4B.2 USE OF A GEOGRAPHIC INFORMATION SYSTEMS (GIS) TO ASSESS GRIDDED WEATHER FORECASTS

Jack B. Settelmaier*

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

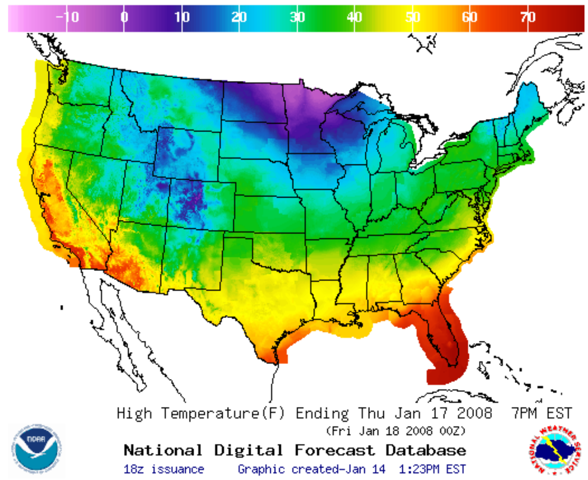
1. INTRODUCTION

For many years, the National Weather Service (NWS) has produced a substantial suite of weather information 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 technologies 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 reference a few prototype efforts by the NWS to share forecast data in GIS/IMS formats. Next, I describe automated steps I employ 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 continued exploration of verification statistics resulting from the geoprocessing of these gridded forecast datasets and assessing the wealth of information that can be generated.

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/.



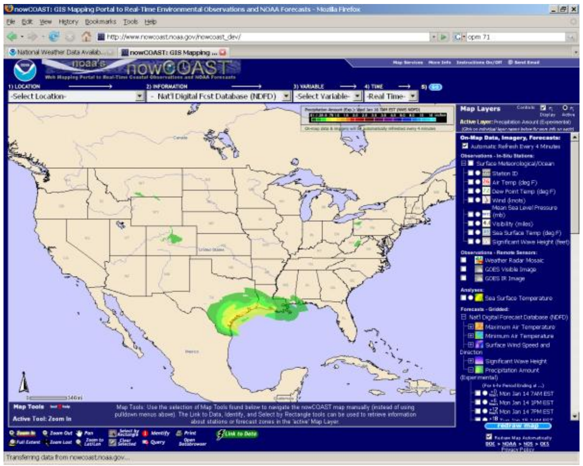
3. INTERNET MAPPING SERVICES (IMS)

With so much digital forecast information available, the NWS is exploring the use of Internet Mapping Services (IMS) to serve some of 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. Links to and information about datasets and services that the NWS is presently offering are described here: www.nws.noaa.gov/gis The NWS has provided this link as a singular location to funnel interested parties to about GIS efforts ongoing within the NWS.

For several years, the NOAA's National Ocean Service (NOS) has been fortunate to have funding to continue work on maturing an IMS portal called nowCOAST. The NWS and NOS, both agencies within NOAA, continue collaboration to explore how best to integrate NWS digital datasets for serving via this GIS-ready portal alongside a number of hydrometeorological datasets already being served there. The figure below is a screen shot of the nowCOAST interface with satellite and NDFD rainfall forecasts depicted.

---

* *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



One of the primary advantages of serving NWS data in GIS-compatible formats is that it allows for better visualization and analysis of real-time forecast weather information. By integrating NWS datasets with more traditional infrastructure-oriented datasets in more common in GIS environments, GIS-capable users 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 are the netCDF read/write capabilities within ESRI's ArcGIS 9.2. netCDF is a data format commonly used within the atmospheric community, but previously rather foreign to the GIS community. The 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

As described in a paper to this conference last year focusing on probability of precipitation (PoP) and quantitative precipitation forecast (QPF) forecasts, efforts continue within the Southern Region of the NWS to make 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 climate anomaly 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 an internal Web site and ArcGIS Server interfaces for viewing and further analysis and assessment

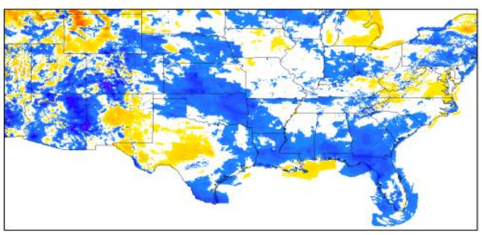
Future plans may include moving portions of the assessment data presently available on an internal ArcGIS Server to a external location available to partners and customers outside the NWS.

6. NWS TEMPERATURE FORECAST QUALITY ASSESSMENT

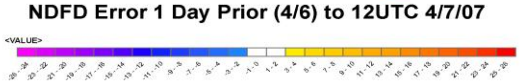
Examples of the graphics and tables generated resulting from the above-described steps can be seen in the graphics below. These graphics and tables are being used to compare 2-m temperature forecasts valid at 12 UTC from both the NDFD and Gridded Model Output Statistics (MOS) (GMOS). The gridded analysis being used is the Real-Time Mesoscale Analysis (RTMA). The above datasets are available on grids with 5km spatial resolution. In addition to the above, lower-resolution (32km) gridded climate datasets from the North American Regional Reanalysis (NARR) are used to provide departure from climatic normal information with regard to both the observed and forecast data.

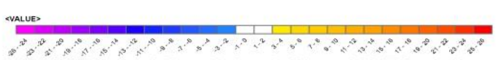
The first example depicts NWS forecast performance during an anomalously cold event that affected the Ohio Valley on April 6-8, 2007.

The first figure shows the difference in forecast errors between the NDFD and the GMOS one day prior to the time of observed—12UTC April 7, 2007. Comparing the images in the figure, one can see at least two improvements made by forecasters reflected in the NDFD versus what was in the initial GMOS guidance. First, there is an overall lessening of the errors in the top image; this can be seen by the increased areas colored white (low error). Second, one can also see that several degrees of forecast error were correctly removed from impacted areas in the heart of the cold air outbreak--western Kentucky southwestward through Arkansas. In similar images but for forecast days further in advance of the observation (not shown), once can also see reductions in the error introduced by NWS forecasters before making these grids available in the NDFD over what was in the GMOS forecasts.

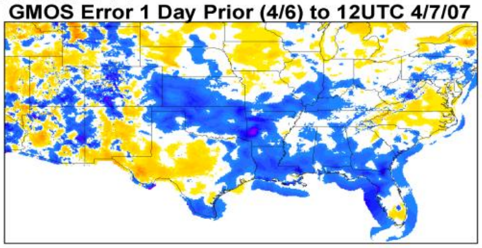


NDFD Error 1 Day Prior (4/6) to 12UTC 4/7/07



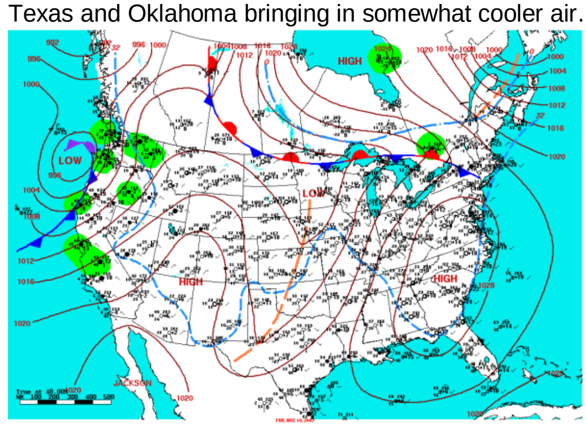


GMOS Error 1 Day Prior (4/6) to 12UTC 4/7/07



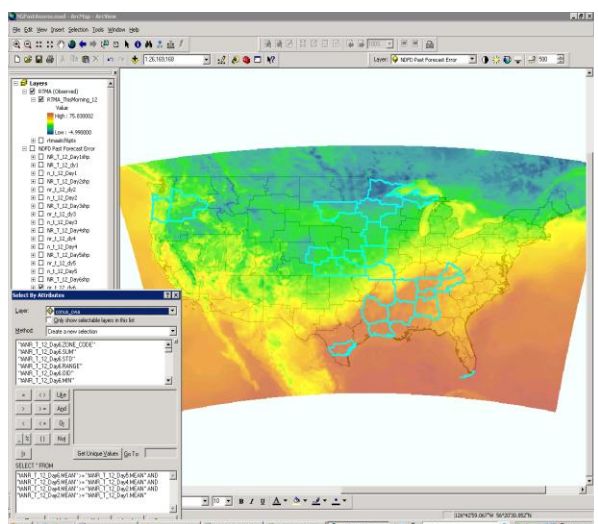
Another way to assess the improvement of NDFD forecasts over that of GMOS guidance, or any other guidance source (e.g. numerical model output), is to compare tables that summarize the errors over geographic extents. An example of a geographic extent I have employed is to summarize over the area of forecast responsibility for each NWS office, also known as a forecast office's county warning area (CWA). In the next example, I will show examples of how this tabular information, in concert with the imagery, can provide an excellent method for summarizing forecast performance for events, or summarized over long periods of time. In addition, if these daily summaries of tabular information were housed in a database, one could write code that would allow users the ability to query the data to meet whatever criteria was of interest. This second example will show what is meant by these queries

The second example I will show is taking a look back at the forecasts leading up to the observed 2-m temperature at 12UTC on Dec 18, 2007. Below is the surface weather chart depicting frontal positions that morning. Two, of many, features that can be seen are the large high pressure system over the southeastern United States that is drawing up warm, moist air over the Mississippi delta states over its western periphery and a trough moving through west Texas and Oklahoma bringing in somewhat cooler air.



Surface Weather Map and Station Weather at 7:00 A.M. E.S.T.

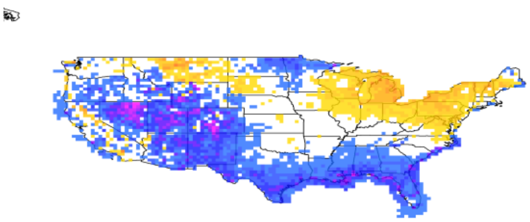
A view of this surface pattern as represented in GIS displaying the RTMA is shown in the following image.



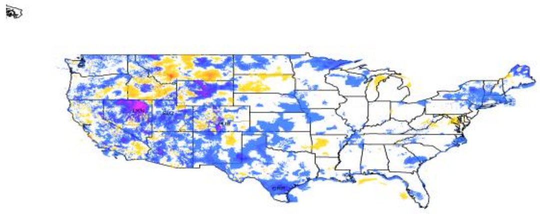
Despite this case depicting a relatively benign weather pattern, one might still be interesting in knowing how well such benign conditions were forecast leading up to the non-event. On the image, I also show the results of a query that I posed of the joined datasets summarizing forecast performance leading up to that date. In this instance, I asked to have highlighted only CWAs whereby with each forecast issuance leading up to the event, the error decreased in time. That is, where the Day 6 forecast error exceeded that at Day 5, Day 5 error was greater than Day 4, etc. As one can see, it appears forecast offices along the area where the temperature gradient is greatest improved over GMOS each and every day. The converse question, or any other, can also be asked with results being displayed graphically.

The last two examples I will show make use of the climatic anomaly information for the forecast/observed time of interest.

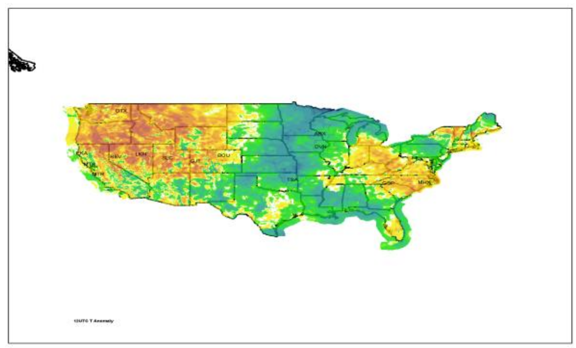
The first looks at future forecast conditions, and can highlight areas where forecasts anomalies exceed a certain criteria and, if desired, when and where significant deviations from GMOS guidance have been inserted into the NDFD by NWS forecasters. In this graphic, I show the Day 2 forecast climatic anomaly for 2-m temperature conditions expected on Jan 14, 2008 at 12UTC.



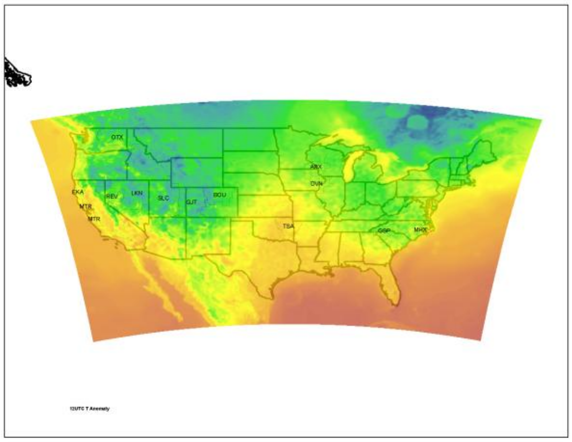
Next, given those Day 2 forecast anomalies, how much, if any, and where did forecasters deviate significantly from GMOS guidance. The next graphic shows where forecasters either warmed or cooled the forecast from what GMOS guidance was indicating by greater than the absolute value of 3 degrees F. Areas where GMOS guidance and NDFD are within 3 degrees F of each other are shown in white. After joining tables that summarize various input fields (climate, NDFD, GMOS) over CWA areas, I used the attribute query option in ArcMap to highlight for which CWAs was a) the forecast climate anomaly greater than the absolute value of 10 degrees F, and b) where the NDFD forecast deviated from GMOS by greater than 3 degrees. Being able to "carve" into the gridded data using the native tools within GIS are invaluable to being able to answer questions about forecast performance during various future and past weather regimes.



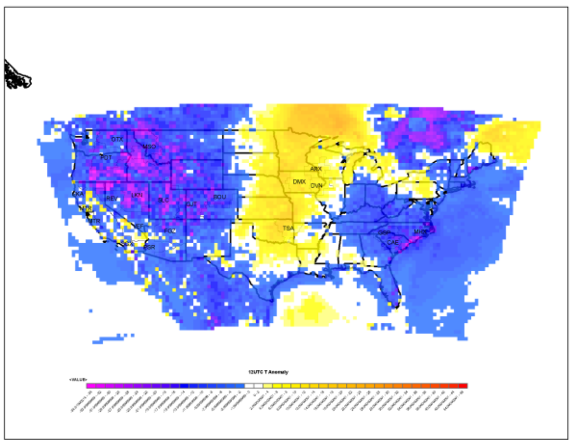
The second looks at past forecast conditions leading up the present. In this example, I focus on interrogating observed conditions and how anomalous they were, as well exploring if there are any relationships between the observed conditions and the forecast performance. That is, "Is forecaster performance better or worse under anomalous conditions?" Understanding these relationships can perhaps lead to implementing ways to improve our forecast performance and services.



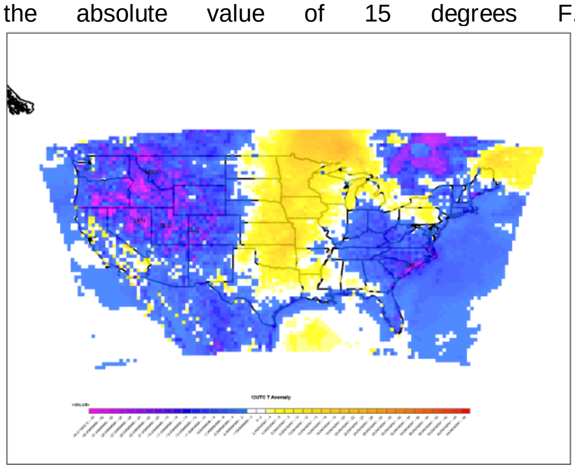
The above image displays NDFD Day 4 forecast errors leading up the 12UTC Jan 16, 2008. Areas with errors closest to zero are depicted in white. Warm and Cold bias forecast errors are depicted in red and blue colors, respectively. In looking at the observed data and the climatic anomaly imagery, in the following two figures, on can see that 4 days prior to the observation time, forecasters were too cold in forecasting conditions across the axis of warm observed forecast anomalies in the upper Midwest. Conversely, forecasters were too warm 4 days in advance over the intermountain west and the mid Atlantic region where cold anomalies were observed.



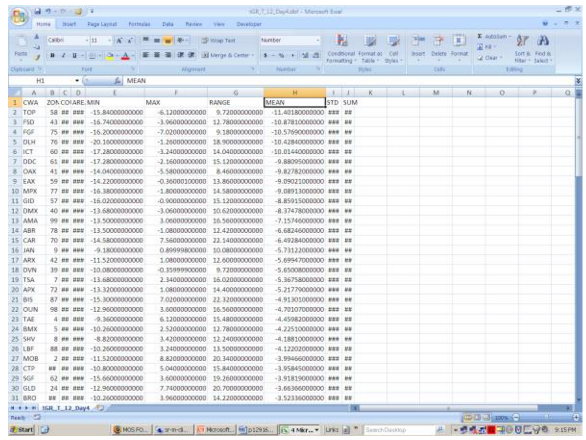
Again, querying tables of data summarized from the above imagery/data over CWAs, one can get answers to questions such as "Show me which CWAs had positive forecast improvement--NDFD errors less than GMOS—for all days leading up to the observed conditions." For this event, the image below highlights these CWAs.



Additionally, one could ask the same question for a specific day (Day 4) and only for CWAs whereby the observed anomaly was significant, say, greater than the absolute value of 15 degrees F.



And, because these queries are acting on tabular information the same interrogation can result from exploring tables of information. Shown below, are screenshots of tables depicting the forecast errors, per CWA, for Day 4 prior to observed conditions on Jan 16, 2008. The first table is showing the forecast error from GMOS. In this table, the average Day 4 error over CWA=TOP is -11.4 degrees F. The error for over that same CWA but for the NDFD (not shown) is -12.0 degrees F. The observed anomaly over that CWA was 11.8, so nearly all the error can be explained by guidance and human forecasts 4 days in advance that were not able to forecast the anomalously warm conditions observed at that time.



	CWA	ZON	CO	ARE	MIN	MAX	RANGE	MEAN	STD	SUM
2	TOP	58	##	###	-15.84000000000	-6.12000000000	9.72000000000	-11.40180000000	###	##
3	FSD	43	##	###	-16.74000000000	-3.96000000000	12.78000000000	-10.87810000000	###	##
4	FGF	75	##	###	-16.20000000000	-7.02000000000	9.18000000000	-10.57690000000	###	##
5	DLH	76	##	###	-20.16000000000	-1.26000000000	18.90000000000	-10.42840000000	###	##
6	ICT	60	##	###	-17.28000000000	-3.24000000000	14.04000000000	-10.01440000000	###	##
7	DDC	61	##	###	-17.28000000000	-2.16000000000	15.12000000000	-9.88095000000	###	##
8	OAX	41	##	###	-14.04000000000	-5.58000000000	8.46000000000	-9.82782000000	###	##
9	EAX	59	##	###	-14.22000000000	-0.36000100000	13.86000000000	-9.09021000000	###	##
10	MPX	77	##	###	-16.38000000000	-1.80000000000	14.58000000000	-9.08913000000	###	##
11	GID	57	##	###	-16.02000000000	-0.90000000000	15.12000000000	-8.85915000000	###	##
12	DMX	40	##	###	-13.68000000000	-3.06000000000	10.62000000000	-8.37478000000	###	##
13	AMA	99	##	###	-13.50000000000	3.06000000000	16.56000000000	-7.15746000000	###	##
14	ABR	78	##	###	-13.50000000000	-1.08000000000	12.42000000000	-6.68246000000	###	##
15	CAR	70	##	###	-14.58000000000	7.56000000000	22.14000000000	-6.49284000000	###	##
16	JAN	9	##	###	-9.18000000000	0.89999800000	10.08000000000	-5.73122000000	###	##
17	ARX	42	##	###	-11.52000000000	1.08000000000	12.60000000000	-5.69947000000	###	##
18	DVN	39	##	###	-10.08000000000	-0.35999900000	9.72000000000	-5.65008000000	###	##
19	TSA	7	##	###	-13.68000000000	2.34000000000	16.02000000000	-5.36758000000	###	##
20	APX	72	##	###	-13.32000000000	1.08000000000	14.40000000000	-5.21779000000	###	##
21	BIS	87	##	###	-15.30000000000	7.02000000000	22.32000000000	-4.91301000000	###	##
22	OUN	98	##	###	-12.96000000000	3.60000000000	16.56000000000	-4.70107000000	###	##
23	TAE	4	##	###	-9.36000000000	6.12000000000	15.48000000000	-4.45982000000	###	##
24	BMX	5	##	###	-10.26000000000	2.52000000000	12.78000000000	-4.22510000000	###	##
25	SHV	8	##	###	-8.82000000000	3.42000000000	12.24000000000	-4.18810000000	###	##
26	LBF	88	##	###	-10.26000000000	3.24000000000	13.50000000000	-4.12202000000	###	##
27	MOB	2	##	###	-11.52000000000	8.82000000000	20.34000000000	-3.99466000000	###	##
28	CTP	##	##	###	-10.80000000000	5.04000000000	15.84000000000	-3.95845000000	###	##
29	SGF	62	##	###	-15.66000000000	3.60000000000	19.26000000000	-3.91819000000	###	##
30	GLD	24	##	###	-12.96000000000	7.74000000000	20.70000000000	-3.66366000000	###	##
31	BRO	##	##	###	-10.26000000000	3.96000000000	14.22000000000	-3.52336000000	###	##

One last item I'd like to share in this paper is the uncertainty in the RTMA analysis being used for observations. The RTMA uncertainty is a function of many facets, including the observation density. Shown graphically below is the RTMA uncertainty for this event.

Largest uncertainty is over the intermountain west, topping out at 3.13 over the BOI CWA. For CWA=TOP, based on tables summarizing this imagery (not shown) the average RTMA uncertainty is 1.4 degrees F. What this means is that, for this event and most events, the forecast error (~12 degrees) is many times greater than the analysis error (1.4 degrees). This can be instructive for those that believe the RTMA is not a good enough analysis to use for such comparisons.

8. CONCLUSION

As has been shown in the examples presented throughout this paper, and in my presentation, utilizing GIS tools to investigate atmospheric datasets provides unprecedented opportunities for data mining and splicing than can greatly increase the ability of atmospheric scientists to understand their gridded forecasting strengths and weaknesses. Similarly, sharing these performance results externally with users of gridded NWS forecasts can allow them to make use of these error characteristics so that they can realize maximum utility from these forecasts.

The technology exists for the NWS to modernize their verification schemes to take advantage of tools such as GIS to increase our understanding of the relatively new gridded forecasts that are being issued by the NWS of today. With additional work and resources, even more complex analysis is possible to explore ways to improve the new gridded forecast datasets now being produced by the NWS.

The National Weather Service continues to be very excited about making broader use of GIS technology throughout the agency to better our overall NWS mission delivery. 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.