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DISSEMINATING FORECASTS IN AREAS OF COMPLEX TERRAIN THROUGH A WEB BASED INTERFACE

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1. INTRODUCTION

The Zone Forecast Product (ZFP) issued by National Weather Service (NWS) Weather Forecast Offices (WFOs) is a text product describing the expected weather over a geographic area for a seven day period. This product is among the most widely used forecast products produced by the WFOs. In areas of complex terrain the forecast parameters for a single zone can have a wide variance due to topographic effects across the zone. In zones such as these, forecasters typically focus the forecast on population centers leaving other areas of the zone without an explicit forecast.

In order to provide an explicit forecast over the entire zone, forecasters at the Tucson WFO have been generating and disseminating digital forecasts over the internet for three years. Using the Graphical Forecast Editor (GFE), NWS forecasters generate a forecast on a 2.5km grid covering the entire Tucson County Warning Forecast Area (CWFA). The GFE allows forecasters to edit weather parameters on the computer using an interface much like a paint or photo editing program.

The digital database that contains the forecast prepared by the Tucson forecasters can be quite large. In order to provide the digital forecast to the public, without transmitting the entire forecast grid, two web pages were designed that only transmit a subset of the entire digital database. The web pages designed for Tucson and southeast Arizona are only a beginning. Future applications using the gridded database will be designed as customer needs are recognized.

2. ZONE FORECAST PRODUCT CONSTRAINTS

In areas of complex terrain, most notably the western United States, the topography across a single NWS forecast zone can range up to 3000 meters (>9000 feet) from valley floor to mountain peak. This topography variation can cause forecast parameters such as temperature and rainfall/snowfall to vary widely. However, it is not just mountainous terrain that can create a wide variance of forecast parameters across a single zone. Any zone with a large body of water on its borders can have a wide variance in the temperature due to sea or lake breezes. Convergence zones formed from sea or lake breezes cause showers and thunderstorms to be focused on a narrow strip of land covering only a small portion of a zone. In zones that span urban and rural areas minimum temperatures have a wide variance that may not be covered in the body of the text.

Figure 1 shows the Tucson Metro zone forecast from the Southeast Arizona Zone Forecast Product (ZFP). Figure 2 shows the topography of southern Arizona along with zone boundaries. The Tucson Metro zone is identified in Figure 2 as well. The elevation in the Tucson Metro zone ranges from 600 meters (2000 feet) to 2800 meters (9200 feet). Temperatures in the body of the forecast text in Figure 1 reflect temperatures expected at valley locations. This can be seen by noting that the spot temperatures given for Mt Lemmon (elevation 2500 meters (8200 feet)) is outside the range given in the text. In a zone like this, including temperatures for all locations in the zone would cause the temperature range to exceed 17° C (30° F). Without specifying where the temperature extremes can be found, a range this large would make the forecast almost useless.

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...SNOW ADVISORY ABOVE 6500 FEET TODAY...
.TODAY...RAIN AND MOUNTAIN SNOW. 4 TO 8 INCHES
  OF SNOW ACCUMULATION ABOVE 6500 FEET.
  HIGHS IN THE MIDDLE 50S. SOUTHEAST WIND 10 TO
  15 MPH.
.TONIGHT...SCATTERED RAIN AND MOUNTAIN SNOW
  SHOWERS. SNOW LEVEL 6500 FEET.  ADDITIONAL
  1 TO 3 INCHES ACCUMULATION POSSIBLE. LOWS IN
  THE LOWER 40S. SOUTHEAST WIND 5 TO 15 MPH.
.WEDNESDAY...A SLIGHT CHANCE OF MORNING
  SHOWERS...FOLLOWED BY PARTIAL CLEARING.
  HIGHS IN THE LOWER 60S. SOUTHEAST WIND 5 TO
  10 MPH BECOMING WEST 5 TO 15 MPH IN THE
  AFTERNOON.
.THURSDAY...BREEZY WITH INCREASING CLOUDS.
  LOWS IN THE LOWER 40S. HIGHS NEAR 60.
.FRIDAY...COLD WITH RAIN AND MOUNTAIN SNOW
  LIKELY. LOWS NEAR 40. HIGHS IN THE LOWER 50S.
.SATURDAY...A CHANCE OF MORNING RAIN AND
  MOUNTAIN SNOW SHOWERS...FOLLOWED BY
  PARTIAL CLEARING. LOWS IN THE 30S. HIGHS IN
  THE UPPER 50S.
.SUNDAY AND MONDAY...PARTLY CLOUDY. LOWS IN
  THE MID TO UPPER 30S. HIGHS NEAR 60.

.<             TEMPERATURE / PRECIPITATION
TUCSON         55  43  62  /  90  40  20
GREEN VALLEY   55  42  62  /  90  50  20
MT LEMMON      33  27  36  / 100  60  30
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Figure 1 - Tucson Metro zone forecast from the southeast Arizona Zone Forecast Product (ZFP)

Temperature is not the only parameter that can suffer a degradation of resolution due to terrain effects (Fig. 1). The Tucson Metro zone encompasses valley locations as well as the Rincon Mountains and the

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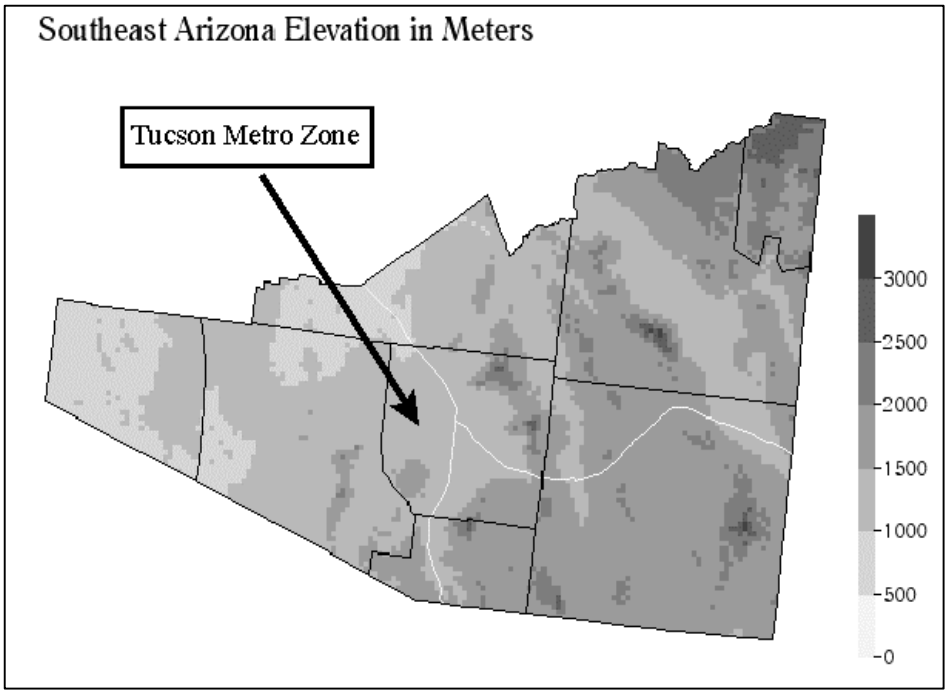

Figure 2 - Southeast Arizona CWFA showing zone outlines, interstate highways, and elevation in meters. The Tucson Metro Zone is identified with the city of Tucson centered near the intersection of the two highways.

Santa Catalina Mountains. The forecast shown in figure 1 has generalized the snowfall expected. There is no delineation for snow amounts on windward versus the leeward side of mountains. Wind is another parameter which suffers a degradation through a generalized format required by the zone forecast format. In complex terrain, wind is highly dependant on topographical features. This resolution has been lost in the forecast shown in Figure 1. Including specific wind information for the entire zone would increase the length of the product to the point of making it unreadable.

Each WFO has developed unique solutions to accommodate terrain effects for their forecast area. In Utah the Wasatch Mountain forecast includes a temperature for a specific elevation (2400 meters or 8000 feet) (Fig. 3). The zone forecast covering the Oregon and Washington Cascade range includes temperatures at pass level (Fig. 4). These temperatures are only included for the afternoon forecast period. No temperature forecast is given for the nighttime hours.

.TONIGHT...CLEAR WITH LOWS AT 8000 FEET IN THE 40S.
.SUNDAY...MOSTLY SUNNY. HIGHS AT 8000 FEET IN THE MID 70S.
.SUNDAY NIGHT...CLEAR. LOWS AT 8000 FEET IN THE 40S TO NEAR 50.
.MONDAY AND TUESDAY...MOSTLY SUNNY. HIGHS AT 8000 FEET IN THE MID 70S.
.WEDNESDAY THROUGH SATURDAY...A SLIGHT CHANCE OF AFTERNOON AND EVENING THUNDERSTORMS EACH DAY. LOWS AT 8000 FEET IN THE 40S. HIGHS AT 8000 FEET NEAR 70.

Figure 3 – Utah Wasatch Mountain zone forecast showing temperature forecast at the 8000 foot level.

.TODAY...SUNNY. FREEZING LEVEL 14000 FEET.
WINDS IN THE PASSES WEST 5 TO 10 MPH.
AFTERNOON PASS TEMPERATURES AROUND 70.
.TONIGHT...CLEAR. FREEZING LEVEL 13000 FEET.
WINDS IN THE PASSES WEST 5 TO 10 MPH.
.MONDAY...MOSTLY SUNNY. PATCHY MORNING CLOUDS AND FOG LOWER SLOPES. FREEZING LEVEL 13000 FEET. AFTERNOON PASS TEMPERTURES AROUND 70.
.TUESDAY...MOSTLY CLOUDY NORTH WITH ISOLATED SHOWERS. PARTLY CLOUDY SOUTH. SNOW LEVEL AROUND 10000 FEET.
.WEDNESDAY AND THURSDAY...MOSTLY SUNNY. PATCHY MORNING CLOUDS AND FOG LOWER SLOPES. FREEZING LEVEL 12000 FEET.
.FRIDAY AND SATURDAY...MOSTLY CLOUDY WITH A CHANCE OF SHOWERS OR DRIZZLE MAINLY NORTH PART. SNOW LEVEL 9000 FEET.

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.<                ELEV  TEMP     /  PRECIP
SNOQUALMIE PASS(3022) 72 51 72 /  0  0  0
STEVENS PASS   (4061) 68 46 68 /  0  0  0
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Figure 4 - Washington Cascade Zone Forecast showing pass temperature forecast in the afternoon with no temperature forecast at night.

3. DIGITAL FORECAST GRID DETAILS

The Tucson NWS WFO has been producing gridded forecasts for their County Warning Forecast Area (CWFA) for the past three years. Forecasters edit the forecast grids using the GFE. The gridded forecasts produced through the GFE are used to generate text products such as the ZFP, the State Forecast Product (SFP), the Selected Cities Forecast (CCF), and the Fire Weather Forecast (FWF).

Currently the resolution of the gridded forecasts used by the Tucson WFO is 2.5 km. The GFE is capable of storing and displaying data at a variety of resolutions. The Tucson WFO has chosen 2.5 km resolution as a balance between higher resolution and the ability of current computer technology to manipulate the grids in a timely manner. At higher resolution, manipulation of the grids on the computer system slows significantly. The number of grid points increases by a factor of four each time the grid resolution is doubled. Lower resolution offers only slightly faster grid manipulation speeds but considerably degrades the forecast usefulness in complex terrain.

The domain over which the Tucson WFO manipulates the GFE grids is shown in Figure 5. This area is a superset of the Tucson CWFA which is shown highlighted in the southeast section of the state in figure 5, and also shown in Figure 6. To cover this area with a 2.5 km resolution grid requires 289x289 grid points. The GFE stores the gridded forecast in a netcdf database. When forecasters compile a complete forecast package for all forecast parameters through seven days, the netcdf files become quite large. A complete package with little or no weather can run upwards of 120 Mbytes in size. When significant weather covers the area that is changing over time, file sizes in excess of 180 Mbytes are possible. Transmitting data files this large in a timely manner requires very fast telecommunications lines.

Since Tucson WFO forecasters only edit grids for the Tucson CWFA, there is no need to transmit grids containing information outside the Tucson CWFA. As a first step to reduce grid size, a subset of the full 289x289 grid was cut out that encompasses a rectangle containing only the WFO Tucson CWFA (Fig. 5). Making this adjustment reduces the grid size by a factor of nearly 4. Thus the grid containing a full forecast package for the Tucson CWFA is reduced in size to between 25 and 50 Mbytes. While this size is still formidable for timely transmission on slower speed connections, through compression the data size can be further reduced to between 3 and 10 Mbytes in size. Future plans call for using a GRIB2 data file. No tests have been run to determine the file size if a GRIB2 format is used.

4. INTERACTIVE DIGITAL FORECAST WEB DISSEMINATION

WFO Tucson has been disseminating simple graphic images generated from the digital data for three years. A sample of the original graphics that were distributed is shown in Figure 6. Color images, like the image shown in Figure 6, are a simple mechanism for conveying the forecast of a single parameter at a specific time across the entire CWFA.

Recently the web interface was modified to expand the data retrieval capabilities. When entering the web page (Fig. 7), a person is presented with two options for retrieving data: (1) select a specific field and a time to retrieve an image (Fig. 6), or (2) select a specific location and the desired forecast parameters for this location.

A specific field is selected from a table containing all available digital forecasts as illustrated in the top portion of Figure 7. This table is updated automatically to reflect the actual digital forecasts created by the meteorologist. For example, the forecaster can change the probability of precipitation fields from 6 hours to 24 hours, and the web interface will automatically reconfigure itself to these new time increments. Thus, the forecaster is free to generate the fields deemed appropriate and the web interface will provide access to the resulting fields.

The new image interface allows customers to zoom into a specific area of the map (Fig. 8). This feature lets the customer focus on a small area. As the customer zooms in, the color scale adjusts itself to match the range of the data displayed in the window.

The second web interface allows a customer to select forecast parameters and a point on the map with the mouse (Fig. 7). When the mouse selection is made, a table of forecast parameters is displayed showing all forecast times and desired parameters for that point (Fig. 9). This retrieval approach of digital forecasts lets a customer focus on a specific site and get the data for that site over 7 days. If a person knows the latitude and longitude of the location, these data can be entered directly into text boxes rather than clicking on the map.

For existing forecast products, such as the ZFP, the forecaster determines the primary area of interest. With the digital forecast display mechanisms employed by the Tucson office, the customer can now focus on areas of concern to them. Therefore the customer has direct access to all the details contained in the digital forecasts.

Both of these web display mechanisms do not require disseminating the full set of grids to the customer. Instead the data transmitted is customer specific and can be as few as several hundred bytes.

5. FUTURE DIGITAL FORECAST POSSIBILITIES

The availability of digital forecasts opens up an enormous potential for future products. As the NWS expands its generation of digital grids to include the entire country, digital grids from each WFO will be incorporated into an NWS Digital Forecast Database. By tying together grids from several WFOs spanning several states, products such as route forecast on the nations highways are possible. By entering a beginning and destination location and time, software can construct a complete forecast for the entire length of the journey. Piecing together a cross country forecast that

would last several days with text products, requires reading forecasts covering hundreds of zones from 30 or more WFOs.

If all forecast parameters were available on grids covering all areas of the country, it would be possible to have the computer generate all routine text products such as the ZFP. Text generation is only being done on a limited basis at the Tucson WFO. Producing text from the grids has not been easy. Computer technology and algorithms to produce text from grids will improve with time to the point that very few text products will be written by forecasters.

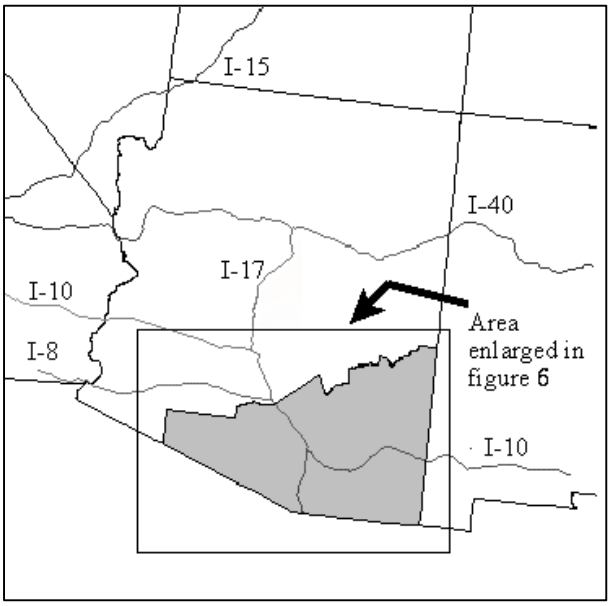

Figure 5 - Map of Arizona showing interstate highways and the Tucson County Warning Forecast Area (CWFA) boundary. The rectangle that encompasses southeast Arizona is enlarged in figure 6.

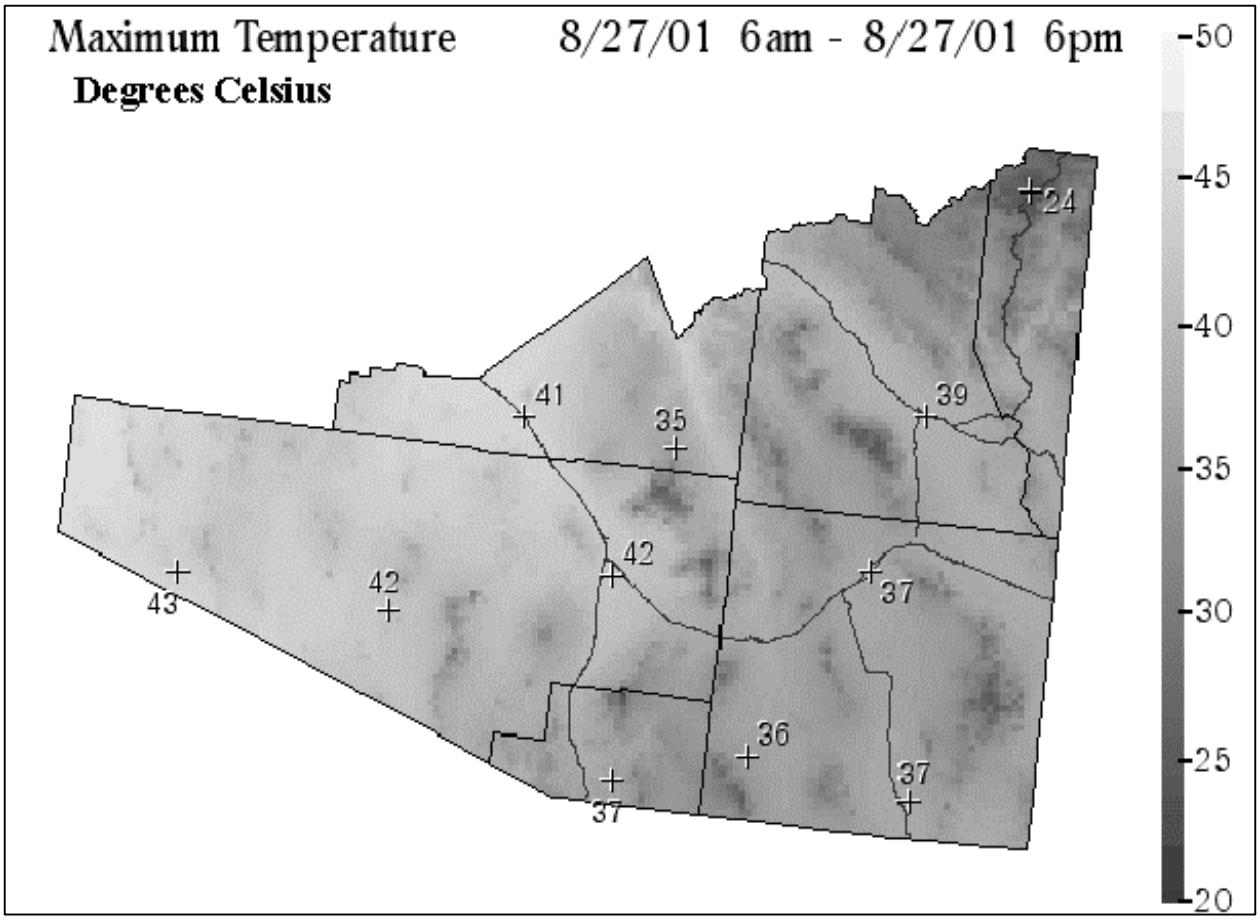

Figure 6 - Digital forecast image generated on a 2.5 km grid. Web images are displayed with a color scale

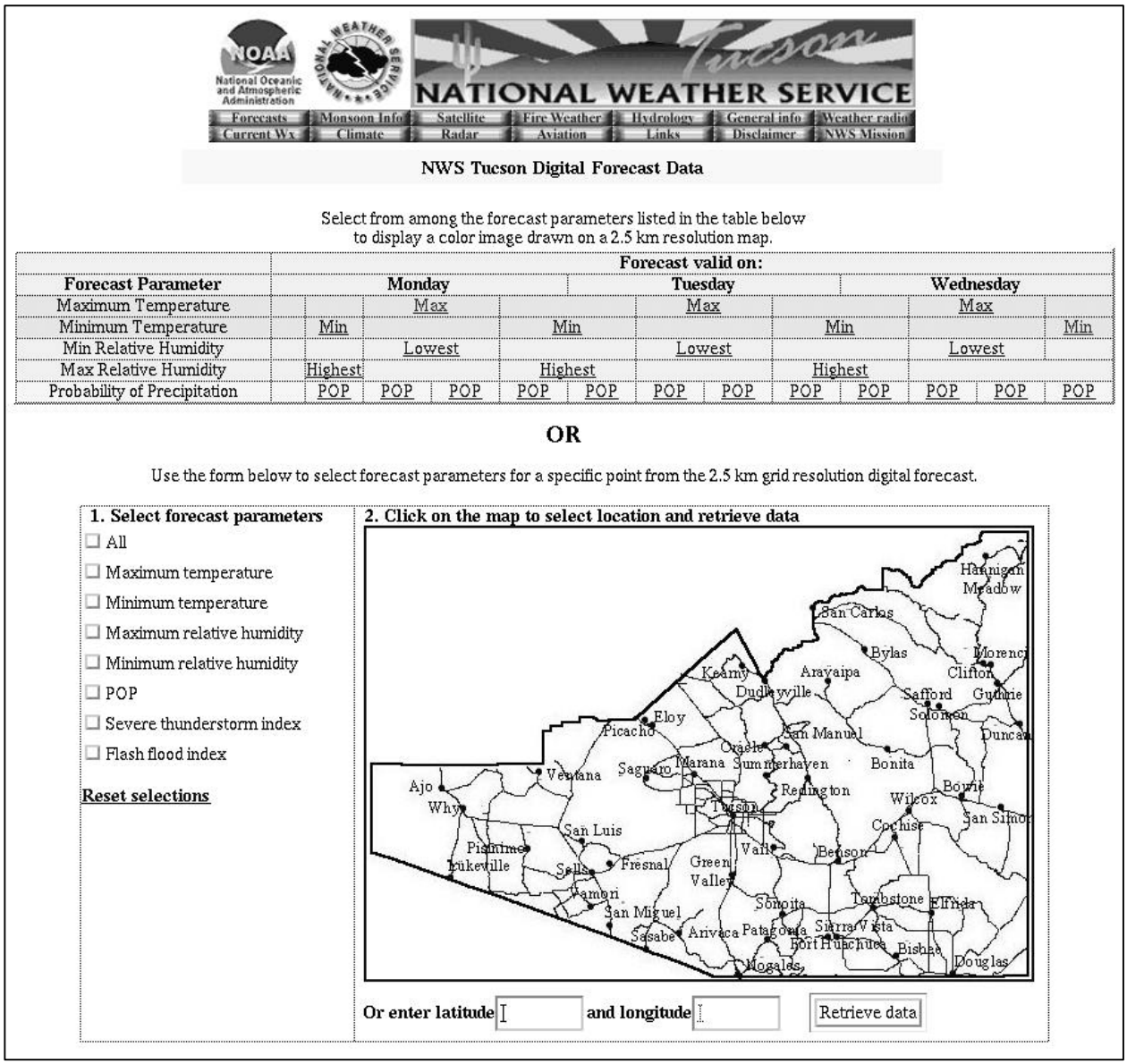

Figure 7 – Web page where selections are made for either a color image of a particular parameter or selecting a point where all parameters will be displayed in a text table. The web page is available at: http://www.wrh.noaa.gov/tucson/gfe/gfe_main.shtml

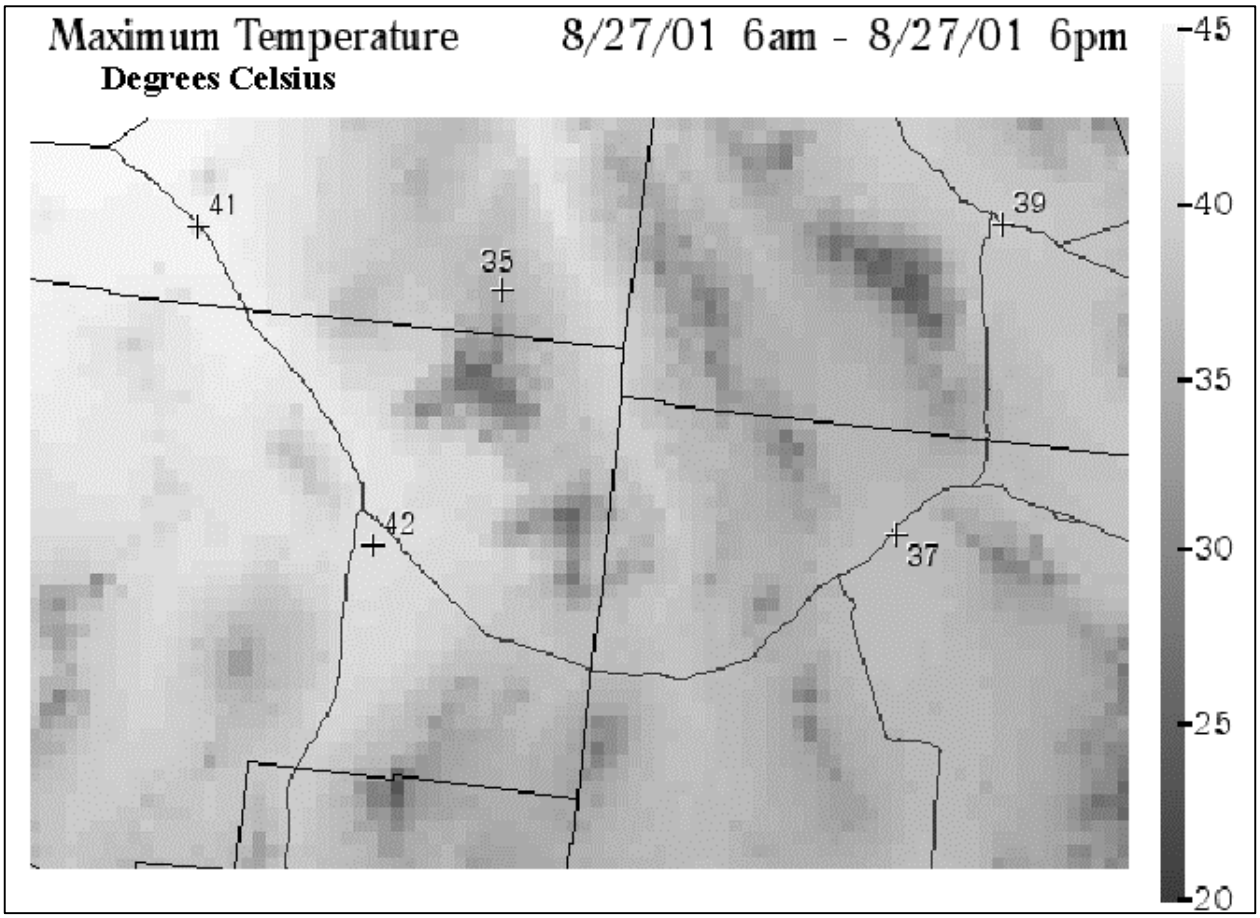

Figure 8 - The same data as figure 6 except displayed at a higher zoom level. At this level the 2.5 km grids are clearly shown. The web images are displayed in color. Spot temperatures are for selected cities and towns. Notice how the scale in this image is different from the scale shown in figure 6. When zooming in at higher levels the scale adjusts to the data visible in the display.

Retrieved data for 32.37 N and 110.14 W: Elevation = 6196 Feet

	Sun	Mon			Tue				Wed				Thu				Fri			
DATE		Aug 27				Aug 28				Aug 29				Aug 30				Aug 31			
MST	18	00	06	12	18	00	06	12	18	00	06	12	18	00	06	12	18	00	06	12	18
MaxT	89				89				86				83				81				81
MinT			56				55				56				56				57		
MaxRH			56				66				73				63				66		
MinRH					17				21				25				27				
PoP	0	0	0	0	0	0	0	0	0	0	0	0	19	14	0	0	19	17	0	0	22
SVRidx	0	0																			
FFidx	0	0																			

Figure 9 - Tabular data available on the web after clicking the mouse on a specific point. This table contains all forecast parameters for all times from the future forward for the specified grid. Temperatures are in degrees Fahrenheit, humidities are in percent.