NDFDCLIMATE

Christopher Mello

Robert LaPlante

NOAA National Weather Service

Cleveland, Ohio

Abstract

NDFDClimate is a computer application that creates images of forecast and climatological parameters for the continental U.S. from two different digital data sets. The first data set is the NDFD (National Digital Forecast Database) weather forecast grids produced by the NOAA National Weather Service (NWS) and the second data set is PRISM (Parameter-elevation Regressions on Independent Slopes Model), an expert system that uses point climatological temperature data and a digital elevation model (DEM) to generate gridded estimates of climate parameters. Each data set has a 5 km spatial resolution. The temperature data available from PRISM are weekly values, while the data available from the NDFD are daily values. Linear interpolation was performed on PRISM weekly fields to estimate daily values. The daily PRISM normal maximum and minimum temperatures were compared with official data from the NCDC (National Climatic Data Center) to validate the linear interpolation for seven selected eastern region sites. Mean absolute error was near 0.25 °F and the maximum daily absolute error was less than 1°F for each of the seven sites. NDFDClimate uses GRADS (Grid Analysis and Display System) to produce images from the daily climatological values (PRISM) and the NDFD for several climatological parameters.

1. Introduction

The NOAA National Weather Service (NWS) National Digital Forecast Database (NDFD) contains digital forecast grids of sensible weather elements such as temperature, wind, and precipitation in a mosaic from collaborating field offices across the U.S. for forecasts out to seven days. NDFDClimate is a new software application that creates images from NWS public digital NDFD temperature forecasts and PRISM derived digital climatological grids for the continental U.S. on a personal computer. These images include NWS digital weather forecasts of daily maximum and minimum temperatures from the day the forecasts were issued through six days from issue time. Daily digital climatology grids of maximum and minimum temperature were created using Parameter-elevation Regressions on Independent Slopes Model (PRISM; Daly et al. 1994) method. PRISM and NDFD data are available to the public at 5 km resolution over the continental U.S. NDFDClimate uses the GRADS (Grids Analysis and Display System; Berman et al. 2002) software application to add,

subtract, and or combine NDFD forecast grids and PRISM climatological grids in numerous ways to create image files representing a derived data grid. As a result, NDFDClimate grids produced include:

- PRISM derived normal daily maximum and minimum temperatures

- NDFD derived forecasted heating and cooling degree days through day 6

- NDFD forecasted daily minimum and maximum temperature anomalies derived from PRISM daily climate fields through day six

- NDFD derived five day total of forecast heating and cooling degree days

- NDFD 60 hour total of liquid equivalent QPF

- NDFD forecasted number of hours the temperature is above or below a defined temperature through day three

- NDFD forecasted 24 and 48 hour forecast temperature changes from forecast issue time.

Currently, the NDFD does not contain climatological data. It was recognized that creating a new separate climate data set to supplement the NDFD would enhance its utility to the public and forecasters.

2. Data and Methodology

The two data sets used in NDFDClimate are PRISM generated digital climate fields and NDFD digital forecast grids.

a. PRISM Climate Data

PRISM is an expert system that uses point climatological temperature data and a digital elevation model (DEM) to generate gridded estimates of climate parameters (Daly et al. 1994. Temperature changes over flat terrain were easily estimated using linear interpolation between official National Climatic Data Center (NCDC) climate points. However, mountainous regions presented the biggest challenge to creating these climate grids. This is due to the potential of great temperature changes over short horizontal distances. Fortunately, PRISM is well suited to mountainous regions. The effects of terrain on climate play a central role in the model's conceptual framework. PRISM recognizes that topography is an important climatic unit and elevation is a primary driver of many climate parameters. PRISM is now used to map temperature, snowfall, and other parameters.

The PRISM system determines climate element values at grid cells by calculating linear regression relationships between the climate element and elevation. Each grid cell estimate is determined from a separate multiple linear regression using data from nearby climate stations. Data from each station in the multiple linear regressions is weighted based on five factors: distance, elevation, vertical layer, topographic facet, and coastal proximity. The horizontal resolution of PRISM data is 5 km across the continental U.S. (2 km scale is available for a fee). Topographic facet, or topographic orientation, is primarily used for precipitation. Rain shadows and upslope enhancement are estimated using regression formulas based on wind flow divided into eight compass points

and changes in elevation. Vertical layer refers to two layers: the boundary layer and the free atmosphere above the boundary layer. By separating into two layers, it became possible to identify temperature inversions in high mountain valleys also using regression. A detailed discussion of these methods is beyond the scope of this paper.

Temperature data from PRISM consist of weekly averages of daily maximum and minimum temperature fields for the period 1971 to 2000. Interpolation between consecutive weekly data points was performed through a linear regression to obtain daily values throughout the year. It was assumed that the rate of change of daily high and low temperature during each week is constant.

Quality control was performed by comparing the derived daily normal maximum and minimum temperatures from NDFDClimate to the official data from the NCDC. All official NCDC daily normal maximum and minimum temperatures and daily NDFD maximum and minimum temperature forecasts are rounded to the nearest °F. Seven official climate sites in the eastern region were examined: Cleveland, OH; Toledo, OH; Erie, PA; Youngstown, OH, Syracuse, NY; Richmond, VA and Greenville, SC, and each site had a mean absolute error near 0.25 °F for both the normal daily maximum and minimum temperature. For all seven sites, the highest daily absolute error was less than 1°F for both the normal maximum and minimum temperature. A 0.25 °F error due to rounding can be expected from any climate or forecast product issued from any NWS office. The temperature error magnitude is deemed acceptable for WFO Cleveland use.

b. NDFD Data
The second data set utilized by NDFDClimate is the NDFD. The NDFD consists of digital forecast data that are produced by local NWS forecast office across the continental U.S., which are merged into a single image or file for each forecast parameter and for each forecast projection. Forecasts grids are produced for 1 to 7 days in the future for the following forecast parameters: maximum temperature, minimum temperature, 12 hour probability of precipitation (POP), wind speed and direction, weather, cloud cover, temperature, dew point, precipitation amount, and snow amount. Grids are currently available at 5 km spatial resolution and a temporal resolution of 3 hours for days 1-3 and 6 hours for days 4-7.

c. NDFDClimate
NDFDClimate utilizes the GRADS (Berman et al. 2002) software, without any modifications, to create images that utilize information from both the NDFD and PRISM data sets. GRADS software is free to download and redistribute as long as the source code of any modifications is included. The GRADS has the functionality to add, subtract, or manipulate fields using many formulas. For example, the NDFDClimate produces temperature anomaly grids by subtracting NDFD maximum and minimum temperature forecasts from PRISM derived daily climatological maximum and minimum temperature grids. Positive values indicate daily forecasted maximum or minimum temperatures are expected to be warmer than climatology and negative values indicate temperatures are expected to be

cooler than normal. Further details of GRADS and related software are beyond this discussion, but can be found on the internet at http://grads.iges.org/grads/grads.html and http://www.nws.noaa/mdl/iwt/grib2/decoder.htm. Additionally, the user can specify the domain and contour interval for images that GRADS produces NDFDClimate combines some fields to generate running totals such as 5 day total heating and cooling degree days and 60 hour total QPF. Four NDFDClimate images produced by this application are shown to illustrate some of its output (Fig. 1-4). These and other NDFDClimate output graphics are available at: http://www.erh.noaa.gov/cle/weather/wseta/NDFDClimate.html .

3. Assumptions

Software requirements
NDFDClimate computer requirements include, Linux software (Red Hat 6.0 and higher), about 300 megabytes of disk space and access to the Internet to download the current NDFD digital forecasts.

For NWS users, NDFDClimate should not be run on a computer inside the AWIPS firewall.

It takes about 10 minutes to run the software on a 2 GHz speed CPU. The software is available on the NWS Eastern Region (ER) shared server at: ftp://ftp.werh.noaa.gov/share/cle/ndfdclimate. If you experience any problems when applying this application, **STOP immediately and contact the author for help**. If the author cannot be reached, contact a member of

Eastern Region Scientific Services Division for help. Please do not spend time troubleshooting. Installation problems are more easily tracked down and fixed if this suggestion is followed.

5. Procedure
For NWS users, NDFDClimate should not be run on a computer inside the AWIPS firewall.

All the files included in the software are located in one compressed tar file, NDFDCLIMATE.tar.gz. Once the software is uncompressed, the NDFDClimate file structure has two important subdirectories, *data,* where temperature and precipitation climate files are located, and *bin*, where scripts are stored.

A. Software Installation
1. Download NDFDClimate.
From the Eastern Region Headquarters (ERH) anonymous FTP server (ftp://ftp.werh.noaa.gov/share/cle/ndfdclimate) using your E-mail address as the password, Download the file:

```
NDFDClimate.tar.gz
```

to a location where there is 300 megabytes of disk space is available. The file size is approximately 162 megabytes. There are 3 subdirectories inside: data, bin, and src.

2. Uncompress the file.

```
$ gunzip NDFDClimate.tar.gz
```

3. Untar the file.

```
$ tar –xvf NDFDClimate.tar
```

4. Create a directory for GRADS.

GRADS will use several files in /usr/local/lib/grads. This directory will have to be created as root.

```
$ cd /usr/local/lib
$ mkdir grads
$ chmod 775 grads
```

5. Copy font files in GRADS subdirectory.

The entire group of font files in the grads subdirectory needs to be copied to /usr/local/lib/grads. Failure to create this directory and move the font files will result in failure of the software to run.

```
$ cp
/path_to_NDFDClimate/NDFDCl
imate/data/*font*
/usr/local/lib/grads
```

B. Software Configuration

The software is currently configured to produce images for the NWS Eastern Region (ER). The user can change the domain or contour interval of the images.

1. Domain Configuration

a. Select a Linux editor of choice.

b. Edit the following lines in NDFDconfig. The domain of the forecast image is at the top of the configuration file NDFDconfig located in the bin directory. The default is set to the ER (see default values below). LAT1 and LAT2 are the latitude boundaries, south to north, respectively. LON1 and LON2 are the longitude boundaries, west to east, respectively. Edit the values to define the domain of choice. Values to 0.01 are acceptable.

Default values:
set LAT1 31.4

set LAT2 47.3
set LON1 -85.46
set LON2 -67.6

2. Directory Configuration

This is the directory where NDFDClimate resides.

Default value is /data/fxa/LOCAL.

```
set HOME_DIRECTORY path to
NDFDClimate
```

3. County Map Configuration

Set the value of county_map to 0.

```
set county_map 0
```

This should only be set to 1 if using the default area (Eastern Region) above. Setting the value to 1 will create county maps for the default area. Contact Chris Mello (Christopher.Mello@noaa.gov) for information on creating background county maps for an area other than the default.

C. Running NDFDClimate

There are two executable programs in the bin directory, get_NDFD.csh and NDFD_image_ALL.tcl. FTP access to the world web is required. The first program will get the current NDFD digital forecasts from the internet. The files are ds.maxt.bin, ds.mint.bin, ds.qpf.bin, and ds.temp.bin.

1. Run get_NDFD.csh

After installing NDFDClimate, the script get_NDFD.csh will download four files from the NDFD server: ds.maxt.bin, ds.mint.bin, ds.qpf.bin, and ds.temp.bin. Each file contains current digital weather forecast grids covering the continental

U.S. on a 5 km scale. The ds.maxt.bin and ds.mint.bin have forecasted high and low temperatures, ds.qpf.bin has six-hour QPF fields and ds.temp has a combination of three and six hourly temperature forecasts. All fields extend through seven days from the issuance time. *There has been observed corruption of these files when downloading at times of high volume.* If problems persist, try downloading at a later time.

This script must be run via cron or from the command line.

```
/NDFDClimate_path/NDFDClima
te/bin/get_NDFD.csh
```

2. Run NDFD_image_ALL.tcl
After downloading files from the above step, the script NDFD_image_ALL.tcl will generate all the images described above and place them in the directory NDFDClimate_path/NDFDClimate/data. Run the script either through cron or from the command line. After specifying the area and intervals above, running the script NDFD_image_ALL.tcl will produce the images listed in the Table 1.

```
/NDFDClimate_path/NDFDClima
te/bin/NDFD_image_ALL.tcl
```

All images files end with png. All old images are deleted when the script runs. There are eight java scripts included in /NDFDClimate_path/NDFDClimate/data that can be used to loop most of the images in Table 1. The scripts that loop maximum temperature fields are max_loop.html, maxclimate_loop.html and max_anom_loop.html. They respectively loop the daily NDFD maximum temperature forecasts, the PRISM normal daily maximum temperatures for the same date and the

forecasted NDFD daily temperature anomaly when compared to PRISM. The scripts that loop minimum temperature fields are min_loop.html, minclimate_loop.html and min_anom_loop. They respectively loop the daily NDFD minimum temperature forecast, the PRISM normal daily minimum temperature for the same date and the forecasted NDFD daily temperature anomaly when compared to PRISM. The script qpf_loop.html produces a loop of qpf images and temp_loop.html creates a loop of hourly temperatures. Each loop can run by launching by any web browser, such as Netscape or Mozilla and typing the full path to the desired java script.

6. CONCLUSION
NDFDClimate is a computer application that creates images of forecast and climatological parameters for the continental U.S from the NDFD and PRISM digital data sets. A linear regression was performed on PRISM weekly temperature fields to interpolate daily values. The mean absolute error of the derived daily temperature values from PRISM was determined for seven locations in the eastern U.S. by comparing the PRISM values to NCDC data. These seven locations had a mean absolute error near 0.25 °F for both the normal daily maximum and minimum temperature. The highest daily absolute error was less than 1°F for both the normal maximum and minimum temperature for all seven sites. Currently, the NDFD does not contain climatological data. The fields produced by NDFDClimate provide additional data the public and forecasters.

Data Access Links
Information on general access to data

and products on NWS file servers:
http://www.nws.noaa.gov/tg/general.html

Access procedures for files available through NWS anonymous FTP (including NDFD files):
http://www.nws.noaa.gov/tg/anonymous.html

GRIB2 Decoder and Encoding Details for the NDFD:
http://www.nws.noaa.gov/mdl/_NDFD_grib2Decoder/

References

Berman, F., A. Chien, K. Cooper, J. Dongarra, I. Foster, D. Gannon, L. Johnson, K. Kennedy, C. Kesselman, J. Mellor-Crummey, D. Reed, L. Torczon, and R. Wolski., 2002. The GrADS Project: Software Support for High-Level Grid Application Development. *International Journal of High Performance Computing Applications*, **15**, 327-344.

Daly, C., R.P. Neilson, and D.L. Phillips, 1994. A Statistical-Topographic Model for Mapping Climatological Precipitation over Mountainous Terrain. *J. Appl. Meteor.*, **33**, 140-158.
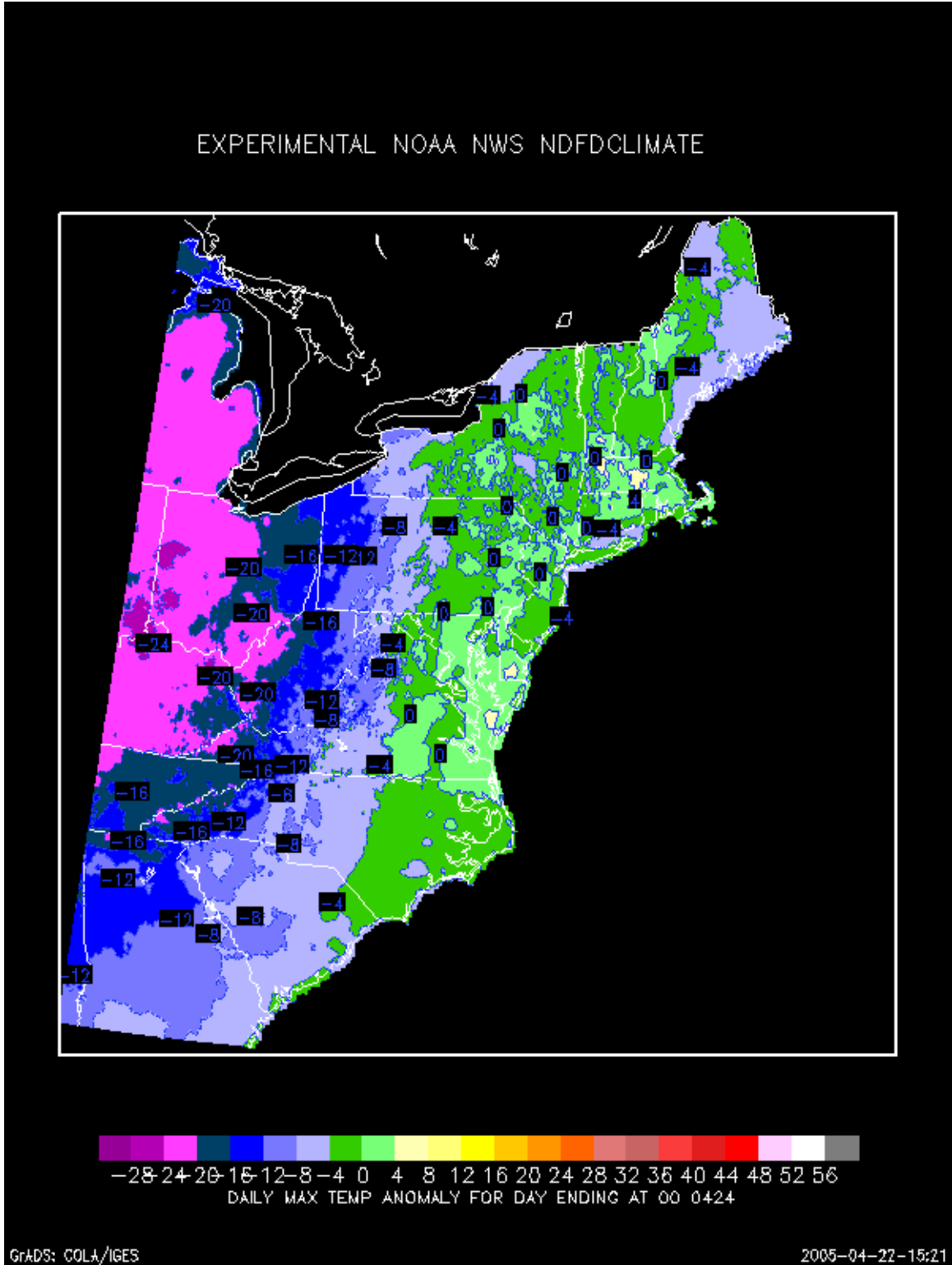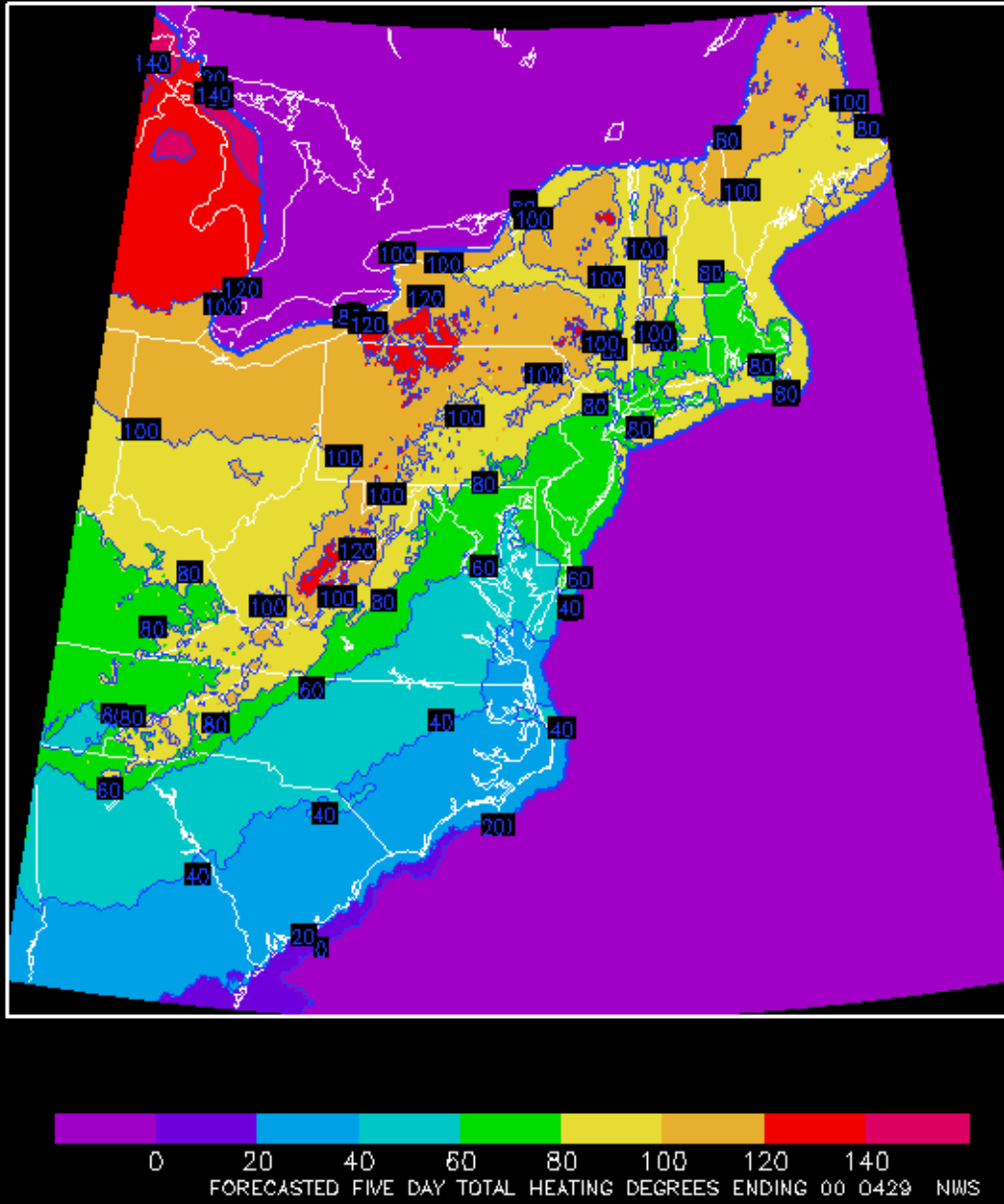
Figures

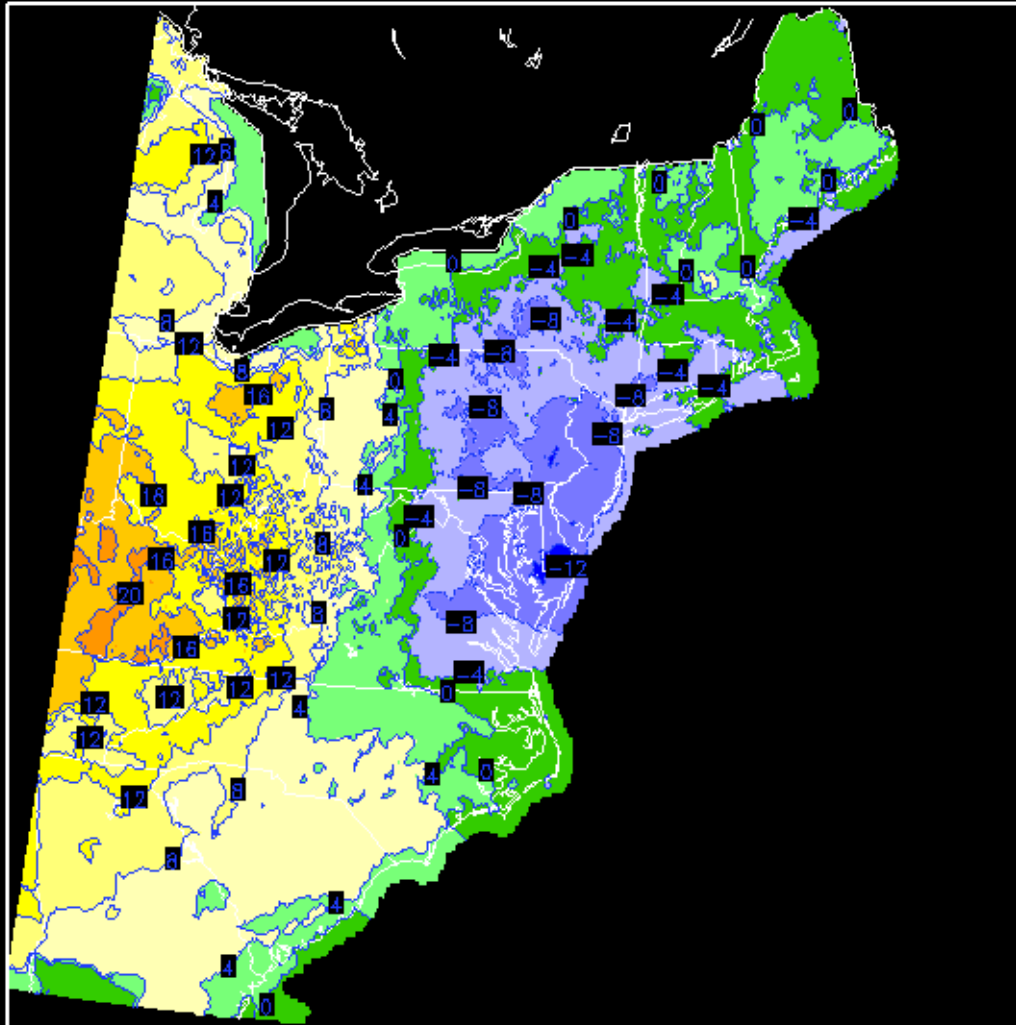Figure 1. Daily maximum temperature anomaly (departure from normal in °F) ending 000 UTC 24 April 2005

Figure 2. Forecasted five day total heating degree days ending 00 UTC 29 April 2005.
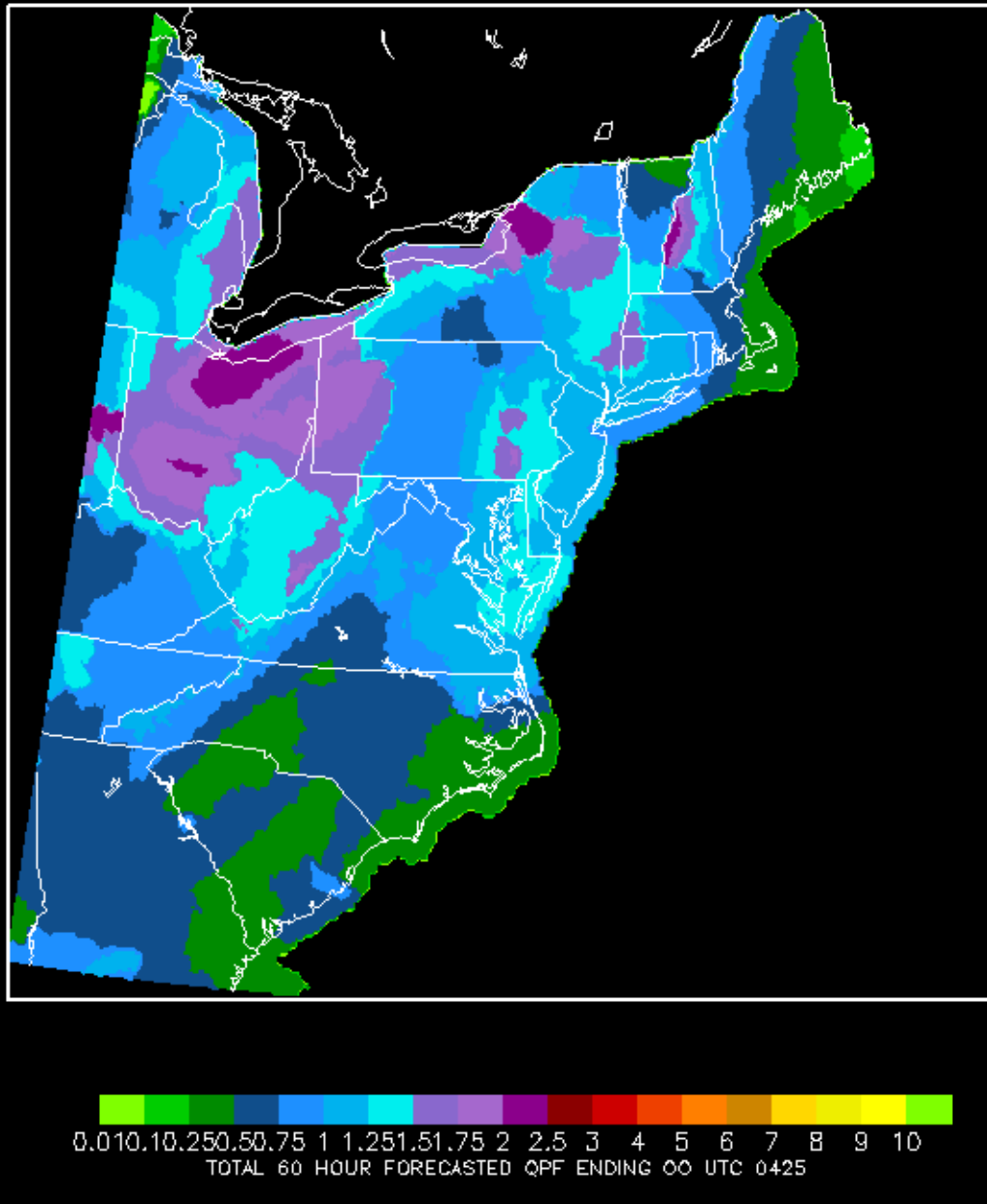
Figure 3. 24 hour temperature change (°F) valid at 00 UTC 23 April 2005

EXPERIMENTAL NOAA NWS NDFDCLIMATE

0.010.10.250.50.75 1 1.251.51.75 2 2.5 3 4 5 6 7 8 9 10
TOTAL 60 HOUR FORECASTED QPF ENDING 00 UTC 0425

GrADS: COLA/IGES

2005-04-22-15:21

Figure 4. Total 60 hour QPF (in) ending at 00 UTC 25 April 2005

Table 1. Sample of NDFDClimate Products where the first number in each small box is the month and the second two numbers is the day. Loop provides an animation of all listed forecast days directly to the right of each parameter.

Experimental NDFDClimate (Software Info)													
Field	**Forecast Day**												
Low Temperature Forecasts													
NDFD Forecasted Daily Minimum	Loop	M	909	910	911	912	913	914					
PRISM Normal Minimum	Loop	M	909	910	911	912	913	914					
Daily Anomaly	Loop	M	909	910	911	912	913	914					
High Temperature Forecasts													
NDFD Forecasted Daily Maximum	Loop	M	909	910	911	912	913	914					
PRISM Normal Maximum	Loop	00	909	910	911	912	913	M					
Daily Anomaly	Loop	00	909	910	911	912	913	M					
NDFD Heating degree days													
Heating Degree Days	NA	M	909	910	911	912	913	M					
5 Day Total	NA	M	M	M	M	M	120	M					
NDFD Cooling degree days													
Cooling Degree Days	NA	M	909	910	911	912	913	M					
5 Day Total	NA	M	M	M	M	M	120	M					
NDFD Temperature Change													
24 And 48 Hour	NA	M	909	910	M	M	M	M					
Forecast Valid time in hours from current time													
Temp	Loop	03	06	09	12	15	18	21	24	27	30	33	36
Forecasts	NA	39	42	45	48	51	54	57	60	63	66	69	72
	NA	75	78	81	84	87	90	93	96	99	102	105	108
NDFD Precipitation Amount													
6 Hour QPF Forecast	Loop	6	12	18	24	30	36	42	48	54	60	66	72
Total QPF Forecast	Loop	6	12	18	24	30	36	42	48	54	60	66	72