

THE INTERACTIVE COMPUTER WORDED FORECAST

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1. INTRODUCTION

The Techniques Development Laboratory (TDL) has developed a family of techniques which enable the forecaster to interactively prepare digital forecasts of weather elements from which many routinely-issued forecast products can be automatically composed and formatted. The significance of these techniques is that they allow forecasters to concentrate on the meteorology of the situation by relieving them of the need to type products in different formats. The common database used to generate these products also allows for more consistent forecasts over time and among products, and for easier monitoring and maintenance of those forecasts.

1.1 History

Computer Worded Forecasts (CWF) entered the National Weather Service's (NWS) field operations in the mid 1970's and their role has continued to grow since. The first operationally-produced worded forecasts were centrally distributed to NWS forecast offices as guidance products. These forecasts, described by Glahn (1979), were based on Model Output Statistics (Glahn and Lowry, 1972). They were produced for cities in the conterminous U.S. daily.

In the early 1980's, the program was expanded to produce worded forecasts for NWS zones (Bermowitz et al., 1980; Miller and Glahn, 1985). This moved the CWF concept closer to the operational mainstream, since zone forecasts were

the "flagship" product of the NWS. Forecasts for zones were interpolated from MOS guidance for nearby stations. Adjacent zones were compared, and zones with similar forecasts were averaged together. MOS forecasts specific to combinations of zones were then used to produce a computer worded zone forecast.

Interactive techniques which enable the local forecaster to control the digital weather forecasts used in automatic product formatting began to be developed in 1985. These techniques, in combination with mainframe CWF programs translated to Automation of Field Operations and Service (AFOS) computers, comprised the earliest Interactive Computer Worded Forecast (ICWF) system. In the ICWF system, menu-driven programs allow the NWS forecaster to revise statistical guidance by adjusting the values of forecast elements displayed on an area map. These digital forecasts are then used to produce products in several formats.

From June of 1986 until the present, evolving versions of the ICWF system have been used operationally at several Weather Service Forecast Offices (WSFO). Enhancements made to the ICWF include:

- software which produces many products in addition to zone forecasts,
- techniques which allow forecaster interaction with explicit weather elements rather than MOS categories and probabilities,
- techniques which check the ICWF database for inconsistent forecasts,
- an option to initialize the ICWF database with updated MOS guidance produced by the Local

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AWIPS MOS Program (LAMP) (Glahn, 1980; Unger et al., 1989), and

- techniques which provide for interaction with forecast grids.

The most successful implementation of the ICWF has been conducted at WSFO Charleston, W. Va. As a result of ICWF technology, this WSFO now automatically generates routine public and fire weather products, and has increased its level of service by adding several agricultural, hydrologic, and public products to the existing product suite (Rezek and Parke, 1990).

Most recently, TDL has implemented the ICWF on pre-AWIPS (Advanced Weather Information Processing System) computers to allow risk reduction testing at the NWS Forecast Office in Norman, Okla. Pending the successful outcome of a formal evaluation currently underway, the ICWF will be implemented nationally on AWIPS soon after that system becomes available.

1.2 Overview

This paper describes the ICWF conceptually without regard to its specific computer implementation. Processes are discussed in an order which traces the flow of data through the ICWF system:

- initializing forecast grids with guidance,
- forecaster modification of gridded forecasts,
- deriving zone forecasts from grids,
- forecaster modification of zone forecasts,
- specifying Watches, Warnings, and Advisories, and
- generating forecast products.

2. INITIALIZING FORECAST GRIDS

The ICWF stores forecasts as a set of grids. Geographically, the grids consist of arrays of 19 x 19 data points spread evenly over a Lambert conformal projection of the forecast area (the AWIPS "local" scale). Grids are defined for each hour from 0000 or 1200 UTC model cycle time out to 72 hours for 10 weather elements. These elements, which pertain to the surface of the earth or what can be observed from the surface, are daytime maximum and nighttime minimum temperatures, temperature, dew point, probability of precipitation for a 12-h period, precipitation amount over a 6-h period, snowfall over a 12-h period, wind direction, wind speed, cloud layers, and precipitation areas.

The elements are represented on the grid in two ways. The first eight elements are considered to be continuous and are easily represented. Cloud layers and precipitation areas, however, are "dis-

crete" weather elements which require special techniques.

The cloud grid at each hour is defined by a table of cloud layers and a set of one or more tags for every gridpoint. Each tag assigned to a gridpoint refers to an entry in the table of cloud layers. These entries specify the probability (slight chance, chance, occasional, or likely), cloud amount, base height, top height, and cloud type for each layer. Similarly, each weather grid is defined by a table of weather types and a set of tags at every gridpoint. Entries in the weather table are probability, visibility, weather type, and wind gust.

Currently, grids can be initialized from two sources: the previous forecast and MOS guidance (Carter et al., 1989). Initializing grids from the previous official forecast involves copying data and changing time references. Grids are initialized from MOS using the following multi-step process.

- MOS guidance, updated by the most recent LAMP output, is interpolated from its 12-, 6-, or 3-h resolution based on synoptic observation times to the appropriate resolution in the local time zone. For example, the probability of precipitation is determined for a period from 6AM to 6PM.
- The guidance 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 gridpoint. A single station is mapped to each gridpoint for non-continuous weather elements.
- Selected continuous elements are spatially smoothed.
- Discrete weather elements are derived for each gridpoint from the MOS guidance at that point. For example, precipitation type is derived from the best category forecast, conditional probabilities of frozen and freezing precipitation, temperature, and dewpoint.
- Areas of precipitation and cloud layers are identified and mapped.

3. FORECASTER MODIFICATION OF GRIDDED FORECASTS

The ICWF enables the forecaster to interactively modify gridded forecasts initialized from guidance by drawing, erasing, and modifying contours representing the gridded field using a mouse (or a trackball). Modifications made to contours are reflected in the data values of the gridded field. The

software also allows the forecaster to directly modify digital values plotted on the grid. Modifications made to the gridded field in this manner are reflected in technique-drawn contours.

Capabilities for the interactive manipulation of cloud layers and precipitation areas on a grid that were developed at TDL in the late 1980's (Ruth and Vercelli, 1989) have not been incorporated into the ICWF. The NWS plans to implement enhanced versions of these techniques as part of the AWIPS Forecast Preparation System (Wakefield et al., 1992) which is being developed by the Forecast Systems Laboratory and TDL jointly. Techniques employed by the ICWF to modify scalar grid fields are described in detail by Ruth (1993).

The ICWF uses the Systematic Interpolative Radial Search (SIRS) method to compute gridpoint values from forecaster-drawn contours (Ruth, 1992). SIRS identifies contours by performing a multi-directional radial search for contours from each gridpoint to be computed. Gridpoints which are coincident with a contour simply take on the value of that contour. Values for all other gridpoints are computed in one of the following ways: averaging the values of the nearest contours, weighted inversely by the distance from the gridpoint to the contour; averaging values determined from directional gradients defined by contours; or averaging values of adjacent gridpoints and contours. The computation performed for any particular gridpoint depends upon the relative positions and values of its surrounding contours.

The ICWF allows the forecaster to directly manipulate gridded values plotted on the display screen. Collections of gridpoints are highlighted by passing the cursor over those gridpoints with the mouse. The forecaster is also able to highlight all points in an area of the grid enclosed by contours by clicking the mouse. Highlighted gridpoints can be manipulated in four ways: value assignment, increment/decrement, translation, and smoothing.

4. DERIVING ZONE FORECASTS

Many NWS forecasts are issued for predefined portions of a local office's area of warning and forecast responsibility. The office defines a number of subareas, called "zones," for public, agricultural, marine, and fire weather forecast products. The ICWF maps a collection of gridpoints to each zone. Office-defined weights for each gridpoint are used to compute zone forecasts from forecast grids (Hawkins, 1992a).

A digital zone forecast in the ICWF consists of a matrix of 23 weather elements specified at

21 time projections. Time projections are 3 hours apart beginning at model start time. The weather elements are maximum/minimum temperature, temperature, dew point, total opaque sky cover, wind direction and speed, probability of precipitation, precipitation amount, snowfall, thunderstorm probability, thunderstorm intensity, obstructions to vision, and 11 elements to describe precipitation.

The precipitation elements use a format called "explicit weather" to describe one, two, or three forms of simultaneously occurring precipitation. Each precipitation is defined by a probability qualifier (slight chance, chance, likely, occasional, or definite), a precipitation type (rain, rain showers, snow, freezing drizzle, etc.), and an intensity (very light, light, moderate, or heavy). If more than one form of precipitation is forecast, connectors (and, or) are defined as well. Using these explicit weather elements, the ICWF can describe precipitation such as "chance of light rain," "occasional drizzle," and "rain likely, possibly mixing with snow."

Extracting the relevant information from a set of forecast grids and producing a forecast for a zone is referred to as "summarizing." Summarizing forecasts for continuous weather elements is a straightforward process. A weighted average of the zone's gridpoints is computed for specified time periods.

Summarizing forecasts for explicit weather is more complex. The input can include as many different types of weather as there are gridpoints assigned to the zone. The summarization techniques do not allow more than one form of liquid (or freezing, or frozen) precipitation in a zone forecast for a 12-h forecast period. This means the summarization algorithms choose between rain and drizzle if both are forecast at the gridpoints. For each zone, the ICWF determines:

- which phases (e.g., liquid) of precipitation are forecast,
- the predominant character (steady or showery) of the precipitation,
- the predominant intensity of the precipitation, and
- the proper handling of probability qualifiers.

5. FORECASTER MODIFICATION OF ZONE FORECASTS

The ICWF allows the forecaster to view, enter, and modify zone forecast matrices in either of two ways: 1) by sequential interaction with submatrices of selected weather elements and forecast projections for points and areas plotted on a geographic map of the local area, and 2) by interaction

with up to four "full matrices" displayed, one in each quadrant, at a time. A "full matrix" contains all weather elements at all forecast projections for a zone. A "sub-matrix" contains a subset of weather elements for a given forecast period (e.g., today, tonight, tomorrow).

The ICWF enables the forecaster to interactively select groups of zones to be combined for preparation as a single forecast matrix. It displays all zone names and draws appropriate zone borders, indicating existing zone combinations, over a map of the area of forecast responsibility. A matrix containing weather elements representative of 12-h forecast periods is plotted over each zone to assist the forecaster in deciding which zones to combine.

The zone combinations displayed initially may be ones recommended by a difference checking algorithm (Hawkins, 1992b), or may be combinations previously selected by the forecaster. The forecaster clicks the mouse button to interactively specify which displayed zones to "add" or "subtract" from the group to be combined. After each selection, boundaries of zone combinations are redrawn on the display screen to reflect the revised arrangement. Once the forecaster is satisfied with the arrangement of zone combinations, the ICWF will average individual zone forecast matrices into a single forecast matrix for each zone combination.

For continuous weather elements, the ICWF provides the capability for the forecaster to increment and decrement the matrix values. Categorical weather elements are represented in the forecast matrix display by numbers, letters, and symbols. For categorical weather elements, the ICWF provides the capability to step through the applicable categories for each element. For example, the weather element for precipitation type has the following sequence: "rain" (R), "rain showers" (RW), "drizzle" (L), "snow" (S), "snow showers" (SW), "freezing rain" (ZR), "sleet" (IP), "freezing drizzle" (ZL).

The ICWF assists the forecaster by automatically modifying related matrix values when the forecaster enters or modifies values for selected weather elements. Related matrix values are automatically modified to enforce meteorological consistency among related weather elements (e.g., temperature and dewpoint), facilitate the entry and modification of weather elements which occur for periods of time (e.g., precipitation events), and provide consistent default values for certain elements related to precipitation (e.g., categorical precipitation probabilities within a 12-h period which are based on the percent probability for the whole period).

The ICWF provides the forecaster with additional information relevant to the matrix currently being modified in special display windows. In one display window, the ICWF displays a row of station models for the matrix currently under the cursor. The station model plots represent all the forecast elements at projections currently displayed on the screen. The station model window helps the forecaster coordinate forecasts among related weather elements when modifying sub-matrices of selected forecast elements.

A second ICWF display window allows the forecaster to consider the current forecast in relation to the previous official forecast, MOS guidance, or updated MOS guidance. The weather elements, forecast projections, and zones displayed correspond to the forecast matrix currently under the cursor. The type of guidance displayed is selected by the forecaster.

Finally, the forecaster is able to perform a set of locally defined quality control checks. The ICWF reports the results to the display screen.

6. WATCH/WARNING/ADVISORY INTERFACE

When "long-fused" Watches, Warnings, or Advisories (WWA) are in effect, most NWS forecast products begin with a headline stating the hazard, location, and valid time (e.g.,... WINTER STORM WARNING THIS EVENING FOR TRUMBULL COUNTY...). The ICWF provides an interface which allows the forecaster to enter this information into the database graphically.

The ICWF WWA interface presents the forecaster with a map of the forecast area and a menu. Initially, the forecaster may want to view a set of recommended WWA's based on the zone forecasts which have been previously entered into ICWF matrices. The ICWF forms its recommendations by scanning the zone forecasts for specific threshold events. For example, a forecast of 4 or more inches of snow requires the issuance of a Winter Storm Warning in most of the United States.

The recommended WWA's are graphically displayed along with all WWA's which are currently in effect. The forecaster has the option to convert the recommendations to actual WWA's, issue new WWA's, cancel current WWA's, or clear portions of current WWA's. For most of these actions, the forecaster first specifies the action to be taken and then indicates the issuance area by pointing to one or more zones with the mouse. When a new WWA is issued, the forecaster must specify its type and valid times as well.

7. GENERATING PRODUCTS

The primary benefit of the ICWF is its ability to generate a large number of products from a forecaster-prepared digital forecast database. The ICWF currently produces public forecasts, agricultural forecasts, narrative fire weather forecasts, and a number of coded and tabular products. WWA information in the database is used to produce a "shell" for certain statements and discussions.

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

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

In contrast to the public forecasts, agriculture, 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 agriculture forecast.

WEDNESDAY...SOUTH WIND 5 TO 10 MPH. 10 TO
11 HOURS OF SUNSHINE. HIGH DRYING
POTENTIAL. MODERATE DEW WILL DRY FROM
VEGETATION BY 1100 AM. LOWEST HUMIDITY
45 TO 55 PERCENT. HIGH IN THE MID 90S.

For each element (e.g., precipitation, cloud, wind), the ICWF selects phrase types which are assembled into a specific phrase structure based on rules of grammar and NWS regulations pertaining to the specific product. The generation of precipitation phrases (Cammarata and Kosarik, 1992a) is the most complex. At present, the ICWF can select from more than 30 phrase types (e.g., RAIN CHANGING TO SNOW). Corresponding precipitation phrase structures consist 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.

The range and sequence of cloud categories during the forecast period determines the selection

of cloud phrases (Cammarata and Kosarik, 1992b). A cloud phrase file allows each site to define (in tenths of opaque cloud cover) the meaning of the various cloud phrases (e.g., PARTLY CLOUDY, MOSTLY CLOUDY). Wind phrases can have both an adjective (e.g., BREEZY, WINDY) and a detail phrase (e.g., SOUTHWEST WIND 15 TO 25 MPH). Site-selectable thresholds determine wind phrase selection (Kosarik and Cammarata, 1992).

As in the case of wind, both an adjective phrase and a detail phrase can be used to describe temperature (Kosarik et. al., 1992). Adjective phrases (e.g., COLD, WARMER) are selected on the basis of temperature, change since the previous day, departure from normal, and the forecaster-selected detail level. The temperature detail phrase is normally limited to reporting high and low temperatures (e.g., HIGH IN THE MID 70S). If the digital temperature forecasts suggest a non-standard diurnal trace, the detail phrase will contain an appropriate description. (e.g., EARLY MORNING HIGH IN THE LOWER 50S...THEN TEMPERATURES FALLING TO THE LOWER 30S).

Once phrases for each element have been built, the ICWF merges them to make the body of the forecast. The forecast body encompasses all pertinent descriptive phrases in a smooth-flowing text with the most important elements appearing first for emphasis. The body is then combined with detail phrases including snow accumulation and probability of precipitation statements.

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