

# NOAA Operational Model Archive and Distribution System (NOMADS) and Aggregation of Ensemble Datasets

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## What is NOMADS

*Designed to provide real-time and retrospective format independent access to climate, ocean and weather model data, and advance the integration of real time model data and applications:*

- ✓ A digital archive of NOAA's operational weather models, and an “innovative data access philosophy to promote interoperable access across the geosciences” (BAMS, Rutledge et. al., 2006)
- ✓ An integrator of common web services infrastructure to support the discovery, access and transport of data (NOAA GEO-IDE Concept of Operations Rept. to the DMC, 2005) and “Completing the Forecast” (NRC, 2006) Recommendation 3.4:
- ✓ Unified Access Framework (UAF) project participant: To build momentum for implementing NOAA Global Earth Observation - Integrated Data Environment (GEO-IDE) through a phased approach to data interoperability that:
  - Engages data providers and users
  - Leverages stable, proven solutions and standards
  - Has a high probability of demonstrable successes



## NOMADS: High availability servers from distributed locations using the same protocol to distribute model data.

- The real time data service is (February 2009) highly available, 24/7, from the NOAA Web Operations Center (WOC) distributing NOAA's Operational Model suite
- Archives at National Climate Data Center (Separate Operations Implemented in 2007)
- Development continues at EMC with servers and non-operational data sets.
- Other agencies use similar protocol to distribute environmental data, eg., GFDL, PMEL, NCAR, NASA... and collaborate through organizations like DMIT, GO-ESSP,...
- NOMADS open source services use:
  - http or fast/partial ftp access: inventory & client script
  - [ftp2/4u](#) (“GRIB filter”), slice, dice and area subset files delivering repackaged GRIB files
  - GDS/OPeNDAP(DODS), Values from http queries
  - pdisp (“Great Displays”) development display program example, and other application examples.
- *Goal: All the model data from NCEP Operations*



# NOAA Web Operations Center (WOC)

## NOMADS Commitment (Beginning Feb 15, 2009)

- ✓ NOAA has committed that the Web Operations Center (WOC) is high availability, 24/7 operations
- ✓ NCEP Central Operations (NCO) is committed to the data flow aspect of NOMADS for data to be present and on time from their Operational super computers.
- ✓ NOAA WOC has committed to maintain NOMADS servers now and into the future, as well as day to day operations with costs shared by NOAA and NCEP base
- ✓ A development commitment continues at NCEP Environmental Modeling Center (EMC), a development division, to keep up with new data sets and create applications
- ✓ Data review groups, official committees and procedures for moving new data sets and applications from development to operations follows the existing NCO framework.

NOMADS-NOAA Operational Model Archive and Distribution System - Windows Internet Explorer provided by Environmental Modeling

http://nomads.ncep.noaa.gov/

File Edit View Favorites Tools Help

**National Weather Service**  
**NCEP Central Operations**

Home News Organization Search

Local forecast by "City, ST"  
City, ST  Go  
Search NCEP  Go

**NOMADS**  
**NOAA Operational Model Archive and Distribution System**  
Description of NOAA's NOMADS servers hosting NCEP model data

Users of NOMADS are reminded that they should use the URL <http://nomads.ncep.noaa.gov> to access the system and they will always be placed on the current active server. As of Tuesday October 7, 2009, users that have been using direct IP addresses to access NOMADS systems may no longer be able to access the system.

**Help Desk:** Questions or problems please use the link to submit a service ticket.  
**Background:** Background documents about the NOMADS project.  
**Service Description:** OCOWS Service Description Document

Click on link in the Data Set field for description and availability info.  
Click on the column headings for description of each data access method.

Data Set	freq	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">gds</a>
<b>Global Models</b>				
FNL	6 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
GFS 1.0x1.0 Degree	6 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
GFS 0.5x0.5 Degree	6 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
GFS 2.5x2.5 Degree	12 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
GFS Ensemble high resolution	6 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
GFS Ensemble Precip Bias-Corrected	daily	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
GFS Ensemble high-resolution Bias-Corrected	6 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
GFS Ensemble NDGD resolution Bias-Corrected	6 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
NAEFS high resolution Bias-Corrected	6 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
NAEFS NDGD resolution Bias-Corrected	6 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<b>Regional Models</b>				
AQM	06Z, 12Z	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
HIRES Alaska	daily	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
HIRES East CONUS	12 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
HIRES Guam	12 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>

USA.gov is the



Home page of WOC NOMADS

Real time GRIB2 data sets



NOMADS-NOAA Operational Model Archive and Distribution System - Windows Internet Explorer provided by Environmental Modeli

http://nomads.ncep.noaa.gov/

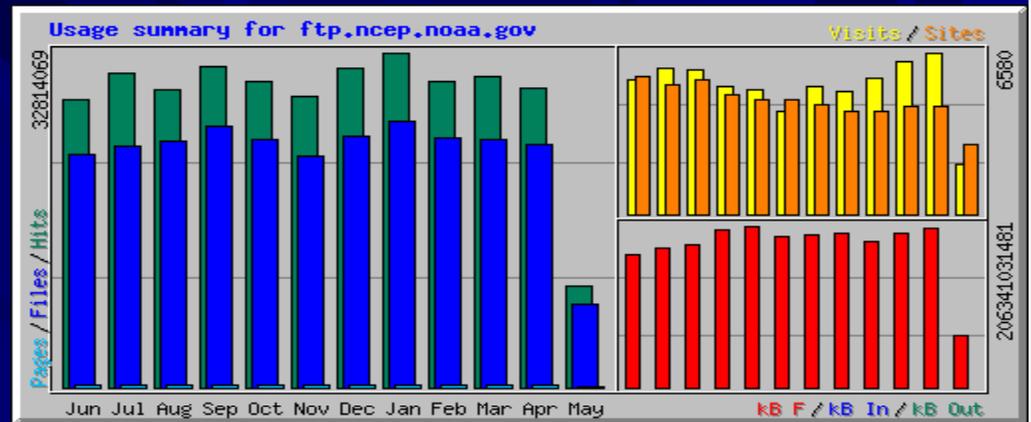
<a href="#">HIRES Guam</a>	12 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<a href="#">HIRES Hawaii</a>	12 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<a href="#">HIRES Puerto Rico</a>	12 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<a href="#">HIRES West CONUS</a>	daily	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<a href="#">NAM-12 Alaska</a>	6 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<a href="#">NAM-12 CONUS</a>	6 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<a href="#">NAM-12 North America</a>	6 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<a href="#">NAM-12 Caribbean/Central America</a>	6 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<a href="#">NAM-12 Pacific</a>	6 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<a href="#">NAM NEST Alaska</a>	6 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<a href="#">NAM NEST CONUS</a>	6 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<a href="#">NAM NEST HAWAII</a>	6 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<a href="#">NAM NEST Puerto Rico</a>	6 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<a href="#">RTMA Alaska</a>	hourly	-	<a href="#">http</a>	-
<a href="#">RTMA CONUS</a>	hourly	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<a href="#">RTMA2.5 CONUS</a>	hourly	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<a href="#">RTMA Guam</a>	hourly	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<a href="#">RTMA Hawaii</a>	hourly	-	<a href="#">http</a>	-
<a href="#">RTMA Puerto Rico</a>	hourly	-	<a href="#">http</a>	-
<a href="#">RUC</a>	hourly	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<a href="#">SREF CONUS (40km)</a>	6 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<a href="#">SREF CONUS (40km) Bias-Corrected</a>	6 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<a href="#">SREF North America (32km)</a>	6 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<b>Ocean Models</b>				
<a href="#">RTOFS</a>	daily	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<a href="#">RTOFS Global</a>	daily	-	<a href="#">http</a>	<a href="#">OpenDAP</a>
<a href="#">RTOFS HIRES</a>	daily	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<a href="#">Sea Ice</a>	daily	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<a href="#">Wave</a>	6 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<a href="#">Multi-grid Wave</a>	6 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<b>External Models</b>				
<a href="#">CMC Ensemble</a>	12 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>
<a href="#">FNMOC Ensemble</a>	12 hours	<a href="#">grib filter</a>	<a href="#">http</a>	<a href="#">OpenDAP</a>

Number and size of Datasets are rapidly growing

WOC servers are handling volume of holdings as well as increasing volume of users and use.

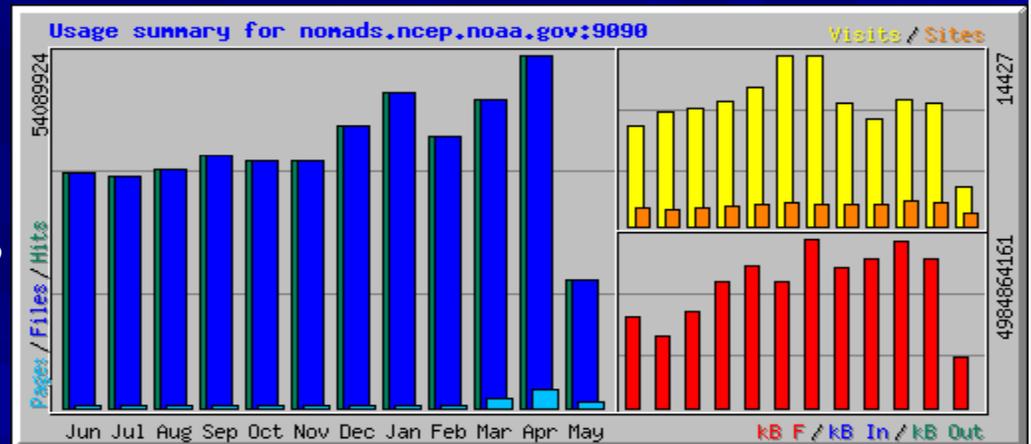
MAX 32M

Usage Statistics for ftp  
ftp.ncep.noaa.gov  
Summary Period: Last 12 Months  
Generated 11-May-2012 09:03 UTC



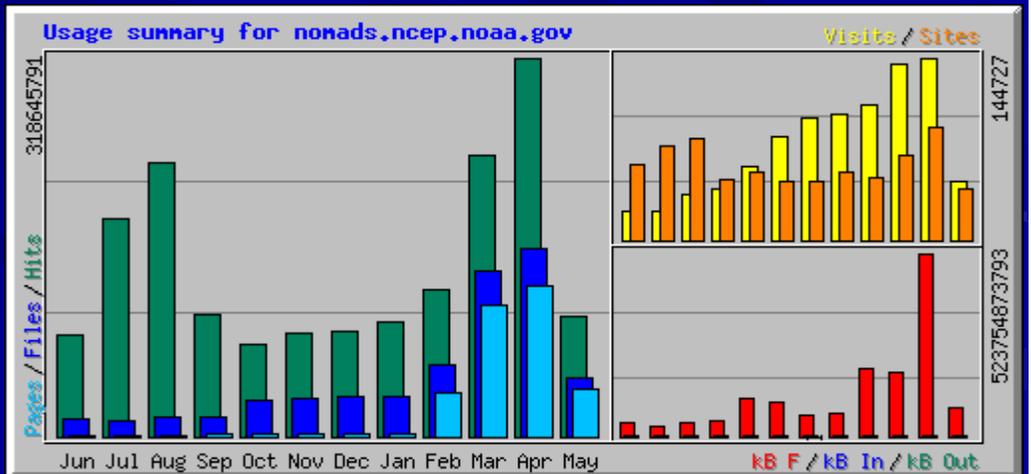
MAX 54M

Usage Statistics for DODS/GDS/OPeNDAP  
nomads.ncep.noaa.gov:9090  
Summary Period: Last 12 Months  
Generated 11-May-2012 09:03 UTC



MAX 318M

Usage Statistics for "Gribfilter"  
nomads.ncep.noaa.gov  
Summary Period: Last 12 Months  
Generated 11-May-2012 09:02 UTC





## *How it is done*

### *Open Source*

- NOMADS participants serve their data sets through a client-server relationship. The data sets have machine and man readable metadata descriptions, GDS/OPeNDAP.
- Display is done by the client.
- Model output files are unpacked, cached and exchange data from many formats using http in response to user queries.
- **This means that server data values can appear to the user or client application as a local file!**



*More details...*

## *Separate files are Aggregated*

- The aggregation of the separate grid binary (GRIB2 or other) model output files, over forecast time and ensemble component, is part of NOMADS
- This means that all the ensemble component files and all the separate forecast files can appear as if they were one dataset
- A 6-Dimensional data cube! Ensemble component, Forecast time, Vertical layer, Latitude, Longitude for each of the many Variables.



## *The GrADS-Data Server GDS/OPeNDAP/DODS*

- NOMADS participants serve their data sets through a client-server relationship. The data sets have machine and man readable metadata descriptions.
- GDS combines both GrADS, a freeware client (from COLA) and DODS (OPeN-DAP) server to unpack, cache and exchange data from many formats using http in response to user queries to create the metadata descriptions from binary files according to control files.
- DODS/OPeNDAP requests are made by many freeware and commercially available high level language clients like GrADS and MATLAB.
- *http queries to the DODS server can create value added products in addition to the basis of scientific work for the public, federal agencies, etc.*



# All NOMADS Holdings have a MetaData Description

GrADS Data Server - info for /gfs/gfs20070517/gfs\_00z : [dds](#) [das](#)

Man or Machine readable

OPeNDAP/DODS Data URL: [http://nomads6.ncdc.noaa.gov:9090/dods/gfs/gfs20070517/gfs\\_00z](http://nomads6.ncdc.noaa.gov:9090/dods/gfs/gfs20070517/gfs_00z)

**Description:** GFS fcst starting from 00Z17may2007, downloaded May 17 04:34 UTC

**Documentation:** (none provided)

**Longitude:** 0°E to 359°E (360 points, avg. res. 1.0°)  
**Latitude:** -90°N to 90°N (181 points, avg. res. 1.0°)  
**Altitude:** 1000 to 10 (26 points, avg. res. 39.6)  
**Time:** 00Z17MAY2007 to 12Z24MAY2007 (61 points, avg. res. 0.125 days)

**Variables:** (total of 139)

- absv** \*\* absolute vorticity [1/s]
- no4lftx** \*\* surface best (4-layer) lifted index [k]
- no5wava** \*\* 5-wave geopot. height anomaly [gpm]
- no5wavh** \*\* 5-wave geopotential height [gpm]
- acpcp** \*\* surface convective precipitation [kg/m^2] (hidden)
- albd0** \*\* surface albedo [%]
- apcp** \*\* surface total precipitation [kg/m^2] (hidden)
- cape** \*\* surface convective avail. pot. energy [j/kg]
- cape180\_0mb** \*\* 180-0 mb above gnd convective avail. pot. energy [j/kg]
- ocfrzr** \*\* surface categorical freezing rain [yes=1;no=0] (hidden)
- ocicep** \*\* surface categorical ice pellets [yes=1;no=0] (hidden)
- cin** \*\* surface convective inhibition [j/kg]
- cin180\_0mb** \*\* 180-0 mb above gnd convective inhibition [j/kg]
- clwmrprs** \*\* cloud water [kg/kg]
- ocprat** \*\* surface convective precip. rate [kg/m^2/s] (hidden)
- ocrain** \*\* surface categorical rain [yes=1;no=0] (hidden)
- ocsnow** \*\* surface categorical snow [yes=1;no=0] (hidden)
- cwacm** \*\* atmos column cloud water [kg/m^2]

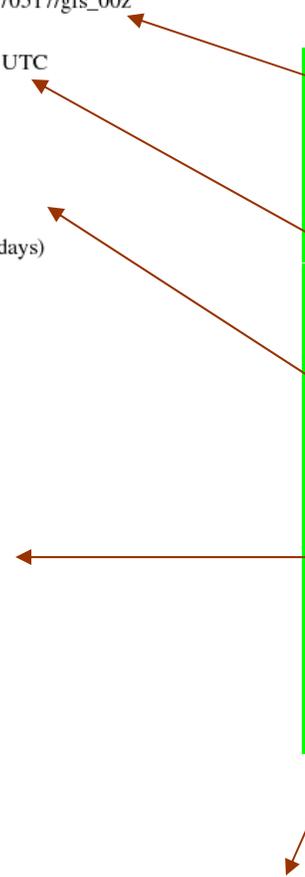
**Data location**

**Description**

**Extent**

**Variables, Units...**

**Geo-spatial**



topoinf  
v5dimpo

ep.tgz



# All NOMADS Holdings have a MetaData Description

Man or Machine readable

GrADS Data Server - info for /gens\_bc/gens20110511/gep\_all\_00z : [dds](#) [das](#)

OPeNDAP/DODS Data URL: [http://nomads.ncep.noaa.gov:9090/dods/gens\\_bc/gens20110511/gep\\_all\\_00z](http://nomads.ncep.noaa.gov:9090/dods/gens_bc/gens20110511/gep_all_00z)

Description:

bias corrected GEFS member fcsts starting from 00Z11may2011, downloaded May 11 05:40 UTC

Documentation:

Longitude:0.0°E to 359.0°E (360 points, avg. res. 1.0°)

Latitude:-90.0°N to 90.0°N (181 points, avg. res. 1.0°)

Altitude:1000.0 to 10.0 (10 points, avg. res. 110.0)

Time:00Z11MAY2011 to 00Z27MAY2011 (65 points, avg. res. 0.25 days)

Ensemble:1 to 21 (21 points) Variables:  
(total of 13)

hgtprs

\*\* (1000 925 850 700 500.. 250 200 100 50 10) geopotential height [gpm]

Data location,  
Description,  
Extent,  
Variables,  
Units...,  
Geo-spatial,



# Using http queries (URLs) to extract data from the GDS server

## Example: Aggregated Global Ensemble data set

...*DODS/OPenDAP/GDS constrained query:*

```
http://nomads.ncep.noaa.gov:9090/dods/gens/gens20110506/gep_all_00z.ascii?tmin2m[0:20][0:21][130:130][255:255]
```

Notice the 5-Dimensional query for each variable (6-D data cube!), e.g, temperature (tmpprs):

<i>j</i> <sup>th</sup> Ensemble component	[0:20]	Lists all 20 Ensemble components at,
Forecast times	[0:21]	1C and every 6-hour interval to 5-days is indicated,
Vertical levels	[1:1]	975Mb indicated, and [0:0] would mean 1000mb,
Latitude,	[129:129]	is measured from SP (0) to NP (for a 1 degree grid)
Longitude,	[243:243]	Beginning at the 0 meridian – we show Baltimore Intl

The ordering of the square bracketed values:

```
[Ens1:Ens2][Fcst1:Fcst2][Level1:Level2][Lat1:Lat2][Lon1:Lon2]
```

Units and other information represented in the metadata description file

A stride is also possible [start:stride:finish] using colon separated values

Use a non-interactive web download program like “wget” or cURL, and place the URL in a cron scheduler using a cgi-bin script to provide user interaction or obtain information for customized data flow.



# Global Ensembles and Event Probability Tools (see Alpert & Wang, 2005, AMS 21 IIPS 17.5)

- NCEP ensembles are constructed from many (20) model integrations by slightly changing the initial conditions.
- Ensembles attempt to span the space of possible forecasts and ensemble members are equally probable forecasts – if not, we can apply a suitable normalization.
- Probability estimates can be defined simply as the percentage of forecasts that satisfy a specified weather event over the total sample space (total number of components).
- We apply this to weather elements like surface temperature, wind speed, or precipitation at a location, at future model forecast times.

The station is: DENVER/STAPLETON\_INTL CO US

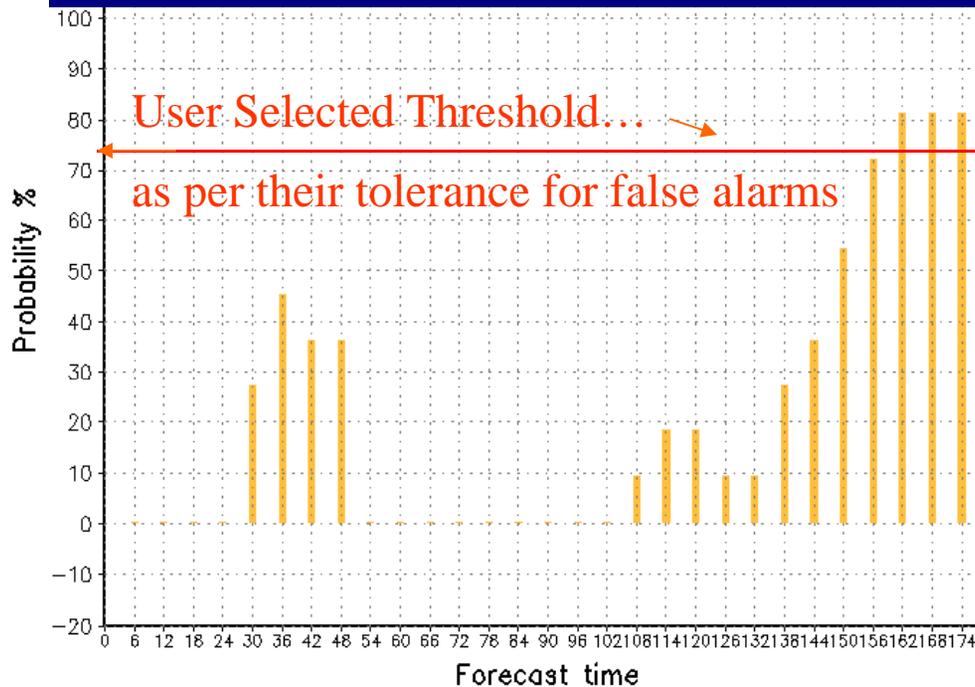
Lat: 39.78 N, Lon:-104.87 W  
FORECAST: 18 Z, oct 15, 2004

Event (Accumulated over the last 6-hrs):  
Temperature, lowest TEMP: lt 32 (273.15 K) -

errcnt=0

*Ensemble probability tool: A web based client application that can be used to provide threshold information to the user. The program obtains the Global Ensemble Forecast information matrix from the server, and returns the information to the user as a display (below) to allow the user to determine a proper threshold of their user defined weather event.*

*The application delivers ensprob program "code" in the form of the returned URL http://:etc... address for the user to repeat the action by copy-pasting it into any browser or...*



User determines their threshold (to tolerate false alarms) for an alert, the application sends an alert to email and cell phone text-message when the threshold is met (next slide).

The user can re-issue this "check for an alert" automatically from a scheduler like cron using a non-interactive web download command like "wget" with the returned URL.

File Edit View Go Bookmarks Tools Window Help

http://nomads6.ncdc.noaa.gov/cgi-bin/var/ensprob\_worldbank3.pl

## Make an Alert of a Weather Event that You Define

TODAY is: 2009, 08, 05  
Please select :

STATION NAME (Select Below) or enter latitude and longitude  
BISHKEK,KYRGYSTAN KZ

STATION Latitude: 74.36 STATION Longitude: 42.52

Date (HR/DD/MM/YY)GMT 09 05 08 09  
Cycle 00z

Create an event (results are shown through a 7 day forecast on 6-hr intervals):

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 highest temperature.

Lowest TEMP: Higher than UNIT: F

Highest TEMP: Higher than UNIT: F

Precipitation  
Higher than 6 mm/day

Wind Speed  
Higher than UNIT: m/sec

EMAIL address jordan.alpert@noaa.gov

EMAIL address (cell phone) 4438128934@vtext.com

Probability threshold 0.5

Click YES to show URL query for ensemble members:

NO  
 YES

Event Probability Reset

Done

Computer  
wd23ja's Ho  
Trash  
untitled fold  
Cover1 (Page)  
chap4.d#8  
Link To Old De  
Google Ear  
PastedTex

Like the Ensprob tool, the user chooses the location from the station list, or enters Lat/Lon and defines the weather event.

A user selects the threshold of probability by their experience of false alarms for an alert, and the application sends an alert to email or cell phone text-message.



# Result from the World Bank Example App

----- Original Message -----  
Subject: ALERT WEATHER EVENT:  
Precip: gt 5 mm/day  
Date: Fri, 31 Jul 2009 16:01:39 -0400  
From: Apache <apache@noaa.gov>

Information and communications technologies (ICT), in particular, high-speed internet connections, content servers, and mobile application services are transforming public service delivery of critical information and democratizing innovation (McNamara, K. S., “Workshop on Mobile Innovations for Social and Economic Transformation”, World Bank, September 16, 2009).

Precip: gt 5 mm/day > 50%, chance @ ft=  
2009 aug 01 18Z  
24 hr fcst



Mobile platforms (cell phones) are emerging as the single most powerful way to extend ICT opportunities and key services to millions of people. Poor access to information and communication is an intangible dimension of rural poverty.

Our goal is to increase smallholder productivity and incomes by reducing uncertainty for variables of interest of agricultural importance. In this case we use forecasts from National Weather Service (NWS) operational Global Forecast System (GFS) global spectral model ensemble to alert agriculture users if and when their selected weather events will occur. The opportunity and challenge is to frame the response as useful and understandable answers to the questions that need to be answered. Verification to identify practical lead times for the economically important variables is a needed first step. (See AGU Poster U21A-0007).



# Future NOMADS

- Including high resolution operational model datasets: Ensembles that are calibrated (bias corrected) and other (NDFD) data sets are implemented into WOC operations

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- BUFR/NetCDF files for Operational Conventional and non-conventional Observations to be served in a similar way to grid fields
- NCEP catalog/aggregation server, **THREEDS/TDS** now running on NCEP development servers
- Continue development with NCDC archives, NCEP real time model data and observations for seamless access of data and to promote useful applications. (CFS(R) and ensemble archives)



# NOMADS Servers for NCEP Model Data

(High availability Servers)

- <http://nomads.ncep.noaa.gov> (Model Data)
- <http://nomads.ncdc.noaa.gov> (Archives)

(NCEP Development)

- <http://nomad1.ncep.noaa.gov> (Data/Applications)
- <http://nomad3.ncep.noaa.gov> (Data/Applications)
- <http://nomad5.ncep.noaa.gov> (Data/Applications)
- <http://nomads6.ncdc.noaa.gov> (Data/Applications)

Global ensemble probability threshold alert to a cell phone text message:

[http://nomads6.ncdc.noaa.gov/cgi-bin/var/ensprob\\_worldbank4.pl](http://nomads6.ncdc.noaa.gov/cgi-bin/var/ensprob_worldbank4.pl)

Global Ensemble probability event display:

<http://nomads.ncdc.noaa.gov/Ensprob>

Rutledge, G.K., J. Alpert, and W. Ebisuzaki, 2006: NOMADS, a climate and weather model archive at the National Oceanic and Atmospheric Administration. *Bulletin of the American Meteorological Society*, 87 (3), 327-341