurately represents the desired forecast solution. The forecaster may first produce some annotated overlays by displaying conventional model depictions (e.g., eta 850-500 hPa thickness, 700 hPa temperature) and drawing the rough positions of the fronts, troughs, cloud areas, and precipitation areas. She may correct these annotations in terms of position and speed based on her knowledge of the models and the particular weather situation. These annotated overlays will probably be produced by standard AWIPS capabilities and will not be a unique feature of the forecast preparation system. Once the annotations are completed, they may be overlaid with spatial depictions of weather elements.

The forecaster first chooses to modify the cloud depictions. She selects the cloud element for the present time and overlays it on a satellite image for comparison. Satisfied that they agree, she selects tonight's cloud element depiction, overlays tonight's annotation and model relative humidity fields, and discovers that the depicted cloud field is farther west than she expects it to be. Using the bounded area modification tool, she redraws the cloud field in the correct location. At the same time, she decides to overlay the "weather" weather element and correct that field. Skipping ahead to tomorrow's late afternoon forecast, she redraws the cloud and precipitation fields to accurately represent their position. Upon command, the interpolation tools fill in all cloud and precipitation depictions between tonight's and tomorrow's late afternoon forecast. The forecaster rapidly scans through the entire cloud and precipitation sequence using standard AWIPS animation features. Satisfied with the results, she proceeds to the temperature and dew point fields.

A cold front is expected to pass through the area tomorrow and drop the temperature by about 15�. The forecaster decides to see how the guidance represents this by displaying temperature time series for three points in her forecast area of responsibility. Realizing that the front is moving faster than the model predicted, the forecaster modifies the three time lines to represent this change. Referring back to the spatial depiction, she draws an area of influence around each of the three points, then clicks the interpolate button. She has now modified many temperature depictions for her entire area of responsibility by editing three time lines. Interpolation routines handle the area of influence, the boundaries between the three outlines, and the time interpolation.

The forecaster quickly checks the wind forecast. Displaying the spatial depiction for the time the cold front will pass through the area, she modifies the data to accurately represent the gusty winds and wind shift expected with the front. Satisfied, she copies the winds in the region around the front to a different area and time, thus keeping the winds around the front consistent.

The areal forecast is nearly complete. Selecting several key locations in her area of forecast responsibility, the forecaster displays station model plots by time. Satisfied, she then turns to those tasks requiring more specific forecasts such as aviation.

The forecaster selects her terminal forecast sites using the locator map for the time series depiction, and displays the aviation terminal forecast tool shown in Figure 14. The weather elements have been initialized from the general weather elements with which she has been working. Knowing that one particular airport always retains low stratus after a front longer than other sites since it is surrounded by low hills, she changes the clouds for that site. Forecasts for the other sites are accurate, so no other changes are necessary.

Satisfied that the depictions accurately represent her view of the forecast, the forecaster saves her worksheet as the official forecast in the database.

6.3 Product Generation Selection

Once the forecaster has finished modifying the worksheet and has produced the official forecast, the product generators can be invoked through the product generation selection interface. A conceptual example of this user interface is shown in Figure 17. (Also included in the figure are controls for consistency checkers and time interpolation, which will not necessarily appear on the same menu as the product generation selection.)

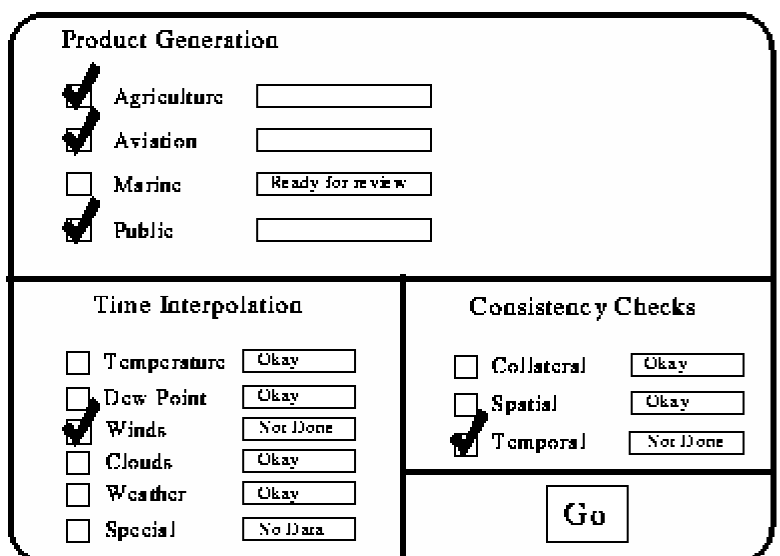


Figure 1 - Product Generation and Related Tools Interface

The interface consists of a list of forecast products and several status boxes. The forecaster checks the product(s) to generate(2) and selects "Go." The display will indicate the status of the product generation, such as in progress, completed, or released at 1527.

The software will prevent the forecaster from selecting a product to be generated if the forecast database contains inadequate information for the product. For example, there could be field inconsistencies or interpolations to be performed.

Footnotes

(1)

Note that eta model output is available at 2-hour intervals out to 18 hours (then every 3 hours to 36 hours). The other hours will be filled in by interpolation.

(2)

Note that it is not necessary to generate all forecasts at any given time. For example, selected updates may be produced upon receipt of new data. In the future, if portions of the forecast database itself are made available to users, it will be more important to monitor the significance of changes, and ensure that text and graphic forecasts are consistent with the database. Automated techniques should be able to assist.

7 Deriving Product Parameters from Weather Elements

Once the forecast has been edited and stored in the database, product generators will be invoked to create text products for dissemination. Many of these products cannot directly use the information in the database. Some require information for specific points or over areas. Some require parameters that are not part of the weather elements.

Deriving product parameters from weather elements requires one or two basic steps:

- summarizing the data for areas and points, and/or
- computing product parameters from the (summarized) weather elements.

Product parameters needed for forecast verification will be stored in the database. This information can be viewed and edited if necessary. Since the format of much of the data is not gridded, the interactive tools will be different from those described in the previous chapter.

7.1 Extracting Point and Areal Data from Grids

Techniques for extracting areal data from grids have been developed by TDL as part of FEFS (see Section 1.4.4.1).

Summarizing weather and cloud information requires a meteorological assessment of the gridpoint data. The grids of weather and cloud information can contain many overlapping areas. These weather and cloud areas will normally not be aligned with forecast boundaries. The algorithms must determine

- what fraction of an area must be covered before a weather or cloud area applies to that area,
- which phases (liquid or solid) of precipitation are present,
- the predominant character (steady or showery) of the precipitation,
- the predominant intensity of the precipitation,
- the proper handling of any probability qualifiers, and
- an average sky cover for the area.

For public zone forecasts, the ICWF applies a special technique to reduce the amount of text produced. During the process of extracting a zone average from the grids, adjacent zones are combined when possible, so that the effective number of zones is reduced. Preferred and prohibited zone combinations may be specified by each local office.

This technique may be of even greater utility in the restructured NWS, since forecast zones will be as small as a single county. Until and unless some more specific dissemination system is devised, it will be necessary to create such zone combinations, lest the recipient be overwhelmed with repetitive text.

Zone combinations will be determined automatically by algorithms within the product generators. Forecasters may override the chosen combinations.

7.2 Computing Product Parameters

Specific product parameters are required for some forecasts. For example, public forecasts require wind chill, which is easily computed from temperature and wind fields.

More difficult problems are encountered in other programs. For example, marine forecasts include statements about heavy surf and beach erosion, when necessary. These can be derived from wind forecasts, plus information about coastal topography.

As an illustration, Table 11 lists the weather elements currently used to create routine zone forecasts. This list will be modified and expanded as necessary to reflect the requirements for public forecasts in the future. Similar lists have been developed for marine, hydrology, fire weather, agriculture, and aviation product generators.

Table 11 - *List of Weather Elements Required by the ICWF Area Forecast Generator*

Element	Projection Interval (hours)	Unit	Values
Maximum/minimum temperature	12	Degrees F	-80 - 150
3-h temperature	3	Degrees F	-80 - 150
3-h dew point	3	Degrees F	-80 - 150
Cloud	3	Tenths of sky cover	0 - 10
12-h probability of precipitation	12	Percent	0 - 100
Thunderstorm	3	Parameters	slight chance, occasional, likely, unqualified, null
Thunderstorm intensity	3	Parameters	frequent lightning, heavy down pours, gusty winds, hail, slight chance of severe, chance of severe, damaging wind, large hail
QPF	12	Hundredths of an inch	0 - 999

Wind direction	3	Tens of degrees	0 - 36
Wind speed	3	Miles per hour	0 - 200
Obstructions to vision	3	Parameters	fog, heavy fog, haze, blowing snow, smoke, blowing dust, null
Precipitation types 1, 2, and 3	3	Parameters	rain, rain showers, drizzle, snow, snow showers, ice pellets, freezing rain, freezing drizzle, null
Probability for types 1, 2, and 3	3	Parameters	slight chance, occasional, likely, unqualified, null
Intensity for types 1, 2, and 3	3	Parameters	very light, light, moderate, heavy, null
Snow amount	12	Inches	0 - 99 where 99 indicates a trace
Mixture of precipitation 1-2 and 2-3	3	Parameters	and, or, null

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8 Product Generators

An integral part of the AWIPS automated product preparation process is the final formatting of products. Traditional text products can take the form of plain-language sentences grouped into paragraphs, tables, or strings of hydrometeorological symbols and characters. These three types are referred to as free-form, tabular, and coded products, respectively. AWIPS will also create "broadcast-ready" products, prepared for voice generation for NWR. Eventually, as the NWS moves well into its modernized operations, products will also be produced as graphics, images, and gridded data sets. These products will service all NWS program areas including public, aviation, marine, agriculture, hydrology, and fire weather.

Because of the large number of text products to be issued, some as frequently as hourly, the process must be as automated as possible. The forecaster will always have the facilities to review and edit these products before release, but the goal is to minimize the necessity of manual intervention. Further, any such forecaster editing or modification of the machine-generated products will require additional quality control to correct spelling or other typographical errors. This is particularly important for products prepared for NWR which will be converted from text to voice. If the forecaster feels that changes are necessary in the substance of the forecast, then he or she should modify the database and regenerate the text. This will insure the integrity of the verification and forecast monitoring programs.

8.1 Products

NWS products include observations, climatological summaries, routine forecasts, watches, warnings, advisories, statements, and outlooks. These product types are described in Table 12 on page 56.

The NWS defines automated product formatting as the transformation of observations and/or forecasts of hydrometeorological elements and events into products according to user-specific content and form. Depending on the product, this process can include the computation of additional parameters from general forecasts and current weather observations. It can also include the insertion of headlines highlighting hazardous weather conditions. Formatting may also involve the addition of certain protocol and routing information which defines the product, valid time, and where it is to go.

Table 13 on page 56 lists the routine forecast products that will be supported by AFPS. Many products which will be automated or semiautomated on AWIPS are not included in this list. For example, watches, warnings, advisories, and statements will be centrally generated or supported by AWIPS IDB software. Observations summaries and climate reports also fall in this category.

Table 12 - *NWS Product Types*

Product Type	Description

Observations	Reports which contain information about observed weather conditions either at a specific time or over a period of time, generally within the past 24 hours.
Climatological summaries	Summaries of weather conditions for a fixed period of time for selected locations. These cover periods of one day, one month, a season, or the year.
Routine forecasts	Products that describe the current forecasts for the next few hours out to several days.
Watches	Forecast products issued when hazardous weather threatens but the occurrence is neither certain nor imminent.
Warnings	Forecast products issued when hazardous weather is imminent or occurring.
Advisories	Forecast products issued when hazardous weather is imminent, is occurring, or has a high probability of occurring. Advisories are issued for events that are expected to be less severe than for warnings.
Statements	Products issued as follow-up information to watches, warnings, or advisories; to cancel watches, warnings, or advisories; to clear watches; and to provide information on non-severe, but potentially hazardous conditions.
Outlooks	Products issued to provide preliminary discussions for potentially hazardous weather. In general, these are free-form products and their preparation will not be automated.

Table 13 - Products to be supported by AFPS.

Public	**Aviation**	**Marine**	**Agriculture**	**Fire Weather**	**Hydrology**
Coded Cities Information	TAF(a)	Coastal Marine	Agricultural	National Fire Danger Rating System	Quantitative Precipitation
Zone	TWEB	Great Lakes Nearshore Marine	Fruit Frost	Fire Weather Presuppression	River Recreation Statement
Area		Local Marine		Fire Suppression	
		Great Lakes		Smoke Management	
		Alaska Coastal Marine		Land Management	
		Offshore			

- -

(a)

The TAF is expected to replace the FT for domestic use before is deployed.AFPS

Product formats are governed largely by the product types and the dissemination media. For example, observations and climatological reports distributed as text over NOAA Weather Wire Service (NWWS) are formatted as tables. The best example of this type of product is the hourly weather roundup, which is generated automatically today on AFOS in tabular form and released without forecaster review or intervention.

This same product is also broadcast over NWR after being read into a microphone by a forecaster or technician. In the AWIPS era, this product will be machine-formatted into a paragraph of complete sentences and made ready for text-to-voice conversion by NWR computers.(1)

W/W/A products will be formatted as paragraphs much as they are today. These products will contain information on the area affected, a description of the hazardous weather or flooding, a call-to-action statement, and a basis statement. They will be generated for both long-fuse (several hours away) and short-fuse (within 6 hours) phenomena. The NWWS and NWR products will look much the same because they are in paragraphs. Because the basis statements are manually prepared, these products will require quality control before being released for transmission or broadcast.

Statements will be largely manually prepared. W/W/A information will be available to provide "boiler plate" information for the products, however.

Routine forecast products such as service area forecasts (zone forecasts), agricultural forecasts, and some marine forecasts offer the most challenges for automated preparation. The products are created by assembling plain-language phrases that decision algorithms select from tables of expressions. These products' formats have been migrating toward a common, period-by-period layout, making their structure similar. This will simplify software development by allowing much code to be shared. (As with some of the products mentioned above, some routine forecast products contain free-text sections that will have to be added by the forecaster. Nonetheless, much of the text can be machine-generated.)

The techniques developed to generate these products will follow AWIPS specifications being prepared by TDL with assistance from OM and OH. Not all products have been specified, but as an example, we cite the formatting of today's zone forecast by ICWF. AWIPS will be able to produce the forecasts at any time of the day. Further, the software will refer to local geography. This will include automated inclusion of local effects, such as "heavier snow near lakes" or "fog in low-lying valleys." Such phrases and areas will be specified office by office. Likewise, recognition of areas that are "always" 5� cooler, for example, will be largely automated. (This method effectively increases the resolution of the grid to accommodate small-scale forecast issues.) Hazardous weather headlines will be inserted automatically into the forecasts through AWIPS data files containing the status of current W/W/As.

The AWIPS forecast database will contain hourly data. Thus, there will be an opportunity to add more detailed forecasts. For example, a public rush-hour forecast could easily be generated from information in the database.

During Phase I, TDL will concentrate on developing product generators to meet routine forecast requirements. Schedules for this development are given in Section 9.3.2.4.

8.2 Product Generation Methodology(2)

Many of the routine forecasts issued by forecast offices are in a form which can be generated, at least in part, by machine. These products include the 1- to 2-day public forecast, the agricultural forecast, the fire weather forecast, and the marine forecast. In general, they will be in a plain-language, paragraph, period-by-period format in the AWIPS era. Coded messages, such as some aviation forecasts, can also be machine-generated. Examples are International Aerodrome Forecasts (TAFs) and TWEBs.

8.2.1 Plain-language Forecasts

The public forecast contains a "body" portion accompanied by detail phrases. The body is designed to capture the character of the day, and the detail phrases add definition. Detail phrases are generally sentence fragments covering temperature, wind, snow accumulation, and probability of precipitation. The following is part of a sample public zone forecast. The detail portion is underlined.

TODAY...SHOWERS AND THUNDERSTORMS LIKELY THIS MORNING. BECOMING PARTLY SUNNY THIS AFTERNOON. SEASONABLE TEMPERATURES. HIGH IN THE MID 60S. VERY LIGHT WINDS. CHANCE OF RAIN 80 PERCENT.

In contrast, agricultural, marine, and fire weather forecasts contain only detail phrases. The detail sentences are in an order determined by NWS operations manuals or the local forecast office. The following is an example of an agricultural forecast.

WEDNESDAY...SOUTH WINDS 5 TO 10 MPH. 10 TO 11 HOURS OF SUNSHINE. HIGH DRYING POTENTIAL. MODERATE DEW WILL DRY FROM VEGETATION BY 800 AM. LOWEST HUMIDITY 45 TO 55 PERCENT. HIGH IN THE MID 90S.

All forecast product generators must accurately represent the forecasts contained in the database as plain language products according to NWS operations manuals. TDL has been developing product generators since the early 1970s. Over the last few years, TDL has substantially rewritten the software to generate public zone forecasts. It is this revised software that will be the basis for several of the above products prepared on AWIPS.

Public, agricultural, marine, and fire weather forecasts have many elements in common. For example, the public forecast includes information on temperature, clouds, weather, and winds, while marine forecasts include information on winds, waves, and significant weather.

For each element (e.g., precipitation, temperature, wind), there are a number of phrase types the generator must produce. Each corresponds to a particular weather situation. For example:
rain changing to snow,
rain tapering off to drizzle,
mostly sunny this morning...cloudy this afternoon,
south winds 10 m.p.h.

8.2.1.1 Zone Forecast Example

TDL's ICWF approach has been to build modules in which the phrase types are assembled in a specific phrase structure based on rules of grammar and NWS regulations pertaining to the specific product. A high-level description of the requirements for formatting each element is given below to give the reader some idea of the approach to be used. The discussion and examples are not intended to be exhaustive.

Precipitation Phrases(3)

Precipitation information can be complex; many weather elements are devoted to letting the forecaster express this complexity. These are the majority of the weather elements prepared by the forecaster. A forecaster may select up to three possible precipitation types, and each type is described with a probability and intensity. In addition, thunderstorms of several intensities may be forecast with or without precipitation. There are a finite number of phrase types for precipitation, each corresponding to a particular weather situation. For example

- precipitation (with no qualifier),
- precipitation *x* changing to precipitation *y*,
- precipitation *x* mixing with precipitation *y*,
- precipitation *x* mixing with and changing to precipitation *y,*
- precipitation *x* beginning as a brief period of precipitation *y*.

In general, there is a phrase structure corresponding to each type of phrase. Each phrase structure consists of one or more parts describing the precipitation type, intensity, probability, beginning and/or ending times, the time of change from one precipitation type to another, etc. There is a particular ordering (Table 14) of the parts (including punctuation) that form the phrase.

Table 14 - Example Phrase Structure

PROBABILITY	TYPE	TIME	INTENSITY
A chance of	rain	this afternoon	heavy at times
A slight chance of	snow	this evening	
Occasional	sleet	after midnight	

In addition, for precipitation, there are three groups or families of phrase structures: simple, complex, and thunderstorm. The simple structure does not express any change of state, whereas the complex does.

Cloud Phrases(4)

The range and sequence of cloud categories during the forecast period determine the type of cloud phrase to be included in the product. Little change in cloud cover during the forecast period will result in a simple cloud phrase, such as PARTLY CLOUDY.

If both sunny and cloudy periods occur during the forecast, more description is included in the product. Either there is a trend in the forecast cloud amount or the situation is variable. In either case, an attempt is first made to determine whether the period can be split. The period can be split if cloud conditions in one part of the forecast period differ significantly from cloud conditions in the other part of the period. If the period can be split, an attempt is made to describe cloud conditions in each part of the split period. For example:
SUNNY THIS MORNING...THEN INCREASING CLOUDINESS THIS AFTERNOON.
If the period cannot be conveniently split, a more general cloud phrase results:
VARIABLE CLOUDINESS...
All of these conditions fit into one of five basic structures:

- [CLD1]
- [CLD1] [TIME1]....THEN (BECOMING) [CLD2] [TIME2]
- [CLD1] THROUGH [TIME1]....THEN (BECOMING) [CLD2]
- BECOMING [CLD2] BY [TIME2]
- A PERIOD OF [CLD2] AROUND [TIME2]....OTHERWISE [CLD1]

Wind Phrases(5)

The modules that build wind phrases for the detail portion of a forecast also produce adjective phrases for the body of the public forecast. The wind direction and speed phrase relays information on the speed and direction of the wind during the forecast period, including significant changes in direction and/or speed and wind gusts.

A complete direction/speed phrase is generated from five basic wind direction/speed phrase structures:

- [DIRECTION] winds [SPEED] miles per hour
- [DIRECTION] winds [SPEED] miles per hour shifting to [DIRECTION] [occur time] (and increasing/decreasing to [SPEED] miles per hour)
- [DIRECTION] winds [SPEED] miles per hour increasing/decreasing [occur time] to [SPEED] miles per hour
- Light [DIRECTION] winds becoming [DIRECTION] [occur time] at [SPEED] miles per hour
- DIRECTION winds SPEED miles per hour becoming light [DIRECTION] [occur time]

The direction is determined first. A significant change in direction results in a change of direction phrase (the second phrase above). If no change of direction is found, then a check is made for a change in speed. If no speed change is found, then the first phrase is constructed.

The wind adjective phrase consists of one or several words describing the speed of the wind. For the public zone forecast, the wind adjective is merged into the body of the forecast with elements like sky cover and precipitation. Examples of adjective phrases include BREEZY, WINDY, VERY WINDY, STRONG, BECOMING WINDY, and DIMINISHING WINDS.

Temperature Phrases(6)

As does the wind-phrase module, the temperature module generates an adjective phrase for the body of the forecast and a detail phrase. The maximum/minimum detail temperature phrase provides information on the maximum or minimum temperature during the forecast period. This phrase is usually a stand-alone sentence or sentence fragment for each forecast period. There are three phrase structures:

- When the high and low temperatures occur at normal times, then simple phrases like HIGH NEAR 90 and LOW NEAR 32 are chosen.
- If the maximum or minimum occurs at a climatologically abnormal time, or temperatures are nearly steady during the period, then one of six special phrases is selected and built, such as TEMPERATURES FALLING TO THE LOW 30S.
- If the maximum or minimum does not occur during the forecast period, then a generalized temperature description is selected and constructed, such as TEMPERATURES RISING THROUGH THE 70S.

The 1-hour resolution of temperature data will allow for more detail in these phrases. (It also will be useful for forecasts requiring more temporal detail, such as agricultural forecasts, which also need the full dynamic resolution of the data in the database.)

Temperature adjective phrases consist of one or more words describing the temperature relative to local climatology or a previous temperature. In the public zone forecast, the temperature adjective phrase is merged with the body of the forecast to be part of one or two sentences or sentence fragments describing the weather in general.

The appropriate adjective phrase is retrieved after checking temperature thresholds such as the forecast maximum/minimum temperature, the normal maximum/minimum temperature, and yesterday's maximum/minimum temperature.

Examples of adjective phrases include VERY HOT, UNSEASONABLY WARM, MUCH COOLER, MILD, BITTER COLD, and TURNING COLDER.

8.2.1.2 Other Forecast Phrases

The above phrase types appear in the public zone forecasts and in some other routine forecasts. For other forecast products, there are additional phrase structures for

- QPF and snow amount,
- drying potential/conditions,
- maximum/minimum relative humidity,
- dew intensity and dry-off time,
- hours of sunshine,
- lightning activity level,
- 10-hour time lag fuel moisture,
- free air wind, etc.

Phrases referring to these elements are constructed as freestanding or detail phrases and are not typically part of any forecast body. As generators are developed for additional products, program modules will be written to construct these phrases.

8.2.1.3 User Control of Phrase Structure

Each phrase-formatting module provides the user with two levels of control over phrase construction. Control constants are thresholds that specify local climatological conditions and phrase selection. These constants relay to the formatters local forecast office conventions such as how cold is "cold" or what wind speed constitutes "windy."

The user also may change the detail level, which controls the descriptive content of the phrases. More or less detail may be desired, depending on the forecast period and the other weather elements. For example, the temperature may be "unseasonably cold," it may be "cold," or the detail phrase may be omitted altogether.

8.2.2 Coded forecasts

Aviation forecasts, including TAFs and TWEBs, are coded messages. Generators for these products require cloud height and amount forecasts for a maximum of three individual layers, visibility, weather types (including obstructions to visibility), and winds, all for projections from 1 to 24 hours. For TAFs, cloud types will also be needed. In addition, forecast information will be needed for prevailing (likely), occasional, and chance conditions. The information for occasional and chance will be used only when clarification or expansion of the prevailing conditions is required.

To create the individual sentences of the TAF, the generator will test the prevailing forecasts for significant changes. Only ceiling height, visibility, weather type, wind speed, and wind direction will be tested. Two sets of criteria will be used to determine significant changes: official criteria (the NWS TAF amendment criteria) and user-defined criteria. The latter will be forecaster-selectable and will allow each office to fine-tune how its terminal forecasts are prepared.

When the prevailing forecast sentences have been determined, the generator will summarize the prevailing conditions within each group, starting with the cloud values and followed by visibility, weather types, and winds, in that order. Then the occasional and chance phrases will be summarized in the same way. Summarization will be performed only for conditions that differ from or clarify the prevailing conditions.

Although the details of TWEB generation have not yet been worked out, the general approach will be to summarize information from the gridpoints along the specified routes.

Footnotes

(1)

> As part of their work on text generators, TDL will prepare products suitable for NWR voice generation.

(2)

The discussion and examples in this section are based on current ICWF practice, and are intended to illustrate the approach. Detailed forecast-formatting requirements will be prepared in the course of development.

(3)

See Cammarata, M. W., and J. M. Kosarik: The automatic generation of precipitation phrases for the Interactive Computer Worded Forecast. TDL Office Note 92-9, 27 pp.

(4)

See Cammarata, M. W., and J. M. Kosarik: The automatic generation of cloud phrases for the Interactive Computer Worded Forecast. TDL Office Note 92-4, 17 pp.

(5)

See Kosarik, J. M., and M. W. Cammarata: The automatic generation of wind phrases for the Interactive Computer Worded Forecast. TDL Office Note 92-3, 17 pp.

(6)

See Kosarik, J. M., M. A. Przybocki, M. W. Cammarata, J. F. Wantz, J. Lang, and M. R. Peroutka: The automatic generation of temperature phrases for the Interactive Computer Worded Forecast. TDL Office Note 92-8, 20 pp.

9 Development Plan

9.1 Methodology

The term methodology encompasses several topics related to the need to plan and manage a project so that it is done as effectively as possible and so that user needs are met. Included in methodology are issues such as traditional project management, software standards, computer system management, software tool selection, system design, documentation requirements, and risk reduction.

9.1.1 Method of Software Development

Risk reduction is essential to the success of this project. The goal of risk reduction is the creation of a problem-free system that meets users' needs. Risk reduction activities will be performed throughout the development stages of the project. In simple terms, risk reduction comprises iterative prototype development and testing, or a cyclic process of development, testing, and refinement. The steps in the cycle usually include

- determine requirements as completely as possible;
- identify risks or problem areas, as well as alternative solutions and constraints;
- build a functional prototype, addressing the highest risks;
- test the prototype in an operational or near-operational setting; and
- identify problems and improvements.

The pattern can be followed both for complete systems and for individual components.

A pattern of software development very similar to the risk reduction methods used by both FSL and TDL called "The Spiral Model of Software Development and Enhancement" has been completely described by B. Boehm, IEEE Computer, May 1988, pp. 61-72. This model is shown in Figure 18 on page 64.

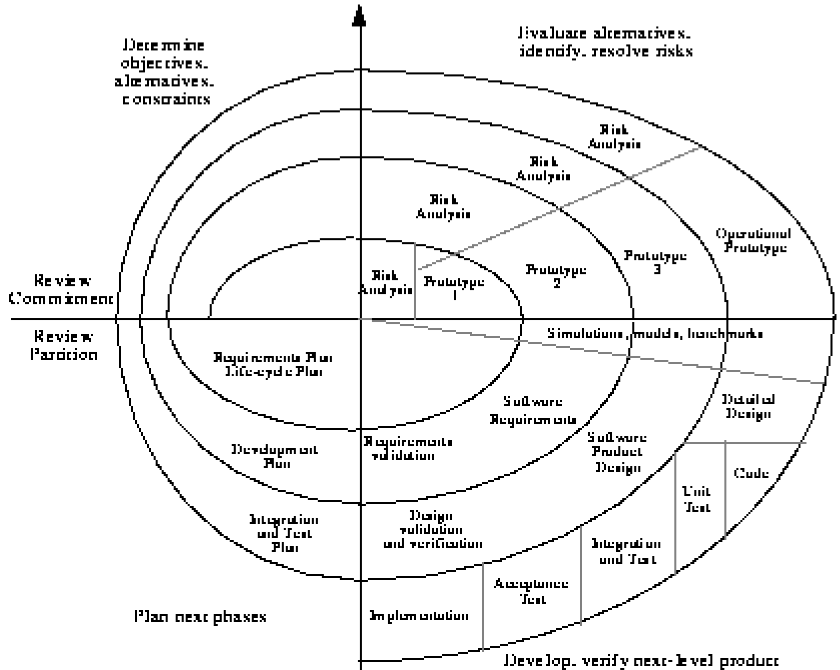

Figure 1 - Spiral Model of Software Development

As a project develops, a spiral path is traced on the diagram. Angular position on the spiral indicates the stage of development, cycling through requirements definition; consideration of alternatives, constraints, and risks; building a prototype or enhanced system; testing and evaluation; and restatement of improved requirements. Distance out from the center indicates a maturing project and use of time and other resources.

FSL has experience in risk reduction in developing the DAR3E and DARE II systems, and intends to follow a similar and more refined approach for this project. A similar approach will be followed by TDL in text generation development.

9.1.2 Software Development Environment

9.1.2.1 New Development Environment - FSL

FSL is using an industry-standard, open-systems(1) platform for development. This will make it easier to move software to the AWIPS platform, and it has the advantage of providing the most effective platform for developing an interactive graphical workstation. We plan to use standards, such as ANSI and POSIX, wherever possible, and will use commercial off-the-shelf products compatible with AWIPS when available.

We are using standard software development tools such as a source code management system, debugger, source code browser, and graphical "widget" editor. These have been shown to be of considerable help in effectively and quickly developing code that is easy both to maintain and to port to other workstation environments.

FSL will use a coding standard defined by an FSL committee to ensure that the software developed is clear, consistent, modular, portable to AWIPS, and efficient throughout, and to make it easier to maintain and modify.

FSL will prepare documentation throughout the project, following the guidelines of the AWIPS Software Development Management Plan (being developed by the SPO). Since the first part of this project is investigative, it is not now possible to exactly describe the contents of the documents or when it will be appropriate to write them. As described below, periodic progress reports will be made to a steering committee outside FSL and TDL to assess and guide progress.

Interim Development System

In October 1990, FSL began investigating computer systems needed to provide a development platform for enhancements to AWIPS. Delivery of the development system was completed in March 1992.

The development platform (Figure 19) consists of 10 Sun Microsystems SPARCstation 2/GX-plus color graphics workstations and one Sun Microsystems 670MP 4-processor network server. Each workstation has a 28 MIPS processor, 32 megabytes of memory, an 800 megabyte disk, I/O and bus connections, UNIX, X Window System and XGL graphics software, OSF/Motif graphical user interface software, compilers, and other development software. The network server has four 28 MIPS processors with an aggregate processing power of 90 SPECmarks, 64 megabytes of memory, 4 gigabytes of disk storage, I/O and bus connections, CD-ROM, 150 megabyte tape cartridge, and an 8 mm tape drive.

The FSL development system is connected to the Internet, allowing transfer of software and documentation between NWS headquarters and FSL.

FSL has trained its staff in the new software environment. A three-week UNIX course and a five-week course in the C programming language were completed in December 1991. Each course involved about 20 hours per week, and included laboratory sessions where each staff member had access to a graphics workstation. Instructors were drawn from FSL staff with UNIX and C experience. C++ training (vendor-taught) was completed in August 1992. A series of in-house X/Motif lectures was prepared by one of our staff; more extensive training will be developed as the need arises.

We have connected the GDP to our Sun network and will use the development platform to access AWIPS. In late 1993, we will replace our Sun workstations with AWIPS-compatible HP systems. Our primary work platform will be AWIPS during the Build Stage.

Object-Oriented Programming

Oversimplified, AFPS can be thought of as weather elements accessed by a user interface. Since the basis for the user interface is already an object and the data types and operations for weather elements look like they would work well treated as objects, the project would seem to benefit greatly from object-oriented programming.

Data represented within the forecast database and the tools within the interactive tool kit may readily be viewed as objects. We plan to manipulate worksheets and portions of worksheets as objects. We plan to create advanced hybrid tools by combining individual tools in different configurations. Both the forecast database and the tool kit could be easier to implement and configure if we choose to design and program them using object-oriented programming (OOP).

FSL has begun using C++ and object-oriented techniques as the primary programming language for the project. We feel that due to the investigative nature and numerous prototypes that will be tested during our development, the flexibility of C++ will benefit us greatly.

Critics of C++ have stated that there is a great cost to using C++ in the first year. We agree with their assessment, and initial prototype development has been slow. However, our Prototype Stage is 2 years long; advocates agree that substantial benefits may be realized with projects over 1 year. Our experience to date seems to bear this out.

We are aware of the concern that the AWIPS contractor may not be willing to accept C++ code. In the worst case, C++ translators can be used to convert the code to ANSI C. In reality, we feel that the professional software developers at the AWIPS contractor's site will, for maintainability and other reasons,(2) prefer obtaining C++ code from FSL.

The ANSI standard for C++ is currently being developed, and the ANSI C standard was developed with C++ compatibility in mind. It is important to recognize that the software development environment is changing rapidly. Five years ago, X was largely unknown and Motif did not even exist. C++ has already gained wide commercial acceptance. Literature indicates that C and C++ will probably merge in the next few years.

Graphics Library

During the first few months of the Prototype Stage, we have been investigating the use of tools that enhance productivity. Although we could use the lowest level of X, Xlib, for drawing graphics, it makes more sense to use a more powerful package. Our tests showed that XGL (Sun's implementation of GL, an industry-standard graphics environment) is much faster than X for on-host applications. (The overhead associated with the X protocol is unnecessary and inefficient when a network connection is not involved.) Using such a package will save us thousands of lines of code. Unfortunately, although the AWIPS graphics environment, HP Starbase, is also GL-based, XGL and Starbase are not compatible. When we convert from Sun to HP platform, we will redevelop our graphics system with Starbase.

9.1.2.2 New Development Environment - TDL

TDL has continued ICWF development on Pre-AWIPS equipment, and is now beginning to use the GDP equipment. This work includes the interactive techniques as well as the product generation and formatting techniques. As programs are developed, risk reduction activities will be carried out at WSFO Norman and other sites as time permits.

In November 1992, FSL installed a SPARCstation 2/GX-plus workstation, configured similarly to those described above, at TDL. This has allowed TDL to become familiar with the UNIX environment and allows FSL and TDL to exchange software and documents such as this one for development purposes.

In late 1992, TDL, working with other OSD laboratories, contracted for operating system and language training for the AWIPS environment. PRC delivered AWIPS hardware and commercial off-the-shelf software (a GDP) to NWS headquarters developers (including TDL) in early April 1993. This has allowed TDL to begin developing many of the advanced product generation techniques on the AWIPS platform. As will FSL, TDL will use standard software development tools such as debuggers and source code management programs.

TDL follows internally developed coding standards to ensure that software is well written and maintainable. TDL will also prepare standard development documentation as specified by the SPO-developed AWIPS Software Development Management Plan.

9.2 Development Responsibilities

This is a joint project between FSL and TDL. Success of this project is possible only if both organizations carefully coordinate their efforts. Figure 20 on page 68 illustrates the overlap of responsibilities between the two laboratories.

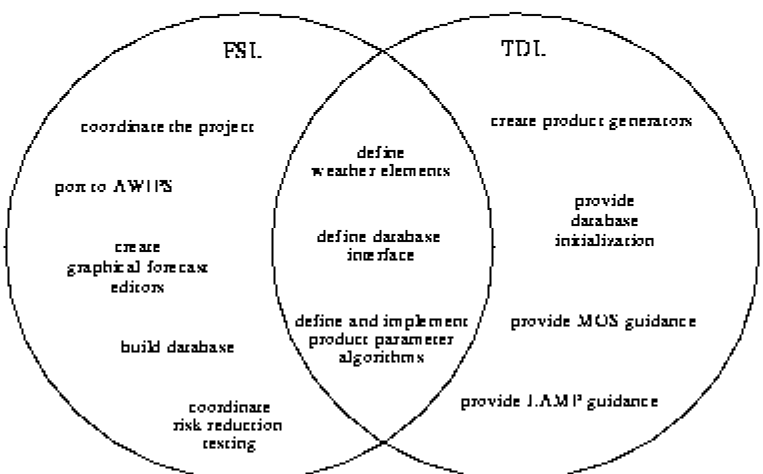

Figure 1 - Division of Responsibilities

9.2.1 FSL

To reach the goal of the complete database-supported forecast system, FSL will

- define, in consultation with TDL, the contents of the forecast database, and the interfaces in and out of the weather elements database;
- develop a prototype database;
- design and build interactive tools used by forecasters to display and edit weather elements;
- cooperate with TDL in defining and implementing algorithms for deriving product parameters from weather elements;
- define the output of the interactive techniques required for input to product parameter derivation algorithms;

- port the operational prototype to AWIPS for risk-reduction testing; and
- oversee testing of all components, and testing and risk reduction for the entire system.

At every stage of testing, appropriate evaluations will be made. The FSL Modernization Division, in which FSL's portion of development is being performed, already has a full-time evaluation team for Pre-AWIPS testing; the team's services will be extended to AFPS risk reduction. Changes to the developing system will be based on test results.

FSL prepares quarterly progress reports, which are distributed to members of the AFWG, as well as members of the AWIPS Working Group on Deferred Capabilities.

9.2.2 TDL

TDL's responsibilities include

- defining the product parameter input necessary for the product generators;
- developing and implementing algorithms to determine initial values of weather elements based on various guidance sources;
- developing product or text generators which convert the numerical derived product parameters to English-language forecast products;
- cooperating with FSL in defining the contents of the forecast database, and in defining the interfaces in and out of the database;
- cooperating with FSL in defining and implementing algorithms for deriving product parameters from weather elements; and
- providing statistical guidance with which to initialize the forecast with weather values based on central and local models.

9.2.3 AWIPS Contractor

The AWIPS contractor will play an important role in the successful implementation of AFPS. PRC will be responsible for

- integrating FSL and TDL software into AWIPS after the Risk Reduction Stage is completed;
- integrating AFPS with the forecast monitoring, verification, and quality control programs; and
- providing consultation service for FSL's and TDL's GDPs.

9.2.4 The AFWG

The NWS has appointed an AFPS Forecaster Working Group to assist in the development of AFPS. The group comprises NWS operational forecasters from each NWS region to aid in the requirements, analysis, and risk reduction portions of the project. The first meeting of this group was held in February 1993. This and later meetings will be used to evaluate direction and progress, and to provide guidance for future activities. AFWG meetings will be held approximately every 6 months.

9.3 Development Plans

In this subsection, we present an overview of ICWF and AFPS plans and development schedules, and schedules for product generators and statistical guidance development.

These schedules are linked to a number of other schedules including AWIPS, the NWR upgrade (Console Replacement System), and NMC restructuring and modernization. The dates in the figures and discussed in this section are based on the AWIPS contract award date of 29 December 1992. It may be necessary to adjust these schedules based on completion of milestones during the AWIPS Development Phase.

Schedules for derivation of weather elements from guidance and development of product parameter algorithms have not yet been determined.

9.3.1 FSL

Figure 21 on page 70 shows FSL plans in relation to AWIPS schedules. The Phase I tasks are divided into three stages: Prototype, Build, and Risk Reduction. These stages are amplified below.

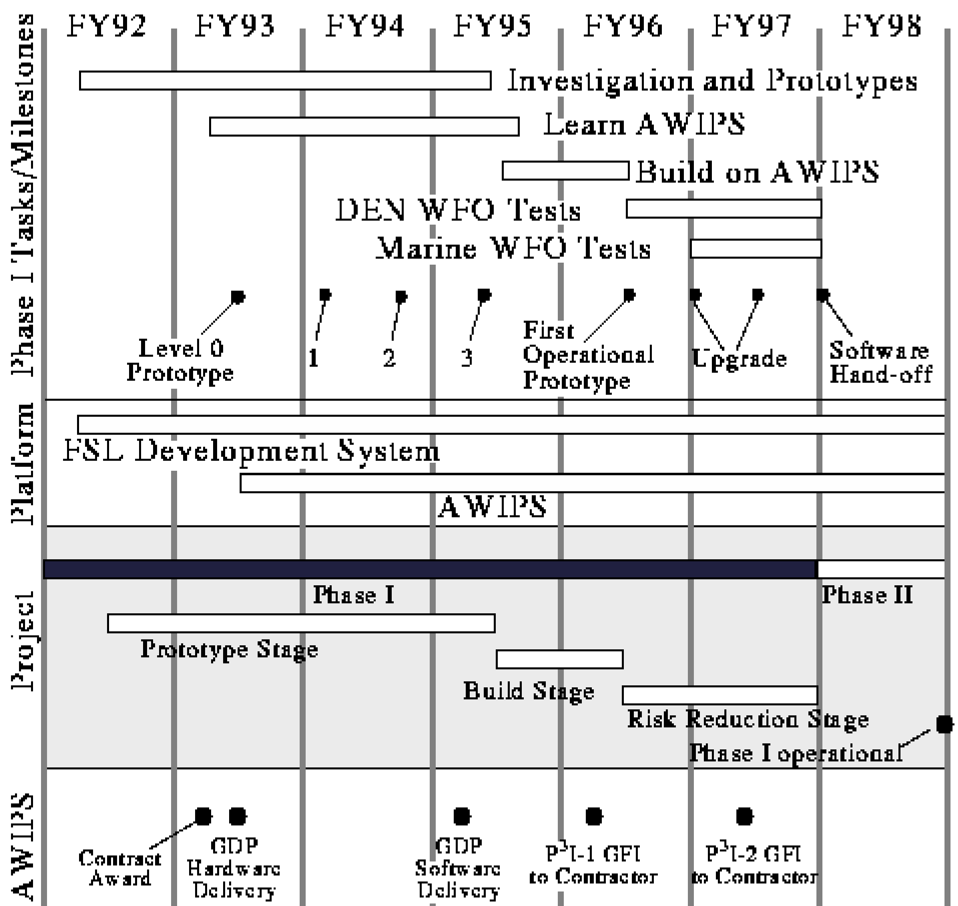

Figure 1 - Schedule Overview

9.3.1.1 Prototype Stage

During the Prototype Stage, all development will take place on the FSL development platform. Prototype systems will be ported to the GDP for testing.

There are many unanswered questions in this project, and it will be necessary to develop and test some completely new ideas in order to achieve the project goals. As a result, it is not practical to develop AFPS in the traditional method of requirements specification, system design, coding, testing, and deployment. FSL has planned an extensive period of exploratory work in the hopes of answering these questions and solving these problems. A time line for these investigations is shown in Figure 22.

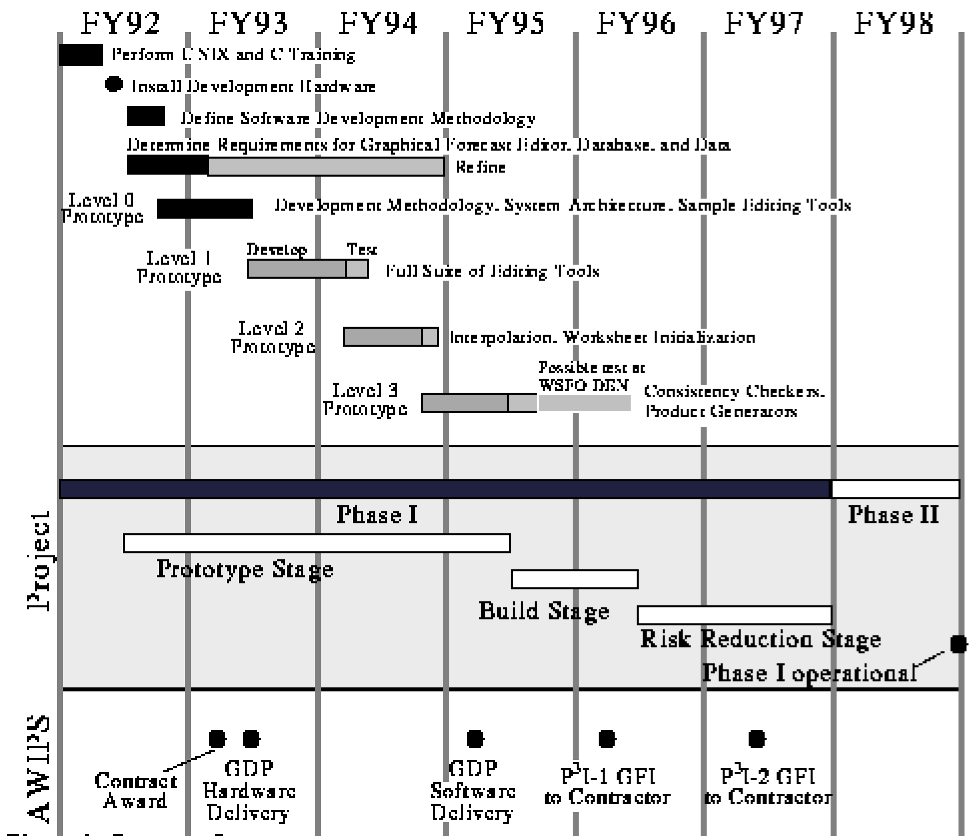

Figure 1 - Prototype Stage

Tool Prototypes

The proper set of tools is very important to the success of the project. If inadequate tools are implemented, the forecaster will be able to write the forecasts with a text editor faster than with the graphical tools, thus resulting in no savings of time. An adequate set of tools must allow the forecaster to accurately and quickly define the forecast. It is expected that there will be several iterations of tool development.

We have prepared a set of requirements for the Graphical Forecast Editor tools and presentation methods, with accompanying conceptual tool designs. We plan to provide spatial, temporal, and matrix depictions, as well as hybrid tool depictions such as the station model plot. We will build prototypes of the displays and presenting them to forecasters for evaluation. We will define the specific editing procedures after the basic tools and depictions are defined, and test prototypes of them as well. We will use the members of the AFWG as a sounding board to review both the requirements and the proposed tools.

The development of the tool kit will continue with the creation of hybrid tools from combinations of the basic tools. Forecaster-defined combinations of tools are potentially very powerful.

Throughout the Prototype Stage, FSL will be in contact with TDL, NMC, OH, NWS' Alaska Region, and AES and will incorporate their contributions and experiences.

Consistency Checks

We intend to define the level of consistency checking that is required. We could decide to perform no consistency checks at all or we could decide to adjust other fields automatically when an inconsistency is found. An intermediate solution could be to perform consistency checks transparently to the user and highlight a user interface object when an inconsistency is detected. The user could address the problem at his/her convenience.

Once the type of checking has been determined, the algorithms to be used for the consistency checks must be defined. The algorithms would function in two steps. First, they would identify a problem. For example, the dew point cannot exceed the temperature. Second, they would correct the problem. For example, the dew point could be set to the temperature. We will build prototypes for the algorithms and test them on weather element data.

We foresee three basic types of consistency checks that can be applied to the weather elements: collateral, temporal, and spatial.

The collateral check ensures that the various weather elements are in agreement with each other for a specific time. For example, snow should not be depicted when the temperature is 75�F. The temporal check will compare the change in the forecast over time. For example, changes in temperature exceeding some threshold in 1 hour (or multiple hours) may be flagged. Spatial checks look for horizontal discontinuities and also will be used for comparison with forecasts from adjacent offices.

There are other points in the data flow where other checks may be beneficial. For example, the bounded area tag could be validated as the forecaster enters the data. We will investigate other areas where quality control checks may be beneficial.

Interactions Between Depictions

We believe there is value in providing multiple depictions to the forecaster for viewing and editing. We intend to explore the possible interactions between depictions and solve any inherent problems.

It is envisioned that the forecaster will have a series of spatial depictions for editing. At any time, a time series may be displayed for a specific point for a continuous field. If we permit the forecaster to edit the time series, which we intend, then we must be concerned about the corresponding effect on the spatial depiction.

Temporal and Spatial Interpolation

There are many weather elements, and more time steps; hence, there are potentially hundreds of depictions that the forecaster could edit. However, we envision the forecaster modifying only a few depictions. The remainder of the depictions must be automatically created using temporal interpolation techniques.

We will refine the requirements for interpolation. We intend to examine existing interpolation techniques in the FPA and ICWF systems. We will try various interpolation schemes and run tests to ensure that they work properly and do not introduce any inconsistencies.

Temporal and spatial interpolation schemes will also be applied to the input weather element grids to convert them to the required internal resolution.

Field Representations

Once we have defined the list of weather elements, we must then define their representation in the database and to the user. We will define the options of representing the weather elements, both for the database and for the tools. We will determine whether a specific element is best represented by a continuous field, a bounded area, or another type.

Prototype weather element displays will be evaluated by NWS forecasters to find the best type of display for each element. For example, wind can be represented by a continuous field of speed and a separate continuous field of direction, by a two-dimensional vector field (and then by vectors or wind barbs), or by a bounded area specifying a range of direction and speed. We intend to determine the best approach for representation based on forecaster acceptance while considering the long-term goals of this project (support for all current and future products).

Forecast Database

The domain, temporal and spatial resolution, and representation types that will be in the forecast database will be defined by FSL with assistance from TDL. A basic version of this database will be created on the FSL development system. We will design and implement the appropriate access routines that are required to store and retrieve the data. Diagnostic tools will be created as needed to examine the contents of the database.

Note that we are building only a test database. We will investigate using the GDP commercial database software, but may not be able to make full use of it until delivery of AWIPS software in late 1994.

User Interface

We will define the user interface for the Graphical Forecast Editor. This user interface will tie together the individual tools in the tool kit, the consistency checkers, initialization interface, and the product generator interface. We will build prototypes of these interfaces for evaluation.

We expect to take the approach of a modular user interface instead of one large interface. We will determine the portions that can be logically separated into "subinterfaces." We are using a commercial user interface tool kit, OI, for the user interface. OI produces an interface that has the "look and feel" of OSF/Motif.

Weather Elements

FSL and TDL will jointly define the weather elements that will be contained in the forecast database. We will ensure that they will be adequate for all products to be generated.

We will determine the effectiveness of our multilevel weather elements approach. For example, is it sufficient to apply a simple model to calculate the agricultural drying conditions from the general weather elements? Or must this be a service-specific weather element that can be viewed and edited if desired by the forecaster?

As discussed in Section 3.4, we will define the temporal and spatial resolution for each weather element.

Integrated Prototypes

During the Prototype Stage, FSL will build four integrated prototypes. These are illustrated in Figure 22. Each prototype will be built on top of its predecessor. Each will be evaluated by in-house meteorologists and NWS forecasters.

- The Level 0 prototype allowed us to evaluate our system architecture and become fluent in our development environment, while producing a prototype user interface and some limited graphical editing tools. (This prototype was completed in April 1993.)
- The Level 1 prototype will include the weather element database, and will incorporate a complete user interface and tool kit. Its primary purpose is to evaluate the Graphical Forecast Editor tool suite.
- The Level 2 prototype will incorporate the worksheet concept and spatial and temporal interpolation routines.
- The Level 3 prototype will incorporate the consistency checkers, a limited set of weather element derivation from guidance, and a small suite of product generators. The last two will be provided by TDL. This prototype will be tested during an Operational Simulation Exercise at FSL in 1995. It also may be tested quasi-operationally at the Denver WSFO.

Note that none of these integrated prototypes will be built on AWIPS, although the GDP will be used to verify software compatibility.

9.3.1.2 Build Stage

The next portion of development hinges on the date of the receipt of AWIPS System Software. Build Stage activities are outlined in Figure 23. During the Build Stage, most, if not all, of the development work will be performed on the GDP.

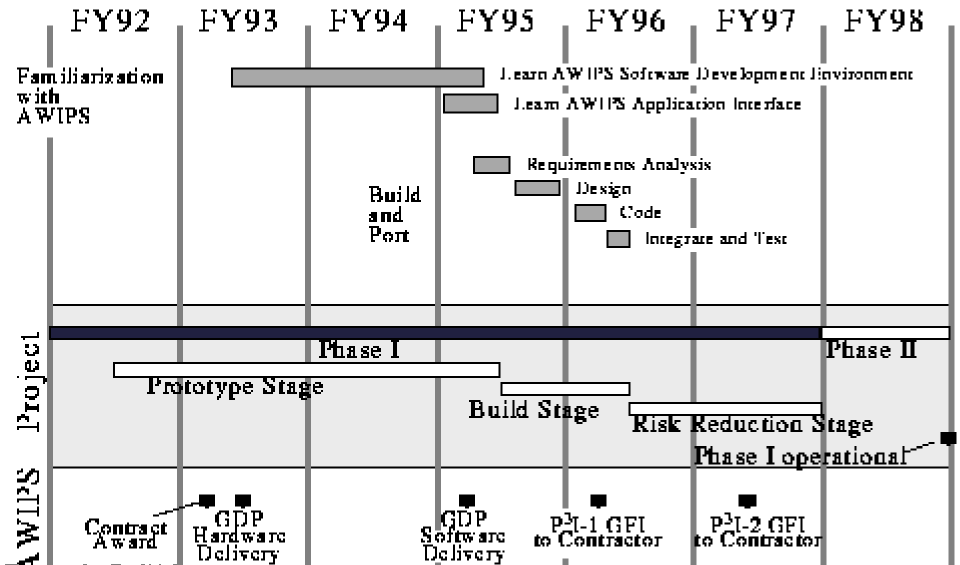

Figure 1 - Build Stage

Familiarization with AWIPS

By the end of the Prototype Stage, complete AWIPS systems will be available at FSL and TDL. Following a learning period, AFPS will be built on the FSL AWIPS platform. The FSL project team will be assisted in learning AWIPS by the FSL ADF team and the AWIPS contractor. During the period when FSL and TDL are learning AWIPS and adding our software to AWIPS, complete cooperation will be needed between the AWIPS contractor and FSL/TDL. This may require AWIPS contractor personnel at FSL in Boulder or FSL personnel at the contractor's facility for a period of several weeks for consultation on the best approach for integration into AWIPS. We anticipate that 3 to 6 months will be required for learning the AWIPS platform before building AFPS on AWIPS can begin.

Build Operational Prototype on AWIPS

After the investigative and prototype work has been finished, FSL will embark on a 12-month building task. The FSL development platform will be used in conjunction with the GDP to increase the development capacity of the AWIPS platform and to ease the transition to AWIPS. After 12 months, it is expected that the first version of AFPS will be ready for field testing.

In-house testing will occur at strategic points throughout the Build Stage.

FSL and TDL will be working closely together to integrate additional guidance, initialization, and product generators throughout this stage in preparation for the Risk Reduction Stage.

9.3.1.3 Risk Reduction Stage

We plan to carry out operational risk reduction activities at Denver and a WFO with marine forecasting responsibilities; they provide varied terrain and forecast requirements for testing. This work cannot commence until AWIPS is installed at those sites. As the time line above shows, risk reduction activities are expected to continue until the end of FY97, several months after the scheduled delivery of P3I-2 GFI (Government-Furnished Information for the Second P3I). Since AFPS is slated to be a major part of P3I-2, there is clearly a scheduling issue to be resolved. The P3I dates are included in the AWIPS contract; the SPO and the NWS will have to address this problem.

Risk reduction activities are illustrated in Figure 24. Comments from the risk-reduction activity will be fed back to the development staff. Two software upgrades are planned, at 6 months and 12 months after testing begins.

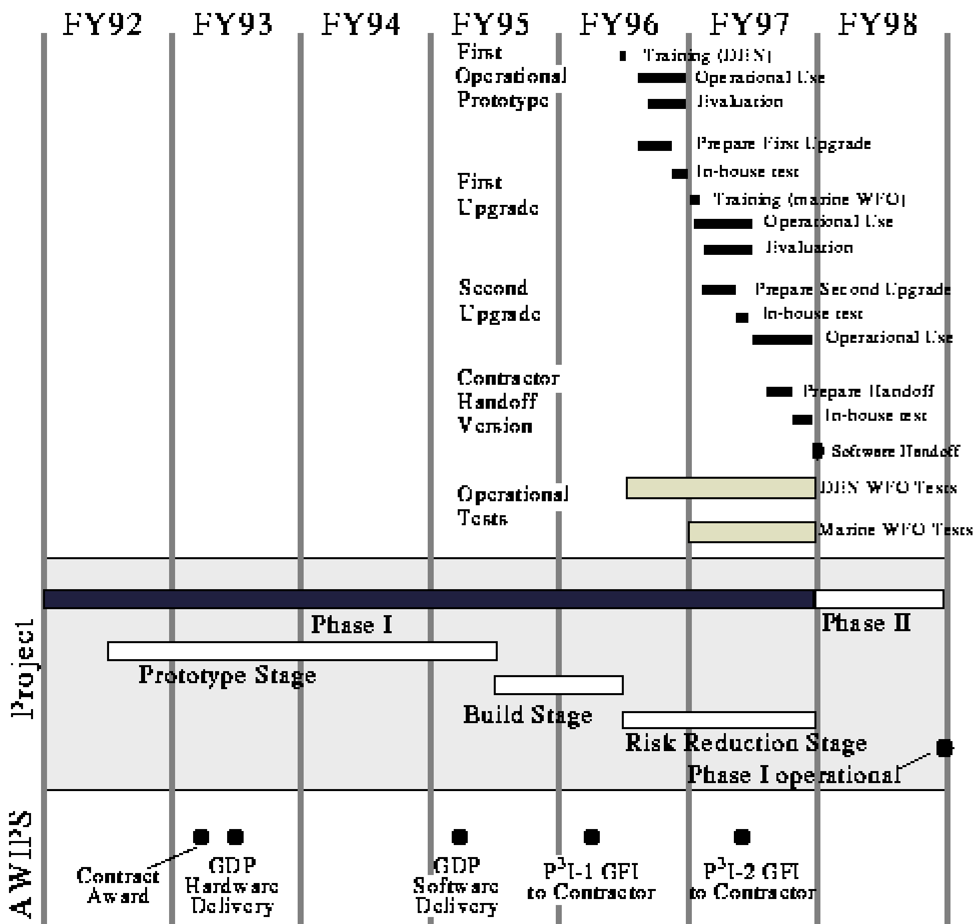

Figure f - Risk Reduction Stage

DEN WFO Risk Reduction

An 18-month risk-reduction activity is planned for WFO DEN starting about 3 years after award of the AWIPS Development Phase contract.

The risk reduction exercises will consist of a training period, operational use, and an evaluation period. We will be examining such major issues as

- Do the forecasts generated through AFPS represent the forecaster's thoughts?
- Does AFPS enhance productivity and does it save the forecaster time?
- How "forecaster-friendly" are the user interface and interactive tools?

We will also be concentrating on other issues that already will have been investigated during the Prototype Stage, such as

- Do the interactive tools adequately represent the forecast?
- Are the weather elements sufficient to describe the forecast for all services?

Marine WFO Risk Reduction

Six months after the Denver WFO tests begin, operational field testing will begin at a marine-oriented WFO for a 12-month period. As with the Denver site, the start of this test is contingent on the test site's receipt of AWIPS equipment.

This focus of this exercise will be similar to that of the Denver exercise, with the addition of "Does AFPS meet the goals of the marine program?"

Software Handoff to Contractor

The Phase I software will be handed off to the AWIPS contractor for integration upon successful completion of the risk-reduction tests. As noted earlier, this is intended to coincide with the P3I-2 GFI delivery date. It is expected that FSL and TDL will be heavily involved as consultants with the contractor between the handoff date and contractor delivery of the integrated software. AFPS will be deployed nationwide after the contractor has integrated it into AWIPS, probably in late 1998.

9.3.2 TDL

9.3.2.1 ICWF

As shown in the top part of Figure 25 on page 78, TDL plans to continue work on ICWF into the AWIPS Development Phase. ICWF risk-reduction activities will be carried out at WSFO Norman throughout the Development Phase. The initial results of these activities will provide input for the ICWF documentation packages for the AWIPS contractor. Later information will be used to refine requirements provided to the AWIPS contractor during requirements and design specification stages.

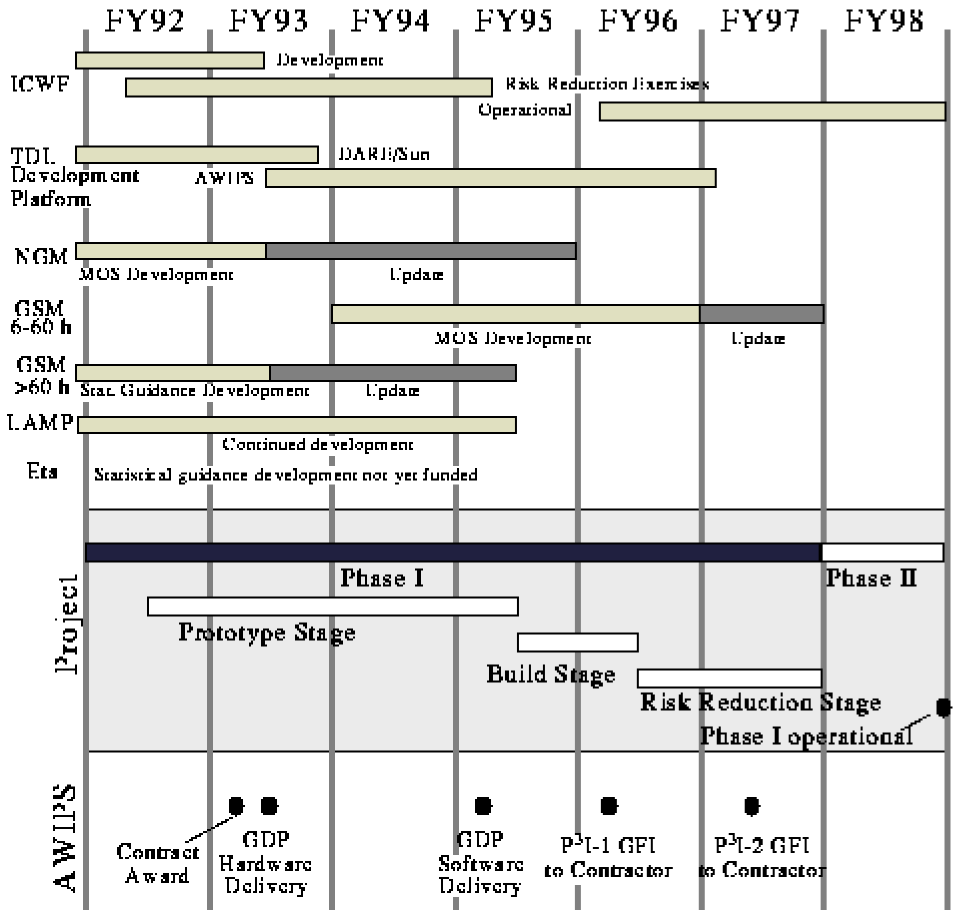

Figure : - TDL ICWF and Guidance Development

9.3.2.2 Statistical Guidance

Statistical guidance techniques for the contiguous United States will be developed according to the schedules shown in Figure 25. Plans for Alaska, Puerto Rico, and Hawaii have also been prepared; execution of these plans will depend on available resources. The statistical approaches are discussed in Chapter 4.

The first set of MOS guidance development from the Nested Grid Model (NGM) will be completed in FY93. Selected forecast elements will be updated during FY94 and FY95 as more NGM output data are archived, and as remote-sensing data become available.

Statistical guidance is also being developed for the Global Spectral Model (GSM). (The GSM is also known as the AVN, or "aviation run," for projections <= 60 ηουρσ, ανδ ασ τηε MP&PHgr;, ορ Μεδιυ�-Ρανγε &PHgr;ορεχαστ, &phis;ορ �ροφεχτιονσ &γτ; 60 η.) &PHgr;ορ <= 60 η, ΜΟΣ δεϖελο��εντ ωιλλ εξτενδ &phis;ρο� &PHgr;Ψ94 τηρουγη &PHgr;Ψ96; σελεχτεδ ϖαρια�λεσ ωιλλ �ε υ�δατεδ τηερεα&phis;τερ. Μεδιυ�-ρανγε γυιδανχε ισ �ειν γ δεϖελο�εδ υσινγ �οτη α �οδι&phis;ιεδ Περ&phis;εχτ Προγ α��ροαχη ανδ α χαλι�ρατεδ ΜΟΣ τεχηνι&thetas;υε. Α χο��λετε γυιδανχε �αχκαγε ωιλλ �ε αϖαιλα�λε �ψ �ιδ-&PHgr;Ψ93. Σελεχτεδ ϖαρια�λεσ ωιλλ �ε υ�δατεδ δυρινγ τηε συ�σε&thetas;υεντ τωο ψεαρσ.

TDL is also developing a MOS update guidance system called LAMP (Local AWIPS MOS Program). With LAMP, MOS forecasts are updated locally as frequently as hourly for projections from 1 to 20 hours. This development will continue into FY95.

Although development of statistical forecast techniques for NMC's operational mesoscale model (eta) is not funded at this time, TDL will prepare a plan in which necessary resources will be identified.

9.3.2.3 Worksheet Initialization

As noted in Chapter 5, TDL has developed techniques to initialize weather elements grids from MOS point data. Also as noted in Chapter 5, methods of initializing weather elements from model grids are being developed at FSL. Responsibility for developing such techniques for AFPS will not rest solely with TDL and FSL; NMC and OH may become actively involved in developing these techniques because of their special knowledge of the guidance forecasts they provide.

9.3.2.4 Text Generators

TDL is tasked with developing specifications for a number of product generators for all NWS program areas (see Table 13 on page 56 for a list of products). Although many of these text products are similar in format, many individual products will need to be developed and tested before AWIPS specifications can be prepared. Preparing prototype generators will allow the NWS to test and evaluate the techniques for a variety of weather situations. Figure 26 on page 80 shows the proposed specification and development period. These periods are shown corresponding to work leading up to the IDB, the first P3I, and the second P3I.

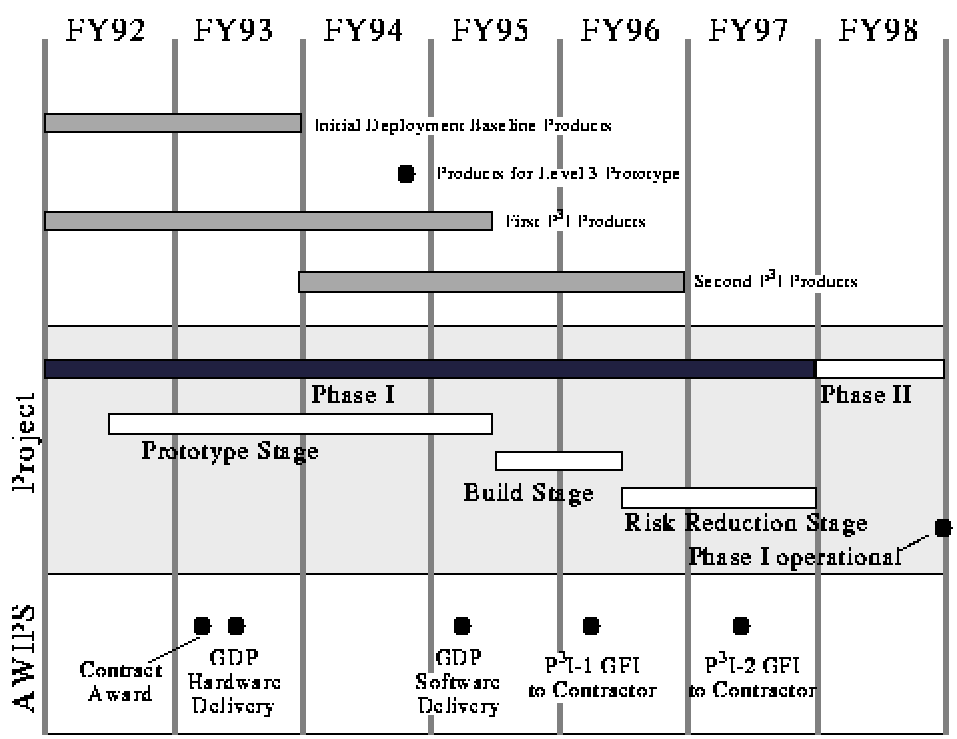

Figure 1 - Product Generators Development Schedule

Included in Figure 26 is a set of text generators that will be used by FSL for the Level 3 prototype in early FY95. These include the terminal (TAF), coded cities, zone, area, agricultural, and fire weather forecasts. In keeping with current practice, the ZFP and AFP will include extended periods.

Footnotes

(1)

"Open" systems do not use proprietary hardware or software, provide independence from hardware vendors, utilize industry-standards like ANSI, TCP/IP, and X, and provide interoperability across heterogeneous platforms.

(2)

For example, we have found that using C++ typically requires our staff to write only 50% as much code as is necessary using C.

10 Phase II

Phase II begins immediately after the Phase I software is handed off to the AWIPS contractor (at the second P3I). The software development approach for Phase II will be similar to Phase I, with Prototype, Build, and Risk Reduction stages followed by a software handoff to the AWIPS contractor. Figure 21 on page 70 summarizes both phases.

An updated plan for Phase II will be developed toward the end of Phase I.

10.1 Watch/Warning/Advisory Integration

Phase I is intended to produce only routine forecast products. A separate graphical warning program will be available in the initial operational loads of AWIPS for production of warnings, watches, and advisories.

It is desirable to combine the graphical warning capabilities with AFPS in order to

- include warning information in routine forecast products,
- derive warning information from the forecast database, and
- present a single interface to the forecaster for issuing both types of products.

We will determine the best approach for combining the graphical warning program and AFPS and will integrate them during Phase II.

10.2 Improved Derivation of Weather Elements

In Chapter 3, we presented a list of weather elements required to produce WFO-generated products. Current techniques to derive first-guess, service-specific elements are not all of high quality. As improved algorithms are developed, they should be easy to install. We want the focus of the forecasting staff to be on detecting and predicting weather elements instead of translating those elements into parameters required by the users. Algorithms could come from improved models, more complete MOS techniques, etc.

We may find that our choice of weather elements could be improved. Consider, as an example, one of our proposed weather elements, the surface wind. This may not be the most efficient element for the forecaster to manipulate to generate wind forecasts. There are a number of reasons to consider an alternative approach. First, some NWS service programs, such as the fire weather program, require forecasts of the winds at some designated height above the terrain. Second, in complex terrain, the surface winds may be a difficult and complicated field to manipulate. Third, the surface winds fields derived from model data (a likely source of a first guess forecast) are generally poor for areas with complex terrain.

One alternative to explore is to allow the forecaster to manipulate the winds above the boundary layer. At this level, the effects of terrain and friction are negligible. The forecaster could use model wind fields as the first guess. The advantage is that at this level, winds are dominated by synoptic-scale forcing and should be easier to modify. To compute the surface winds from the winds above the boundary level, some parameterization technique using terrain data will need to be developed. Where the winds above the boundary layer are weak, then surface winds are dominated by local effects, such as drainage winds during the evening. When the winds are strong, the surface wind parameterization can take into account areas of stronger or weaker winds caused by their direction relative to terrain features. This parameterization approach would allow wind forecasts to be tailored for individual terrain features.

A related example of this approach is used today. The Sangster winds are generated every 3 hours and represent what the winds would be if restricted to geostrophic components only. Basically, the Sangster winds eliminate friction and local effects and can be thought of as representing the wind field a few thousand feet above the surface. Typically, forecasters in the Midwest use these winds to forecast afternoon surface wind gusts. The idea is that as surface heating allows momentum to be transferred down to the surface, the maximum wind gusts will be the speed of the wind above the boundary layer.

10.3 Developing 3-d Visualization and Manipulation Tools

Phase I will provide a set of two-dimensional visualization and manipulation tools to the forecaster for drawing weather depictions. As the forecaster becomes comfortable manipulating weather elements and our ability automatically to produce weather elements improves, we will then move to our eventual goal of 3-d visualization and manipulation. We must be cautious that opening up the third dimension does not require too much effort by the forecaster to view and modify these fields.

Many current forecasts, such as public, are two dimensional. Complete support of aviation products, such as route forecasts, turbulence, and icing, probably requires the development of a 3-d representation of the atmosphere.

10.4 Four-Dimensional Database

We have taken a stepped approach to the implementation of a four-dimensional (x, y, z, and time) database. Phase I does not require a full 4-d database; a 2-d (plus time) surface-based database is sufficient. Algorithms and models used to derive product parameters (for aviation products, in particular) will become more sophisticated with time and will require increasing vertical resolution. As a result, it will be necessary for the weather elements, which are currently surface based, to become multilevel.

10.5 Interoffice Coordination and Boundary Reconciliation

Currently, 52 WSFOs are responsible for issuing forecasts. Under the NWS modernization, they will be replaced by 115 WFOs. The area of forecast responsibility will decrease significantly. As a result, interoffice coordination will become even more essential than it is today.

Adjacent offices will need to coordinate their efforts and have the means (preferably automated) to reconcile differences across their boundaries. Such reconciliation has the potential to consume large amounts of forecaster and computer time. As such, a careful analysis and design of a solution is imperative.

We will investigate and develop automated techniques to reconcile differences across WFO boundaries.

10.6 Graphical and Gridded Forecast Products

The forecast database makes it possible to create new types of products for sophisticated users.

Graphical depictions of the basic weather elements can be drawn by the forecaster and disseminated or they can be generated automatically from the forecast database. The forecast database itself could be a forecast product. Sophisticated users could be sent a copy of the official forecast from the forecast database.

We will investigate and implement graphical and gridded products as needed.

10.7 Related Programs

In Chapter 7, it was noted that Phase I forecast monitoring, quality control, and verification will use product parameters derived from the forecast weather elements. We plan to investigate the feasibility of converting these related programs to use the forecast database. Sections 2.4.2 and 2.4.4 provide more information.

10.8 Restricted Text Product Editing

As noted earlier, there is some danger in letting forecasters edit the text produced by the generators. We propose to address this problem in Phase II. Possible approaches include the following:

- Create a restricted text editor that allows a user to edit only selected words or phrases. This would not be a keyboard-based editor; the user would choose replacement text from a list.
- Let the forecaster edit in the standard way, then analyze the resultant text for significant changes. An artificial intelligence (AI) technique would probably be required to implement this approach. If discrepancies were detected, the user could reedit the text, or return to the worksheet to modify the forecast.
- Install a system similar to the Canadian FPA Bulletin Editor, which presents forecast parameters graphically, then lets the forecaster modify them. These data feed directly into the text generator. This gives the forecaster great control over forecast content, but precludes problems with phrasing or spelling. (The question of consistency of forecast and database remains, however.)

10.9 Editing Model Output

In Phase I, the forecaster can choose a model to initialize the forecast grids. However, some forecasters may prefer to adjust strength, timing, and position of model features, which could then be used to generate weather elements. For example, the forecaster could adjust the location of a vorticity center and the strength of a trough.

In Phase II, we will investigate the feasibility of editing model output fields and relating meteorological features to weather elements. It is unlikely that first-guess forecasts derived this way will be of as high quality as those produced by MOS or Perfect Prog, but this method has the distinct advantage of being applicable to any model, including those run locally.

10.10 Editing Model Input

One can imagine forecasters editing model input and rerunning the model. In Phase II, we will investigate the feasibility and available technology of editing model input. We may want to change the approach of AFPS from a qualitative system using weather elements to a quantitative system using state variables.

Editing model input has major ramifications. Can the forecaster be expected to visualize the atmosphere in state variables, such as 700 hPa moisture, and can he or she be expected to maintain atmospheric consistency?

After model input has been edited, the model must be rerun. Is this one of the operational NMC models? Does each WFO have the capability of running these models? Could they be rerun at NMC?

Clearly, this idea both has NWS policy implications and requires processing resources far beyond the scope of the present AWIPS requirements.

Glossary

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--------------------------------------------
ADF                 FSL's Advanced Development Facility group
AES                 Atmospheric Environment Service (Canada)
AFOS                Automation of Field Operations and Services - the NWS'
current communications and display
                    system, to be replaced by AWIPS
AFP                 Area Forecast Product
AFPS                AWIPS Forecast Preparation System
AFWG                AFPS Forecaster Working Group
ANSI                American National Standards Institute
ARTT                AWIPS Requirements Task Team
ASOS                Automated Surface Observing System
AVN                 "aviation run" - common name for the twice-a-day, 72-hour
run of NMC's GSM
AWIPS               Advanced Weather Interactive Processing System
AWIPS

              period during which PRC (and subcontractors) are building the
AWIPS IDB
Development
Phase
AWIPS Extended      period during which two competing consortia prepared bids
for developing AWIPS
Definition Phase
AWIPS Local         an area of 750 km x 750 km, generally centered on a WFO
site, over which data will be displayed
scale               on AWIPS. This is the area which will be represented in
the forecast database.
AWIPS System        all of the software written specifically for AWIPS by PRC
and subcontractors. This includes
Software            menus, decoders, display techniques, etc.
bounded area        a representation of a weather element that covers limited
parts of the forecast database. Areas are
                    depicted as closed curvilinear polygons.
C                   an industry-standard computer programming language
C++                 an object-oriented programming language, based on C
CCF                 Coded Cities Forecast
CD-ROM              Compact Disk - Read-Only Memory - a high-density data
storage medium
continuous field    a representation of (gridded) weather element that covers
the entire spatial domain of the forecast
                    database. Data may be depicted as contours, wind barbs,
vectors, or streamlines.
COTS                Commercial Off-the-Shelf
CWF                 Computer Worded Forecast
DAR3E, DARE II      Denver AWIPS-90 Risk Reduction and Requirements
Evaluation (versions 1 and 2)
eta                 NMC's operational mesoscale model
FAC                 AWIPS First Article Capability
FEFS                Forecast Entry and Formatting System
Forecast Bulletin   graphical editor for the FPA, which allows the forecaster
to fine-tune product-specific data
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Editor
forecast database   repository for gridded and bounded-area weather elements which constitute the official weather
forecast; a portion of the AWIPS database
forecast

the worksheet containing weather elements which, when stored in the forecast database, will

worksheet   constitute the official forecast
FPA   Forecast Production Assistant - an AES graphical forecast support system
FSL   Forecast Systems Laboratory
GDP   Government Development Platform - a complement of AWIPS hardware and COTS software
general weather   a weather element that applies to forecasts from more than one service (public, hydrology,
element   marine, etc.)
GFE   Graphical Forecast Editor - a suite of tools with which forecasters will manipulate weather

elements
GFI   Government-Furnished Information
GL   an industry-standard graphics system
GSM   NMC's Global Spectral Model
GUI   Graphical User Interface
Haines Index   the popular name for the Lower Atmospheric Severity Index (LASI) for Wildland Fires, after its
author, Donald Haines
HP   Hewlett-Packard
hPa   hectopascal, an SI (International System of Units) pressure unit equivalent to the more common
millibar
ICWF   Interactive Computer Worded Forecast
IDB   AWIPS Initial Deployment Baseline
LAMP   Local AWIPS MOS Program
LAPS   FSL's Local Analysis and Prediction System
MAPS   FSL's Mesoscale Analysis and Prediction System, the basis of the RUC
matrix depiction   a textual view of weather element values. Two of three attributes (element, location, time) may
vary along the rows and columns, with the other fixed.
MIPS   Million Instructions Per Second, a common measure of computer processor speed
MOD   NMC's Meteorological Operations Division
MOS   Model Output Statistics
MRF   Medium-Range Forecast - common name for the once-a-day, 10-day run of NMC's GSM
NEXRAD   Next-generation weather radar
NGM   NMC's Nested Grid Model
NHC   National Hurricane Center (part of NMC)
NIEP   National Institutes for Environmental Prediction - the future name of the reorganized NMC
NMC   National Meteorological Center
NOAA   National Oceanic and Atmospheric Administration

NSSFC   National Severe Storms Forecast Center (part of NMC)
NWR   NOAA Weather Radio
NWS   National Weather Service
NWWS   NOAA Weather Wire Service
OH   NWS Office of Hydrology
OI   Object Interface, a commercial C++ GUI library
OM   NWS Office of Meteorology
OOP   Object-Oriented Programming
OSD   NWS Office of Systems Development
OSF/Motif   an industry-standard GUI system, marketed by the Open Software Foundation
P3I   Pre-Planned Product Improvement
Phase I   AFPS work through about 1997, including components necessary to support generation of most WFO routine forecast products
Phase II   proposed future AFPS enhancement work
PoP   Probability of Precipitation
PRC   Planning and Research Corporation
Pre-AWIPS   Norman AWIPS risk-reduction system
product generator   software that creates a (usually text) product from the contents of the forecast database, other data from the AWIPS database, and static (e.g., station) information
product parameter   a weather element that is computed for use in a forecast, but is not edited by the forecaster; e.g., wind chill
Prototype Stage   period during which FSL will be developing and refining requirements, testing concepts, and building prototypes of AFPS
QC   Quality Control
QPF   Quantitative Precipitation Forecast
reference worksheet a read-only worksheet, constructed from the output of a single numerical model
RFC   River Forecast Center
RFP   Request for Proposal
Risk Reduction Stage period during which FSL will test an operational prototype of AFPS in two WFOs
RUC   NMC's Rapid Update Cycle mesoscale model
service-specific weather element   a weather element that applies to forecasts from only one service
spatial depiction   a geographical view of a weather element
SPECmark   an industry-standard computer "horsepower" rating unit
SPO   NOAA Systems Program Office
Starbase   HP's GL-based graphics system
TAF   Terminal Aerodrome Forecast
tag   a label for a bounded area
TDL   Techniques Development Laboratory
temporal depiction   a time-series view of a weather element
text generator   a text product generator

TSP	Technique Specification Package
TWEB	Transcribed Weather Broadcast - an aviation route forecast
UNIX	an industry-standard computer operating system
weather element	an atmospheric property or phenomenon that is required for one or more of the NWS products supported by AFPS, will be graphically manipulated by the forecaster, and will be stored in the forecast database
WFO	Weather Forecast Office
window	a rectangular region on the display, used to contain weather element depictions, menus, etc.
worksheet	the forecaster's "window" into the forecast database, comprising a matrix of views of weather elements vs. time
WSFO	Weather Service Forecast Office
WSO	Weather Service Office
WSR-88D	Weather Service Radar, 1988, Doppler (the individual radar units of NEXRAD)
W/W/A	Watch/Warning/Advisory products
X	common name for the X Window System, an international standard windowing system for distributed computing environments
XGL	Sun Microsystems, Inc.'s version of GL
Xlib	a standard library of low-level X routines
ZFP	Zone Forecast Product

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