Something Old, Something New, Something Blue
A Marriage of Weather and GIS

Jack Settelmaier, National Weather Service, Southern Region HQ, Fort Worth, Texas

Introduction

The core mission of the National Weather Service (NWS) is to help protect against life and property losses, while promoting commerce. To support this mission, over 122 weather forecast offices are located around the United States constantly monitoring weather conditions, releasing forecast information, and issuing life- and property-saving weather warnings as threatening conditions warrant. Increasingly, these forecasts and warnings are available in data formats easily ingestible by modern computer systems to aid users, customer and partners in their weather-based decision-making.

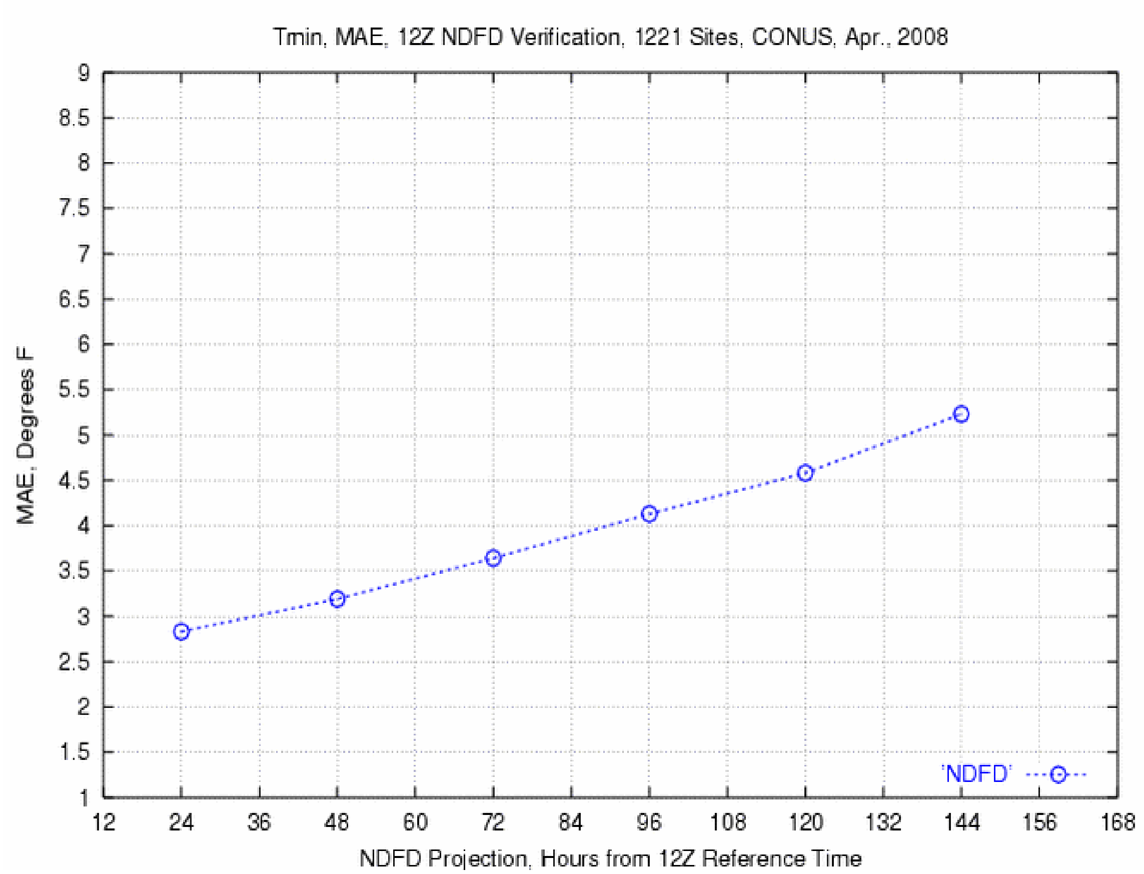
Delivering NWS products and services in modernized formats has made nearly all of our weather information nearly directly-usable by Geographic Information Systems (GIS), like ESRI's ArcGIS, for display as well as for further analysis.

In earlier issues of Atmospheric Front, Ken Waters detailed for us how the NWS made use of ESRI's ArcGIS technology to help move the NWS to operational status with their storm-based warnings paradigm shift. In this issue, I share three additional ways the NWS is marrying NWS data with ESRI's GIS tools to help NWS meteorologists attain a broader understanding of our forecast operations and performance.

Something Old

For nearly its entire existence, the NWS has been keeping verification statistics to monitor its weather forecast and warning performance. These "old" statistics have predominantly been used internally. More recently, however, verification statistics have been used to satisfy the Government Performance Result Act (GPRA) of 1993. This Act sets performance requirements to ensure agencies in the federal government are meeting defined performance goals and, therefore, should continue to be eligible for funding.

An example of the performance statistics the NWS maintains is the average error, in degrees Fahrenheit, for minimum temperature forecasts issued up to a week in advance of occurrence. Figure 1 shows a graph of these average forecast errors for overnight minimum temperature based on forecasts from the NWS' National Digital Forecast Database (NDFD) for the month of April 2008. This chart indicates our nationwide average minimum temperature forecast error for April 2008 ranged from 5.25 degrees for forecasts issued a week in advance to about 2.75 degrees for forecasts issued one day prior to the overnight temperature being observed. This month's statistics are just a snapshot of our forecast performance, which varies depending on factors such as the what weather patterns are experienced during a month, or whether one is in a summer month when temperature forecast errors tend to be smaller given the lower diurnal range in temperatures. For example, for August 2008, the week-prior and day-prior average forecast errors range from 4.25 to 2.50, respectively.

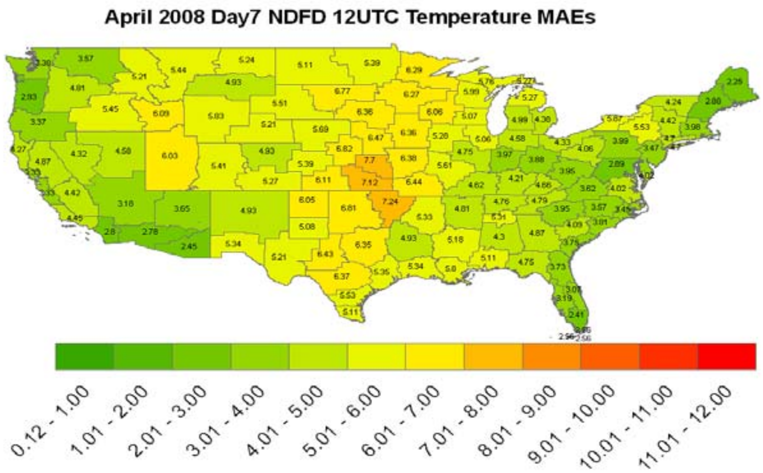


To assess the impact of a month's weather patterns on performance, one can utilize GIS to display and analyze verification statistics geospatially to obtain a greater understanding of the relationship between forecast performance and weather patterns.

As an example of gleaning increased geospatial understanding, in Figure 2, I used ArcGIS to display average day 7 (week in advance) morning (12UTC) temperature forecast errors from April 2008. The forecast error statistics have been extracted from gridded NDFD forecasts and averaged over each NWS weather forecast office's area of forecast responsibility, also known as county warning areas (CWA).

Figure 2 NDFD Day 7 (forecast hour=168 hours) grid-based mean absolute errors (MAE) for April 2008 summarized for each NWS forecast office across the country.

Displaying even "old" performance statistics in GIS, one is immediately drawn to the higher forecast errors located in the center part of the country and may be curious as to why errors are larger there. As an atmospheric scientist, I can then use this displayed information to explore and conduct further analysis to understand what may have influenced these larger errors observed in the center of the country for this particular month. In this case, most of the higher errors in minimum temperature forecasting can be partially explained by recognizing the larger climatic



variability in this area of the country experienced many months out of the year. During Spring, in particular, cold and dry and warm and moist air masses are nearly in constant battle over this Midwest United States area—hence it earning its name Tornado Alley, given the high frequency of tornadoes that result from these air mass conflicts. As one may surmise, forecasting minimum temperatures, or any other weather conditions, 7 days in advance in an area with as varying conditions as are experienced in Tornado Alley, is not easy, hence the larger errors observed.

Utilizing GIS, a meteorologist can choose how detailed an analysis he/she wants to conduct, based on the number of influencing factors that can contribute to the phenomena being explored. In this example of springtime temperature forecast performance, although I'm reasonably certain seasonal climatology explains much of why the pattern of errors is as it is, in the next section, I will show how GIS can assist a more detailed exploration and analysis of these errors. What is clear, is that even if I were to stop my analysis here, using GIS has added to my overall understanding of these NWS temperature forecasts performance statistics.

Something New

In this section, we will explore NWS performance statistics in more time and space detail to increase our understanding of weather forecasting performance at these higher resolutions. While the previous section explored monthly statistics on both a nationwide scale and at specific NWS weather forecast office areas, in this section we will use GIS to better understand weather forecast performance characteristics on a temporal scale of days, and on a spatial scale of NDFD's 5x5km forecast grid boxes grid boxes.

This "new" approach explores tapping high-resolution forecast and observation data to calculate performance statistics. For forecast data, we use the gridded NDFD and a gridded automated

statistical forecast system called Gridded MOS, which stands for [Gridded Model Output Statistics (GMOS)](). Both these forecasts are being compared to hi-resolution analyses of observed conditions available from the Real-Time Mesoscale Analysis (RTMA). In short, the GMOS is an automated forecast system developed by the NWS to provide a viable first-guess forecast of weather conditions from which local office NWS forecasters can make improvements upon at forecast times and locations where they see chances to improve upon the first-guess. In assessing these two forecast systems' performance characteristics, we hope to glean a better understanding of how forecast performance is related to the observed atmospheric conditions, so that NWS forecasters can use that information to hone in on areas and time periods where they can continue to make incremental changes to automated first-guess forecasts that result in improved forecasts to support the NWS mission.

The methodology we employ to undertake this analysis is via automated routines that do the following: a) collect the forecast data from NWS servers from each forecast source for each of 7 forecast days leading up to an observed event; b) convert the collected data from GIS "unfriendly" formats to GIS formats; c) geoprocess using Python tools from ESRI's ArcGIS toolboxes. The resulting data are then arranged into ArcMap documents that can be perused or served as a service via ArcGIS Server, and are also exported out to static graphics to populate webpages. An example of the imagery is shown in this 3-paneled image in Figure 3.

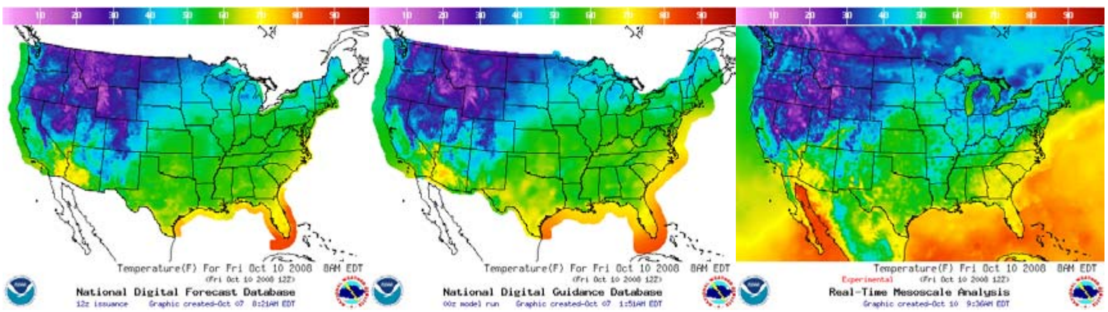


Figure 3 (a) GMOS and (b) NDFD morning temperature forecasts compared with the (c) RTMA observed conditions.

Using the same color curve for all three images in this figure allows for easy subjective comparison of the Day 3 morning temperature forecasts from the NDFD and the GMOS, versus the temperatures that were observed the morning of Oct 10th, 2008 represented by the RTMA on the far right. Despite the color scales being identical, even when looking at larger images than are inserted here, it is quite difficult to see the subtle differences between the NDFD and GMOS, which represent areas where forecasters made alterations to the first-guess forecasts. Given these are Day 3 forecasts, it is easier to see, for example, that both forecast schemes had forecast cooler temperatures (green/cooler) over Georgia and the Carolinas than were observed (yellow/warmer). Using ESRI's ArcGIS Desktop 9.3, we further analyze and process the data that feeds the above 3-image mosaic to make determinations of where significant edits to the first-guess forecasts have been made. We delineate insignificant edits (defined as changes within +/- 3 degree F for Days 1-3, and +/- 5 degrees F for Days 4-7) as white in the resulting image as is shown Figure 4.

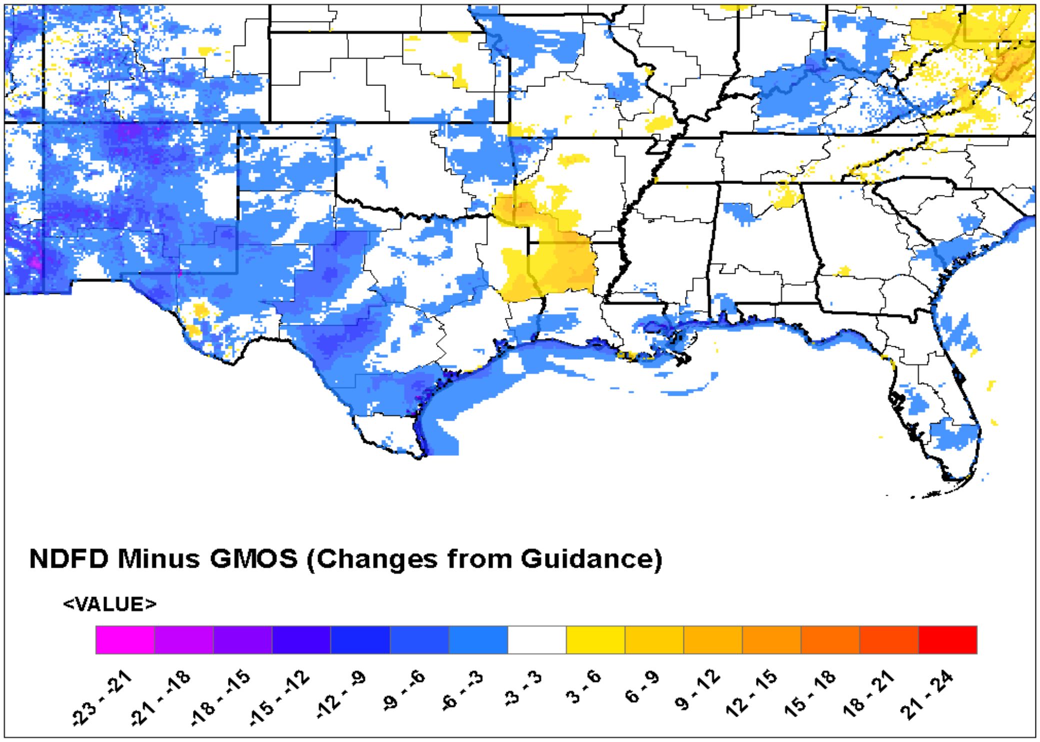


Figure 4 Color-highlighted areas showing where NDFD forecasts were either warmed (yellow to red colors) or cooled (blue to purple colors) from what was initially forecast in the GMOS first-guess forecasts. Areas with no color are where the NDFD and GMOS forecasts were withing 3 degrees F of each other.

Colorizing areas only where significant edits to the first-guess GMOS were introduced by forecasters in the NDFD makes it easier to assess where local office forecasters decided to either warm (yellow to red colors) or cool (blue to purple) the forecast database. After denoting where "significant" edits were made, one can interrogate additional images, resulting from further ArcGIS automated processing, that show the forecast errors associated with the NDFD and GMOS, as well as how climatologically anomalous the observed conditions were. The 3-paneled image below in Fig 5 shows these errors (either too warm or too cool) for the southern US. Comparing the two left most images, one can see that the NDFD had a larger cold-bias error in Georgia and the Carolinas than did the GMOS. Elsewhere, aside from perhaps New Mexico, the NDFD and GMOS performance characteristics were very similar for this event.

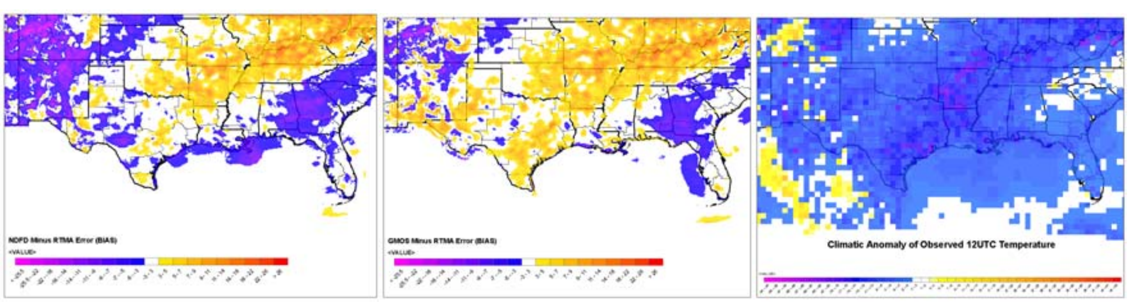


Figure 5 (a) GMOS and (b) NDFD morning temperature forecast errors, compared to (c) observed climatic anomaly for the morning temperature that day. Note the errors tend to be greatest near the leading edge of observed cold anomaly (just behind a cold front).

Something Blue

By “something blue,” I am making a veiled reference to our blue planet as viewed inside ESRI’s geobrowser ArcGIS Explorer or ArcGlobe. Beginning in late summer 2008, the headquarters of the Southern Region of the NWS, located in Fort Worth, TX, became a partner in a NASA-funded project to evaluate the use of touchtable technology as a collaborative tool. For regular attendees of ESRI’s User’s Conference, you’ve probably seen Jack Dangermond manipulating such a touchtable during the plenary session demos or perhaps visited one in the Exhibit Hall. For those unfamiliar with what a touchtable is, in short it’s a large display monitor, akin to a computer or television screen, that can be utilized either in a vertical or horizontal, table-like, position. The monitor displays whatever software is loaded onto a personal computer that feeds the system, but what puts the touch in touchtable, is the ability for users to manipulate or control the computer software via touching the screen. Sensors located around the monitor respond to touch, and software developed takes those touch cues and relates them to the underlying software on the machine.

The touchtable we are using was configured by StormCenter Communications and is built upon ESRI software, so its geographic underpinnings should be familiar to most ESRI software users. Users simply configure what they want to display and manipulate on the touchtable by authoring a document in ArcGlobe. [Given that ArcGlobe by default opens up displaying our blue planet, I named this section “something blue.”] After using ArcGlobe to configure the layers, symbology. etc. the next step, assuming all input layers are resident on all the participants machines or are linked over the Internet, one simply starts a collaboration session. All participating in the collaboration session will then be viewing the same data layers. From that point forward any annotations, zooming/panning, or turning off/on layer manipulations are instantly viewable on the screens of all the participants. In this way, along with an audio connection via telephone, briefings can take place on any number of topics.

One example of how we will use our touchtable to brief our NWS partner FEMA Region VI, based in Denton, TX, is to review datasets that can communicate the impacts weather may have on mitigation, response, and recovery operations prior to, during, or after a events. Hurricanes often strike the southern United States and are a common event we collaborate with our state and federal partners to ensure we fulfill our property- and life-saving NWS mission. Another tropical-related event we recently needed to collaborate with our partners was the catastrophic flooding that occurred along the Rio Grande river on our southern Texas border near Presidio, Texas. Heavy rainfall concentrated in the Mexican high-country watersheds that feed into the Rio Grande river near Presidio, TX caused there to be releases from the reservoirs that were too great for the protective levees in and around Presidio, so that significant flooding occurred. Figure 6 shows a screenshot captured from the touchtable display used to convey the severity of the fullness of the reservoir upstream from Presidio. By using the Swipe tool, between layers showing the mean reservoir conditions and LANDSAT imagery showing the conditions during this event, we were able to convey just how full the Mexican reservoir was in comparison to normal conditions. The LANDSAT imagery in this figure is the pink-colored one, with the deep black showing inundated nearshore areas that are normally dry (this is easier to see when alternating between the two images).

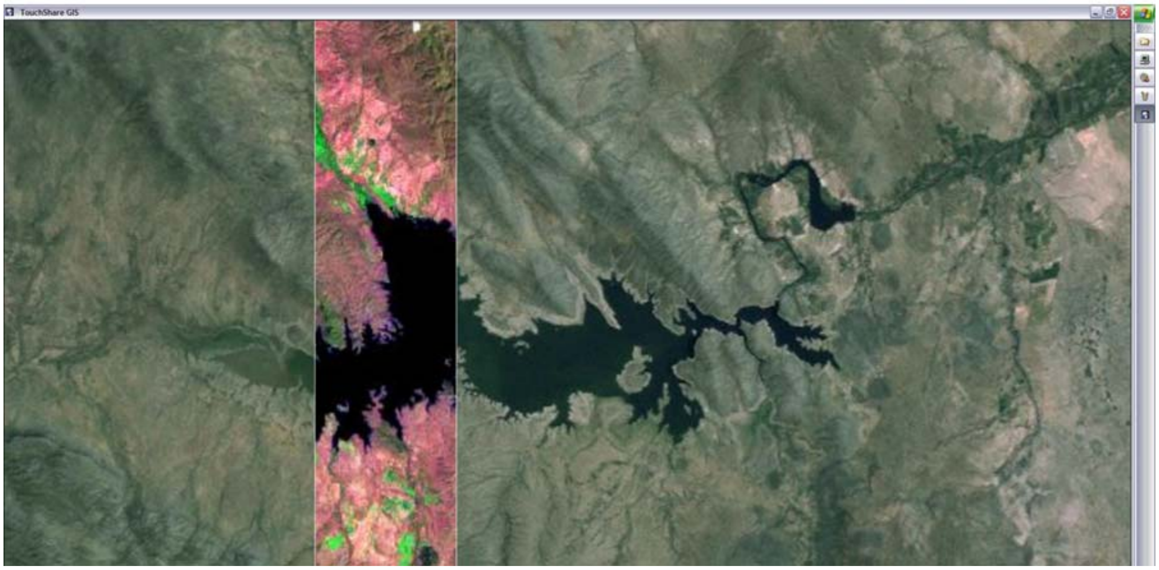


Figure 6 Pre- and Post-event comparative image showing a sliver of a LANDSAT image (screenshot while using the "Swipe" tool) depicting the extent of the flooding (black areas) covering areas that are normally dry.

When this reservoir was forced to release water to prevent a dam break, many downstream areas were inundated. Some, which were used to being irrigated via smaller releases, were able to handle the deluge better, whereas other areas were not able to cope with the high flows, and levees built to protect areas from more normal flooding, were destroyed, which led to greater flooding outside of areas thought to be more safe from flooding.

In Figure 7, I show a 2-image mosaic of an area on the Mexican side of the border adjacent to Presidio that had large areas flooded outside of where the levees were built to most-often protect. In the image on the left, you can see many mostly agricultural areas that are submerged in the flooded image on the right. In the image on the right, you can perhaps barely see the faint white lines indicating the levees, which were overtopped, and broken in many places to allow the flooding.

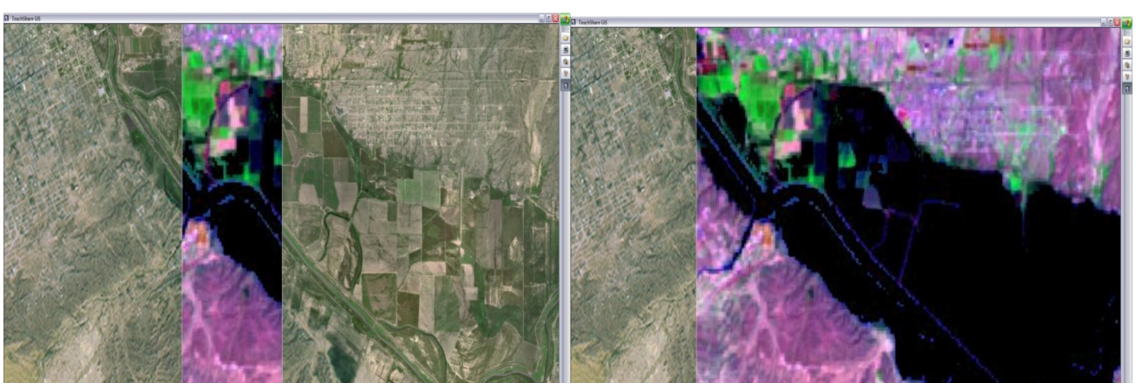


Figure 7 Similar to Fig 7, except depicting the inundation of farmland areas in the vicinity of Presidio, Texas.

In Figure 8, I show a similar image as above showing overtopped levees, but included are some examples of how, during a collaboration session, users can annotate images using some of the built-in tools available on the touchtable.

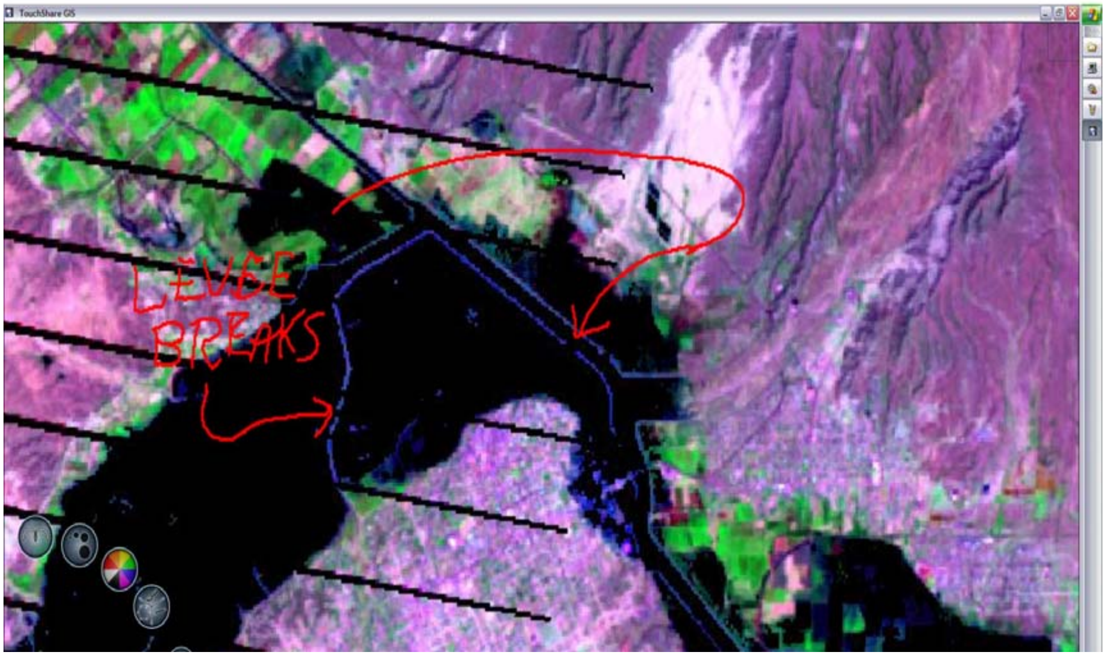


Figure 8 A closer view of the area shown in Fig 7, that shows the annotation capability of the touchtable to point out breaks in the levee.

Conclusion (or is it a new beginning?)

I have shared just a few examples of how the NWS is marrying weather-related datasets with the powerful GIS tools ESRI continues to promote and make available in their suite of products. I assure you NWS meteorologists are continuing to explore ways to marry weather data and GIS. Explaining and understanding our environment and the impacts weather has on all of our lives is mission-critical to the NWS. Keep an eye on just some of the datasets the NWS is making available in GIS-ready formats at this regularly-updated website: http://weather.gov/gis

Author Info: Jack (Jack.Settelmaier@noaa.gov) is the Digital Techniques Meteorologist within the National Weather Service's Southern Region Headquarters Science and Technology Services Division in Fort Worth, Texas.