National Weather Service
Concept of Operations

Gridded Model Output Statistics (MOS) Guidance

Approved: _____ Date:

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Concept of Operations

1. Introduction and Scope:

Executive Summary:

To support the National Digital Forecast Database (NDFD), National Weather Service (NWS) forecasters must produce accurate forecasts on a high-resolution grid in an optimal manner, using guidance available on a grid at a resolution comparable to that used in the Weather Forecast Office (WFO) forecast process. The Meteorological Development Laboratory (MDL) of the NWS's Office of Science and Technology (OST) is proposing the development of a new generation of statistical guidance valid on grids with the resolution of the NDFD. Support for the project has come from the Interactive Forecast Preparation System (IFPS) Science Steering Team (ISST) which acknowledges that the MDL Gridded Model Output Statistics (MOS) activity would eliminate some of the model bias and would improve the centralized guidance.

System Overview and Vision

MDL is proposing to correct this deficiency by generating and dissemination MOS guidance on grids with the resolution of the NDFD, currently set at 5 kilometers (km) over the CONUS. The project objective is to produce the MOS guidance on a high-resolution grid (spacing of 2.5 to 5 km between grid points) with a level of accuracy and skill comparable to that of the station-based MOS guidance.

CONOPS Overview

This Concept of Operations (CONOPS) is the result of a requirement for MDL to provide gridded MOS guidance in gridded formats. This document addresses an issue of significant importance to the WFOs, and seeks new solutions to the problem of making more direct use of MOS in the creation of digital products.

1.1 Identification:

a. Identification

Number: CON-04-009

Originator: Kathryn Hughes, W/OST22, 301 713-0023 x130

Reference: SON-04-009, Gridded Model Output Statistics (MOS) Guidance, final version submitted to OCWWS on 10/12/2004

b. Sponsors

MDL will be responsible for the development, implementation and maintenance of the gridded MOS system. Coordination with the National Center for Environmental Prediction (NCEP), the Office of Operational Systems (OOS), the Office of the Chief Information Officer (OCIO) and the staff at the AWIPS Network Control Facility (NCF) is required, since this system will run centrally on the NWS Central Computing System and be sent to the NWS Telecommunications Gateway, which is managed by the OCIO for transmission to the users. The primary NWS users of the gridded MOS guidance will be the WFO and NCEP forecasters.

2. The Current System

2.1 Background:

For years, NWS forecasters have used the Model Output Statistics (MOS) guidance as an aid in producing the text forecast products that are issued to the user community. The MOS guidance provides an objective interpretation of the underlying numerical weather prediction (NWP) model in terms of the weather elements that the NWS forecaster needs to include in many of the daily products. This objective interpretation removes the systematic bias of the NWP model, provides probabilistic estimates for the occurrence of certain weather elements, calibrates the station-specific guidance to the observations, enhances the NWP model forecast by the use of additional forecast variables, and tends toward mean conditions as uncertainty in the model solution increases

2.2 Operational Policies and Constraints:

The existing station, or point-based, MOS guidance products were sufficient to support traditional text-based products issued by forecasters at the WFOs. However, the NWS is changing its approach. The NWS goal is to provide customers and partners with a seamless set of digital forecast weather fields for the entire nation (See NWSI 10-506). Offices now produce quantitative forecasts of every required weather element on grids of 5 km resolution or finer, covering their entire County Warning Area (CWA). Grids from each office are combined into the NDFD to provide full gridded coverage for the entire country.

Despite this new approach, MOS guidance still only provides predictions for specific points. NWS forecasters could make more direct use of MOS in their creation of digital products, if the MOS guidance was available on a grid.

2.3 Description of the Current System or Situation:

Forecasters currently have direct model output from NCEP numerical models, and other higher resolution local models, most available at a coarser resolution than desired. Statistical guidance adds value to the direct model output by objectively interpreting the

model, and predicting needed sensible weather elements not available in raw model output. The current station-based MOS guidance is based on output from several NWS numerical models.

The MOS guidance is produced in the NCEP job stream as part of the model post-processing. The output is disseminated to public and private forecasters using existing NWS dissemination systems. The current MOS guidance system is available for approximately 1700 traditional hourly observation stations, and another 6000 limited observing sites in the contiguous United States, Alaska, Hawaii, and Puerto Rico. Most frequently, the MOS guidance is valid for specific observing sites, and the vast majority of the current MOS guidance is issued in text or binary format for specific sites. The use of remote sensing data as a source of observations allows the MOS approach to be modified, since the observations, being random in space and time, are usually projected onto a grid of regularly spaced points for a specific interval of time. With this approach, the guidance (for example, for the probability of thunderstorms) is valid for a grid of some pre-specified resolution.

2.4 Users of the System:

Forecasters at the NWS forecast offices and NCEP centers provide the primary class of users that interact with the current MOS guidance. This interaction occurs via the AWIPS and N-AWIPS systems, respectively.

Until recently, the primary forecast generated by NWS offices was a descriptive text product called the Zone Forecast Product (ZFP). This forecast normally was broken into several pieces by geographical area to account for variations in weather across an office's CWA. Offices also produced a quantitative forecast of precipitation probability and high and low temperatures for just a few specific points in their CWA. This product, called the Coded Cities Forecast (CCF), provided the numbers used for forecast verification purposes. Under this system, a forecast for one specific point was used to represent the expected weather for a broad area.

Forecasters at NCEP's Hydrometeorological Prediction Center (HPC) currently use station-based MOS forecasts of maximum and minimum temperature (max/min), and the probability of precipitation, as the starting point for their medium-range (days 4-7) forecasts of these parameters for about 380 locations in the U.S. Newer requirements at the WFOs have led to HPC producing forecasts on a 5 km grid. The station-based MOS forecasts are combined with digital climate data sets from the PRISM (Parameter-elevation Regressions on Independent Slope Models) program to help produce a detailed 5 km grid for maximum, minimum and dew point temperatures.

2.5 Support Environment:

MDL is responsible for the development, implementation, and maintenance the current MOS guidance system on the NWS Central Computing System. Support is

currently provided by NCEP, OOS, and OCIO/TOC for the operations and dissemination of the current MOS system. MOS guidance is available as text products, Redbook graphics, and BUFR and GRIB messages which are decoded and stored in the appropriate databases.

3. Justification For and Nature of Changes

It is of paramount importance that forecasters be given the highest quality model grids used to populate the official forecast grids. It is recognized that statistical post-processing techniques provide significant improvement in forecast quality over a simple use of the raw direct model output. A need exists to provide statistically-based forecasts in gridded form, while also incorporating probabilistic information into the forecast grids. For more documentation, see "SOO/DOH IFPS Whitepaper Implementation: Requirements and Approaches, A Report on the 2003 WR SOO/DOH Workshop."

3.1 Justification for Changes:

a. User Needs:

NWS products and services are evolving to enable the production of a seamless suite of digital forecast data. In support of this mission, MDL is proposing the development of a new generation of statistical guidance valid on grids with the resolution of the NDFD.

b. Deficiencies of Current System:

At the NWS forecast offices, the Graphical Forecast Editor (GFE) software that is used for editing grids, forecasters have a tool which uses interpolation to project MOS point data onto a grid. The drawbacks to this approach are numerous. To begin with, the statistically generated point forecasts may not be representative of the area between the points. For example, MOS would account for local urban heating effects that might not apply to areas outside a city. Also, the GFE tool reverts to raw model output at grid points far from any MOS location. This produces considerable noise in the grid fields. Finally, the interpolation routine does not account for terrain effects, which may be quite significant.

Additional 5 km gridded guidance produced by HPC including sky cover, wind speed/direction and weather type currently do not utilize MOS because there is no known method to derive a high resolution grid of these parameters from MOS. Gridded MOS has been targeted by HPC as a preferred starting point to its medium range forecast process. HPC would not have to post-process the MOS station data with PRISM to generate the max/min and dew point grids. Furthermore, HPC would be able to utilize a statistically corrected output grid at a resolution comparable with operationally produced grids requested by the WFOs for additional parameters (pop/sky cover/weather type/wind) – and at a higher temporal resolution than currently produced.

3.2 Description of Desired Changes*:*

- Generate and disseminate MOS guidance on 5 km or higher resolution grids
- Guidance based on GFS model output
- Updated two times daily (0000 and 1200 UTC)
- Forecast projections out to 192 hours in advance
- Available in GRIB2 format
- Initial forecast elements: max/min temperature, 2-m temperature, dew point, probability of precipitation, precipitation amount and type, wind direction and speed, thunderstorms, sky cover, snowfall amount

See Section 4 for more details

3.3 Priorities Among Changes

The priority of the proposed system is to meet the needs of the operational forecaster, by creating guidance on grids for the required forecast fields in the NDFD grid production. These forecast elements are specified in the table portion of NWSI 10-506. Digital Data Products/Services Specification. this can be found at http://weather.gov/directive/010/pd01005006a.pdf Some of them have been described below in Section 4.

4. Description of the Proposed System

4.1 Background, Objectives, and Scope:

As part of the NWS modernization, the methods that the forecasters use to generate the standard forecast products have changed. In addition, the products themselves have been modified, and new products have been added to the daily workload. To facilitate the forecast process, the forecasters use the IFPS to prepare a digital database of gridded data from which official and experimental products are generated. The IFPS Graphical Forecast Editor (GFE) provides the forecasters with tools to edit grids and thus to prepare the gridded forecast database. Initially, algorithms within IFPS projected the MOS guidance onto a grid, and this gridded rendition of the MOS guidance provided the forecasters with a first guess for the digital database. However, this grid lacked the spatial resolution needed by the NWS forecasters. Consequently, the forecasters are not able to use the MOS guidance effectively and so must spend time manipulating direct model output grids or introducing detail into the MOS grids. In either case, the forecasters are hindered in their mission to provide an accurate, timely digital database to NWS customers and partners.

MDL is proposing to correct this deficiency by generating and disseminating MOS guidance on grids with the resolution of the NDFD, currently set at 5 km over the CONUS. The project objective is to produce the MOS guidance on a high-resolution grid (spacing of 2.5 to 5 km between grid points) with a level of accuracy and skill comparable to that of the station-oriented MOS guidance. Support for the project has come from the ISST which acknowledged that the MDL gridded MOS activity would eliminate some of the model bias and would improve the centralized guidance. The initial implementation of gridded MOS products will focus on grids for the CONUS, with grids for Alaska to follow approximately 1 year later. Grids for Hawaii and the western Pacific will follow in subsequent years as the methodology for producing the grids matures.

The MOS gridded guidance will be based on output from the NWS Global Forecast System (GFS) model. Initial plans are to produce grids for maximum/minimum (max/min) temperature, 2-m temperature and dew point, probability of precipitation (PoP), precipitation amount and type, wind direction and speed, thunderstorms, sky cover and snowfall amount for appropriate forecast projections out to 192 hours after the initial model times of 0000 and 1200 UTC. The grids should be sufficient to support the NWS forecaster in producing the required temperature, relative humidity, wind, sky cover, precipitation, and weather grids at the local office. In subsequent years, gridded guidance will also be generated from the 0600 and 1800 UTC forecast cycles.

Like the station-oriented MOS guidance, the gridded MOS guidance will be produced in the NCEP job stream as part of the GFS model post-processing. The grids will be put into GRIB2 format and will be transmitted on the SBN to AWIPS. At the local WFO, the gridded MOS products will need to be decoded and stored in NetCDF files for further processing.

4.2 Modes of Operation:

The gridded MOS guidance will be run on regular schedule in the NCEP job stream, updated twice a day for 0000 and 1200 UTC cycles. In this environment, production of the guidance is monitored to ensure that the grids are produced in a timely manner at the NCEP Central Computer System. Except in the event of a model or communications failure, the grids will be available daily. In the event of a scheduled back-up test at NCEP, no provision is currently available to generate the GFS-based MOS guidance. However, once back-up operations are established, the gridded MOS guidance should be reliably available to the WFO's.

Since the gridded MOS guidance is available for the CONUS, if a WFO is in degraded status and another WFO is providing service back-up, gridded MOS guidance must be available to initialize forecast grids for a larger area, which includes the service back-up area of responsibilities. The availability of data over a larger area depends, of course, on decoding and storing the guidance over that larger area.

The gridded MOS guidance will be transmitted in GRIB2 format with WMO headers on the SBN to private-sector users as well as the WFO's. Operational modes for this class of users will be identical to those for the NWS.

4.3 User Classes and/or Other Involved Personnel

WFO and NCEP forecasters provide the primary class of users that will interact with the gridded MOS guidance. This interaction will occur via the AWIPS and N-AWIPS systems, respectively. Thus, the MOS grids must be decoded and stored in the appropriate databases. Visualization of the MOS grids is important, and so the entire grid should be viewable. However, the WFO forecasters will need to interact with the gridded MOS binary data over the WFO area of responsibility, and any service backup responsibilities. The gridded MOS data must be extracted for this area and stored so that the GFE process can be used to interact with and modify the MOS grids. The NCEP forecaster has responsibility for a much larger area, and so interaction with the entire grid must be feasible in N-AWIPS.

4.4 Support Environment:

MDL will be responsible for developing, implementing, and maintaining the gridded MOS system on the NWS Central Computing System. As part of this responsibility, MDL will need to coordinate closely with NCEP's NCO and will require sufficient computing cycles and storage resources to generate the guidance. The guidance will be transmitted using existing NWS dissemination systems, so the efforts of OCIO support staff and the NCF will be required to establish transmission headers and monitor the daily products. Since the guidance will be stored at local WFO's, maintenance of the proper GRIB2 decoders, creation and maintenance of a gridded MOS database, and support of the software that interacts with the gridded MOS products will be required. See Appendix A for a flow diagram which demonstrates the pathways from the central computing system to the users.

5. Operational Scenarios:

National Weather Service Forecast Office Scenario:

When assembling a set of forecast grids at a WFO, NWS meteorologists would use gridded MOS data in much the same way they use grids from numerical models. A forecaster would begin by assessing the quality of gridded MOS guidance relative to guidance from other sources. The sources determined to be most reliable could be used to populate the initial gridded datasets automatically, or the forecaster could simply refer to these sources while manually adjusting the forecast grids. For certain forecast elements, the gridded MOS dataset may reflect unique local effects not captured by numerical models. Even without populating the entire dataset with gridded MOS guidance, the forecaster could use gridded MOS to incorporate these local effects into the forecast grids.

NCEP Center Scenario (HPC example)

HPC medium-range forecasters edit 380 sites, CONUS-wide for selected parameters (max/min temperature, 12h probability of precipitation) and derive a wind field from its forecast of pmsl. Five km grids of these parameters; dew point, sky cover, and precipitation type, are derived by applying the differences between HPC and MOS forecasts over the entire 5 km MOS grid. The resultant 5 km grid is then transmitted to the WFOs as guidance.

HPC will rely heavily on the climatology information found in the PRISM data, developed by Oregon State University, until gridded MOS becomes available. For more information on HPC's current process see http://www.hpc.ncep.noaa.gov/5km_grids/5km_gridsbody.html .)

6. Summary of Impacts

No hardware changes are required. Possible software changes are expected, as tools are developed to ingest and manipulate the MOS grids. Documentation of the gridded MOS system will be provided to the users upon its completion.

6.1 Operational Impacts:

The gridded MOS guidance will provide a skillful first-guess field to the forecasters preparing NDFD grids. This will have a positive impact by reducing the time and effort the forecasters spend initializing the grids.

6.2 Organizational Impacts

There are no perceived organizational changes

6.3 Impacts During Development

No additional resources have been given to the group responsible for the MOS guidance; therefore significant enhancements to the traditional station-based MOS products are not likely during this time of development.

6.4 Impacts During Transition to Proposed System

An increase in workload is possible while the forecasters are becoming familiar the new gridded guidance.

7. Analysis of the Proposed System

A key Weather and Water Mission Goal outcome is to provide: "Better, quicker, and more valuable weather and water information to support improved decisions. "The

provision of improved, higher resolution central guidance to initialize weather element forecasts on a 5 km grid will provide NWS forecasters with the ability to provide a nationwide forecast with improved geographic detail in a more accessible and adaptable gridded format to our customers and partners. The NWS Strategic Plan mentions that "tomorrow's products will further evolve into improved digital formats, which can better communicate the details of NWS forecasts. "Gridded MOS directly contributes to this objective.

A proposed Corporate Performance Measures to be considered for the FY08 budget is the improvement of customer satisfaction with Weather and Water products and services. Providing this guidance on a grid, in a digital format will increase the application and accessibility of weather and water information as the foundation for creating and leveraging public, private and academic partnerships.

7.1 Summary of Improvements:

- MOS guidance generated and disseminated on 5 km or higher resolution grids
- GRIB2 products will provide the guidance in a digital format.
- Increased resolution will provide more geographic detail than the current guidance system. See Appendix B for a comparison.
- Statistical post-processing of the direct model output will improve the quality of the model output, and reduce the amount of time forecasters spend on manual editing.
- MOS guidance will be more consistent with NDFD grid production requirements

7.2 Disadvantages and Limitations

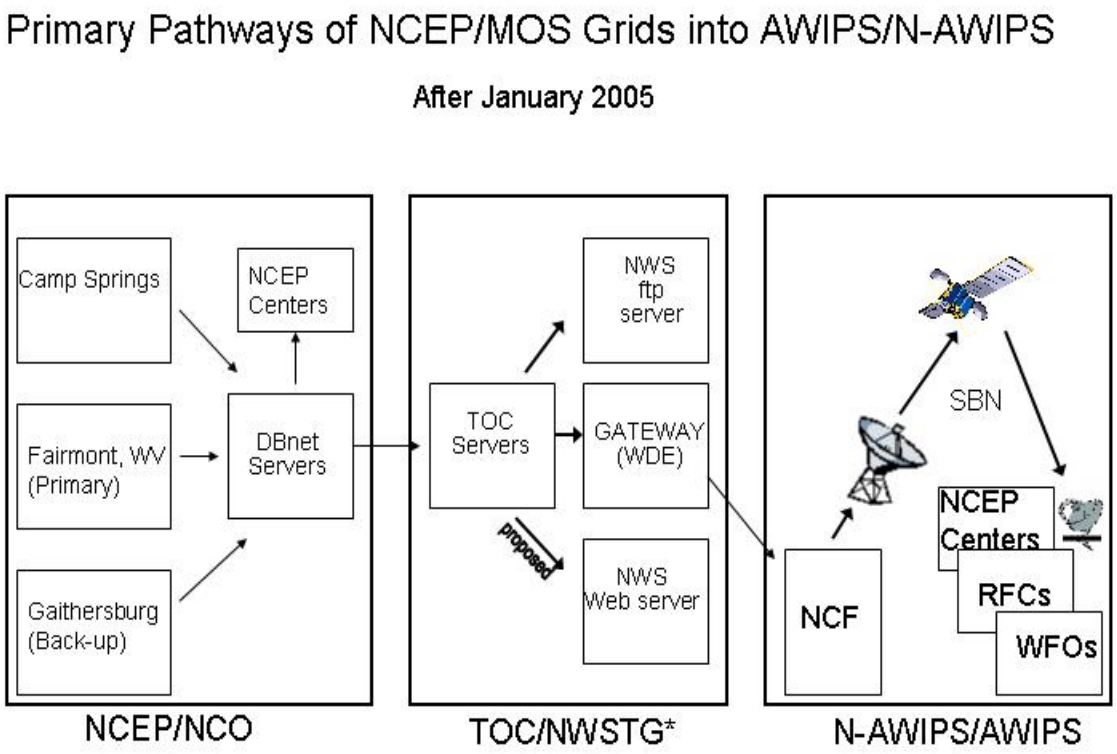
This system is a proposed solution to a known deficiency in the NWS process used to initialize the grids for NDFD. There are no known disadvantages in providing additional guidance.

7.3 Alternatives and Trade-offs Considered

NCEP is providing daily experimental runs of the Downscaled GFS/Extended Eta (DGEX). It provides NWS forecast offices with first guess fields for NDFD, and reduces the effort required for the forecaster to create 8-day forecast grids with IFPS. However this was meant to be a temporary solution. It is computationally expensive to run, and doesn't contain the most recent NWP guidance. For instance, the 1200 UTC products are based on 0600 UTC output. In addition it is getting mixed reviews from the users. For example, HPC does not typically favor DGEX over the GFS UNLESS its solution is GFS-like AND the GFS solution is preferred. Although the DGEX synoptic signal is over all inferior to the GFS, it was noted that the DGEX did not suffer from dramatic gridscale feedback like the GFS.

Appendix A

Gridded MOS CONOPS



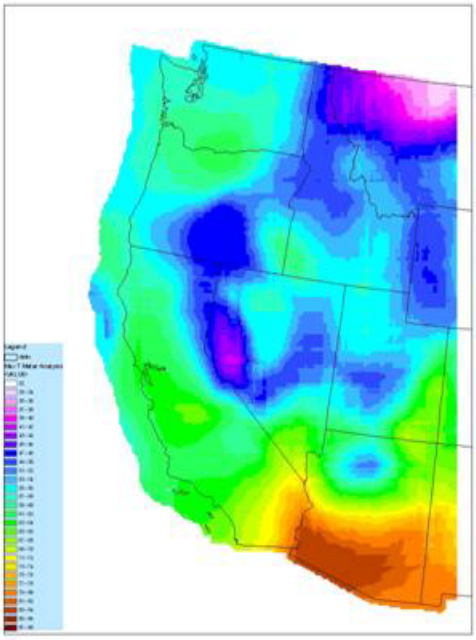
Slide A

Appendix B

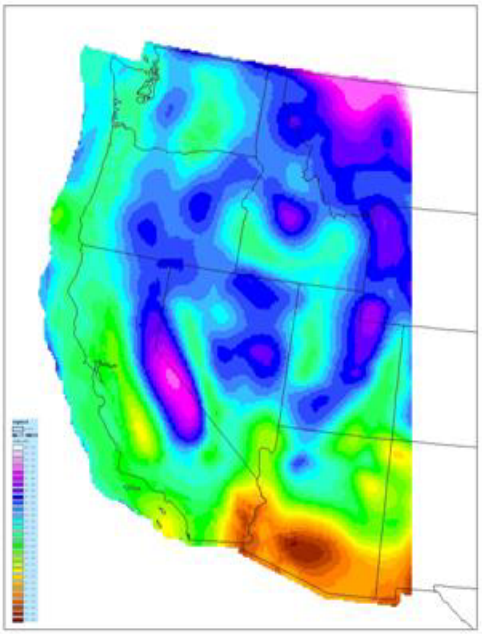
Gridded MOS CONOPS

MOS daytime max guidance valid

October 20, 2004



Traditional MOS sites analyzed on a grid

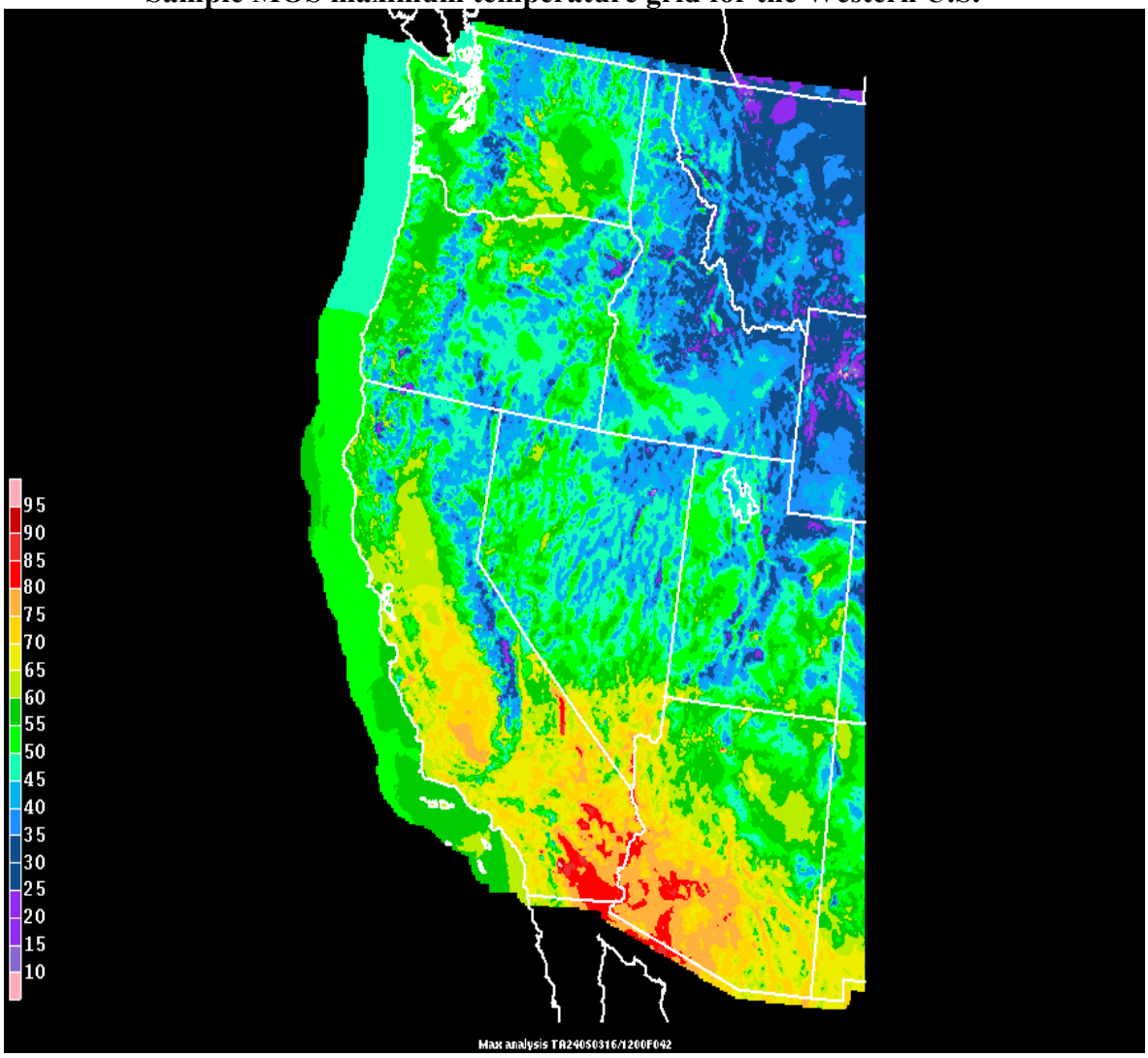


Gridded MOS

Appendix C

Gridded MOS CONOPS

Sample MOS maximum temperature grid for the Western U.S.



See http://www.mdl.nws.noaa.gov/~smb/gmos/ for more examples