JP4.1

FORECAST CONSIDERATIONS: APPLICATION OF THE POINT FORECAST MATRICES IN HEAT/HEALTH WARNING SYSTEMS

Douglas C. Young *
NOAA/NWS, Silver Spring, Maryland

1. INTRODUCTION

The National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) Point Forecast Matrices (PFM) product is the piloted source of meteorological input variables necessary for Heat/Health Warning Systems (HHWS). These systems are uniquely tailored for specific locations and are based on actual weather-health relationships as described by Sheridan and Kalkstein (1998). This paper provides a brief description and history of the PFM, and identifies the benefits of utilizing this product in HHWS. In the concluding section, the importance of PFM reliability, timeliness, accuracy and resolution are emphasized.

2. POINT FORECAST MATRICES OVERVIEW

The PFM is an automatically generated tabular product consisting of various forecasted and derived weather parameters for public weather verification sites, selected cities, towns, or *any* other pre-defined points within a Weather Forecast Office's (WFO) County Warning and Forecast Area (CWFA). NWS forecasters modify surface weather fields using the Interactive Forecast Preparation System (IFPS) Graphical Forecast Editor (GFE) software. IFPS is housed in the Advanced Weather Interactive Processing System (AWIPS) available at each WFO. The PFM is automatically generated by sampling the "value added" local forecast database at specified grid point locations.

2.1 *Format*

The PFM has a quasi-static matrix format allowing for rapid visual scanning of a large number of forecast parameters (Fig 1). In addition, the forecast data is decodable by computers for those who wish to extract specific parameters as a source of input into other programs (e.g., HHWS), and for those who wish to create derived products. The PFM contains detail which is supplemental to and/or higher resolution than other standard NWS products. For detailed PFM format and content information, refer to National Weather Service Instruction 10-503, *WFO Public Weather Forecast Products Specification* (available online from the NWS Directives System page at: www.nws.noaa.gov/directives/010/pd01005003a.pdf)

* *Corresponding author address*: Douglas C. Young, NOAA/NWS 1325 East-West Hwy., SSMC2, Silver Spring, MD 20910; e-mail: Douglas.Young@noaa.gov.

```
INZ004-280000-
SOUTH BEND-ST. JOSEPH IN
41.71N 86.32W
400 AM EST MON OCT 27 2003

DATE                MON 10/27/03            TUE 10/28/03            WED 10/29/03
UTC 3HRLY       08 11 14 17 20 23 02 05 08 11 14 17 20 23 02 05 08 11 14 17 20 23
EST 3HRLY       03 06 09 12 15 18 21 00 03 06 09 12 15 18 21 00 03 06 09 12 15 18

MAX/MIN                        45          38          48          38          51
TEMP            38 37 38 42 45 44 41 40 39 39 39 45 48 47 42 40 40 39 39 46 51 49
DEWPT           35 35 34 33 32 32 32 33 35 38 39 43 44 43 42 40 38 37 37 37 38 38
RH              89 92 85 70 60 62 70 76 85 96100 93 86 86100100 92 92 92 71 61 66
WIND DIR        SW  W  W  W  W SW SW  S  S  S  S SW SW  W  W  W  W  W SW SW SW  S
WIND SPD         4  6  8 10  9  8  9 11 14 18 18 16 16 16 14 13 13 13 13 13 12 12
CLOUDS          BK BK BK BK BK BK SC SC SC BK BK BK BK BK BK BK BK SC SC SC SC BK
POP 12HR                       20          50          50          30          30
QPF 12HR                        0           0        0.04        0.02        0.02
RAIN SHWRS       C  S  S
SNOW                                  C  C  C
RAIN                                  C  C  C  C  C  C  C  C  C  C  C  C  C  C
WIND CHILL            32          35 33 31 30 30                32 32 31 31
MIN CHILL          32    31             33    30    28          32    31    30


DATE                 THU 10/30/03  FRI 10/31/03  SAT 11/01/03  SUN 11/02/03
UTC 6HRLY       05   11 17 23 05   11 17 23 05   11 17 23 05   11 17 23
EST 6HRLY       00   06 12 18 00   06 12 18 00   06 12 18 00   06 12 18

MIN/MAX              38    55      45    60      47    59      46    55
TEMP            41   39 49 54 47   45 55 58 50   47 55 57 49   47 52 53
DEWPT           38   39 44 49 47   45 50 54 50   47 55 56 49   47 52 50
PWIND DIR             S     S      SE     S       S     S       W    NW
WIND CHAR            BZ    BZ      BZ    BZ      BZ    BZ      GN    LT
AVG CLOUDS      BK   BK SC SC SC   SC BK BK BK   BK BK BK BK   BK BK BK
POP 12HR             10    10      10    30      30    30      30    30
RAIN SHWRS                            C  C  C     C  C  C  C    C  C  C
```

FIG. 1. Example of the Point Forecast Matrices (PFM) product.

2.2 *Issuance Criteria*

PFMs should be generated by WFOs whenever necessary to always depict the latest expected weather conditions through seven days. Furthermore, PFMs are customer-driven and may be created and disseminated to meet local, regional, or national user needs. However, at a minimum, PFMs are issued twice daily to remove the outdated first period of the forecast and to add an additional 12 h to the end of the forecast. These mandatory issuance times occur no later than 4:00 a.m. and 4:00 p.m. local time.

3. HISTORY OF THE PFM

The PFM originated from an experimental NWS product called the Revised Digital Forecast (RDF). The very first version of an RDF encoder (EFPC.SV) was distributed in December 1987 to NWS Weather Service Forecast Offices (WSFO) that were prototyping an Interactive Computer Worded Forecast (ICWF) technique. In early 1988, WFSO Charleston, West Virginia, began using ICWF operationally to produce the NWS Zone Forecast Product (ZFP) on the Automation of Field Operations and Services (AFOS) computer. This version of the RDF was identical in form to the Limited-area Fine-mesh (LFM) Model Output Statistics (MOS) bulletin known as the FPC. The familiar format was relatively easy for forecasters and external users to interpret, but equally important, the same applications software could be used to decode either product.

It became apparent early on that the potential for using a single dataset to produce various products was the future. Acknowledging this fact, WSFO Charleston, WV and the NWS Techniques Development Laboratory (TDL) worked collaboratively to develop and release a second version of the formatter (EFPC2.SV), which automatically generated the RDF in July 1990 (Fig. 2).

The RDF was disseminated experimentally and used both internally by forecasters and externally by customers and partners. The data within the product could be visually scanned or extracted by automated software and used to create other products in various formats (e.g., iconic images). WFOs could also modify the product format and meteorological variables to meet local needs. The popularity of the product continued to grow through the 1990s and into the beginning of the 21st century. However, as the RDF became more widely utilized, the diversity of formats and lack of comprehensive documentation made it increasingly difficult for customers to use automated techniques to extract data.

Responding to customer requirements for an expanded and nationally standardized product, the NWS Office of Climate, Water, and Weather Services (OCWWS) accepted the challenge to modify the format.

```
CRWFPCW09
TTAA00 KCRW 171200
                     \     WED  07/18/90     \     THU  07/19/90     \
EDT           17 20 23 02 05 08 11 14 17 20 23 02 05 08 11 14 17 20 23 02 05 08
WVZ009
POP 06HR                3     0     1     8     3     1     5    17
POP 12HR                      3           8           4          19
QPF 12HR                  <0.25       <0.25       <0.25
TSTM 12HR                     5          20          14          20
SNOW 12HR                 00-00       00-00       00-00       00-00
MN/MX                        55          85          57          85          61
TEMP          80 74 62 58 56 60 75 82 82 75 65 61 59 62 77
DEWPT         60 63 63 63 63 59 64 62 62 65 65 65 65 61 66
WIND DIR         SE    SE    --     W    SW    SW    --     W     N
WIND SPD          2     2     0     7     2     2     0     5     1
CLOUDS          SCT   CLR   SCT   SCT   SCT   CLR   SCT   SCT   SCT
PRECIP TYPE             RW          RW          RW          RW
SUNSHN HRS                               12                      10


CRWFPCW09
TTAA00 KCRW 180000
                 WED  07/18/90     \     THU  07/19/90     \     FRI  07/20/90
EDT           05 08 11 14 17 20 23 02 05 08 11 14 17 20 23 02 05 08 11 14 17 20
WVZ009
POP 06HR                3    13     6     4     8    19
POP 12HR                     15           9          23          17
QPF 12HR                  <0.25       <0.25       <0.25
TSTM 12HR                    33          18          35
SNOW 12HR                 00-00       00-00       00-00
MX/MN                        83          60          84          63          84
TEMP          61 64 75 81 81 75 67 64 62 66 77 81 81 76 69
DEWPT         59 60 64 62 62 64 63 63 63 62 65 65 65 66 65
WIND DIR          S     W     S    SW     S    SW     S     S     S
WIND SPD          1     7     4     2     2     7     4     5     3
CLOUDS          SCT   BKN   SCT   SCT   BKN   BKN   SCT   SCT   BKN
PRECIP TYPE             RW          RW          RW
SUNSHN HRS                   10                       9
```

FIG. 2. Morning and evening examples of the Revised Digital Forecast (RDF), Ver. 2–July 1990.

Beginning in the autumn of 2001 and continuing through the summer of 2003, OCWWS worked closely with NWS regional representatives and software developers at NOAA's Forecast Systems Laboratory (FSL) and the NWS's Meteorological Development Laboratory (MDL) to construct the new product. The results of this effort actually yielded two products: an Area Forecast Matrices (AFM), which is presently valid for the same geographic areas as the RDF, and the PFM.

Both the AFM and PFM have an expanded list of weather parameters and forecast projections that extend out to Day 7 (as compared to 2.5 days in the RDF) from the initial issuance time. The new products were written into NWS policy in the fall of 2003. The PFM will be disseminated from all conterminous United States WFOs beginning in January 2004, but the AFM is an optionally issued product.

4. UTILIZING THE PFM (and AFM) IN THE HHWS

Heat Health Warning Systems require particular meteorological forecast data to successfully identify periods when there is a high risk of heat-related mortalities. More specifically, HHWS take advantage of web technology to gather temperature, dew point, wind direction, wind speed, and sky cover data for participating cities. Data is collected for specific time projections out to 60 h into the future. PFMs supply this information for cities and other selected points, while AFM data can be used to represent "areas" or even entire regions depending upon the number of grid points sampled.

Several factors make the PFM/AFM ideal products for initial forecast data: (1) added value of ingesting NWS forecasted weather parameters rather than using direct numerical weather prediction model guidance and MOS; (2) flexibility for targeted expansion to new cities or regions; and (3) ability to extend the HHWS guidance in time from the current two days to a maximum of seven days into the future.

4.1 *PFM vs. Model Output Statistics*

Prior to the summer of 1995, the Synoptic Climatology Laboratory, with support form the U.S. Environmental Protection Agency Climate Change Division, developed the Philadelphia Hot Weather-Health Watch/Warning System (PWWS). PWWS used NWS forecast model data to identify weather and climate conditions that posed risks to health up to two days prior to their occurrence (Kalkstein et al. 1996). The weather parameters were taken from the Nested Grid Model (NGM) MOS guidance. Unfortunately, the NGM is comprised of a relatively course 16 vertical layers and 84 km horizontal resolution, with its MOS data developed and archived on an approximate 190.5 km grid (at 60°N).

More recent Heat Watch-Warning Systems have been designed using a series of UNIX-run scripts and FORTRAN programs to input objective point forecast data from the Global Forecast Systems model (AVN-MOS) guidance. The AVN MOS expanded the temporal range from 60 h (2.5 days) out to 72 h (3 days). Both the horizontal and vertical resolutions (55 km and 64 layers) were also significantly increased. The AVN MOS equations were developed on a 95.5 km grid (at 60°N). These higher resolutions primarily improve the representation of topography, including surface height and land/sea interfaces (UCAR 2002). Using the PFM is expected to further enrich HHWS by ingesting data resulting from human (forecaster) intervention, and utilizing software tools which infuse sound scientific techniques on higher resolutions than the numerical models. NWS maximum temperature verification data supports this improved forecast expectation. For example, during the summer months (June, July, August) of 2001 through 2003, forecasters in the conterminous U.S. have demonstrated more than a 15% improvement in forecast accuracy over AVN MOS guidance.

The forecaster “added-value” is accomplished through the use of the Graphical Forecast Editor (GFE), which was developed by FSL based on NWS field forecaster input during the last decade. The GFE is the forecast grid editing component of IFPS and permits forecasters to manipulate gridded values of surface-based sensible weather elements such as temperature, dew point, and wind that define the future state of the atmosphere (LeFebvre et al. 2002). Throughout the forecast process, NWS meteorologists use the GFE to populate forecast periods with weather grids based on numerical model output. However, numerical models run at relatively course resolutions (as noted previously) and do not always produce fields of sensible weather at the surface.

Forecasters (applying their meteorological skills and knowledge of the atmosphere and local area) use the GFE to modify these numerical models and MOS grid fields at resolutions of 5 km or less. The grid manipulation is achieved through a series of basic and advanced editing tools. Basic tools are used to assign specific values to a geographic area, slightly adjust existing values, and smooth out gradients in the grid fields. These changes may be drawn by hand, or calculated based on other grids. In addition to the Basic Tools, advanced tools known as "Smart Tools" were designed to add meteorological concepts into the system and work effectively during all seasons and dissimilar climate regimes. A framework was developed by FSL in which forecasters, researchers, and software developers could employ their own ingenuity to invent localized tools (LeFebvre et al. 2002). These Smart Tools may encapsulate a meteorological concept, or perhaps, a local rule-of-thumb from the human knowledge-base. For instance, forecasters could apply Smart Tools to automatically modify temperature and dew point parameters (from which relative humidity is derived) to account for the effects of terrain, urban heat islands, rural cold spots, and marine environments. Basic Tools and Smart Tools can also improve forecasts for other statistically significant contributors to human mortality during hot weather such as cloud cover (Kalkstein and Davis 1989), and wind speed (Steadman et al. 1979). This added scientific precision is then integrated into the PFM/AFM when the modified grid points are sampled during creation of the products.

Sample Message

```
KMEM   AVN MOS GUIDANCE    9/19/2002  1200 UTC
DT /SEPT 19/SEPT 20                /SEPT 21                /SEPT 22
HR   18 21 00 03 06 09 12 15 18 21 00 03 06 09 12 15 18 21 00 06 12
N/X                     72          80          65          84    63
TMP  84 84 79 77 76 74 73 74 77 78 76 72 70 67 66 74 81 83 78 68 64
DPT  74 73 73 73 72 70 70 69 67 66 65 64 62 61 61 61 60 59 59 59 59
CLD  OV OV OV OV OV OV OV OV OV OV BK CL CL CL CL SC SC SC SC CL SC
WDR  19 19 18 17 19 19 19 21 24 25 28 29 35 01 01 04 01 01 02 04 03
WSP  13 11 09 10 10 10 11 11 09 09 06 03 04 04 04 06 06 07 07 05 06
P06         51    59    73    64    32     4     3     0     0  0  2
P12                     92          87          10           0     2
Q06          1     4     5     4     1     0     0     0     0  0  0
Q12                      6           4           0           0     0
SNW                                  0                       0
T06     25/ 2 36/ 4 32/ 1 21/28 14/ 1  6/ 2  0/ 0  0/26  1/ 1  1/ 0
T12           45/10       33/28       14/ 2        0/26     1/ 6
POZ   0  0  0  0  0  0  0  1  0  0  0  0  0  0  0  0  0  0  0  0  0
POS   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
TYP   R  R  R  R  R  R  R  R  R  R  R  R  R  R  R  R  R  R  R  R  R
CIG   7  6  6  6  5  4  4  4  4  4  7  7  7  7  7  7  7  7  7  7  7
VIS   7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7
OBV   N  N  N  N  N  N  N  N  N  N  N  N  N  N  N  N  N  N  N  N  N
```

FIG. 3. AVN-Based MOS MAV guidance.

Through the local knowledge and experience of forecasters, continued improvements in Basic Tools and advanced Smart Tools, and a high resolution GFE database, many meteorological forecast elements in the PFM can be uniquely modified to better reflect local weather conditions. In the future, advanced statistical techniques taking advantage of high-density mesonets such as the Texas Mesonet (Tribe 1999) or cooperative networks (e.g., MesoWest) could also find their way into IFPS to further improve the resolution and accuracy of sensible weather parameters in the PFM.

4.2 *Flexibility to expand forecast data to new locations*

In late 2003, there were approximately 20 U.S. cities involved in HHWS projects. These cities (located in parts of the Upper Mid-West, Mid-Atlantic, Southeast, and Gulf Coast regions) primarily utilized 60 h of the AVN MOS guidance to supply the initial input parameters. Gradually, HHWS are transitioning over to utilization of the PFM because of its flexibility to be expanded to several targeted sites. While AVN MOS sites are plentiful {approximately 1400 in the contiguous United States (CONUS) and still expanding}, their locations may not always be ideal for the purposes of HHWS data input. For example, Hart et al. (2002) noted that the majority of western U.S. MOS sites are located at valley airports and are of limited utility for weather prediction in adjacent mountainous regions. Several other MOS sites may be in locations that do not accurately represent either the urban or rural climatic regimes.

The benefit of using the PFM as a source of forecasted input data is that a site can be selected for *any* point-specific location. Each location of interest is based on a grid which best represents the desired latitude/longitude. AFMs have the additional advantage of being used for selected areas (e.g., a metropolitan area) or entire regions. In these instances, weather forecast parameters are derived from various algorithms performed on all selected grids locations. New AFM/PFM sites can also be initiated relatively quickly by the NWS. Continued production of these products is automated, and requires no additional workload on the part of forecasters.

4.3 ABILITY TO EXTEND FORECAST DATA IN TIME

Current HHWS developed for several cities and regions across the United States extend out to two days and in some cases a maximum of three days into the future. Largely, the temporal limitation on the system has been a result of the availability of MOS guidance used as input (i.e., AVN-Based MOS MAV alphanumeric message which extends to 72 h). The current PFM, however, provides temperature and dew point data in 3-h time projections out to 60 h, then 6-h projections out to a maximum of 168 h (7 days). Deterministic wind speed and direction are available in 3-h time projections through 60 h, followed by 12-h predominant wind directions, and wind character codes representing a particular range of wind speeds. The predominant and categorical forecasts are employed to account for the uncertainty involved in longer range forecasts. If used as input to HHWS, the PFM can potentially provide valuable long-range forecast information. Within a reasonable margin of accuracy, this could allow HHWS to identify oppressive air masses (which adversely affect human health) up to one week in advance.

5. SUMMARY AND FUTURE CHALLENGES

The benefits of using the PFM as a source for meteorological forecast data in HHWS include, but are not limited to: 1) the added human value (local weather knowledge and expertise) provided by forecasters, 2) the flexibility for potential targeted expansion to new locations, and 3) the ability to extend forecast data out to seven days.

To ensure that PFMs are maintained for this purpose, they must be reliable and timely. Over 120 WFOs will eventually be creating PFMs for multiple sites, and issuing these products at scheduled times, and event-driven times based on changing weather conditions and customer needs. The challenge will be to ensure they are all issued by the mandatory deadlines, properly formatted, and can be easily retrieved from a host of Internet sites. If the most recent product cannot be found, the possibility exists for old or incorrect data to be used as input into HHWS. A central repository will be explored to provide a more efficient means to access to this information.

It is paramount that the PFM forecast data is as accurate as possible. While forecast accuracy naturally varies, the potential for higher quality forecasts should come with improvements to numerical weather prediction models, increased temporal and spatial resolution of the local digital database, growing forecaster familiarity with the new forecast process, and finally the added value provided by forecaster modifications to the database. Forecasters must be encouraged to spend time incorporating their knowledge into the database using all means available at the local WFO. For purposes of HHWS, this is especially critical during the first 72 h of the forecast. Additionally, forecasters should ensure that PFMs are updated and disseminated whenever significant modifications are made to the local digital databases. Inaccurate or outdated data within the PFM would result in poor performance of HHWS.

Forecaster attentiveness and familiarity with the database, combined with an expanded number of Smart Tools, improved observational networks, and higher resolution grids, should help ensure continued future improvements to the PFM forecast data. Furthermore, as the NWS digital database is upgraded, PFMs can be more uniquely tailored for specific locations—making them an ideal data source for Heat/Health Warning Systems.

6. REFERENCES

Hart, K. A., Steenburgh, W. J., Onton, D. J., and A. J. Siffert, 2002: An Evaluation of Mesoscale Model Based Model Output Statistics (MOS) During the 2002 Olympic and Paralympic Winter Games. [Available online at http://www.met.utah.edu/jimsteen/mos_paper.pdf]

Kalkstein, L. S., and Davis, 1989: Weather and human mortality: an evaluation of demographic and inter-regional responses in the United States. *Ann. Assoc. Amer. Geog.*, **79**, 44-64.

____ , P. F. Jamason, J. S. Greene, J. Libby, and L. Robinson, 1996: The Philadelphia Hot Weather-Health Watch/Warning system: development and application, Summer 1995. *BAMS* **177**, 1519-1528.

LeFebvre, T., M. Romberg, T. Hansen, 2002: Initializing gridded fields from numerical models. *Interactive Symp. on the Advanced Weather Interactive Processing System (AWIPS)*, Orlando, FL, Amer. Meteor. Soc., 41-45.

Sheridan, S.C., and L.S. Kalkstein, 1998: Health watch/warning systems in urban areas. *World Resource Review*, **10**, 375-383.

Steadman, R.G., 1979: The assessment of sultriness: Part I: A temperature-humidity index based on human physiology and clothing science. *J. Appl. Met.,* **18**, 861-873.

Tribe, K., cited 1999: The Backyard Forecast. [Available online at http://mesonet.tamu.edu/background/news10.html]

University Corporation for Atmospheric Research (UCAR), cited 2002: New GFS Higher-Resolution NWP Model Operational 29 October 2002. [Available online at http://meted.ucar.edu/nwp/pcu2/gfsannounce.htm]