4B.2 UTILIZING GEOGRAPHIC INFORMATION SYSTEMS (GIS) TO ASSESS GRIDDED NWS FORECASTS OF PROBABILITY OF PRECIPITATION (POP) AND QUANTITATIVE PRECIPITATION FORECASTS (QPF)

Jack B. Settelmaier*

NOAA/National Weather Service/Southern Region HQ, Fort Worth, Texas

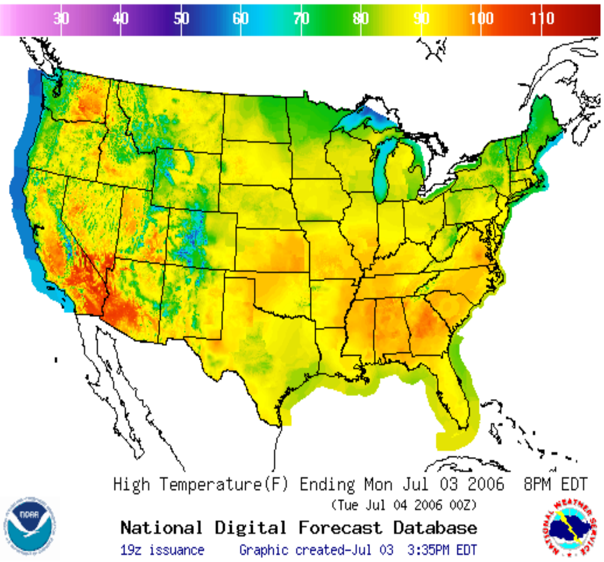
1. INTRODUCTION

For many years, the National Weather Service (NWS) has produced a substantial suite of products, primarily text, to fulfill its mission to protect life and property in the U.S. These products include issuing hazardous weather watches and warnings, as well as routine public forecasts. As technology and user capabilities continue to evolve, the NWS has been exploring opportunities to evolve by making their products easier to integrate into Geographic Information Systems (GIS) through the use of Internet Mapping Services (IMS). In addition, GIS and IMS technology are also being explored in-house to assist in assessing and evaluating the skill of the forecasts used as input to NWS products and services. In this paper, I first describe a few prototype efforts by the NWS to share forecast data in GIS/IMS formats. Next, I describe automated steps I employed to gather, convert, geoprocess, and display gridded hydrometeorological forecast datasets as a means to begin to assess their accuracy and value. Lastly, I describe the exploration of verification statistics resulting from the geoprocessing of these gridded forecast datasets.

2. NWS' DIGITAL FORECAST INFORMATION

The NWS makes available a number of its forecasts in digital format via the National Digital Forecast Database (NDFD). The database consists of forecasts of several sensible weather elements covering the entire country.

The current spatial resolution of the database is 5 km, with a move to higher spatial resolution planned. The temporal resolution of the sensible weather elements varies, with the highest resolution currently available being 3-hourly. The sensible weather elements available in the NDFD include fields such as temperature, dew point, probability of precipitation, and wind speed and direction. Further information about the NDFD, including current graphical depictions similar to the sample shown below, can be obtained at this Web site: http://www.weather.gov/forecasts/graphical/sectors/.

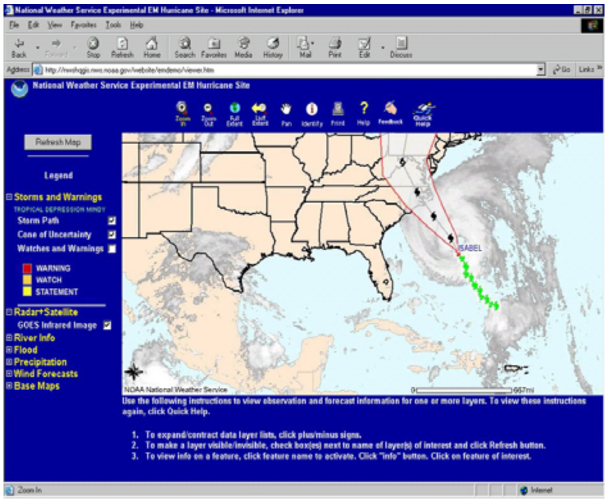


3. INTERNET MAPPING SERVICES (IMS)

With so much digital forecast information available, the NWS is exploring the use of Internet Mapping Services (IMS) to serve its digital information. Several prototypes have been set up to assist decision makers (local and regional emergency managers) as they assess potential impacts to life and property influenced by weather forecasts. One such NWS prototype, called EMHURR, was run during the hurricane seasons of 2003-2006, and focused on the east and southeast United States. This IMS prototype allows emergency management community users to overlay multiple fields, such as forecasts of wind speed and near-real-time information from NWS weather satellites and river gauges, to aid users in assessing potential impacts to an area of interest with the approach of tropical weather systems. A screen shot showing the EMHURR interface as it was when Hurricane Isabel was approaching the mid Atlantic region is shown below.

---

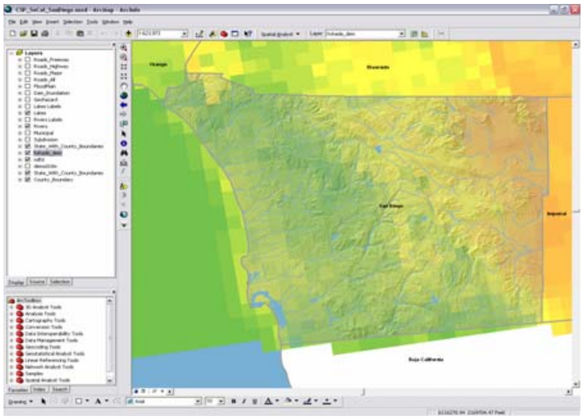
* *Corresponding author address:* Jack B. Settelmaier, NOAA/NWS/Southern Region, 819 Taylor Street, Room 10A06, Fort Worth, TX 76102
e-mail: jack.settelmaier@noaa.gov



Use the following instructions to view observation and forecast information for one or more layers. To view these instructions again, click Quick Help.

1. To expand/contract data layer lists, click plus/minus signs.
2. To make a layer visible/invisible, check box(es) next to name of layer(s) of interest and click Refresh button.
3. To view info on a feature, click feature name to activate. Click "info" button. Click on feature of interest.

A second NWS prototype, with sample data shown in the figure below, is an effort underway between the National Oceanic and Atmospheric Administration's (NOAA) Coastal Services Center working with the California Office of Emergency Services Southern Region and local offices of emergency services. The intent of this prototype is to serve real-time and forecast NWS weather and other hazards planning information into a portal to allow for on-line access by emergency managers. The provided information can then be assessed to monitor the potential hazards and impacts associated a coastal storm approaching California. The figure below shows a 2-day forecast minimum temperature over San Diego (note the pixilated imagery resulting from the 5km horizontal spatial resolution forecast data available from the NDFD) as viewed in this desktop GIS platform.



A third NWS prototype (not shown), is one centered around Los Angeles County that aims to assist LA County emergency management, and the LA police and fire departments to better integrate NWS digital data sources into their GIS operations. The focus is similar to the above prototypes in that it hopes to enhance the ability of emergency management to assess the influence of weather conditions on their operations. In this case, specifically the weather impacts as they relate to an already-elevated risk of wildfires stemming from conditions already favorable for wildfires this 2006 fire season.

Lastly, the NOAA's National Ocean Service (NOS) and NWS are collaborating to explore how best to integrate NWS digital datasets within a more mature IMS portal for maximum utility. NOAA's NOS has already developed a portal called nowCOAST, which provides access to a number of hydrometeorological datasets utilizing IMS technology. Being assessed are such options as to whether it is most feasible, from a user and technological/system point of view, to have a Feature Service, an Image Service, a WFS, a WCS, and/or a blend of several, given current resources. The figure below is a screen shot of the nowCOAST interface with satellite and radar data depicted.

All of these NWS IMS prototypes allow for better visualization and analysis of real-time forecast weather information already generated by the NWS, but previously not in GIS-compatible formats. By integrating NWS datasets with more traditional infrastructure-oriented datasets more common in GIS environments, emergency managers can increase their ability to assess threats and potential hazards caused by any number of weather-related hazards, including tropical or non-tropical coastal storms, severe weather, or hazardous fire weather conditions. For example, users could monitor the amount of precipitation forecast in an area, while simultaneously viewing the flood zones, and even taking into consideration which slopes might have been recently been denuded by forest fires and are therefore much more at risk for mudslides. Making use of Internet Mapping technology modernizes the NWS' dissemination of weather information and better integrates our information into GIS platforms readily used by many of our key decision-making partners. This win-win situation allows both our partners and the NWS to more efficiently execute the NWS mission—to protect life and property of the American people and to maximize economic capacity.

4. ATMOSPHERIC AND GIS COMMUNITY COLLABORATION

The NWS is evolving its service paradigm to deliver more services in gridded and graphical form. Likewise, the exploratory prototypes detailed above provide evidence that NWS data delivered through the use of GIS and IMS technology can greatly aid the NWS to make this evolution, and do so transparently as part of the broader weather enterprise. Similarly, using GIS and IMS technology in-house as an aid to evaluate the forecast skill of those forecasts that go into the products and services we disseminate is also being explored. Before the remaining portion of this paper details these in-house initiatives, we first must acknowledge that many of these efforts were at least partly enabled due to increased collaboration between the atmospheric and GIS communities. The ESRI atmospheric special interest group has been instrumental in bringing together GIS and atmospheric scientists to better understand the needs of each as they explore ways to move forward together. An example of these two communities working together to move forward is the coming capability with the release of ESRI's ArcGIS 9.2 later this year to read netCDF—a data format commonly used within the atmospheric community, but previously rather foreign to the GIS community. Making use of this ability to read atmospheric datasets in their native netCDF format will allow atmospheric community users to integrate GIS tools and functionality even further.

5. AUTOMATED GEOPROCESSING OF HYDROMETEOROLOGICAL DATASETS USING GIS

An effort currently underway within the Southern Region of the NWS is making use of geoprocessing scripts to convert, decode, process, and display information used to assess a myriad of NWS hydrometeorological forecast data. These processes run automatically, several times a day, and provide graphical and tabular output that is used to assess NWS forecast information for accuracy and overall utility. In short the 4 main steps in this automated processing are as follows:

1) download and convert native hydrometeorological data (GRIB→shapefile),

2) prepare, using Python geoprocessing scripts, multiple datasets of forecast, model, and observed data (convert to rasters, create yes/no precipitation mask fields, etc.) to be used as input below,

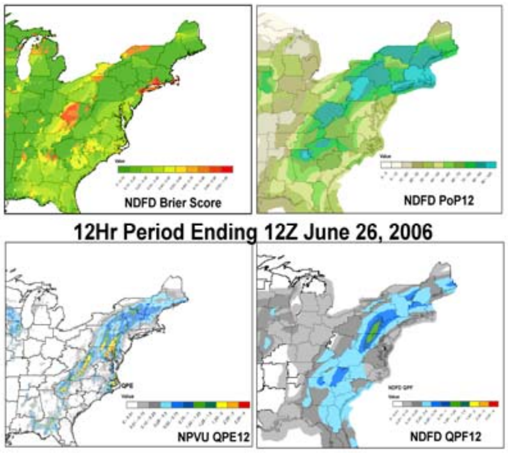
3) continue geoprocessing by a) calling map documents that auto-shutdown after generating graphics, and b) create tabular output based on the raster input data,

4) upload graphics and tables to a Web site for viewing and further analysis and assessment

Future plans are to make the raster data available in a catalog over an internal network to provide greater opportunity for further analysis. Even without sharing the underlying the data, the "summary information" available in the generated images and tables provides atmospheric scientists with feedback as they consider ways to improve our forecast products and services for the benefit of all.

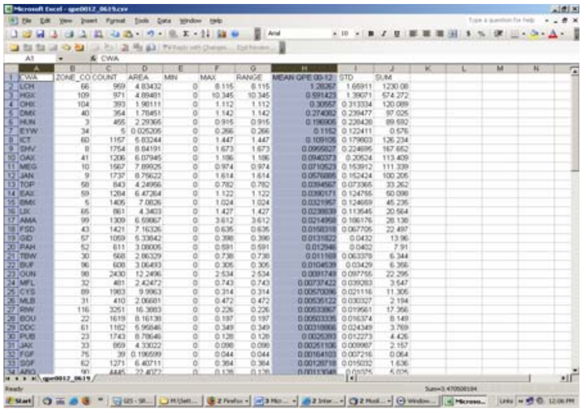
6. NWS POP/QPF FORECAST QUALITY ASSURANCE

Specific examples of the graphics and tables generated resulting from the above-described steps can be seen in the 4-panel graphic below. These graphics can be used to compare NWS probability of precipitation (PoP) and quantitative precipitation forecast (QPF) forecasts against both model-derived forecasts of the same fields and observed precipitation amounts. This particular example depicts NWS forecast performance during a flooding rain event in the northeast US in late June earlier this year. In the top right of the 4-panel image are NWS forecasts of the probability of (greater than or equal 0.01 inches of) precipitation (PoP) for a 12-hr period; the bottom right are experimental NWS forecasts of the quantitative precipitation forecast (QPF), also known as precipitation amount, for the same 12-hr period. The bottom left panel depicts the "observed" or quantitative precipitation estimates (QPE) as derived from a blend of radar estimates and observed gage values. The top left image is the result of calculating a gridded Brier Score for the event.



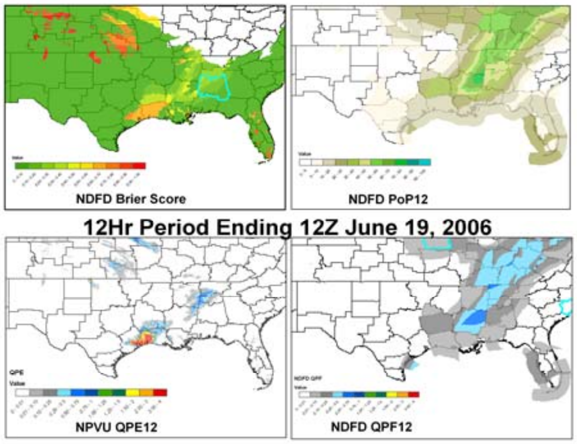
This Brier Score is a statistical measure to assess, in this case, how well the PoP forecast shown in the top right scored for this particular 12-hr period given an observed field of yes/no precipitation occurrence based on the QPE data in the bottom left image. Lower Brier Score values (green color shading) show where forecasts were most accurate. Increasing values (yellow, orange, and red shading) of the Brier Score depict where precipitation was observed but the PoP forecasts were less than the ideal of 100%. The NWS has for a long time issued their forecasts of precipitation in terms of probabilities, or chances of rain. While precipitation forecasting has improved, it remains an inexact science. For this reason, especially when increasing the lead time before an event, the NWS issues chance (or probability) of precipitation (PoP) forecasts to give users a value best indicating the likelihood that measurable rain will occur. Lower chances of measurable precipitation (>= 0.01 inches) for a defined area, such as 10 to 30%, are often assigned, in a worded NWS forecasts, terms such as "isolated" or "scattered"; whereas higher chances of precipitation happening, such as 60% or greater, are assigned stronger wording such as "likely."

Additional complexity in predicting measurable precipitation and/or precipitation amount arises when forecasters attempt to determine the geographical coverage of precipitation occurrence, the duration, or indicate the amount expected to fall. Each of these aspects is made more difficult if the forecast is for several days in the future, say 5 days from now, versus a forecast for a period much closer to now, say overnight. These inherent difficulties in forecasting precipitation must be taken into account when assessing the value of the forecasts issued by the NWS. For these reasons, these 4-panel graphics are not all that are generated to aid in this assessment. The raster data used as input for these graphics is further geoprocessed to summarize the information contained in the data into tables. In the image below, is a table that contains summarized values of the data contained in the graphics, but summarized to show statistics specific to the area of responsibility for each NWS forecast office.



	CWA	ZONE_CO	COUNT	AREA	MIN	MAX	RANGE	MEAN QPE 00-12	STD	SUM
2	LCH	66	959	4.83432	0	8.115	8.115	1.28267	1.66911	1230.08
3	HGX	109	971	4.89481	0	10.345	10.345	0.591423	1.39071	574.272
4	OHX	104	393	1.98111	0	1.112	1.112	0.30557	0.313334	120.089
5	DMX	40	354	1.78451	0	1.142	1.142	0.274082	0.239477	97.025
6	HUN	3	455	2.29366	0	0.915	0.915	0.196906	0.228428	89.592
7	EYW	34	5	0.025206	0	0.266	0.266	0.1152	0.122411	0.576
8	ICT	60	1167	5.83244	0	1.447	1.447	0.109106	0.179803	126.234
9	SHV	8	1754	8.84191	0	1.673	1.673	0.0955827	0.224695	167.652
10	OAX	41	1206	6.07945	0	1.186	1.186	0.0940373	0.20524	113.409
11	MEG	10	1567	7.89925	0	0.974	0.974	0.0710523	0.153912	111.339
12	JAN	9	1737	8.75622	0	1.614	1.614	0.0576885	0.152424	100.205
13	TOP	58	843	4.24956	0	0.782	0.782	0.0394567	0.073365	33.262
14	EAX	59	1284	6.47264	0	1.122	1.122	0.0390171	0.124755	50.098
15	BMX	5	1405	7.0826	0	1.024	1.024	0.0321957	0.124659	45.235
16	LIX	65	861	4.3403	0	1.427	1.427	0.0238839	0.113545	20.564
17	AMA	99	1309	6.59867	0	3.612	3.612	0.0214958	0.186176	28.138
18	FSD	43	1421	7.16326	0	0.635	0.635	0.0158318	0.067705	22.497
19	GID	57	1059	5.33842	0	0.398	0.398	0.0131822	0.0432	13.96
20	PAH	52	611	3.08006	0	0.591	0.591	0.012946	0.0402	7.91
21	TBW	30	568	2.86329	0	0.738	0.738	0.011169	0.063378	6.344
22	BUF	96	608	3.06493	0	0.306	0.306	0.0104539	0.03429	6.356
23	OUN	98	2430	12.2496	0	2.534	2.534	0.0091749	0.097755	22.295
24	MFL	32	481	2.42472	0	0.743	0.743	0.00737422	0.039283	3.547
25	CYS	89	1983	9.9963	0	0.314	0.314	0.00570096	0.021116	11.305
26	MLB	31	410	2.06681	0	0.472	0.472	0.00535122	0.030327	2.194
27	RIW	116	3251	16.3883	0	0.226	0.226	0.00533867	0.019561	17.356
28	BOU	22	1619	8.16138	0	0.197	0.197	0.00503335	0.016374	8.149
29	DDC	61	1182	5.95846	0	0.349	0.349	0.00318866	0.024349	3.769
30	PUB	23	1743	8.78646	0	0.128	0.128	0.0025393	0.012273	4.426
31	JAX	33	859	4.33022	0	0.098	0.098	0.00251106	0.009987	2.157
32	FGF	75	39	0.196599	0	0.044	0.044	0.00164103	0.007216	0.064
33	SGF	62	1271	6.40711	0	0.384	0.384	0.00128718	0.015032	1.636
34	ARO	90	4445	22.4072	0	0.128	0.128	0.00113048	[illegible]	[illegible]

This table is a tabular summary of the data used to generate the graphic below, which is from a heavy rain event over the Houston metropolitan that ended the morning of June 19, 2006. The highlighted columns indicate the average amount of precipitation (MEAN QPE 00-12 UTC) that fell over each particular office's area of responsibility. For example, the MEAN QPE over the Houston/Galveston office's area of responsibility was 0.59 inches. Comparing these figures to similar figures, but for what was forecast, can be very instructive as to whether or not a bias may exist in the forecasts issued by an office. Taken a step further, this data can be classified by storm types, or meteorological regimes, to see if, for instance, an office readily forecasts too-low precipitation amounts or chances of measurable rain, thus exhibiting a bias that, once identified, can then be corrected. Analyzing the data in this fashion, using the readily-available tools provided in many GIS software packages, gives the atmospheric scientist more detailed information from which to then collate, combine, and assess the forecasts and observations any number of ways to better determine the utility of the forecasts issued. These data can be summarized over large amounts of time (monthly or seasonal) or can be inspected to assess performance on a specific rainfall event, such as a flooding event taking place overnight or over several days.



Analyzing either, or both, the graphical and tabular representations of the forecast PoP and QPF data, atmospheric scientists can more easily see and understand their performance in forecasting for a given event—whether that event spans hours, days, or even longer. Improvements in forecasting the timing, coverage, amounts, and duration of precipitation are just some of the potential outcomes possible from using even just these two datasets.

7. VERIFICATION STATISTICS BASED ON GRIDDED NWS POP AND QPF FORECASTS

Traditionally, the NWS has issued PoP forecasts valid for specific points (e.g. airports) and has verified these forecasts utilizing precipitation observations taken at those same points. In issuing QPF forecasts, traditionally the NWS has produced gridded forecasts from local weather offices (WFOs), river forecast centers (RFCs), and from a national center (NCEP's HPC). Each of these QPF forecasts conveys QPF information generated for a rather targeted set of users. The WFO QPF gets inserted into the NDFD, the RFC QPF is used to drive river forecasting models, and HPC QPF is often used as a synoptic scale look at expected precipitation and as initial guidance for use by the field structure. Each of these gridded QPF forecasts is verified against a quality-controlled quantitative precipitation estimate (QPE) observed gridded field that is produced by mosaicking RFC QPE grids.

In the late 1980s and early 1990s, with the advent of radar-estimated QPE, verification of QPF moved from point-based verification to more grid-based. With the advent of digital forecasts available from the NWS' NDFD, PoP forecasts valid at 5km (and even higher from some WFOs) spatial resolution are now being produced and are beginning to be verified against the same observed QPE field available at similar (4km) spatial resolution.

As I have shown in graphical examples above, producing verification numbers based on applying traditional point-based (brier score) verification techniques to gridded data yields brier scores that are scaled differently than the kinds of scores one sees by gaging scores based on sample observation points (airports) located across a WFO's county warning area (CWA). To make statements that would directly compare the brier scores based on point data versus those based on gridded data can be risky. Numerous factors influence the scores that one sees in gridded results. Given that there are no gaps in the gridded forecasts and observations, the resulting grid-based scores are much more sensitive to factors such as areal coverage of forecast and observed precipitation over the period of time over which you are evaluating the results. While this finding is expected, the analysis required to assess the gridded forecasts with respect to scores based on point forecasts is not trivial. In fact, the extra analysis required to ascertain results from this kind of verification is precisely indicative of the additional verification potential that can be tapped when utilizing GIS to assess NWS gridded PoP forecasts in this manner.

8. CONCLUSION

The opportunities that GIS tools applied to atmospheric datasets provides for data mining and splicing greatly raises the ability of atmospheric scientists to apply these techniques to heighten their overall level of awareness about the very hydrometeorological forecasts that are issued by the NWS on a daily basis. It was my hope to indicate to you through interpreting the graphical and tabular displays shown above just one way that GIS tools can be employed to assess forecast performance. And, with additional work, the opportunity for more complex analysis is also possible to explore ways to improve the new gridded forecast datasets now being produced by the NWS.

The National Weather Service is very excited about making broader use of GIS and IMS technology, both internally and externally, to better our overall NWS mission delivery. The IMS prototypes we are exploring should help to cement our position as a vital cog within the broader emergency management community of decision-makers. Similarly, exploiting the myriad of GIS tools available for data analysis and investigation will allow the NWS to modernize the ways we assess and monitor our forecast information so as to constantly improve upon the products and services we deliver for the American people.