

## A CLIENT APPLICATION FOR REAL TIME NOMADS AT NCEP TO DISSEMINATE NOAA'S INFORMATION DATA BASE

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### 1. INTRODUCTION

A National Weather Service priority, as stated in the FY07-11 *Baseline Assessment*, is to "Disseminate and deliver NOAA's information and services." An important component of NOAA's information data base is the forecast data from NOAA Atmospheric, Ocean and Climate numerical weather prediction (NWP) models operationally prepared at the National Centers for Environmental Prediction (NCEP). Recommendation 5 of the National Research Council's *Fair Weather: Effective Partnerships in Weather and Climate Services*, states that "The NWS should make its data and products available in Internet-accessible digital form".

The *Real Time (RT) NOMADS (NOAA Operational Model archive distributing System)*, project is providing a service to federal agencies, the scientific and university community, and the public by serving environmental data sets from NOAA and other organizations. It is described in a number of reports such as (Alpert and Wang, 2004, Alpert et al., 2002). The RT-NOMADS project is a working prototype employing client-server technology and freely distributed utility programs to disseminate and document digital data. The software effectively provides the NOAA real time operational NWP model data sets to the public, federal agencies and the scientific community.

#### *A Client-Server Framework*

A client-server framework is a cost effective way to serve a large database to a number of varied users. It could be considered for serving Weather Forecast Offices (WFO) from a weather service national center

or regional office. It represents the most efficient and secure use of available bandwidth drawing on existing infrastructure and is scalable in its nature. For a wide range of applications, the data located centrally on these servers appear as if the data were from local disk storage. The script/programs on the server are efficient because they can take advantage of special arrangements of the database, such as data restructuring over time or space or variable or level for customized and efficient access. The clients can be centrally written and executed or the users have the entire set of tools available to them to construct their own custom made applications as the database appears local.

A wide range of environmental information, in digital form with the necessary supporting infrastructure is contained on NOMADS servers at many NOAA and other organizations. NCEP and the National Climate Data Center (NCDC) have partnered to deliver a seamless framework for serving NOAA's real time and past archives of NWP model run history database. As one of many participants of NOMADS, NCEP serves the operational model data base in real time using OPEN-DAP (also called DODS) client-server framework under GDS (GrADS-DODS server) and other services.

#### *For The Project That Needs to Serve Data*

As pointed out in Alpert and Wang, 2004, NOMADS offers a collection of guidelines as well as tested and widely used server software and client examples to participants who embrace the protocols. Participants can then say "*NOMADS inside*" on their servers and participate to influence the future development of NOMADS guidelines. The RT-NOMADS project has developed web based file transfer protocol (ftp) known as the *ftp2u* client, and *pdisp* (known as "*Great Displays*"), a grid analysis

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and display application. The data sets are internet ready and their display is done by the client. These programs are freely distributed modules, including source code, allowing modifications, customization and development. For example, NCDC uses a version of *ftp2u* called *ftp4u* with a number of innovations. NOMADS software calls on existing and proved, freely available, open source software such as JAVA, Tomcat, Apache, OPEN-DAP and GrADS-DODS (GDS) server under the Linux operating system banner.

#### *For The Users Who Need to Receive Data*

In the case of *ftp2u*, the user is prompted to pare down (*slice and dice*) large files of high resolution model results and can re-group different files to create needed products, for example, initialization files for model development. Users can obtain subsets of the data in parameter space (variables), physical space (longitude, latitude, height level), and over time. The results are delivered to a users ftp server if they have one, or to NOMADS ftp servers and web sites at the users discretion. The URL produced by this process is available to users to be re-used in a suitable Unix script with non-interactive web based download programs to control the data flow. For example, data can be obtained at regular intervals by utilizing these URL constructs in Unix scripts in *cron* giving the user complete and customized control of their data flow needs.

The *pdisp* client will display selected parts of the data base for a large number of views including time, hovmoeller diagram, cross sections, animation and standard (weather) maps across the selectable 5 dimensions (time, height, longitude, latitude and parameter space). These client programs can be executed on the server with direct access to the data base or they may run equally well on the users computer (the client) accessing the DODS (OPEN-DAP) server and gaining access to the data base over network resources. Like the *ftp2u* client, these programs compose a URL from user input, including commands and keywords understood by the server and quantified by the users input from the web based prompts. The resulting URL can be thought of as a constrained query which the user can modify in a suitable script with custom modifications. This result can be re-sent to the server with the attribute changes using an open source web command free ware program such as *wwwgrab* and *wget*. Automatic

operations can be done by placing the users script into *cron*.

Most use of NOMADS is made through the above mentioned client applications but the OPEN-DAP/DODS servers are also accessible through commercial and open source software. Examples of commercial client applications are MATLAB and IDL and a freeware application example is Graphical Analysis and Display System (GrADS). In addition (users) client applications can be created to perform data base access tasks creating unique products.

For this report we will show an OPEN-DAP client application that provides a request-and-fulfill mechanism for access to archive and real time records. As an example of the OPEN-DAP service, we show a client application which accesses the NCEP Global Ensemble model forecast data to produce user selected weather element event probabilities. The event probabilities are easily extended over model forecast time to show probability histograms defining the future probability trend of user selected events. In the next section we show both examples and suggest some extensions.

## **2. OPEN-DAP CLIENT EXAMPLES**

### *Weather Event Probabilities from the NCEP Operational Model Ensemble*

Ensemble forecasts attempt to address the uncertain nature of NWP. Both initial condition errors and errors in the formulation of the physics forcing are compounded in NWP non-linear models degrading the accuracy of forecasts. The NCEP operational ensemble model suite utilizes a breeding process (Toth et al. 1997) to account for the increased uncertainty from growing instabilities. It is noted that an ensemble can also be constructed from any group of separate model runs, e.g. the daily runs from national meteorological centers (Alpert and Brill, 1998). A goal in the construction of ensembles is to properly span the space of possible forecasts. In addition, if the ensemble members are equally probable (otherwise a suitable weighting can be applied), then probability estimates can be defined simply as the percentage of forecasts of the total number that satisfy a specified given event. We may apply this to a weather element, for example, temperature, wind speed or precipitation, at a location and future (model forecast) time.

File Edit View Go Bookmarks Tools Window Help

Back Forward Reload Stop http://nomad3.ncep.noaa.gov/cgi-bin/var/ensprob1.pl Search Print

Home Bookmarks Red Hat, Inc. Red Hat Network Support Shop Products Training

## Find the Probability of a Weather Event that You Create

TODAY is: 2004, 10, 14  
Please select :

STATION NAME (Select Below) or enter latitude and longitude ..... Then Select Forecast Time and Model Cycle

DENVER/STAPLETON\_JNTL CO US

STATION Latitude: 39.78 STATION Longitude: -104.87

Date (HR/DD/MM/YY)GMT 12/18/10 00z

Cycle

**Create an event:**

☒ Temperature:  
Notes: you can create a temperature event by giving a lowest temperature or a highest temperature or a range of temperature. For example, for freezing event, giving lowest temperature lower than 32F and do not check the highest temperature.

☒ Lowest TEMP: lower than 32 UNIT: F

☐ Highest TEMP: Higher than UNIT: K

☐ Precipitation  
Higher than mm/day

☐ Wind Speed  
Higher than UNIT: m/sec

**Click YES to show URL query for ensemble members:**

☒ NO  
☐ YES

Event Probability Reset

Fig 1. A screen snap shot of the web page containing the prompts and user entered responses for a 4 1/2 day forecast of the probability of frost (<32F) at Denver, CO.

By making queries to all ensemble components, the frequency of a suggested event at a particular location can be determined as well as the event's probability. We note that forecast accuracy is only as good as the accuracy of the ensemble model ability to predict realistic probabilities.

As an example, to see how to construct an OPEN-DAP constrained query, we show a program that uses OPEN-DAP to construct a weather element event at a place and future time, under user control, using the

NCEP ensemble forecast data base to calculate the event probability. We assume a perfect ensemble of forecasts in that the probabilities are perfectly calibrated. The NCEP operational ensemble consists of 11 model runs of the Global Forecast System (GFS) posted to a 1x1 degree grid on 6-hr intervals each out to a 180-h forecast. The 5 fastest growing modes are found from a 6 hr forecast, and after some adjustment, are added to a control run (c0) initial condition to create 5 initial conditions (p1-p5) and subtracted from the control run initial condition to form another 5 initial conditions (n1-n5) for a total of 11 initial conditions c0, n1-n5, p1-p5. Each of these initial conditions is integrated using the NCEP operational GFS making an ensemble of 11 forecasts. To begin our example, to find the probability of a user chosen weather event, we

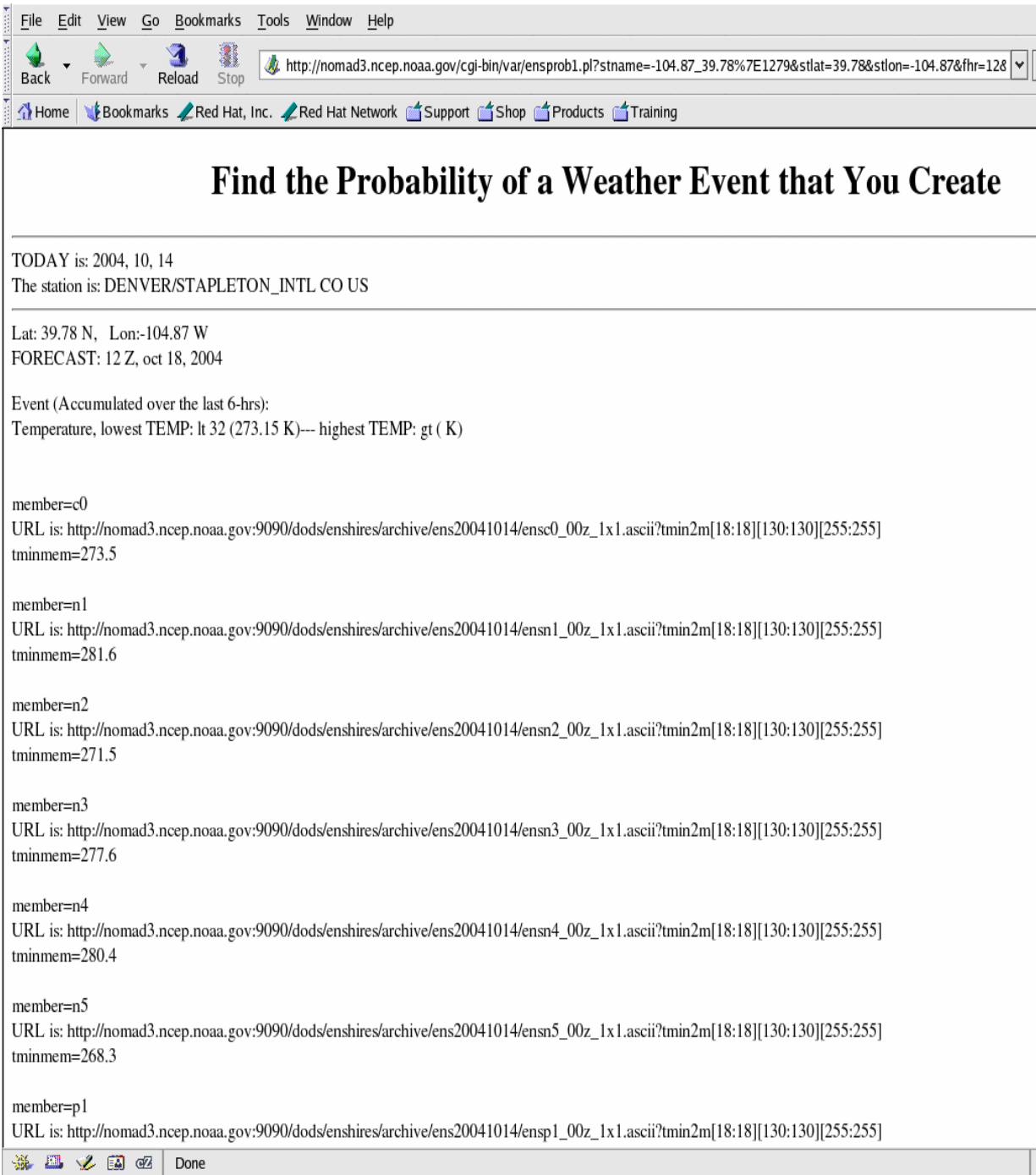


Fig 2. Excerpt of the resulting web page from the user selected event shown in Fig 1, for a 4 1/2 day forecast of the probability of frost (<32F) at Denver, CO, showing the URL queries of the ensemble data base.

execute the web based (cgi-bin) program called, *ensprob1.pl*, located at URL:

<http://nomad3.ncep.noaa.gov/cgi-bin/var/ensprob1.pl>

This presents a web page to the user with several prompts for the user to choose a weather event, desired future forecast time, and location as shown in Fig 1. We chose to write the program in the Perl language but this is a personal preference, other languages could be used. Let us say a user wants to know the probability of frost some days into the

future at a particular city. A user would select a city, model cycle (today's run is assumed) and time in the future when the weather event will be valid. Shown in Fig 1, for the city of Denver (Stapleton international airport, CO), a 4 1/2 day forecast from initial conditions of 14OCT2004, is an image of the screen as it appeared. Note the temperature and lowest temperature boxes are checked and "lower than" is selected with 32 F, for frost at the particular city, to compose this weather event example. Clicking on the "Event Probability" button will start the calculation that accesses the OPEN-DAP server by constructing constrained queries to obtain, in this case, the forecast temperature from each member of the ensemble. The selection of "URL query for ensemble members" at the bottom of Fig 1 (setting yes) will show (print) each URL constructed query to the ensemble forecast data set of the given event, in this case, frost. Fig 2 shows an excerpt of these results that are returned on the web page. The date and time of the ensemble initial conditions as well as the location of the event are shown at the top of Fig 2 followed by the user selected event, the lowest temperature less than 32 F. The first constructed query in Fig 2 is for c0 and is the URL address:

[http://nomad3.ncep.noaa.gov:9090/dods/enshires/archive/ens20041014/ensc0\\_00z\\_1x1.ascii?tmin2m\[18:18\]\[130:130\]\[255:255\]](http://nomad3.ncep.noaa.gov:9090/dods/enshires/archive/ens20041014/ensc0_00z_1x1.ascii?tmin2m[18:18][130:130][255:255])

This URL address contains the server address including the port (:9090) followed by the data base location including directory name, usually based on time: ...enshires/archive/ens20041014. This address is the location of metadata descriptions which contain all the properties digitally describing a data file, including 4 dimensional description, variable, units, projection information, etc... The metadata descriptions are machine and human readable, a point we will discuss later. The next part of the URL query points to the 00z Cycle control (c0) ensemble forecast on a 1x1 degree grid. The .ascii keyword signals the OPEN-DAP server to return ascii characters after locating and unpacking the required GRIB record. The ?tmin2m includes a leading separator followed by the variable name for minimum 2-m temperature over the last 6 hours, tmin2m. This variable is stored on the server over forecast times with other variables on a 2-dimensional latitude/longitude 1x1 degree GRIB grid. If the command ended at this point, without the following bracketed constraints, the entire (65K values) global grid of values would be returned. However, we need only the value at the point in

question, Denver, so time and location are constrained by the values in square brackets that follow. The first constraint is over forecast time, in this case 6-hr intervals. That is [0:0] indicates the initial condition of the forecast and [18:18] indicates the 4 1/2 day forecast. The value [0:18] would result in all 6-hr forecasts from the initial condition to 4 1/2 days inclusive. The next constraint is the number of latitudes north of the South Pole, starting at 0 degrees, which on the 1x1 degree grid is nearest to 40 N (Stapleton international airport is 39.78N). The last bracketed quantity is the longitude measured eastward from the Greenwich meridian [255:255], 105W (Stapleton international airport is 104.87W). If one were to copy-paste this URL into a common browser the result would be the value indicated in Fig 2 from the c0, 4 1/2 day ensemble forecast, 273.5K, including time, variable dimension and location information which is returned from the server. The remaining ensemble forecast n1-n5 and p1-p5 values are found subsequently, with excerpts shown in Fig 2. The number of resulting temperature values satisfying the given event are counted, giving the frequency which can be divided by the total number of ensemble components, to form the probability. The probability for our minimum temperature event appeared (not shown) at the end of the page (It was 36%).

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line_1.....if (defined($lowtmp)){
line_2.....$url=$urlorg."\".$modela$member"."_"
$cycle"."_1x1"."\.ascii?tmin2m\[ $tm1:$tm1\]
[ $lat1:$lat1\]\[ $lon1:$lon1\]";
line_3.....if ($urlqry eq "yes") {
line_4.....print "URL is: $url<br>\n";
}
line_5.....$myvarurl=`$wwwgrab $url`;

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Fig 3. Pearl code fragment from *ensprob1.pl* showing the composition of the URL constrained query.

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These queries are composed and delivered to the server using a non-interactive web page download program such as *wwwgrab* or *wget* within the script program source code. A fragment of the *ensprob1.pl* code that composes the URL for the ensemble

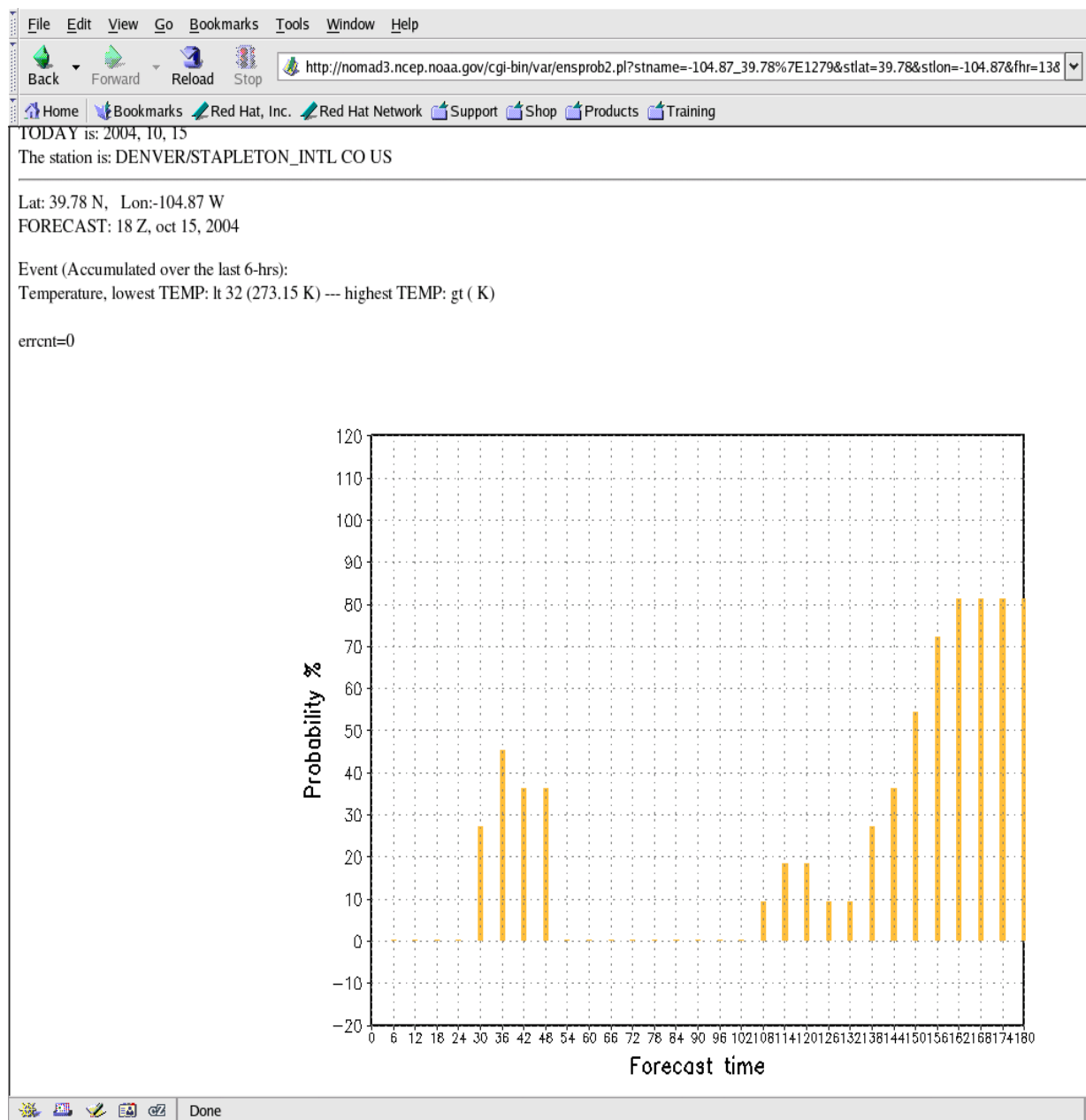


Fig 4. Probability of the event shown in Fig 1 but for forecast times out to 180-h from the *ensprob2.pl* program.

minimum temperature is shown in Fig 3. If the minimum temperature exists as tested in line\_1, then the URL is composed with the address located in variables *urlorg* with *modela*, *member*, and *cycle* variables differentiating the available models as directory names thus, constructing the above URL example. The *.ascii* command and variable name are hard wired and the forecast time and location are provided as the user entered these values from the

web page prompts of Fig 1 and are composed on line\_2. The final URL and web access command, *\$url*, is executed, that is, sent to the OPEN-DAP server at line\_5 using the web download program *wget*, and the response located in the variable (memory) *myvarurl*. If the user set “yes” to the “URL query for ensemble members” option shown in Fig 1, then the URL query is to be printed by setting *urlqry* to “yes” in line\_3, then it is shown by line\_4. The dimension, time and location information as well as the returned result (2m minimum temperature) are easily parsed from the returned information in *myvarurl*. Much more complicated calculations may be made with these results than the

simple event probability calculation shown on this web page. For example, one could obtain the wind field, calculate the divergence and find its 3 dimensional extent and compare with severe weather watches and warnings which is the subject of another report.

### *Ensemble Probabilities from Weather Events for All Forecast Times*

A second example follows immediately from the above *ensprob1.pl* program to add a loop over all forecast times. As there are 180-h (7 ½ day) forecast on 6-hr intervals, including an initial condition and forecasts for each of 11 ensembles, we need to make 31X11=341 queries for an event like surface (2m) temperature. One would need twice as many queries for wind magnitude found from the model forecast u- and v- components of the wind. To do this we have constructed a similar program to the one shown above located at:

<http://nomad3.ncep.noaa.gov/cgi-bin/var/ensprob2.pl>

This code will find all user selected events through 180-h forecasts and includes a plot of the results on a probability vs time plot. We choose, frost once again (<32F) at Denver and show the results for all forecast times for initial conditions of 15OCT04 12z in Fig 4. The bar graph indicates the probability of temperature less than 32F over the 180-h forecast period. The probability of frost increases toward the end of the period.

### *Timing*

The time to serve the data is an important aspect of the GDS server. There are 341 queries, in this case, for one temperature value each to construct the figure. The raw model output GRIB grid data are stored in files, one for each time period, therefore, one query per value is required. However, when larger amounts of data are needed the efficiency of

the data transfer increases. When the number of values is large, the time to obtain the data is mostly constrained by the bandwidth of the network not the server. When only one value per query is needed then the opening of the file and other I/O overhead is the limiting factor. The timing for the above example

which is a case where one value per query is needed was 50 seconds for 341 queries or one every 0.14 seconds. The server has 1.8Mhz CPU speed. Separate tests show that for larger amounts of data, bandwidth speed is the limiting factor and file control overhead is negligible.

## **3. VALUE ADDED PRODUCTS**

One could generalize this approach to finding probable events anywhere and for all forecast times over the globe. The selection of the ensemble data base of NOMADS is arbitrary. Multiple events over many forecast times for a number of variables require some care in ordering the queries but this is not a problem because programs can be written to exercise efficiencies of the server when the complexity of the server is required and, when display and versatility are needed, the client can be used. For example, large memory and direct I/O for unpacking and calculating are efficient on the server, and the display tools of the client for customized results. Thus, a commercial enterprise or value added retailer (VAR) may use this system to reduce programming time, increase bandwidth efficiency, and gain access to data not previously available. A VAR in a remote location can access and manipulate needed data into a useful form and then display locally, interacting under the users (client application) control which most likely appear as a web page interaction or automatically sequenced program.

NOMADS software uses the common software of the internet upon which our most used and secure software is evolving.

## **4. SUMMARY**

NOMADS servers are regarded as a prototype system with constrained resources however, the client-server framework is now accepted to disseminate the data results of a number of projects within and outside of NOAA. The NOMADS framework is scalable and can be run equally well over private tcp/IP connections as well as the common internet. It represents an efficient use of hardware for serving large databases, an efficient use of bandwidth as it uses transmit only what is needed and utilize their own resources for customized use.



We will leave it as an exercise for the user to query NOMADS servers to find the solution for sifting out the probability of an event over a particular area and forecast time. The solution and other source code will be posted on the authors web site:

<http://wwwt.emc.ncep.noaa.gov/gmb/wd23ja/index1.html>

## 5. REFERENCES

Alpert, J.C., G.K. Rutledge, R. Stouffer, B. Doty, S. Hankin and B. Domenico, 2002: The plan to access real-time NWP operational model data sets using NOMADS, AMS 18th Conf on IIPS, Orlando FL, J4.16, 73-74.

Alpert, J.C., and J. Wang, 2004: The real time NOMADS project: Access to operational model data and value added products, AMS 20<sup>th</sup> Conf on IIPS. Seattle, WA, P1.25

Toth, A., E. Kalnay, A.M. Tracton, R. Wobus and J. Irwin 1996: A synoptic evaluation of the NCEP ensemble. *Wea, & For.*, **12**, 140-153

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Data from NOMADS clients or DODS servers are available at the web sites:

<http://nomad1.ncep.noaa.gov>

<http://nomad2.ncep.noaa.gov>

<http://nomad3.ncep.noaa.gov>

<http://nomad5.ncep.noaa.gov>