NATIONAL WEATHER SERVICE
OPERATIONS AND SERVICES IMPROVEMENT PROCESS

PROGRAM PLAN

Gridded Model Output Statistics (MOS) Guidance

Prepared by:

National Oceanic and Atmospheric Administration
National Weather Service
Office of Science and Technology
Meteorological Development Laboratory
1325 East West Highway
Silver Spring, MD 20910

Revision History

Date	Version	Description	Author
07/1/2005	1.0	First Version	JPD
07/22/2005	1.1	Revised, per comments from IWT	JPD
02/01/2006	1.2	Revised, per comments from Stage 2 OSIP Review	JPD
02/17/2006	1.3	Added Executive Summary for Stage 3 reviewers	KKH
03/20/2006	1.4	Modified thunderstorm tgftp file names in appendix C	KKH
07/27/2006	1.5	Updated schedule and milestone dates, and revised Sections 4 and 5 in preparation for Gate 4 meetings.	KKH

TABLE OF CONTENTS

6. Appendices

Gridded Model Output Statistics

Executive Summary: MOS guidance provides an objective interpretation of the underlying numerical weather prediction model in terms of weather elements the NWS forecast must include in many of the daily products. This plan documents the research, development, implementation, and deployment of MOS guidance on grids with the resolution of the National Digital Forecast Database. In preparation for Gate 4 review, Sections 4 and 5 (pp. 14-20) have been updated with our latest achievements, milestones, and details regarding assessments and verification. A PowerPoint presentation is available to the reviewers containing the Stage 4 checklist, information requested in the Deployment Decision document; and the Deployment, Assessment, and Lifecycle Support Plan.

Implementation Strategy: In preparation for Stage 5 – Successful completion of IOC

- Successful testing of product flow across the TNCF, receipt at testbed, and analysis of data completed and confirmed by Raytheon July 2006
- CONUS grids containing temperature, dew point, relative humidity, Tmax, Tmin, wind speed, wind direction, probability of precipitation, and thunderstorm probabilities flowing through the SBN August 15, 2006
- **Initial Operating Capability (IOC) expected by September 2006**
- Available in AWIPS 7.1, System Verification Review (SVR) by September 08, 2006
- Usable for grid initialization in AWIPS 7.1 SVR by September 08, 2006

Implementation Strategy: Final Operating Capability (FOC), April 2009

- Grids cover CONUS and OCONUS areas
- All grids are populated (18 weather elements)
- Operational data stream
- Available in AWIPS
- Usable for grid initialization

Implementation Strategy: In Preparation for OCONUS grids

- Initial grids over Alaska are deployed – Tmax, Tmin, temperature, dew point, relative humidity, wind speed and direction, precipitation type, snowfall amount, thunderstorms, and probability of precipitation, September 2007
- Deploy grids for wind gusts, precipitation amount and sky cover over Alaska, April 2008
- Initial grids over Hawaii and Puerto Rico are deployed – – Tmax, Tmin, temperature, dew point, relative humidity, wind speed and direction, and probability of precipitation, September 2008
- Deploy grids for wind gusts, precipitation amount and sky cover over Hawaii and Puerto Rico, April 2009

1. Introduction

1.a Document Overview

This project plan contains five sections and four appendicesappendices with additional technical details. The first section places the development and deployment of gridded Model Output Statistics guidance into the context of the NOAA and NWS vision for future weather services. Section 2 describes the meteorological research that is required for the development of a gridded statistical guidance system. Section 3 provides details about the necessary analysis prior to development and deployment. This section attempts to cover as many of the analysis functions as known by the authors of this document. With such a broad approach, organizational components of the Office of Science and Technology (OST), National Centers for Environmental Prediction (NCEP), Office of the Chief Information Officer (OCIO), NWS Western Region Headquarters, and the Office of Atmospheric Research (OAR) are all potentially affected. Section 4 describes the developmental efforts needed to produce a fully functional gridded guidance system, and Section 5 summarizes resources for deployment, maintenance, and product improvement. Because of the diversity of the organizations involved in this effort, the authors were unable to address all resource issues completely. In those instances, we have tried to indicate portions of the plan that may need revision as the gridded MOS project moves through the approval process.

1.b Statement of Need

For years, NWS forecasters have used the Model Output Statistics (MOS) guidance as an aid in producing text forecast products issued to the user community. The MOS guidance provides an objective interpretation of the underlying numerical weather prediction (NWP) model in terms of weather elements that the NWS forecaster must include in many of the daily products. This objective interpretation removes some of the systematic bias of the NWP model, provides probabilistic estimates for the occurrence of certain weather elements, tunes 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. Use of the MOS approach requires an historical sample of observations and coincident NWP model forecasts. 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 this approach to be modified, since the remote sensing data, 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, MOS guidance (for example, the probability of thunderstorms) is valid for a grid of some pre-specified resolution.

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 Interactive Forecast Preparation System (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. Algorithms within IFPS project the MOS guidance onto a grid, and this gridded rendition of the MOS guidance provides the forecasters with a first guess for the digital database. However, this grid lacks 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.

OST's Meteorological Development Laboratory (MDL) is proposing to correct this deficiency by generating and disseminating MOS guidance on grids with the resolution of the National Digital Forecast Database (NDFD), currently set at 5 km over the contiguous United States (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 comparable to that of the station-oriented MOS guidance. The initial implementation of gridded MOS products will focus on grids for the CONUS, with grids for Alaska to follow 1 - 2 years later. Grids for Hawaii and Puerto Rico will follow in subsequent years as the methodology for producing the grids matures. Development of grids for the western Pacific is not addressed in the plan because of a recommendation made by the Pacific Region Headquarters.

1.c Objectives

The objective of the program is to produce MOS guidance on a high-resolution grid, initially with a spacing of 5 km between grid points. The guidance is to be created at the NOAA Central Computing System (NCCS), packed into GRIB2 format, and transmitted on the SBN to the local WFOs. The GRIB2 data are also to be stored on the NWS ftp server. At the WFOs, the data are to be decoded and stored in netCDF files for possible use by the forecasters in producing local forecast grids. The local forecasters may choose to view the gridded MOS or they may choose to ingest the data into the IFPS GFE as a means of initializing the local grids. The data are also to be made available to NCEP's Hydrometeorological Prediction Center (HPC) for consideration in generating the HPC guidance grids.

Initial plans are to produce guidance grids for maximum and minimum (max/min) temperature, 2-m temperature, 2-m dew point, 2-m relative humidity, wind direction, wind speed and gusts, probability of precipitation, precipitation amount and type, probability of thunderstorms, sky cover, and snowfall amount. These grids will be made available twice daily, from the 0000 and 1200 UTC runs of the Global Forecast System (GFS) model, and will provide guidance out to 7 days in advance for many of the elements.

1.d Relation to NOAA/NWS Strategic Plan

The work described in this program plan is designed to support two objectives in the NOAA strategic plan (see http://www.spo.noaa.gov/). In particular, MOS guidance provided to the forecasters will help to increase the lead time and accuracy for weather and water warnings and forecasts, as well as assist in reducing weather related transportation crashes and delays. In the NWS strategic plan (see http://www.nws.noaa.gov/sp/), statistical forecast models such as MOS are required to "improve the reliability, lead-time, and understanding of weather and water information and services." Efforts such as the development, implementation, and dissemination of MOS grids will also serve to "develop and infuse research results and new technologies more efficiently to improve products and services, to streamline dissemination, and to communicate vital information more effectively. Finally, guidance provided by the high-resolution MOS grids should help to "increase the capabilities, efficiencies, and accuracy of transportation-related products and services" and "support decisions on aviation, marine, and surface navigation efficiencies."

1.e Relation to NOAA Mission Goals

The scientific research, development, and evaluation required to support the gridded

MOS guidance is done within the Statistical Modeling and Evaluation Branches of the Meteorological Development Laboratory, OST. The MOS development is part of the NOAA mission goal team for Weather and Water, and is located within the Environmental Modeling Program.

2. Research

2.a Description

The MOS approach is a well-documented, frequently-used approach for the objective interpretation of NWP model output. For over 30 years, NWS forecasters have had access to MOS guidance based on the output of a succession of NWP models run within the NWS. In general, the forecasters could choose to use or ignore the guidance. A number of verification studies have shown that the forecasters improved upon the MOS guidance for certain weather elements, particularly in highly unusual weather events. For many weather elements, both the human forecaster and the MOS guidance had comparable levels of skill. In almost all cases, with the exception of thunderstorm probabilities, the MOS guidance was valid for specific observing sites, and the essence of the MOS approach was to correlate observations at specific sites with model forecasts interpolated to those sites. The requirement for guidance on a 5-km grid, however, challenges the traditional MOS approach since observations are normally unavailable at such a high spatial resolution. The research done for this program will determine if the MOS approach or an adaptation of it can produce guidance grids with the detail and accuracy that the forecaster needs to initialize more efficiently the local digital database. The objective of the research and development is to produce gridded MOS guidance with accuracy comparable to that of the station-oriented guidance. Observations from both mesonet systems and remote-sensing platforms will be incorporated into the MOS system, and a tailored analysis system will be developed to blend the station-specific information with high-resolution geophysical and climatic data to create guidance grids. The meteorological and statistical research will be done by staff of the Statistical Modeling Branch of MDL/OST. Necessary software development will be done at MDL facilities or via remote access to the NCCS.

For more detailed explanations of the MOS approach used to generate the gridded guidance, please consult the following:

http://www.nws.noaa.gov/mdl/synop/amspapers/dallavalle2005AMS_13B2.pdf
http://www.nws.noaa.gov/mdl/synop/amspapers/sheets2005AMS_13B1.pdf
http://www.nws.noaa.gov/mdl/synop/amspapers/glahn2006AMS_2.1.pdf

2.b Roles and Responsibilities

Members of the Statistical Modeling Branch of MDL/OST (W/OST22) are responsible for research and the necessary software to do that research. Members of the Interactive Forecast Preparation System Science Steering Team (ISST) and the Western Region Scientific Services Division are available for informal consultation on meteorological issues, particularly over areas of complex terrain.

2.c Work and Budget Breakdown

The fully-staffed Statistical Modeling Branch contains 11 full-time equivalent federal employees, and 1 contractor. Costs for the Branch are approximately $1.1 million annually, and are obtained via the NOAA planning, programming, and budget execution process.

Work tasks include the following:

- Coordination with NCEP for use of necessary resources on the NCCS
- Acquisition, quality control, and preparation of observational datasets
- Preparation of required NWP model output datasets
- Development of appropriate MOS forecast test equations
- Testing and evaluation of forecasts from test equations
- Redevelopment of MOS operational equations
- Implementation of MOS operational equations in the NCCS parallel system
- Preparation of appropriate post-processing software to check MOS forecasts for meteorological consistency and/or to compute additional variables
- Development and testing of appropriate analysis/downscaling techniques
- Evaluation by ISST or other NWS forecasters of gridded guidance
- Modification of process used to create gridded guidance
- Reimplementation of enhanced process used to generate guidance

These tasks may be required multiple times, according to the geographical area covered by the grids, as well as the weather elements for which the guidance is valid.

2.d Acquisition Strategy

Budget resources are obtained via the normal NOAA budgeting process. The Statistical Modeling Branch is funded through the NOAA Weather and Water Goal Team, Environmental Modeling Program. The contractor employee is hired through the NWS task order contract with RSIS.

2.e Performance Measures and Success Criteria

Standard verification procedures will be used to evaluate objectively the quality of the gridded products. In particular, the values from selected grids will be interpolated to specific observing sites and then will be compared to both the station-specific MOS guidance at that point as well as the operational NDFD forecast. While the gridded MOS guidance interpolated from grids back to stations will be less accurate than the original station-specific MOS guidance, both sets of MOS guidance should be of approximately the same accuracy as the NDFD forecasts.

Point verification does not address the quality or usefulness of the grids, particularly for locations between observing sites. An initial and important component of the gridded verification will be a subjective evaluation of grid quality and usefulness to be carried out by members of the ISST, HPC forecasters, and WFO forecasters. Another approach is to verify the gridded guidance against an analysis of a particular weather element like temperature or dewpoint. This “analysis of record” (AOR) would have the spatial resolution of the NDFD and would provide accurate detail between the normal observing sites. Unfortunately, such an AOR does not currently exist. NCEP has initiated an effort (see OSIP Analysis of Record (AOR) Concept of Operations and Operational Requirements) to do a Real-Time Mesoscale Analysis (RTMA) which would have some of the characteristics of the AOR. Until these high-resolution analyses are available, however, MDL’s efforts at gridded verification focus on obtaining some of the Rapid Update Cycle

(RUC) analyses and downscaling them via linear interpolation to the NDFD grid. The gridded verifications resulting from this approach will compare the gridded MOS products, the NDFD grids, and the HPC grids.

Success for this effort will be established by the accuracy measures as well as by the subjective evaluation of the representatives of the user community.

2.f Schedules and Milestones

March 31, 2005 – Develop techniques to produce prototype gridded products for the western U.S. that contain temperature and dewpoint guidance
September 30, 2005 – Obtain historical mesonet data from the Forecast System Laboratory's Meteorological Assimilation Data Ingest System (MADIS) to be used in MOS development for the CONUS
October 31, 2005 – Establish quality-controlled archive of MADIS data for selected networks over the CONUS
December 31, 2005 – Develop and test experimental temperature, dew point, wind direction, wind speed, probability of precipitation, and probability of precipitation amount forecast equations for CONUS
April 30, 2006 – Develop and test prototype high-resolution gridded thunderstorm probability guidance system for Alaska
June 30, 2006 – Complete processing of high-resolution precipitation estimates over the CONUS for use in developmental MOS system
August 31, 2006 – Develop and test experimental precipitation type forecast equations
December 31, 2006 – Develop and test prototype high-resolution precipitation amount forecast system for a test area in the CONUS
March 31, 2007 – Complete processing of high-resolution satellite-based cloud estimates over the CONUS; obtain and process 1-h precipitation amount data from Stage II radar estimates for use in a precipitation occurrence/intensity forecast system
April 30, 2007 – Develop and test methods for producing prototype gridded products over Alaska that contain temperature, dewpoint, and wind guidance
June 30, 2007 – Develop and test high-resolution cloud forecast system over the CONUS
July 31, 2007 – Expand prototype high-resolution precipitation amount forecast system to CONUS
September 30, 2007 – Develop and test algorithms for generating high-resolution 6-h snowfall prediction system from available 24-h snowfall, hourly precipitation type, and 6-h quantitative precipitation amount guidance
September 30, 2007 – Develop and test methods for producing gridded products over Alaska that forecast clouds and precipitation
April 30, 2008 - Develop and test methods for producing prototype gridded products over Hawaii and Puerto Rico that contain temperature, dewpoint, and wind guidance
September 30, 2008 – Develop and test methods for producing gridded products over Hawaii and Puerto Rico that forecast clouds and precipitation

2.g Assumptions and Constraints

The schedule shown above assumes that the Statistical Modeling Branch is staffed with its full complement of federal employees and contractors. At this time, all employees in the Branch, except for two, are working on the gridded MOS development. The other two employees are supporting MOS development for the western Pacific and/or supporting general OST functions. In fact, because of funding difficulties within the NWS, the Branch is currently not staffed fully, lacking two full-time employees, a student, and two contractors formerly working within the Branch. If the shortage of staffing continues for long, deadlines will not be met. We've also assumed that the NWS requires gridded MOS guidance from two forecast cycles (0000 and 1200 UTC) for projections of 1 to 7 days in advance. If this requirement is inaccurate, then staffing resources within the Branch may be inadequate.

This plan assumes that adequate computer resources are available to do this work. Computer resources include resources available through the NCCS, local personal computers, and ARCINFO software. In general, the NCCS has always provided adequate resources for MOS development; that support must continue. OST provides funding for local personal computers and software.

2.h Risk Assessment and Mitigation

The MOS approach itself is a highly developed technique that has been shown to produce good guidance at observation sites. The development of MOS is a very low risk process. However, the application of MOS at mesonet sites or by using remote-sensing data is somewhat more problematical because of the quality of the observational data. MDL, however, completed a risk-reduction effort by ingesting mesowest data and creating the gridded prototype MOS products for the western U. S. MDL also has some experience with using remote-sensing data in development of thunderstorm probability equations. Thus, MDL recognizes the need for extensive quality control of all new observational datasets. This data processing is a time-consuming task; additional human resources and appropriate GIS techniques will be applied to mitigate the risk of schedule delays.

The greatest risk of the gridded MOS project is associated with the scientific problem of putting the MOS guidance on a high-resolution grid and providing realistic detail between observing sites. Realistic detail will be particularly troublesome for weather elements such as wind direction and speed which are affected by terrain and water bodies. This problem will be solved in incremental steps. Repeated verification and evaluation by the users will indicate problems. MDL plans to do periodic updates to improve the quality of the guidance products.

3. Analysis

3.a Description

Successful implementation of the gridded MOS products demands that extensive analyses be completed to evaluate the requirements for specific guidance, the accuracy of the gridded guidance, and its usefulness to NWS forecasters. In addition, the impact of generating, encoding, transmitting, receiving, decoding, and storing the guidance must be assessed from the perspective of the NCCS, the Telecommunications Gateway, the Satellite Broadcast Network (SBN), the local WFO, the Western Region (WR) Headquarters, and the HPC. At all steps of the process that produces the grids and finally makes them available to the forecaster, an assessment of the required computer resources, staff hours required to develop and deploy changes to numerous systems, and timeliness of the grid-generation process must be made. Transmission of the high-resolution grids on the SBN will require that the size of the GRIB2 product files be estimated. When the products reach individual WFOs, they must be decoded, stored in the appropriate netCDF file, and made available to the forecaster for use in the Graphical Forecast Editor (GFE) and for viewing via the volume browser. Appendix A contains a preliminary list of gridded MOS products which will eventually be produced. Appendix B contains the list of WMO headers.

Appendix C contains the file structure established on the Telecommunications Gateway ftp server for containing the gridded products. Appendix D provides the survey instrument used within the Western Region to assess subjectively the quality of the MOS grids. In addition to this subjective assessment, MDL, the Western Region, and the NCEP's HPC will collaborate on an objective verification of maximum/minimum temperature and dewpoint forecasts for selected sites in the western CONUS. The MOS guidance will be produced retrospectively for the period of December 2004 through September 2005 and will be compared to the actual NDFD and HPC forecasts for the same time period. Both the subjective and objective comparisons were suggested by the ISST.

3.b Roles and Responsibilities

Members of the Statistical Modeling Branch of MDL/OST (W/OST22) are responsible for evaluating the accuracy of the grids. Members of the Evaluation Branch of MDL/OST (W/OST25) are responsible for comparing the accuracy of the MOS grids relative to NDFD and HPC grids. Members of the ISST, forecasters designated by NWS Regional Headquarters, and/or forecasters from HPC will assist in the subjective evaluation of the grids. The Office of Climate, Water, and Weather Services (OCWWS) provides requirements for guidance products and training needs. Statistical Modeling Branch employees together with NCEP's Central Operations (NCO) Division will assess the impact of gridded MOS on the NCCS. The NCO and HPC are responsible for determining the effort required to ingest and modify the gridded MOS products in N-AWIPS. The Data Review Group and the Telecommunications Operations Center/OCIO are responsible for assigning WMO headers and measuring the impact of the MOS grids on the SBN, the NWS ftp server, and the communications pathway between the NCCS and the Telecommunications Gateway. Members of OST's Systems Engineering Center (SEC) will be responsible for assessing the impact of gridded MOS on AWIPS, including but not limited to, determining hardware and software changes and coordinating with FSL on changes to the GFE.

3.c Work and Budget Breakdown

Work tasks include, but are not restricted to, the following:

- Validate operational requirements for specific grid products and forecast cycles
- Verify test forecasts for each grid type; summarize grid accuracy
- Establish an instrument for a field forecaster evaluation of the grids
- Provide a subjective evaluation of the grids
- Implement the process that generates the gridded MOS products in the NCEP parallel jobstream; assess computer resources used
- Prepare and submit a Request for Change to the Data Review Group, asking for WMO headers
- Obtain Data Review Group approval
- Provide prototype GRIB2 products to SEC
- Coordinate with NCO and HPC to assess resources required to ingest and modify gridded MOS products
- Coordinate with NCO/TOC for transmission of guidance products to TOC
- Coordinate with TOC to provide data to the test NCF
- Coordinate with SEC on assessing impact on AWIPS
- Validate that the GRIB2 decoder can decode the gridded MOS products
- Assess the amount of effort required to modify the GFE and the AWIPS volume browser to use or display the gridded MOS products
- Assess the amount of effort required to provide "smart tools" to the WFOs to use the gridded MOS products

Assess the level of training required to enable the WFO forecasters to use the gridded MOS products

3.d Acquisition Strategy

Budget resources are obtained via the normal NOAA budgeting process. MDL's Statistical Modeling and Evaluation Branches are are funded through the NOAA Weather and Water Goal Team, Environmental Modeling Program. Resources required for tasks to be done by OCWWS, NCO, HPC, SEC, OCIO, and WRH will need to be assigned according to priorities set by the individual offices. The initial approach is to assess resources required for implementation of CONUS grids. Implementation of grids for OCONUS areas will require subsequent analysis.

3.e Performance Measures and Success Criteria

Success for this effort will be measured by completing the Data Review Group process within a timely manner, by the establishment of accuracy measures provided by MDL's Statistical Modeling Branch, and by the subjective evaluation completed by representatives of the user community. ReportsReports which assess the availability of human and computer resources required to do the development and deployment of gridded MOS will also be one of the outputs of the analysis effort.

3.f Schedules and Milestones

March 31, 2005 – Implement process to produce MOS grids in NCEP parallel jobstream
July 31, 2005 – Submit Request for Change to obtain CONUS headers
August 31, 2005 – Provide gridded MOS test data for temperatures, dew points, probability of precipitation, and relative humidity to SEC,
September 30, 2005 – Establish process with ISST for forecaster evaluation of grids; estimate level of effort required to implement changes in AWIPS to process and use MOS grids
October 31, 2005 –Validate Validate requirements for gridded MOS forecast elements
February 28, 2006 – Provide gridded MOS test data for thunderstorm probabilities, wind speed and direction, and snowfall amount to SEC
February 28, 2006 – Establish training requirements; assess changes required to ingest MOS grids at HPC
February 28, 2006 - Provide gridded MOS data to the test NCF
March 31, 2006 – Provide verification statistics for MOS grids over western CONUS; add equations to parallel system so that MOS grids contain guidance values for temperature, dewpoints, probability of precipitation, and relative humidity, instead of missing data, over the entire CONUS area
November 30, 2006 – Provide gridded MOS test data for wind gusts, precipitation amount, precipitation type, and sky cover to SEC
December 31, 2006 – Submit Request for Change to obtain WMO headers for products over Alaska, Hawaii, and Puerto Rico

3.g Assumptions and Constraints

The assumption is that adequate resources, namely staff and computer support (computing cycles and disk storage), are available to do this analysis. Adequate resources mean that each of the involved offices must commit staff to investigate the various issues and to complete the appropriate assessment. One of the constraints at this time is the moratorium that the OCIO has placed on new products being transmitted from the NCCS to the Telecommunications Gateway and then to AWIPS. If the moratorium is strictly enforced, then a complete assessment may be delayed until after January 1, 2006, and the schedule given above will slip by 4 to 6 months. In fact, the moratorium was strictly enforced, and was scheduled to be lifted in February 2006. Some of the information in section 3.f above was modified in response to this delay.

3.h Risk Assessment and Mitigation

Doing the required analyses is a relatively low-risk activity, as this type of work is done frequently by the individual groups. Completing the activities in a timely fashion is a problem because of the lack of staff to do the work. Also, as mentioned previously, the OCIO moratorium could delay some of the assessment activities, particularly in sending data to the test NCF. To mitigate potential problems, members of the offices doing the analysis are working with one another to find alternative solutions. As of July 1, 2005, SEC made a commitment to conduct the analysis and design of the gridded MOS implementation as well as to do the coding and testing needed to implement the gridded MOS data transmission and display on AWIPS. This commitment was predicated on SEC's understanding of the effort needed to implement gridded MOS.

4. Operational Development

4.a Description

After the research and analysis phases are completed, much of the operational development for MDL is straightforward, albeit intensive. The complete set of required equations for all weather elements must be developed; this set will be quite extensive. Software required for the operational implementation must be written and/or updated to handle the CONUS grids. The necessary control files and operational processes must be created for use at the NCCS. Part of the development process also requires that the operational MOS guidance be archived and that the gridded guidance be verified periodically in comparison to the HPC guidance and the NDFD forecasts.

The analysis stage will determine the work required to modify software and processes, particularly on AWIPS and at HPC. MDL may also find that modified processes will be required to produce the MOS grids in a timely manner at the NCCS.

4.b Roles and Responsibilities

Members of the Statistical Modeling Branch (SMB) of MDL/OST are responsible for development of the operational equations, control files, software, and processes required to make the gridded MOS products on the NCCS. SMB employees also maintain archives of the gridded MOS guidance. Members of MDL's Evaluation Branch are responsible for establishing verification of the gridded MOS guidance on a monthly basis and for comparing the accuracy of the gridded MOS with the accuracy of the HPC guidance and the official NWS forecasts provided in the NDFD. NCEP's NCO maintains and manages the operational jobstream used by MDL to create the gridded products. The developmental portion of the NCCS which is used by SMB as its developmental computer platform is supported by NWS funds provided to NCEP. SEC is responsible for updating the AWIPS GRIB2 decoder and the netCDF structure on AWIPS, and for ensuring the gridded MOS products are available to GFE and the AWIPS volume browser. OCWWS manages the NWS training task that provides training materials to WFO forecasters. HPC and NCO staff members are responsible for updating the systems required to support HPC forecasters.

4.c Work and Budget Breakdown

The following work breakdown tasks have been completed for the initial operating capability, expected September 2006, with the release of OB7.1. Some of these tasks will be repeated with ongoing improvement and enhancements efforts.   Completed tasks include, but are not limited to, the following:

Development of appropriate MOS max/min temperature, temperature, dewpoint, wind speed, wind direction, wind gust, probability of precipitation, precipitation amount, snowfall, sky cover, thunderstorm, and precipitation type forecast equations for the CONUS

Development of operational software required for post-processing the MOS guidance and generating the gridded products on the NCCS

Modification of AWIPS GRIB2 decoder, if necessary

Modification or addition on AWIPS of netCDF files

Modification of GFE and "smart tools,," if necessary

Modification of AWIPS volume browser

Modification of processes used by HPC to ingest and modify MOS guidance

Development of appropriate training materials through collaboration of OCWWS and MDL

Development of appropriate verification processes required to compare the accuracy of the gridded MOS guidance, the HPC guidance, and the official NDFD forecasts on a monthly basis; initial verification processes are based on interpolating gridded forecast data to observation sites

The work breakdown tasks below are under development. Ongoing tasks include, but are not limited to, the following:

Enhancement of initial probability of precipitation and precipitation amount equations by use of remote-sensing estimates of precipitation and high-resolution precipitation climatologies in the equation development

Development of appropriate MOS forecast equations for Alaska

Enhancement of initial sky cover forecast equations by use of remote-sensing estimates of sky cover in the equation development

Enhancement of the verification process to produce gridded verifications based on the availability of data from the Analysis of Record; also requires gridded forecast metrics

Development of appropriate MOS forecast equations for Hawaii and Puerto Rico

4.d Acquisition Strategy

Budget resources are obtained via the normal NOAA budgeting process. MDL's Statistical Modeling and Evaluation Brancheses are funded through the NOAA Weather and Water Goal Team, Environmental Modeling Program. The contractor employee in SMB is hired through the NWS task order contract with RSIS. Resources required for tasks to be done by OCWWS, NCO, HPC, SEC, OCIO, and WRH need to be assigned according to priorities set by the individual offices. The initial approach is to obtain and expend resources required for development and subsequent implementation of CONUS grids. Development of grids for OCONUS areas require additional resources which must be obtained at a later time. Because much of the AWIPS and training preparation work required for the CONUS grids will also accommodate the OCONUS grids, the resources required for the latter should be somewhat less.

4.e Performance Measures and Success Criteria

Success is measured by developing the appropriate equations needed to generate the MOS guidance with the necessary level of accuracy. Development and software modifications must be completed in a timely manner according to prescribed schedules. Other criteria for success include creation of grids with realistic detail, delivery of those grids to the WFOs in a timely manner, and ingest of those grids into the IFPS forecast preparation and the MDL verification processes. Verification scores should initially show that the gridded MOS and station-oriented MOS have comparable levels of accuracy and that the accuracy of the gridded MOS is comparable to that of either the HPC guidance or the NDFD forecasts. Initial verifications do indicate the accuracy of the gridded MOS guidance is comparable to that of either the HPC guidance or the NDFD forecasts.

Reference: M. Schenk, 2006: Performance of Three Forecast Systems at Selected MOS and Non-MOS Stations *MDL Office Note 06-01* available at
http://www.nws.noaa.gov/mdl/synop/gmos/mosnonmos.pdf

4.f Schedules and Milestones – *Updated 7/27/2006*

September 30, 2005 – Development of appropriate thunderstorm forecast equations for the CONUS; development of processes on the NCCS to generate gridded MOS guidance for probability of precipitation, probability of thunderstorms, and relative humidity *(completed)*

February 28, 2006 – Development of operational maximum/minimum temperature, temperature, dewpoint, wind direction, wind speed, probability of precipitation, and probability of precipitation amount forecast equations for the CONUS *(completed)*

February 28, 2006 – Complete modifications to AWIPS software and processes required to ingest, decode, store, and use the first operational set of gridded MOS products (maximum and minimum temperature, temperature, dewpoint, relative humidity, wind direction and speed, probability of precipitation, and probability of thunderstorms) at the WFOs *(completed)*

March 31, 2006 – Development of processes on the NCCS to generate gridded MOS guidance for wind speed and direction *(completed)*

May 31, 2006 – Complete modifications to software and processes used by HPC to ingest gridded MOS guidance *(completed)*

September 30, 2006 – Development of appropriate training materials for WFO forecasters

September 30, 2006 – Development of operational sky cover and wind gusts equations for the CONUS

December 1, 2006 – Complete modifications to AWIPS software and processes required to ingest, decode, store, and use the second operational set of gridded MOS (wind gusts, precipitation amount, precipitation type, and sky cover) products at the WFOs

February 28, 2007 – Development of precipitation type and precipitation amount for the CONUS

March 31, 2007 – Development of processes on the NCCS to generate gridded MOS guidance for wind gusts, precipitation amount, snowfall amount, precipitation type, and sky cover.

August 31, 2007 – Development of enhanced, high-resolution probability of precipitation and precipitation amount; and sky cover forecast equations for the CONUS

August 31, 2007 – Development of operational temperature, dewpoint, wind speed, and wind direction forecast equations for Alaska

February 29, 2008 – Development of operational sky cover, probability of precipitation, precipitation amount, thunderstorm, precipitation type, and snowfall forecast equations for Alaska
August 31, 2008 - Development of operational temperature, dewpoint, wind speed, and wind direction forecast equations for Hawaii and Puerto Rico
February 28, 2009 – Development of operational sky cover, probability of precipitation, and precipitation amount forecast equations for Hawaii and Puerto Rico

4.g Assumptions and Constraints

The assumption is that adequate resources, namely staff and computer support (computing cycles and disk storage), are available to do this work. Without these resources, the development of the operational system will not be completed in a timely manner. As mentioned in Section 2.g, the Statistical Modeling Branch of MDL is short-staffed. Since the developers and implementers are the same staff members, a lack of human resources may also delay development of the necessary MOS equations. The OCIO moratorium described briefly in Section 3.g and the delayed implementation of the Weather Research Forecast model at NCEP also have adversely impacted completion of developmental tasks, particularly those related to training, communications testing, and AWIPS changes. The schedule shown above reflects these delays.

4.h Risk Assessment and Mitigation

As mentioned in Section 4.g, a shortage of staff resources threatens timely completion of developmental tasks. Mitigation strategies have been implemented recently to add temporary developmental personnel and to reduce some of the tasks required during development..

In addition to the scientific risk of providing guidance with insufficient accuracy to be useful to the forecasters, we face a significant risk of not providing the operational gridded guidance in a timely manner. The amount of calculations required to support a gridded MOS system is quite large and exceeds anything that MDL has ever encountered. Since the development and implementation is being done at the NCCS, we may need to convert the MOS implementation software into an architecture that can do parallel processing, in lieu of the traditional serial processing. Only experimentation and analysis of the time required to produce the grids will answer the question. Up to this point, creation of the grids on the NCCS has not required an excessive amount of computation time. If parallel processing were required, some MDL staff members would need to attend training in programming on a massively parallel system.

5. Deployment, Maintenance, and Assessment

5.a Description

For successful deployment and use of gridded MOS by the forecasters, a number of tasks must be completed. The necessary MOS guidance equations, software, and operational processes must be implemented in the NCEP operational jobstream. Products must be generated in GRIB2 format at the NCCS and transmitted to the Telecommunications Gateway. The products must be transmitted on the SBN to the local WFOs, decoded, and stored as netCDF files. The MOS variables in these files must be displayable in the d-2-d volume browser and must be available to the Grid Forecast Editor (GFE) for use as a possible method of initializing the local office grids. The local forecaster must have been trained in the use and value of the guidance grids and must have access to the appropriate tools required to manipulate the grids. The MOS grids must also be transmitted to HPC and must be available for grid manipulation by the HPC forecasters. An archive of the guidance grids must be established, and regular verification of the grids must be done. Initially, verification of these grids will be dependent on interpolation of the guidance to a set of observing points. Eventually, however, as fields become available from the Analysis of Record, processing will be expanded to include gridded verification in which the Analysis of Record provides the "observations." The MOS developers will need to work regularly on improving the quality of the grids. Improvements could occur because of improvements in the traditional MOS forecast equations, in the method of rendering the MOS station guidance to a high-resolution grid, in the use of remote sensing data to develop the MOS equations, or in the use of the Analysis of Record as "ground truth" for development of MOS equations. Finally, the process to add grids or new variables to the AWIPS datastream must be flexible enough that major code modifications are not required at the local WFOs, whenever MDL enhances the gridded MOS suite of products.

5.b Roles and Responsibilities

Members of the Statistical Modeling Branch of MDL/OST are responsible for deploying the operational equations, control files, software, and processes required to make the gridded MOS products on the NCCS. Staff within MDL's Evaluation Branch are responsible for maintaining verification of the gridded MOS guidance on a monthly basis and for comparing the accuracy of the gridded MOS with the accuracy of the HPC guidance and the official NWS forecasts provided in the NDFD. NCEP's NCO is responsible for implementing and maintaining the gridded MOS guidance in operations. The OCIO is responsible for assigning WMO headers for the products, adding those headers to the switching directory, and monitoring the daily transmission of the guidance products. The Network Control Facility will validate that the gridded MOS products are received at AWIPS sites once transmitted over the SBN. Members of SEC/OST are responsible for establishing the processes and configuration files on AWIPS that are required to decode and database the guidance products. SEC is also responsible for updating the AWIPS GRIB2 decoder. The Training Branch of OCWWS is responsible for providing training to the field.

5.c Work and Budget Breakdown

The tasks below have been completed for the initial operating capability. Grids are scheduled to be distributed through the SBN, via NCEP's operational job stream, on August 15, 2006. AWIPS will process gridded MOS products with the deployment of OB7.1 beginning September 8, 2006. Tasks include, but are not limited to, the following:

- Implementing into the NCCS operational jobstream the MOS equations and processes required to create the gridded guidance
- Creating the processes at the NCCS to transmit the MOS grids to the Telecommunications Gateway
- Entering all WMO headers in the appropriate database at the Telecommunications Gateway
- Modifying processes at the local WFOs so that the MOS grids are ingested, decoded, and stored in netCDF files
- Validating receipt of the MOS grids at the AWIPS sites
- Modifying d-2-d and the volume browser so that the MOS grids are treated as another source of model data
- Modifying operational processes, software, and tools so that the WFO forecasters can interact with the MOS grids within GFE

Modifying operational processes, software, and tools so that the HPC forecasters can interact with the MOS grids in the HPC work environment
Preparing a training module or teleconference presentation about the MOS grids
Preparing an objective and subjective evaluation of the quality and usefulness of the grids

5.d Acquisition Strategy

Budget resources are obtained via the normal NOAA budgeting process. MDL's Statistical Modeling and Evaluation BranchesBranches are funded through the NOAA Weather and Water Goal Team, Environmental Modeling Program. Resources required for deployment tasks to be done by OCWWS, NCO, HPC, SEC, OCIO, and WRH will need to be assigned according to priorities set by the individual offices.

5.e Performance Measures and Success Criteria

Criteria for success include creation of grids with realistic detail, delivery of those grids to the WFOs in a timely manner, and ingest of those grids into the IFPS forecast preparation and the MDL verification processes. Success is also indicated by the ability of the WFO forecasters to use intelligently the grids in the forecast process. Verification scores should initially show that the gridded MOS and station-oriented MOS have comparable levels of accuracy and that the accuracy of the gridded MOS is comparable to that of the HPC guidance and the NDFD forecasts.

5.f Schedules and Milestones – *Updated 07/27/2006*

July 31, 2005 - Submit Request for Change to obtain WMO product headers for maximum/minimum temperature, temperature, dewpoint, relative humidity, wind direction and speed, snowfall amount, probability of precipitation, and probability of thunderstorms (*completed)*
November 30, 2005 – Implement process to produce grids in NCEP operational jobstream; *(completed)*
March 31, 2006 - Produce grids at the NCCS for max/min temperature, temperature, dewpoint, relative humidity, wind speed, wind direction, thunderstorm probability, and precipitation probability; transmit GRIB2 products to TOC *(completed)*
August 15, 2006 – Implement MOS equations and processes for max/min temperature, temperature, dewpoint, relative humidity, wind speed, wind direction, thunderstorm probability, and probability of precipitation so that the NDFD grid over the CONUS is fully populated with MOS guidance *(scheduled)*
September 8, 2006 – Begin deployment of AWIPS OB7.1 modified to handle the gridded MOS products *(scheduled)*
September 30, 2006 – Complete training on use of gridded MOS by WFO forecasters
September 30, 2006 - Submit Request for Change to obtain WMO product headers needed to transmit precipitation type, precipitation amount, sky cover, and wind gust grids for CONUS
October 31, 2006 - Submit Request for Change to obtain WMO product headers for Alaska gridded MOS products
May 1, 2007 - Produce grids for precipitation type, precipitation amount, snowfall, sky cover, and wind gusts over the CONUS
June 1, 2007 – Begin deployment of AWIPS OB8.1 modified to process the second suite of gridded MOS products over the CONUS – sky cover, precipitation type, precipitation

amount, wind gusts
September 30, 2007 – Produce grids for max/min temperature, temperature, dewpoint, relative humidity, wind speed and direction, precipitation type, snowfall amount, and precipitation probability over Alaska
October 31, 2007 - Submit Request for Change to obtain WMO product headers for gridded MOS products for Hawaii and Puerto Rico
April 30, 2008 – Add grids for wind gusts, precipitation amount, and sky cover over Alaska
September 30, 2008 – Produce grids for max/min temperature, temperature, dewpoint, relative humidity, wind speed and direction, and precipitation probability over Hawaii and Puerto Rico
April 30, 2009 – Add grids for wind gusts, precipitation amount, and sky cover over Hawaii and Puerto Rico

5.g Assumptions and Constraints

All of this work is predicated upon adequate staff and computer resources being made available to the participating organizations. Lack of resources or a ban on changes being made to systems at the NCCS, the Telecommunications Gateway, or the local AWIPS platforms will cause significant delays. The moratorium during late 2005 into early 2006 that the OCIO placed on new products being transmitted from the NCCS to the Telecommunications Gateway and then to AWIPS delayed deployment by 4 to 6 months and has been incorporated into the revised milestones.

5.h Risk Assessment and Mitigation

The probability is high that completion of some of these milestones will be delayed, particularly the implementation of the MOS forecast processes. The development of gridded products for Alaska, Hawaii, and Puerto Rico each require almost the same level of effort that was needed to implement the gridded MOS for the CONUS. Moreover, the scarcity of observations for those OCONUS areas will likely mean that the guidance will not be as good as that provided over the CONUS. Test verifications and subjective assessments by the affected WFOs will provide feedback to the developers of the guidance.

As mentioned earlier in Section 4.h, there is a risk that the MDL processes to create the MOS grids in the NCCS operational environment will not complete quickly enough. Parallel processing may be necessary to alleviate this problem.

APPENDIX A

Table A.1. GFS-based MOS maximum (max) and minimum (min) temperature gridded products projections. As noted in the table, guidance is available from either the 0000 or 1200 UTC cycles only. Note that the projections for the max and min temperature are only approximations, and denote daytime and nighttime valid periods, respectively.

Type															
	24	36	48	60	72	84	96	108	120	132	144	156	168	180	192
Max	00Z	12Z	00Z	12Z	00Z	12Z	00Z	12Z	00Z	12Z	00Z	12Z	00Z	12Z	00Z
Min	12Z	00Z	12Z	00Z	12Z	00Z	12Z	00Z	12Z	00Z	12Z	00Z	12Z	00Z	12Z

Table A.2. Projections for the GFS-based MOS temperature, dew point, relative humidity, wind direction, wind speed, wind gust, sky cover and precipitation type gridded products. Guidance is available from both the 0000 and 1200 UTC cycles. Projections refer to hours after 0000 or 1200 UTC.

Type	**Forecast Projections**
Temperature	Every 3 h from 6 to 192 hours
Dew Point	Every 3 h from 6 to 192 hours
Relative humidity	Every 3 h from 6 to 192 hours
Wind direction	Every 3 h from 6 to 192 hours
Wind speed	Every 3 h from 6 to 192 hours
Wind gusts	Every 3 h from 6 to 192 hours
Sky cover	Every 3 h from 6 to 192 hours
Precipitation type	Every 3 h from 6 to 192 hours

Table A.3. Projections for the GFS-based MOS probability of precipitation and probability of thunderstorms gridded products... Guidance is available from both the 0000 and 1200 UTC cycles. Projections refer to the hour after 0000 or 1200 UTC that the period ends.

Type	**Forecast Projections**
Probability of precipitation – 6 h period	Every 6 h from 12 to 192 hours
Probability of precipitation – 12 h period	Every 6 h from 18 to 192 hours
Probability of thunderstorms – 3 h period	Every 3 h from 9 to 84 hours
Probability of thunderstorms – 6 h period	Every 6 h from 12 to 192 hours
Probability of thunderstorms – 12 h period	Every 6 h from 18 to 192 hours

Table A.4. Projections for the GFS-based MOS quantitative precipitation and snowfall amount gridded products. Guidance is available from both the 0000 and 1200 UTC cycles. Projections refer to the hour after 0000 or 1200 UTC that the period ends.

Type	**Forecast Projections**
Quantitative precipitation – 6 h period	Every 6 h from 12 to 156 hours
Quantitative precipitation – 12 h period	Every 6 h from 18 to 156 hours
Snowfall amount – 24 h period	Every 12 h from 36 to 132 hours

Appendix B - WMO Headings for Gridded MOS Products

WMO headings have the format of $T_1T_2A_1A_2ii$ CCCC

1. The CCCC for all gridded MOS product WMO headings is **KWBQ**.

2. The T_1 for all gridded MOS products based on the global model is **L**.

3. The T_2 represents the weather element type designator. The following values are used for a T_1 = **L**. When feasible, these values match those used for the NDFD WMO headers.
Values for T_2 are:
A = sky cover
B = wind direction at sensor height (nominally, 10 m)
C = wind speed at sensor height (nominally, 10 m)
D = probability of precipitation (12 h)
E = temperature at sensor height (nominally, 2 m)
F = dewpoint temperature at sensor height (nominally, 2 m)
G = daytime maximum temperature at sensor height (nominally, 2 m)
H = nighttime minimum temperature at sensor height (nominally, 2 m)
I = quantitative precipitation (6 h)
J = thunderstorms (6 h)
K = severe weather (6 h)
L = precipitation type
M = precipitation characteristics
N = precipitation occurrence
O = obstruction to vision
P = visibility
Q = ceiling height
R = relative humidity
S = snowfall amount (24 h)
T = apparent temperature
U = probability of precipitation (6 h)
V = quantitative precipitation (12 h)
W = wind gusts
X = thunderstorms (12 h)
Y = thunderstorms (3 h)
Z = unassigned

4. The A_1 designates the geographical area. The following designators follow the conventions established in the NDFD WMO headers.
A = Puerto Rico
R = Alaska
S = Hawaii
T = Guam
U = CONUS

5. The A_2 and ii follow the convention established in the NDFD. These three characters together represent the day and hour (UTC) for which the product is valid. The following convention for A_2 and ii is used for the gridded MOS products:
A = Day 0; ii = hour (0-23)
B = Day 1; ii = hour (0-23)

C = Day 2; ii = hour (0-23)
D = Day 3; ii = hour (0-23)
E = Day 4; ii = hour (0-23)
F = Day 5; ii = hour (0-23)
G = Day 6; ii = hour (0-23)
H = Day 7; ii = hour (0-23)
I = Day 8; ii = hour (0-23)
J = Day 9; ii = hour (0-23)

Table B.1. WMO headers for gridded MOS products. The headers shown are for the CONUS only. The complete headers shown in Tables B.2 are given for those elements to be transmitted in the first two releases of the gridded MOS products. Information for the other headers will be added, as available and needed.

Element	**Header**	**No. of grids per cycle**	**First/Last Proj./Time Increment (hr)**	**Bytes per grid/cycle**
Sky Cover	$LAUA_2ii$	63	6/192/3	100K/6.3M
Wind Direction	$LBUA_2ii$	63	6/192/3	225K/14.2M
Wind Speed	$LCUA_2ii$	63	6/192/3	125K/7.9M
PoP (12h)	$LDUA_2ii$	30	18/192/6	100K/3.0M
Temperature	$LEUA_2ii$	63	6/192/3	250K/15.8M
Dew Point	$LFUA_2ii$	63	6/192/3	250K/15.8M
Daytime Max	$LGUA_2ii$	8(00Z) 7(12Z)	24/192/24 36/180/24	250K/2.0M 250K/1.7M
Nighttime Min	$LHUA_2ii$	7(00Z) 8(12Z)	36/180/24 24/192/24	250K/1.7M 250K/2.0M
Quantitative Pre-cip. (6h)	$LIUA_2ii$	25	12/156/6	100K/2.5M
Tstm. Prob. (6h)	$LJUA_2ii$	31	12/192/6	100K/3.1M
Svr. Wx. Prob. (6h)	$LKUA_2ii$	TBD	TBD	100K/TBD
Precip. Type	$LLUA_2ii$	63	6/192/3	100K/6.3M
Precip. Character.	$LMUA_2ii$	TBD	TBD	100K/TBD
Precip. Occurrence	$LNUA_2ii$	TBD	TBD	100K/TBD
Obs. Vision	$LOUA_2ii$	TBD	TBD	100K/TBD
Visibility	$LPUA_2ii$	TBD	TBD	100K/TBD
Ceiling Height	$LQUA_2ii$	TBD	TBD	100K/TBD
Relative Humidity	$LRUA_2ii$	63	6/192/3	100K/6.3M
Snowfall Amount (24h)	$LSUA_2ii$	9	36/132/12	100K/0.9M
Apparent Temp.	$LTUA_2ii$	TBD	TBD	250K/TBD
PoP (6h)	$LUUA_2ii$	31	12/192/6	100K/3.1M
Quantitative Pre-cip. (12h)	$LVUA_2ii$	24	18/156/6	100K/2.4M
Wind Gusts	$LWUA_2ii$	63	6/192/3	150K/9.4M
Tstm. Prob. (12h)	$LXUA_2ii$	30	18/192/6	100K/3.0M
Tstm. Prob. (3 h)	$LYUA_2ii$	26	9/84/3	100K/2.6M

Table B.2. WMO headers for gridded MOS products expected to be transmitted initially on the SBN in 2006.

Element	Header Category	Product Headers
Sky Cover	$LAUA_2ii$	LAUA18 LAUA21 LAUB00 LAUB03 LAUB06 LAUB09 LAUB12 LAUB15 LAUB18 LAUB21 LAUC00 LAUC03 LAUC06 LAUC09 LAUC12 LAUC15 LAUC18 LAUC21 LAUD00 LAUD03 LAUD06 LAUD09 LAUD12 LAUD15 LAUD18 LAUD21 LAUE00 LAUE03 LAUE06 LAUE09 LAUE12 LAUE15 LAUE18 LAUE21 LAUF00 LAUF03 LAUF06 LAUF09 LAUF12 LAUF15 LAUF18 LAUF21 LAUG00 LAUG03 LAUG06 LAUG09 LAUG12 LAUG15 LAUG18 LAUG21 LAUH00 LAUH03 LAUH06 LAUH09 LAUH12 LAUH15 LAUH18 LAUH21 LAUI00 LAUI03 LAUI06 LAUI09 LAUI12 LAUI15 LAUI18 LAUI21 LAUJ00
Wind Direc-tion	$LBUA_2ii$	LBUA18 LBUA21 LBUB00 LBUB03 LBUB06 LBUB09 LBUB12 LBUB15 LBUB18 LBUB21 LBUC00 LBUC03 LBUC06 LBUC09 LBUC12 LBUC15 LBUC18 LBUC21 LBUD00 LBUD03 LBUD06 LBUD09 LBUD12 LBUD15 LBUD18 LBUD21 LBUE00 LBUE03 LBUE06 LBUE09 LBUE12 LBUE15 LBUE18 LBUE21 LBUF00 LBUF03 LBUF06 LBUF09 LBUF12 LBUF15 LBUF18 LBUF21 LBUG00 LBUG03 LBUG06 LBUG09 LBUG12 LBUG15 LBUG18 LBUG21 LBUH00 LBUH03 LBUH06 LBUH09 LBUH12 LBUH15 LBUH18 LBUH21 LBUI00 LBUI03 LBUI06 LBUI09 LBUI12 LBUI15 LBUI18 LBUI21 LBUJ00
Wind Speed	$LCUA_2ii$	LCUA18 LCUA21 LCUB00 LCUB03 LCUB06 LCUB09 LCUB12 LCUB15 LCUB18 LCUB21 LCUC00 LCUC03 LCUC06 LCUC09 LCUC12 LCUC15 LCUC18 LCUC21 LCUD00 LCUD03 LCUD06 LCUD09 LCUD12 LCUD15 LCUD18 LCUD21 LCUE00 LCUE03 LCUE06 LCUE09 LCUE12LCUE15 LCUE18 LCUE21 LCUF00 LCUF03 LCUF06 LCUF09 LCUF12 LCUF15 LCUF18 LCUF21

		LCUG00 LCUG03 LCUG06 LCUG09 LCUG12 LCUG15 LCUG18 LCUG21 LCUH00 LCUH03 LCUH06 LCUH09 LCUH12 LCUH15 LCUH18 LCUH21 LCUI00 LCUI03 LCUI06 LCUI09 LCUI12 LCUI15 LCUI18 LCUI21 LCUJ00
PoP (12 h)	$LDUA_2ii$	LDUB06 LDUB12 LDUB18 LDUC00 LDUC06 LDUC12 LDUC18 LDUD00 LDUD06 LDUD12 LDUD18 LDUE00 LDUE06 LDUE12 LDUE18 LDUF00 LDUF06 LDUF12 LDUF18 LDUG00 LDUG06 LDUG12 LDUG18 LDUH00 LDUH06 LDUH12 LDUH18 LDUI00 LDUI06 LDUI12 LDUI18 LDUJ00
Temperature	$LEUA_2ii$	LEUA18 LEUA21 LEUB00 LEUB03 LEUB06 LEUB09 LEUB12 LEUB15 LEUB18 LEUB21 LEUC00 LEUC03 LEUC06 LEUC09 LEUC12 LEUC15 LEUC18 LEUC21 LEUD00 LEUD03 LEUD06 LEUD09 LEUD12 LEUD15 LEUD18 LEUD21 LEUE00 LEUE03 LEUE06 LEUE09 LEUE12 LEUE15 LEUE18 LEUE21 LEUF00 LEUF03 LEUF06 LEUF09 LEUF12 LEUF15 LEUF18 LEUF21 LEUG00 LEUG03 LEUG06 LEUG09 LEUG12 LEUG15 LEUG18 LEUG21 LEUH00 LEUH03 LEUH06 LEUH09 LEUH12 LEUH15 LEUH18 LEUH21 LEUI00 LEUI03 LEUI06 LEUI09 LEUI12 LEUI15 LEUI18 LEUI21 LEUJ00
Dew Point	$LFUA_2ii$	LFUA18 LFUA21 LFUB00 LFUB03 LFUB06 LFUB09 LFUB12 LFUB15 LFUB18 LFUB21 LFUC00 LFUC03 LFUC06 LFUC09 LFUC12 LFUC15 LFUC18 LFUC21 LFUD00 LFUD03 LFUD06 LFUD09 LFUD12 LFUD15 LFUD18 LFUD21 LFUE00 LFUE03 LFUE06 LFUE09 LFUE12 LFUE15 LFUE18 LFUE21 LFUF00 LFUF03 LFUF06 LFUF09 LFUF12 LFUF15 LFUF18 LFUF21 LFUG00 LFUG03 LFUG06 LFUG09 LFUG12 LFUG15 LFUG18 LFUG21 LFUH00 LFUH03 LFUH06 LFUH09 LFUH12 LFUH15 LFUH18 LFUH21 LFUI00 LFUI03 LFUI06 LFUI09 LFUI12 LFUI15 LFUI18 LFUI21

		LFUJ00
Daytime Max	LGUA$_2$ii	LGUC00 LGUD00 LGUE00 LGUF00 LGUG00 LGUH00 LGUI00 LGUJ00
Nighttime Min	LHUA$_2$ii	LHUB12 LHUC12 LHUD12 LHUE12 LHUF12 LHUG12 LHUH12 LHUI12
Quantitative Precip. (6h)	LIUA$_2$ii	LIUB00 LIUB06 LIUB12 LIUB18 LIUC00 LIUC06 LIUC12 LIUC18 LIUD00 LIUD06 LIUD12 LIUD18 LIUE00 LIUE06 LIUE12 LIUE18 LIUF00 LIUF06 LIUF12 LIUF18 LIUG00 LIUG06 LIUG12 LIUG18 LIUH00 LIUH06 LIUH12
Tstm. Prob. (6h)	LJUA$_2$ii	LJUB00 LJUB06 LJUB12 LJUB18 LJUC00 LJUC06 LJUC12 LJUC18 LJUD00 LJUD06 LJUD12 LJUD18 LJUE00LJUE06 LJUE12 LJUE18 LJUF00 LJUF06 LJUF12 LJUF18 LJUG00 LJUG06 LJUG12 LJUG18 LJUH00 LJUH06 LJUH12 LJUH18 LJUI00 LJUI06 LJUI12 LJUI18 LJUJ00
Precip. Type	LLUA$_2$ii	LLUA18 LLUA21 LLUB00 LLUB03 LLUB06 LLUB09 LLUB12 LLUB15 LLUB18 LLUB21 LLUC00 LLUC03 LLUC06 LLUC09 LLUC12 LLUC15 LLUC18 LLUC21 LLUD00 LLUD03 LLUD06 LLUD09 LLUD12 LLUD15 LLUD18 LLUD21 LLUE00 LLUE03 LLUE06 LLUE09 LLUE12 LLUE15 LLUE18 LLUE21 LLUF00 LLUF03 LLUF06 LLUF09 LLUF12 LLUF15 LLUF18 LLUF21 LLUG00 LLUG03 LLUG06 LLUG09 LLUG12 LLUG15 LLUG18 LLUG21 LLUH00 LLUH03 LLUH06 LLUH09 LLUH12 LLUH15 LLUH18 LLUH21 LLUI00 LLUI03 LLUI06 LLUI09 LLUI12 LLUI15 LLUI18 LLUI21 LLUJ00
Relative Hu-midity	LRUA$_2$ii	LRUA18 LRUA21 LRUB00 LRUB03 LRUB06 LRUB09 LRUB12 LRUB15 LRUB18 LRUB21 LRUC00 LRUC03 LRUC06 LRUC09 LRUC12 LRUC15 LRUC18 LRUC21 LRUD00 LRUD03 LRUD06 LRUD09 LRUD12 LRUD15 LRUD18 LRUD21 LRUE00 LRUE03 LRUE06 LRUE09 LRUE12 LRUE15 LRUE18 LRUE21 LRUF00 LRUF03 LRUF06 LRUF09 LRUF12 LRUF15 LRUF18 LRUF21

		LRUG00 LRUG03 LRUG06 LRUG09 LRUG12 LRUG15 LRUG18 LRUG21 LRUH00 LRUH03 LRUH06 LRUH09 LRUH12 LRUH15 LRUH18 LRUH21 LRUI00 LRUI03 LRUI06 LRUI09 LRUI12 LRUI15 LRUI18 LRUI21 LRUJ00
Snowfall Amount (24h)	LSUA$_2$ii	LSUC00 LSUC12 LSUD00 LSUD12 LSUE00 LSUE12 LSUF00 LSUF12 LSUG00 LSUG12
PoP (6h)	LUUA$_2$ii	LUUB00 LUUB06 LUUB12 LUUB18 LUUC00 LUUC06 LUUC12 LUUC18 LUUD00 LUUD06 LUUD12 LUUD18 LUUE00 LUUE06 LUUE12 LUUE18 LUUF00 LUUF06 LUUF12 LUUF18 LUUG00 LUUG06 LUUG12 LUUG18 LUUH00 LUUH06 LUUH12 LUUH18 LUUI00 LUUI06 LUUI12 LUUI18 LUUJ00
Quantitative Precip. (12h)	LVUA$_2$ii	LVUB06 LVUB12 LVUB18 LVUC00 LVUC06 LVUC12 LVUC18 LVUD00 LVUD06 LVUD12 LVUD18 LVUE00 LVUE06 LVUE12 LVUE18 LVUF00 LVUF06 LVUF12 LVUF18 LVUG00 LVUG06 LVUG12 LVUG18 LVUH00 LVUH06 LVUH12
Wind Gusts	LWUA$_2$ii	LWUA18 LWUA21 LWUB00 LWUB03 LWUB06 LWUB09 LWUB12 LWUB15 LWUB18 LWUB21 LWUC00 LWUC03 LWUC06 LWUC09 LWUC12 LWUC15 LWUC18 LWUC21 LWUD00 LWUD03 LWUD06 LWUD09 LWUD12 LWUD15 LWUD18 LWUD21 LWUE00 LWUE03 LWUE06 LWUE09 LWUE12 LWUE15 LWUE18 LWUE21 LWUF00 LWUF03 LWUF06 LWUF09 LWUF12 LWUF15 LWUF18 LWUF21 LWUG00 LWUG03 LWUG06 LWUG09 LWUG12 LWUG15 LWUG18 LWUG21 LWUH00 LWUH03 LWUH06 LWUH09 LWUH12 LWUH15 LWUH18 LWUH21 LWUI00 LWUI03 LWUI06 LWUI09 LWUI12 LWUI15 LWUI18 LWUI21 LWUJ00
Tstm. Prob. (12h)	LXUA$_2$ii	LXUB06 LXUB12 LXUB18 LXUC00 LXUC06 LXUC12 LXUC18 LXUD00 LXUD06 LXUD12 LXUD18 LXUE00 LXUE06 LXUE12 LXUE18 LXUF00 LXUF06 LXUF12 LXUF18 LXUG00 LXUG06 LXUG12 LXUG18 LXUH00 LXUH06 LXUH12 LXUH18

		LXUI00 LXUI06 LXUI12 LXUI18 LXUJ00
Tstm Prob. (3h)	$LYUA_2ii$	LYUA21 LYUB00 LYUB03 LYUB06 LYUB09 LYUB12 LYUB15 LYUB18 LYUB21 LYUC00 LYUC03 LYUC06 LYUC09 LYUC12 LYUC15 LYUC18 LYUC21 LYUD00 LYUD03 LYUD06 LYUD09 LYUD12 LYUD15 LYUD18 LYUD21 LYUE00 LYUE03 LYUE06 LYUE09 LYUE12

Appendix C – Telecommunications Gateway File Server Structure for Gridded MOS Products

Note that all products are in grib2 format and cover the CONUS on the NDFD grid; at this time, only the western third of the grid is populated with guidance; the remainder of the grid contains missing values.

Guidance products are aggregated for the same weather element and geographical area. Thus, products for the CONUS are in one file system; products for Alaska are in another. The aggregation is stored in individual files on the ftp server where a single file contains individual products for groupings of forecast periods. Groupings of forecast periods are designated as days 1 – 3 and days 4 – 7. For user convenience and for eventual consistency with NDFD, the products for Day 4, hour 00, are included in the days 1 – 3 file. The remainder of the MOS guidance beyond Day 4, hour 00 is included in the days 4 – 7 file.

NDGD tgftp file structure
root: ftp://tgftp.nws.noaa.gov/SL.us008001/

status of data (experimental): ST.expr/ - prior to August 15, 2006
status of data (operational): ST.opnl/ - after August 15, 2006

data format (grib2): DF.gr2/

data category (ndgd): DC.ndgd/

guidance type (gfs-based MOS): GT.mosgfs/

area of data (CONUS): AR.conus/

valid period VP.001-003/ – for days 1 to 3
VP.004-007/ – for days 4 to 7

ds.sssss (file name or data subcategory):

ds.maxt.bin – max temperature
ds.mint.bin – min temperature
ds.temp.bin – 2-m temperature
ds.td.bin – 2-m dewpoint
ds.rh.bin – 2-m relative humidity
ds.sky.bin – sky cover
ds.wdir.bin – wind direction
ds.wspd.bin – wind speed
ds.wgust.bin – wind gusts
ds.pop12.bin – 12h PoPs
ds.pop06.bin – 6h PoPs
ds.pts03.bin – 3h thunderstorm probabilities
ds.pts06.bin – 6h thunderstorm probabilities
ds.pts12.bin – 12h thunderstorm probabilities
ds.qpf.bin – 6h precipitation amount
ds.qpf12.bin – 12h precipitation amount
ds.snw24.bin – 24h snowfall amount
ds.ptype.bin – precipitation type

Thus, as an example, the complete file name (minus, the ftp server name) containing the gridded MOS max temperatures for days 4 through 7 looks like:

SL.us008001/ST.opnl/DF.gr2/DC.ndgd/GT.mosgfs/AR.conus/VP.004-007/ds.maxt.bin

Table C.1. Groupings for gridded MOS products.

Gridded MOS Element	Valid Period (VP)	No. of grids per file(00/12Z)	Time increment/final projection	Size per grid
Temperature	001-003 004-007	23 - 27 36 – 40	3/72 (00Z); 3/84 (12Z) 3/192	250K
Dew Point	001-003 004-007	23 - 27 36 - 40	3/72 (00Z); 3/84 (12Z) 3/192	250K
Relative Humidity	001-003 004-007	23 - 27 36 - 40	3/72 (00Z); 3/84(12Z) 3/192	250K
Daytime Max	001-003 004-007	3 4 - 5	24/72 (00Z); 24/84 (12Z) 24/192	250K
Nighttime Min	001-003 004-007	3 4 - 5	24/72 (00Z); 24/84 (12Z) 24/192	250K
6h PoP	001-003 004-007	11 - 13 18 – 20	6/72 (00Z); 6/84 (12Z) 6/192	100K
12h PoP	001-003 004-007	11 – 13 18 – 20	6/72 (00Z; 6/84 (12Z) 6/192	100K
Wind Direction	001-003 004-007	23 - 27 36 – 40	3/72 (00Z); 3/84 (12Z) 3/192	250K
Wind Speed	001-003 004-007	23 - 27 36 – 40	3/72 (00Z); 3/84 (12Z) 3/192	250K
Wind Gusts	001-003 004-007	23 - 27 36 – 40	3/72 (00Z); 3/84 (12Z) 3/192	250K
Sky Cover	001-003 004-007	23 - 27 36 – 40	3/72 (00Z); 3/84 (12Z) 3/192	100K
Precipitation Type	001-003 004-007	23 - 27 36 – 40	3/72 (00Z); 3/84 (12Z) 3/192	50K
3h prob. of thunderstorms	001-003	22 - 26	3/72 (00Z); 3/84 (12Z)	100K
6h prob. of thunderstorms	001-003 004-007	11 – 13 18 - 20	6/72 (00Z); 6/84 (12Z) 6/192	100K
12h prob. of thunderstorms	001-003 004-007	11 – 13 18 - 20	6/72 (00Z); 6/84 (12Z) 6/192	100K
6h qpf	001-003 004-007	11 - 13 12 - 14	6/72 (00Z); 6/84 (12Z) 6/156	100K
12h qpf	001-003 004-007	11 - 13 12 - 14	6/72 (00Z); 6/84 (12Z) 6/156	100K
24h snowfall	001-003 004-007	5 – 6 4 - 5	12/72 (00Z); 12/84 (12Z) 12/132	100K

Appendix D – Sample Survey Provided by Western Region to Forecasters

In January 2006, the Western Region Scientific Services Division coordinated with a number of offices in the Western Region to provide a subjective evaluation of the initial gridded MOS products over the western CONUS. The following survey was prepared by the ISST and was given to the participating offices to collect information about the usefulness of gridded MOS. The survey along with the introductory comments follows.

IFPS Science Steering Team (ISST) Gridded MOS Assessment

Background

The ISST has been asking for the development of gridded statistical guidance for help with the removing some of the model biases and providing a statistically post-processed guidance at the native resolution of the grids. MDL has begun to create gridded MOS guidance.

The ISST is interested in learn your impressions of the gridded MOS. Is the gridded MOS helpful in the forecast process and does it improve the forecast process?

Please fill out the following survey:

Part I: Quality of Data

1. Have you noticed any of the following **systematic** errors in the gridded MOS data? *

a. Locations where the temperatures (Max, Min, 3 hr T) too cold. (E.g., Max T on mountain tops too cold.)
b. Locations where the temperatures (Max, Min, 3 hr T) too warm. (E.g., Min T in valleys too warm.)
c. Areas where the temperature lapse rate between mountain tops and valleys is not captured well (or is not realistic).
d. Areas where the horizontal spatial variation in temperature is unrealistic (e.g. valleys too warm at night, ridges too cold, or boundaries where no boundaries should exist).
e. Locations where RH/Td is consistently incorrect.
f. Locations where RH/Td along geographical boundaries have consistent errors.
g. Locations where PoP is too large or small on a regular basis.
h. Locations where PoP are inconsistent with neighboring guidance points.
i. Locations along the Pacific coast where the coastal temperature gradient is not realistic (too strong, too weak, too far inland or too far off the coast).

* For test sites, please contact Paul Dallavalle as soon as possible to notify MDL of these errors.

2. Are there situations under which the gridded MOS has systematic errors in the grids?

a. Under high pressure system
b. Near a low pressure system
c. Timing of frontal passage.
d. Other ____

3. Rate how well the gridded MOS (considering the guidance for the available weather variables) captures terrain in your CWA.

Terrain is noticeable							No terrain features noticeable		
10	9	8	7	6	5	4	3	2	1

4. Rate how well the gridded MOS (considering the guidance for the available weather variables) captures geographic features (e.g., rivers, lakes, urban areas, rural areas).

Features is noticeable								No features noticeable	
10	9	8	7	6	5	4	3	2	1

5. Rate how well the gridded MOS predicts the following weather elements in your area:

	Perfect								Rarely/Never	
Max T	10	9	8	7	6	5	4	3	2	1
Min T	10	9	8	7	6	5	4	3	2	1
T	10	9	8	7	6	5	4	3	2	1
RH	10	9	8	7	6	5	4	3	2	1
Td	10	9	8	7	6	5	4	3	2	1
PoP12	10	9	8	7	6	5	4	3	2	1

6. Rate how well the ADJMOS predicts the following weather elements in your area:

	Perfect								Rarely/Never	
Max T	10	9	8	7	6	5	4	3	2	1
Min T	10	9	8	7	6	5	4	3	2	1
T	10	9	8	7	6	5	4	3	2	1
RH	10	9	8	7	6	5	4	3	2	1
Td	10	9	8	7	6	5	4	3	2	1
PoP12	10	9	8	7	6	5	4	3	2	1

7. Rate how well the point MOS predicts the following weather elements in your area:

	Perfect								Rarely/Never	
Max T	10	9	8	7	6	5	4	3	2	1
Min T	10	9	8	7	6	5	4	3	2	1
T	10	9	8	7	6	5	4	3	2	1
RH	10	9	8	7	6	5	4	3	2	1
Td	10	9	8	7	6	5	4	3	2	1
PoP12	10	9	8	7	6	5	4	3	2	1

Part II: Usage Assessment

8. Which gridded MOS elements does your office use regularly to initialize the grids? (Check all that apply)

__Max T __Min T __Temp. __Dew Point __RH __PoP12
__Don't use any of the gridded guidance

9. Please rank the gridded MOS elements for their usefulness (1 being the best and 6 being the worst).

Max T	_____
Min T	_____
T	_____
RH	_____
Td	_____
PoP12	_____

10. Has gridded MOS improved the digital forecast process?

__Yes __No made it worse __Just added another data source __Not sure

11. Rate the following guidance on its usefulness for the first 24 hours of a forecast.

	Best					Worst
Gridded MOS	5	4	3	2	1	0
ADJFWC	5	4	3	2	1	0
ADJMET	5	4	3	2	1	0
ADJMAV	5	4	3	2	1	0
ADJMEX	5	4	3	2	1	0
NAM/Eta Model	5	4	3	2	1	0
GFS Model	5	4	3	2	1	0
Persistence	5	4	3	2	1	0
Climatology	5	4	3	2	1	0
RUC	5	4	3	2	1	0
Local Model/Other please specify:	5	4	3	2	1	0

12. Rate the following guidance on it usefulness for the forecast hours 24-48.

	Best					Worst
Gridded MOS	5	4	3	2	1	0
ADJFWC	5	4	3	2	1	0
ADJMET	5	4	3	2	1	0
ADJMAV	5	4	3	2	1	0
ADJMEX	5	4	3	2	1	0
NAM/Eta Model	5	4	3	2	1	0
GFS Model	5	4	3	2	1	0
Persistence	5	4	3	2	1	0

Climatology	5	4	3	2	1	0

13. Rate the following guidance on it usefulness for the forecast hours 48-72.

	Best					Worst
Gridded MOS	5	4	3	2	1	0
ADJMET	5	4	3	2	1	0
ADJMAV	5	4	3	2	1	0
ADJMEX	5	4	3	2	1	0
NAM/Eta Model	5	4	3	2	1	0
GFS Model	5	4	3	2	1	0
Persistence	5	4	3	2	1	0
Climatology	5	4	3	2	1	0

14. Rate the following guidance on it usefulness for the forecast hours beyond 72.

	Best					Worst
Gridded MOS	5	4	3	2	1	0
ADJMEX	5	4	3	2	1	0
GFS Model	5	4	3	2	1	0
DGEX Model	5	4	3	2	1	0
HPC Guidance 5	4	3	2	1	0	
Persistence	5	4	3	2	1	0
Climatology	5	4	3	2	1	0

15. Any comments on gridded MOS.