

**THE REAL TIME NOMADS PROJECT:
ACCESS TO OPERATIONAL MODEL DATA AND VALUE ADDED PRODUCTS**

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1. INTRODUCTION

As supercomputers increase the temporal and spatial resolution of models, and demands for on-line access to large-array data increase, current communication technologies and data management techniques are inadequate. Rapid development in communications technologies over the last decade has been essential to provide significant gains in our ability to access data archives and other data sets. These technologies have been expected to enable collaborative research between institutions to rapidly grow. However, the difficulties in achieving accessibility and interoperability have delayed the realization of these potential gains. It is clear that it is no longer sufficient for any one national center or laboratory to develop its data services alone. Both researchers and policy-makers alike now expect national data assets to be easily accessible and interoperable with each other, regardless of their physical location. As a result, an effective interagency distributed data service requires coordination of data infrastructure and management extending beyond traditional organizational boundaries. Weather service Operations can also benefit from these advances and still maintain operational reliability and security in data movement.

The NOAA Operational Model Archive Distributed System (NOMADS) is an agreement between agencies who participate, to have common data and observation distribution software, format independent and description methodology, documentation and organization framework, forums to plan, organize and coordinate funding activities. NOMADS provides a service to federal agencies, the scientific and university community, and the public by fostering a common framework and

protocol for serving environmental data sets from NOAA and other organizations. These groups benefit from an active forum for the participants to plan and coordinate software policy decisions and promote growth and development of data access technologies. The customers of NOAMDS are university scientists, students, federal, public and commercial agencies and organizations who need an access mechanism to the data sets that are disseminated.

2. NOMAD PARTICIPANTS

NOMADS offers a collection of tested and widely used software servers and client examples to participants who embrace the protocols.

They can then say "*NOMADS inside*" on their servers and participate and influence the future development of NOMADS guidelines. There are 8 active NOAA participants: National Climate Data Center (NCDC), Pacific Marine Environmental Laboratory (PMEL), National Centers for Environmental Prediction (NCEP), Geophysical Fluid Dynamics Laboratory (GFDL), Forecast Systems Laboratory (FSL), Climate Diagnostic Center (CDC), Program for Climate Model Diagnosis and Intercomparison (PCMDI), and US Global Ocean Data Assimilation Experiment (USGODAE) serving data under the NOMADS framework. A number of participants are outside NOAA and many NOAA projects, who are suppliers of data, have expressed an interest in using NOMADS servers. For example, the NCEP/DOE re-analysis project serves data using NOMADS software. We show that the National Digital Forecast Database (NDFD) operations may be served by NOMADS to increase efficiency, utilize resources and solve dissemination problems. A public organization that has made significant contributions to NOMADS' is the Center for Ocean Land Atmospheres (COLA). For example, COLA had provided their open source software and integrated it with the Distributive Ocean Data System (DODS), one of the primary conduits of NOMADS servers. The National Center for



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Atmospheric Research (NCAR) is another organization that has made contributions on display and dissemination. These participating groups meet from time to time to report on their progress and create the direction and guidelines for NOMADS.

3. NOMADS NCEP REAL TIME COMPONENT

The NCEP component project, called "Real Time (RT) NOMADS", goal is to provide a service to federal agencies, the scientific and university community, and the public by serving environmental data sets from NOAA and other organizations.

A goal of the RT-NOMADS project is to specify operational 24/7 servers for NOAA Operations in forecast offices as well as a working prototype for public use. The serving technology employed in NOMADS, called the Data Applications Protocol (DAP also known as DODS), can effectively provide part or all of the NOAA data sets to the public and federal agencies. The framework can be used for serving Weather Forecast Offices (WFO) from a weather service national center or regional office as if the data was from local disk storage.

Distributed System Architecture Prototype

For this report, we consider that applications are clients that draw on the server for data and computational resources. Clients can also run on the server. Examples of a few client applications that run on the RT-NOMADS server is a web based file transfer protocol (ftp) known as the *ftp2u* client, and *pdisp* (known as "Great Displays") which is a grid analysis and display application. NOMADS participants serve up their data sets through a client-server relationship. The data sets are internet ready and their display is done by the client.

In the case of *ftp2u*, the client pares down large file sizes of high resolution model results and re-groups different files to create needed products, such as 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 *pdisp* client will display selected parts of the data base in a large number of views including time, hovmoeller diagram, cross sections and other maps across selectable 5 dimensions (time, height, longitude, latitude and parameter space). These client programs are executed on the server with direct access to the data base or they run equally well accessing the DODS server and gaining access to the data base over network resources.

Network band width is of importance in client applications. Internet-2 bandwidth is now available with bandwidth speeds that are similar to commonly used direct disk access. An operational weather service server could be populated from data sources at NCEP centers or physically located at the Telecommunications Operations Center (TOC), and Regional offices. WFO's can use existing display clients to view datasets from these servers and maintain quality control, security and other preferences. In this way NOMADS is a service that encourages NOAA projects and operations to distribute data records for NOAA, for science, and the public.

The RT NOMADS prototype is a collection of servers at NCEP and NCDC which have real time data bases, weather service operational suite of model products, forecast information for model comparisons, operational initialization and observations. The NOMADS programming staff maintain the codes, organize documentation, create and maintain utilities for data manipulation and grid transformation and sub-setting. The RT-NOMADS prototype serves as a transferpoint to NCDC for NOMADS archive of reruns and retrospective model cases as the A in NOMADS stands for archive. NCEP historical cases for rerun and retrospective case studies of ocean, atmosphere and climate are in great demand in the meteorological scientific community. As NCEP real time model output is stored at the NCDC NOMADS archive, there is a seamless access to these important data sets. At this time, NCEP real time model run history is carried about 2 months to 1 year before it is queued for transfer to NCDC archives. Resources are planned for a 2-5 year archive of the high resolution model data sets. Currently for the Global Forecast System (GFS), the resolution is 1x1degree every 3-h out to 7 1/2 day forecasts, and the meso Eta is posted at 12 km every hour to 36 hours and 3-h intervals thereafter on a Lambert conformal (NMC#218) grid. Low resolution data sets are also maintained for quick access and to serve a historical service records. A number of data sets with different characteristics are also kept such as the re-analysis-I and II data sets. The type and extent of data sets change with time. NOMADS attempts to keep data sets in the form that they had when produced utilizing server-client software to make needed conversions.

Distributed Administration and Support

NOMADS tests and creates benchmarks to characterize system loads in order to determine costs and give NOAA administration the information it needs to triage data resources. The NOMADS model is a

distributed one and recommends programming resources be distributed. NOAA projects and agencies already budget line items for information technology. The costs for NOMADS should be shared equally between base and project funded information technology budgets. NOMADS success, as the success of any project, depends on adequate support.

NOMADS overcomes the barriers for interoperability by using established and emerging technologies and data transport conventions, but most importantly- partnerships are needed to access and integrate model and other data stored in geographically distributed repositories in heterogeneous formats. As pointed out in *“Fair Weather: Effective Partnership in Weather and Climate Services”* by the National Research Council (2003), recommendation 5, that *NOAA should provide: wider information dissemination through web pages and other avenues, a frame work to create specialized and value added products, facilitate communication among commercial, public, research community and federal agencies.* NOMADS is the solution for recommendation 5 as it makes data and products available in internet-accessible digital form for creation of value added products (VAP) and can be used by value added retailers (VAR).

4. NOMADS IS A SERVER

An important aspect of NOMADS is the use of DODS protocol which utilizes meta-data file descriptions, readable by machine or man. A server-client relationship means that users (read clients) can

access the NOMADS data sets as if they were on the users local disk! The server data base can be accessed by the client applications running on the NOMADS server or the DODS server may be accessed by a client operating on the users personal computer. The results will be the same. The RT-NOMADS prototype client examples can be accessed by users and is run on the server. To access the data base, for example, the re-analysis data base, we show an excerpt of the RT-NOMAD data set list in Table 1. The data set name is shown in column 1. The frequency column indicates the time period of the data set, either the number of daily cycles or the time averaging involved. The plot, ftp, doc and gds labeled columns provide which client should be used to access the data base. That is, the user selects a client, either **plot** (*pdisp* or Great Displays), for making data displays, **ftp**, for *ftp2u* used to “slice and dice” and download digital data, **doc**, for documentation links, or **gds** for DODS server meta-data file descriptions and URL information and addresses. Points of contact and other information are listed to the right (not shown).

We have already mentioned the clients *pdisp* and *ftp2u* which are similar to existing client applications that exist on many web pages. A user client application accessing a NOMADS server to obtain a data request with appropriate constraints is a new concept now available. For example, retailers can add value to their products by utilizing the data they need from weather service operations. Many scientific studies and educational data requests can be satisfied efficiently using DODS server requests.

First, an example of a NOMADS DODS access using the open source client GrADS (Graphical Analysis and Display System, available from COLA) with a data set from the NCEP re-analysis. An excerpt from the GDS/DODS meta-data descriptor file is shown in Fig 1 and can also be viewed at the web site: <http://nomad1.ncep.noaa.gov:9090/dods/reanalysis-2/6hr/pgb/hgt>, that is, the 4x/day pressure GRIB geopotential height. As the meta-data in Fig 1 indicate, this data set contains data from 1979 (Jan) through 2003 (Aug) extending from 1000 hPa to 10 hPa over the globe on a 2.5 degree longitude/latitude equally spaced grid. GrADS is an example of a high level language that can be used to analyze data and display results over time and space or obtain values for other calculations on the server! For example, the command group shown in Fig 2 would display 3 years of 500 hPa height fields consecutively, thus, animating them. The *sdlopen* command in Fig. 2, connects and opens the NCEP data set on the users personal computer to access, in this case, the re-analysis data set. Note that

NOMADS: NCEP server 1 Plots, Data, Points of Contact

The following table list several data sets. By clicking on the appropriate command, you can (1) make plots, (2) FTP the (1) obtain documentation. At this time, some options are not available (N/A). BTW, we know that plots can, at times, be

| Data Set | freq | plot | ftp | doc | gds | contact 1 |
|--|-------------------|----------------------|-----------------------|---------------------|----------------------|--|
| NCEP/DOE Reanalysis (Reanalysis-2) | | | | | | |
| Reanalysis-2 pressure level | 4x daily | plot | ftp2u | doc | DODS | Wesley.Ebisuzaki@noaa.gov |
| Reanalysis-2 non-pressure level | 4x daily | plot | ftp2u | doc | DODS | Wesley.Ebisuzaki@noaa.gov |
| Reanalysis-2 spectral sigma analyses | 4x daily | N/A | ftp2u | ftp | doc | Wesley.Ebisuzaki@noaa.gov |
| Reanalysis-2 sicanl (to run model) | 4x daily | N/A | ftp | doc | N/A | Wesley.Ebisuzaki@noaa.gov |
| Reanalysis-2 pressure level | monthly mean | plot | ftp2u | doc | DODS | Wesley.Ebisuzaki@noaa.gov |
| Reanalysis-2 non-pressure level | monthly mean | plot | ftp2u | doc | DODS | Wesley.Ebisuzaki@noaa.gov |
| Reanalysis-2 diabatic heating etc | monthly mean | plot | ftp2u | doc | DODS | Wesley.Ebisuzaki@noaa.gov |
| NCEP/DOE Reanalysis (Reanalysis-2) Rotating Archive, latest analyses | | | | | | |
| Reanalysis-2 pressure level | 4x daily rotating | plot | ftp2u | ftp | doc | DODS |
| Reanalysis-2 non-pressure level | 4x daily rotating | plot | ftp2u | ftp | doc | DODS |
| Reanalysis-2 model init conditions | 4x daily rotating | N/A | ftp2u | ftp | doc | DODS |
| CDAS-NCEP/NCAR Reanalysis | | | | | | |
| N/N Reanalysis pressure level | 4x daily | plot | ftp2u | doc | DODS | Wesley.Ebisuzaki@noaa.gov |
| N/N Reanalysis pressure level | monthly mean | N/A | N/A | doc | DODS | Wesley.Ebisuzaki@noaa.gov |
| N/N Reanalysis Gaussian grid non-pressure level | monthly mean | N/A | N/A | doc | DODS | Wesley.Ebisuzaki@noaa.gov |
| N/N Reanalysis lat-lon non-pressure level | monthly mean | N/A | N/A | doc | DODS | Wesley.Ebisuzaki@noaa.gov |

Table 1. Excerpt of the RT-NOMAD data set list from http://nomad1.ncep.noaa.gov/ncep_data/index.html

the URL target of the *sdfopen* command is the same as that listed on the metadata file description mentioned above. One is not limited to only one connection but may open multiple data sets at once. No resources are used until a query is made. The example script in Fig 2 initializes a time counter to 1 and sets the display to produce color fill maps in lines 2 and 3. The *while* loop will continue for many days each display including a title with the date from the next 3 lines. The 'd(isplay) hgt' displays the height field and a color bar is shown beneath the map. The counter is incremented and the *while* loop ends.

GrADS-DODS Server - info for /reanalysis-2/6hr/pgb/hgt : dds das

DODS URL: <http://nomad1.ncep.noaa.gov/9090/dods/reanalysis-2/6hr/pgb/hgt>

Description: NCEP/DOE Reanalysis (R-2) 4x daily pressure-level analyses
Documentation: none provided
Longitude: 0°E to 357.5°E (144 points, avg. res. 2.5°)
Latitude: -90°N to 90°N (73 points, avg. res. 2.5°)
Altitude: 1000 to 10 (17 points, avg. res. 61.88)
Time: 00Z01JAN1979 to 18Z31AUG2003 (36036 points, avg. res. 6.0 hours)
Variables: (total of 1)
 hgtprs ** geopotential height [gpm]

Fig 1. Excerpt from the GDS/DODS meta-data descriptor file is shown in Fig 1 at the web site URL: <http://nomad1.ncep.noaa.gov:9090/dods/reanalysis-2/6hr/pgb/hgt>

```
s d f o p e n \
http://nomad1.ncep.noaa.gov:9090/dods/reanalysis-
2/6hr/pgb/hgt
t = 1
'set gxout shaded'
while (t <= 1000)
  'set t 't
  'q time'
  date=subwrd(result,3)
  'draw title hgtprs 'date' 't
  'd hgtprs'
  '/home/wd23ja/grads/lib/cbarn.gs'
  t = t + 1
endwhile
```

Fig 2. command group ion Fig 3 would display 3 years of 500 hPa height fields consecutively, thus, animating the fields.

The script is elementary GrADS commands however, the important idea is that the *sdfopen* URL address gives access to the NOMADS DODS data server and any GrADS commands can be applied. The NOMADS server expends computer resources locating the correct parts of the file requested from the users query (d hgtprs) defaulting to the 1979 GRIB data set. The servers response includes unpacking the WMO standard GRIB file and any other constraints from the users request. Once the results arrive at the users personal computer, instruction for the display are handled locally.

If one does not have the GrADS client one can access the DODS server by URL addressed queries and constraints. These can be used in creating VAPs or for users to directly receive the information they need. For example, a weather service VAR, like the Weather Channel or providers of information to federal agencies and private concerns, obtain environmental data form large and often cumbersome files. NOMADS offers a way for customers to get what they need. We choose for this example the GFS and show surface temperature for a single model point, say at the North Pole, lat: 90.00N, Lon: 0.00 W for 00Z, Oct 20, 2003. The URL address including the query for the 2-dimensional 2-meter temperature field, *tmp2m*, looks like:

[http://nomad1.ncep.noaa.gov:9090/dods/gfs/gfs20031020/gfs_00z.ascii?tmpwm\[0:0\]\[180:180\]\[180:180\]](http://nomad1.ncep.noaa.gov:9090/dods/gfs/gfs20031020/gfs_00z.ascii?tmpwm[0:0][180:180][180:180])

A program to create URL addresses and query lines like the one above from the GFS or meso-Eta model, for initial conditions (the present) and forecasted high and low temperature is located at the web site: <http://noamd1.ncep.noaa.gov/cgi-bin/var/try.pl>

A VAR might need to present, on its own web pages, the latest temperature forecast. With NOMADS, a constraint query, like the one above, is all that is needed to retrieve data from the operational NWS data sets including GRIB or GRIB-2, NETCDF and BUFR station data formats. The command, “.ascii” in the above URL constraint query will deliver values in ascii after unpacking GRIB files on the server and selecting the, “?tmp2m”, 2-meter surface temperature variable, a 2-dimensional field, since it is only at the surface. The constraint part of the query is in square brackets, “[]”. The first [0:0] means the “initial condition” or 00-h forecast. If one replaced this with other values such as, for example, [0:10], the result form the constraint query would be the first 10, 3-h , GFS forecasts starting with the initial condition. The first [180:180] constrains the server to 180 degrees north of the south pole and the last bracked [180:180] shows the point 180 degrees east

of the Greenwich meridian in this case the special point, North Pole. The server returns the data requested in the query. It also returns the described location and dimension of the data, that is, the time, latitude and longitude. One does not need a browser to initiate the query but can obtain the data inside user web programs. The temperature returned in this case was 266.6 K. Commercial clients such as MATLAB, IDL and open source VISAD are a few examples of clients that use the DODS protocol.

4. APPLICATION TO THE NDFD

The National Digital Forecast database (NDFD) is a collection of high resolution 5 km data sets which can be served in the same way the above mentioned model output files are served. For the case where subsets of the data set are needed for use in creating VAPs, NOMADS data servers can respond to constrain queries customized by forecasters at WFO's. The forecasters display system may be used to show the data results. The protocol is based on the most common web technology and language. Security fire walls can be made to allow data population by one protocol (say, secure shell) from source machines at TOC or NCEP while allowing server requests from ports at WFO's through allowed ports providing firewall security.

5. SUMMARY AND FUTURE WORK

NOMADS is an agreement between participants to adhere to a set of guidelines for the purpose of serving, disseminating and documenting data sets. NOMADS is a service to distribute NCEP's operational data set to researcher and the public and to provide server software to NOAA projects who need to serve their data through web services. NCEP RT-NOMADS is the intermediary between NCEP operational computers and NCDC NOMADS archive servers for a seamless real time and archive data base of atmosphere, ocean and climate data. RT-NOMADS provides the framework for long term support to be available to keep up with modeling advances.

The NOMADS server has software tools and provides clients/users with access to common data formats or mitigates between the most commonly used data sets in many formats. Data appears to clients and users as a local file in a standard format.

NOMADS is a concept that can take advantage of the increased bandwidth opportunity at regional centers to use NOMADS to transfer operational data to regional offices servers which in turn would serve data to WFO's.

It satisfies recommendation 5 of "Fair Weather: Effective Partnership in Weather and Climate Services".

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.

Rutledge, G.K., R.J. Stoffer, N. Smith and B. Lawrence, 2002: The NOAA operational model archive and distribution system, AMS 19th Conf on IIPS, Long Beach, CA, 8.1.

6. REAL TIME-NOMADS WEB SITES

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

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

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

