4.3 MODELS, FORECASTERS, AND INTERACTIVE FORECAST PREPARATION IN THE NEW MILLENNIUM

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1. INTRODUCTION

The National Weather Service (NWS) has been developing and testing techniques that support Interactive Forecast Preparation (IFP) for more than a decade. Beginning in 2000, the NWS will introduce IFP into its Weather Forecast Office (WFO) operations nationwide. This is a significant undertaking. Selected staff at each of approximately 120 WFOs will receive two days of IFP manager's training, as well as a 9-day residence course on interactive techniques and site customization at the NWS Training Center. Proceeding at a rate of approximately four new WFOs per month, nationwide spin-up of IFP will take more than two years to complete.

IFP represents a substantial change for forecasters (Maximuk 1998). Instead of manually typing a myriad of forecast products tailored for specific user communities (e.g., public, aviation, marine), forecasters will rely on interactive interpretation and editing techniques (Ruth et al. 1998) to prepare forecasts of weather elements in a common digital database from which forecast products will be automatically composed and formatted (Peroutka et al. 1998). The common digital database used to generate these products will allow for more consistent forecasts over time and among products, and for easier monitoring and maintenance of those forecasts. Moreover, it will provide a foundation for the development of a new generation of grid-based NWS products, including the forecast digital database itself (NWS 1999).

IFP is not unique to the United States. Over the past decade, similar techniques have been developed and implemented at forecast centers in Europe and Canada (Blaauboer 1999). At the same time IFP developers have been striving to enrich their human-machine interfaces, numerical weather modeling has continued to realize steady and significant improvements in both the quality and resolution of numerical forecast guidance (Kalnay et al. 1998). In the new millennium, advances in observation systems, data assimilation techniques, computer performance, and model physics will carry numerical model skill to near the theoretical limits of predictability (National Research Council 1999). Inevitably, it will become difficult for forecasters to add significant value to computer model guidance on a routine basis (Roebber and Bosart 1996).

Today, most IFP tools rely primarily on data entry and drawing techniques. With these tools, forecasters do not fully benefit from the availability of improved high-resolution model guidance. This paper first describes the digital forecast process, and then discusses future IFP tools designed to enable forecasters to take better advantage of advances in numerical model guidance.

2. THE DIGITAL FORECAST PROCESS

Fig. 1 illustrates the digital forecast process. It begins with the assimilation of atmospheric observations as input to numerical forecast models. Numerical models produce output of pressure, temperature, wind, and humidity in accordance with the physical laws of the atmosphere. Numerical output can then be interpreted into sensible weather elements (e.g., max/min temperature, probability of precipitation) needed to prepare forecasts. This is best accomplished with statistical techniques such as Model Output Statistics (MOS) (Glahn and Lowry 1972) or perfect prog (Klein et al. 1959). When statistics are unavailable, meteorological algorithms have also been used to derive forecast surface conditions from extrapolated model based soundings (Wier 1998).

Fields of sensible weather elements can be edited as objects, grids, or matrices. Interactive techniques are discussed in the next section. In the end, text, voice, tabular, graphical, and gridded forecast products are all produced from the forecaster-prepared digital database to support a variety of interests. Of these, the most significant effort has been directed toward the generation of natural language text for digital and voice transmission.

The NWS has had much success generating text by selecting from a library of predefined phrases for individual forecast elements (e.g., precipitation, temperature, sky cover), and then merging these phrases into a smooth-flowing forecast with the important elements emphasized and appearing first. The phrase selection process relies on hundreds of configuration parameters which are set by the WFO to suit its particular preferences. The basic approach for producing public zone forecasts is described by Glahn (1979). Recent additions

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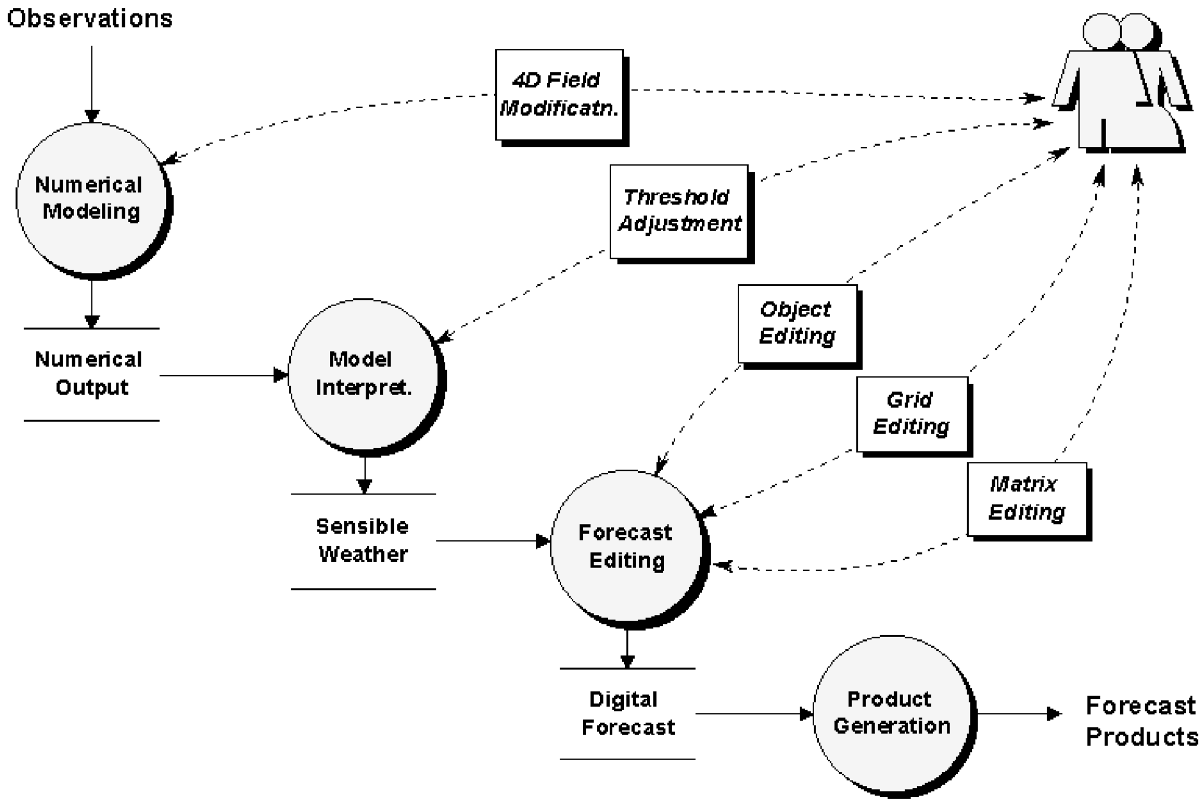

Figure 1: The digital forecast process.

to this software include the production of fire weather forecasts (Peroutka et al. 1997), voice-ready radio forecasts (Calkins et al. 1998), and marine forecasts (Peroutka et al. 2000).

Considerable work on text generation is ongoing in other countries as well. Natural language generation associated with the Canadian Forecast Production Assistant (FPA) has relied upon computational linguistics (Goldberg et al. 1994) to produce bilingual texts for many years. Recently, a new approach with simple ad hoc grammar rules to achieve linguistic renderings with greater configurability has been developed for FPA (Driedger et al. 2000). According to Verret et al. (1999), the knowledge base used to produce plain language forecast bulletins for another Canadian forecast preparation system, called SCRIBE, was recently reengineered to increase modularity and flexibility. And Swedish developers are currently exploring new methods for multilingual text generation via a modular strategy (Vavargard 2000).

Although text will always be important, the Internet is now paving the way for a plethora of new graphics products. The Forecast Systems Laboratory has developed graphical viewing software for WFOs which allows anyone to examine NWS gridded forecasts via the World Wide Web (LeFebvre et al. 1996). As the new millennium begins, the NWS will begin to shift its product base to more digital formats.

3. HUMANS IN THE DIGITAL FORECAST PROCESS

The 20th century has witnessed an increasing reliance by meteorologists on computer technology to complete tasks that were formerly infeasible or accomplished by manual methods. The first major advances came in the field of numerical weather prediction. Although not openly embraced by operational forecasters at the start, a review of numerical model output is now an indispensable part of their daily forecast procedures. The statistical interpretation of numerical model output by computer followed a similar path into operations. MOS forecasts are now developed worldwide and have become the baseline by which many human forecasts are judged.

In a quarter century, on a path parallel to numerical and statistical modeling, the human preparation of forecast products has evolved from teletype tape, to word processors, to graphical computer workstations. Today, the World Wide Web provides a means to furnish detailed forecast information for individual street addresses on a minute-to-minute basis. Mesoscale models are run with increasing frequency, for shorter time steps, and on higher resolution grids. Meteorological details previously unseen, including local effects due to mountains, valleys, cities, and coastlines, are now readily apparent in model output. With the correct approach, IFP provides an opportunity to marry advances in modeling to the human preparation of forecast products.

Table 1 lists techniques used by forecasters to interact with the digital forecast process (Fig. 1) in the United States, Europe, and Canada. Matrix editors enable forecasters to view and edit information for the forecast elements, locations, and time periods that are specific to the products issued. A single screen can provide coordinated spatial and temporal information as well as display the resultant product text. Matrices are best for making forecasts specific to a point or a general forecast for a homogenous area. They have been operationally used for this purpose since the late 1980's.

Table 1. Humans in the digital forecast process.

Interactive Technique	Example	Reference
Matrix Editing	ICWF U.S.A.	Ruth and Peroutka 1993
	SCRIBE Canada	Verret et al. 1995
	SYMPOSIUM France	Benichou 1998
Grid Editing	GFE U.S.A.	Wier et al. 1998
	RiPP Sweden	Nilsson 1998
Object Editing	FPA Canada	Paterson et al. 1993
	SYNERGIE France	Desbois 1998
Threshold Adjustment	"Slider Bars" U.S.A.	Ruth 1998
4D Field Modification	Horace U.K.	Carroll 1998

Grid editors enable forecasters to draw and manipulate fields of sensible weather on a map. Tools can be defined locally that consider meteorological interdependencies among specific weather elements and terrain in both time and space. The development of these "smart" drawing tools is relatively new. It is still unknown how long it will take forecasters to prepare complete sets of forecast grids this way or how forecaster-drawn fields will compare in the end with those from the sophisticated models used to initialize the digital database.

Object editors interact with meteorological objects (e.g., band of precipitation, front, jet core) and their associated attributes (e.g., rate of precipitation). Objects fit in well with the conceptual approach of most forecasters. Object editors have been used in operations for many years. They are especially well-suited for producing synoptic-scale and graphical forecast products.

Interactive model interpretation techniques do not edit sensible weather. They change threshold values used for the interpretation of model guidance into sensible weather. Interactions are at a level similar to the thoughts that commonly appear in forecast discussions such as: more thunderstorms in areas of strong lift in the south, slower onset than indicated by the model, heavier precipitation on the eastern slopes, earlier fog in deep valleys.

The forecaster makes these adjustments by moving slider bars while viewing a color image of the resulting forecast on the screen. Thresholds are reset for selected time projections, linearly interpolated in time at every gridpoint, and then used to reinterpret intermediate model grids. In this manner, the adjusted forecast remains consistent in time and space. That is, there is no disruption to the time-space continuum of high-resolution model guidance that can occur when weather elements are edited directly. Advances in numerical weather prediction will translate directly into improved sensible weather grids. However without good model guidance, interactive model interpretation becomes impractical, and so far has not been widely accepted in operations.

Another way to interact in the digital forecast process is to change the numerical output itself. This can be accomplished by altering the position and intensity of features such as fronts and depressions on a grid at one atmospheric level, and then recalculating grids for other levels by applying the transformation to potential vorticity fields, which, when inverted, yield physically realistic results in three dimensions. Modifications applied at single time projections can be linked to ensure a realistic progression. This type of 4D field modification has been used operationally to generate guidance graphics at the United Kingdom Meteorological Office since 1997.

4. CONCLUSION

This paper describes a variety of techniques by which forecasters can interact with the digital forecast process. The NWS has implemented a number of them within the IFP system it is deploying nationwide. As the new millennium begins, users will demand high-resolution forecasts like those now becoming available from numerical models. Assuming advances in numerical weather prediction continue, forecasters will transition from looking at model guidance, to working with model guidance; from thinking in words, to thinking in numbers; and from data entry and drawing, to interacting with high level functions that retain the full resolution of the model guidance.

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