CENTRAL REGION TECHNICAL ATTACHMENT 94-09

EXAMINING MODEL FORECASTS AND FORECAST ERROR WITH PCGRIDDS MACROS

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1. Introduction

Numerical models play a critical role in the forecast process. With limited time to analyze the large amount of available data and design forecasts, forecasters often have very little time to study model predictions in detail. With PCGRIDDS (developed by Dr. Ralph Petersen) macros, forecasters can quickly examine a particular model forecast, compare it with other model forecasts, and examine the trends of that model. These actions can help the forecaster determine which model solution or trend to follow when designing a forecast.

Macros can be designed to compare model forecasts with later model analyses so the amount of model forecast error can be studied. Also, the error from one model can be compared with that of another model.

The purpose of this report is to show how PCGRIDDS macros can assist both the operational forecaster and the research meteorologist in the efficient examination of model data, and the detection of model error and bias. Baker (1992) and Meier (1993) contain detailed information on how to use PCGRIDDS and how to design and run macros on this software package.

The macros in this report only work when the model data being examined and compared are projected on the same map background. This requirement is met for gridded data retrieved through a PC, but is not met for data retrieved through AFOS.

2. Model Forecast Examination Macros

A. Model Analyses Accuracy

Figure 1 is an example of a macro that compares the initial analyses of two numerical models for various fields. It displays mean-sea-level (MSL) pressure, 850-mb heights, 850-mb temperatures, 850-mb wind speeds, and 700-mb relative humidity. It can be designed to compare and display any desired field.

```
loop
sdif pres msl fil1 f00 pres msl fil2 f00 ci04 dneg
txt2 MSL Pres analysis...pos values = model 1 has higher
pressure
endl
loop
pres msl fil1 & pres msl fil2 dash
txt2 model 1 (solid) and model 2 (dash) pressure fields.
endl
loop
sdif temp 850 fil1 f00 temp 850 fil2 f00 ci03 dneg
txt2 850 mb temps...pos values = model 1 has higher temps (in
Celsius)
endl
loop
temp 850 fil1 ci05 & temp 850 fil2 ci05 dash
txt2 model 1 (solid) and model 2 (dash) temp fields at 850 mb
endl
loop
sdif hght 850 fil1 f00 hght 850 fil2 f00 cil0 dneg
txt2 850 mb heights...pos values = model 1 has higher 850 mb
heights
endl
hght 850 fil1 ci30 & hght 850 fil2 ci30 dash
loop
sdif knot wspd 850 fil1 f00 knot wspd 850 fil2 f00 cil0 dneg
txt2 850 mb windspeed...pos values m model 1 winds higher (10 kt
cgntours)
endl
knot wspd 850 fil1 cil0 & kngt wspd 850 fil2 cil0 dash
loop
sdif relh 700 fil1 f00 relh 700 fi12 f00 ci20 dneg
txt2 700 mb rel humidity...pos values=model 1 higher (20%
ccntours)
endl
relh 700 fil1 ci20 & relh 700 fil2 ci20 dash
stop comm
```

Figure 1. A PCGRIDDS macro which compares two model 00-hour analyses for various fields.

The macro first displays the difference between two model analyses, so the user can see where the models differ. After this, it shows the two model analyses for the field desired, so the user can study the two solutions while knowing where the models differ.

This macro can be used to examine differences between two model analyses, which may lead to differences in the two forecast solutions. The analysis of one model may not be the same as the analysis of another model.

An example of this can be seen from the model analyses valid at 1200 UTC December 3, 1993. Figure 2 shows the extent of the differences between the NGM and Eta model analyses. Positive values indicate where the NGM had higher pressure than the Eta model. Note that the NGM had considerably higher pressure values, by as much as six millibars, across the Rockies and the Southwest. Elsewhere across the country, the analyses are close, generally within three millibars of each other. The NGM had stronger surface high pressure ridges across New Mexico and southern California.

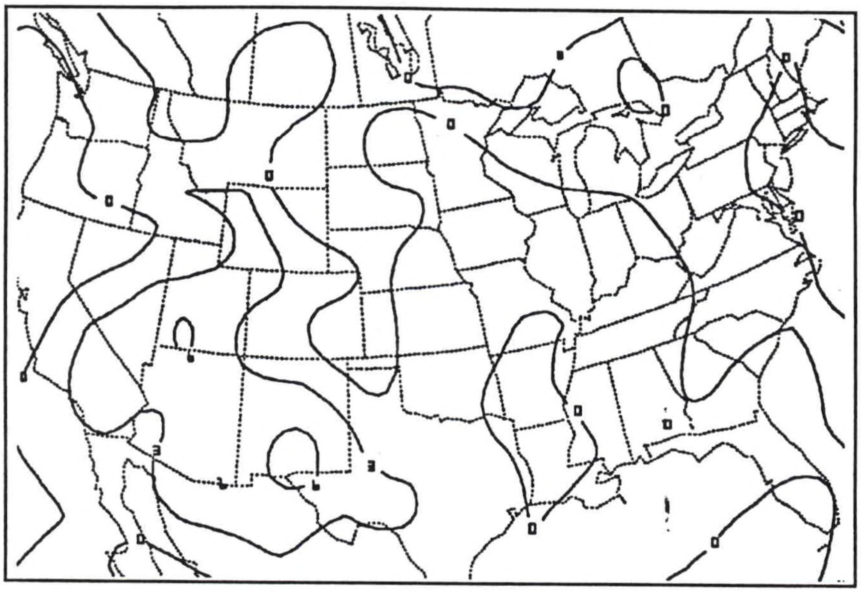

Figure 2. Differences between the NGM and Eta model analyses of surface pressure. Positive values indicate where the NGM had higher pressure than Eta. Values are in millibars.

B. Comparison of Model Forecasts

Figure 3 is an example of a PCGRIDDS macro that compares model forecasts of mandatory level heights. It shows the difference between two model forecasts, and then displays the two forecasts.

```
loop
sdif hght fil1 hght fil2 ci20 f00
txt2 Pos values where mdl 1 has higher hgts than mdl
2...contours every 20 m
endl
loop
hght ci60 fill&hght ci60 dash fil2 f00
txt2 Heights from 1st mdl (solid) & 2nd mdl (dash); 60 meter
contours
endl
loop
sdif hght fil1 hght fil2 ci20 f12
txt2 Pos values where mdl 1 has higher hgts than mdl 2...contours
every 20 m
endl
hght ci60 fil1&hght ci60 dash fil2 f12
sdif hght fil1 hght fil2 ci20 f24
hght ci60 fil1&hght ci60 dash fil2 f24
sdif hght fil1 hght fil2 ci20 f36
hght ci60 fil1&hght ci60 dash fil2 f36
sdif hght fil1 hght fil2 ci20 f48
hght ci60 fil1&hght ci60 dash fil2 f48
stop comm
```

Figure 3. A PCGRIDDS macro that compares two model forecasts for mandatory level heights. The user enters the desired mandatory level with the command "SLVL XXXX", where XXXX is the level, before running this macro.

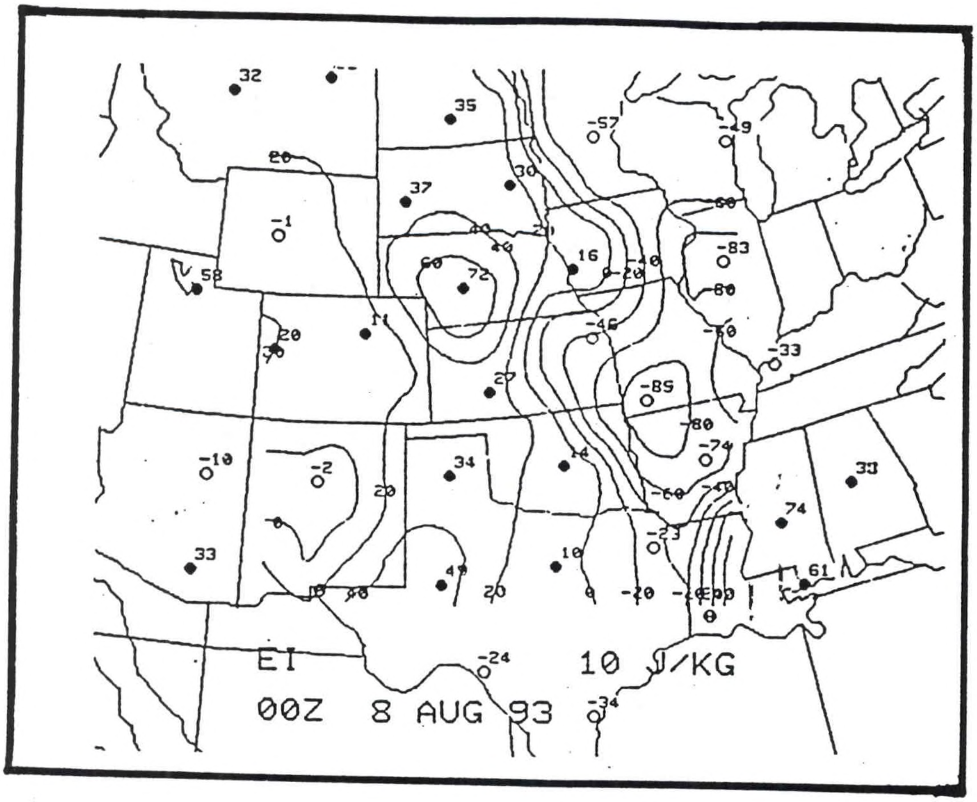

Figure 5. Energy index (EI), as defined by (Stone 1988). 0000 UTC, August 8, 1993.

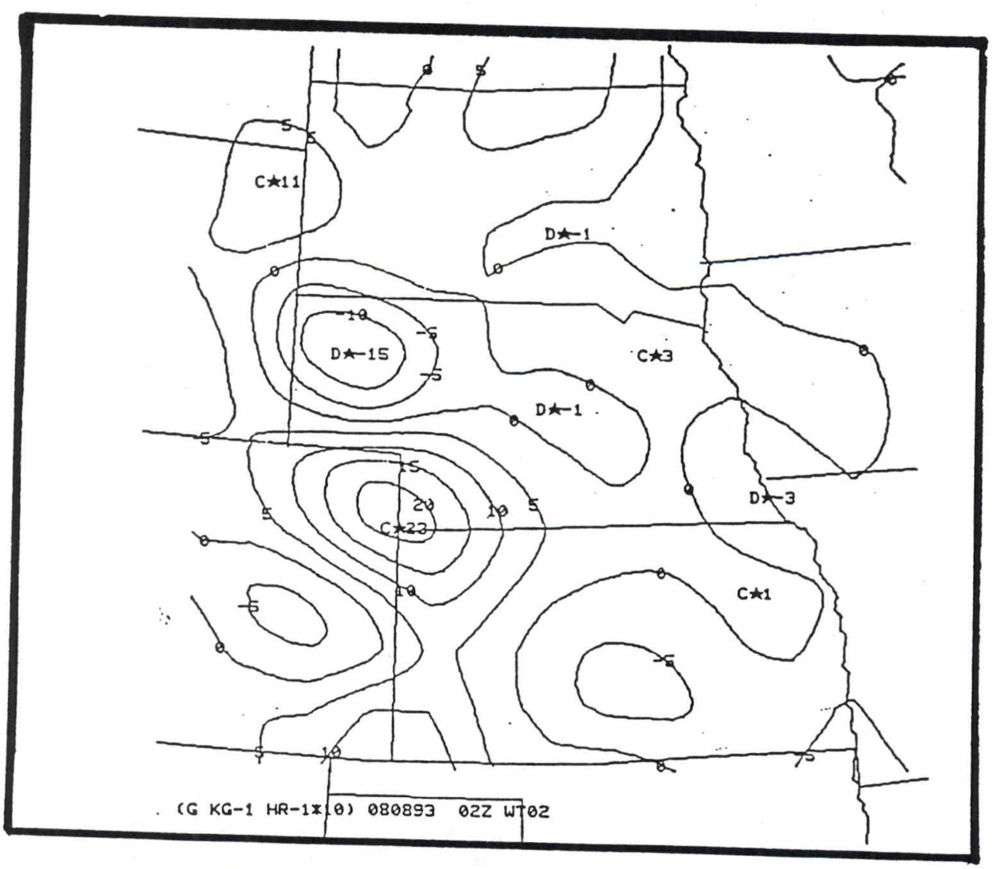

Figure 6. Surface moisture flux convergence g kg^{-1} hr^{-1} at 0200 UTC, August 8, 1993.

Figure 6 shows where these forecasts differ, and how much they differ. Positive values indicate the NGM has higher height values than the Eta model. The NGM heights across Minnesota are 70 to 100 meters lower than the Eta heights. Forecast heights are 40 to 50 meters higher in the NGM forecasts than the Eta forecasts over western Kansas and southeastern Colorado, as well as over eastern portions of Kentucky and Tennessee. Note the patterns of difference across the country. The NGM has higher heights across the East and South, but lower heights across the North.

This type of macro can be designed to display other mandatory level fields, such as vorticity, wind, temperature, dew point, and vertical velocity. Changes with respect to time (e.g. forecast 12-hour height change) can also be examined.

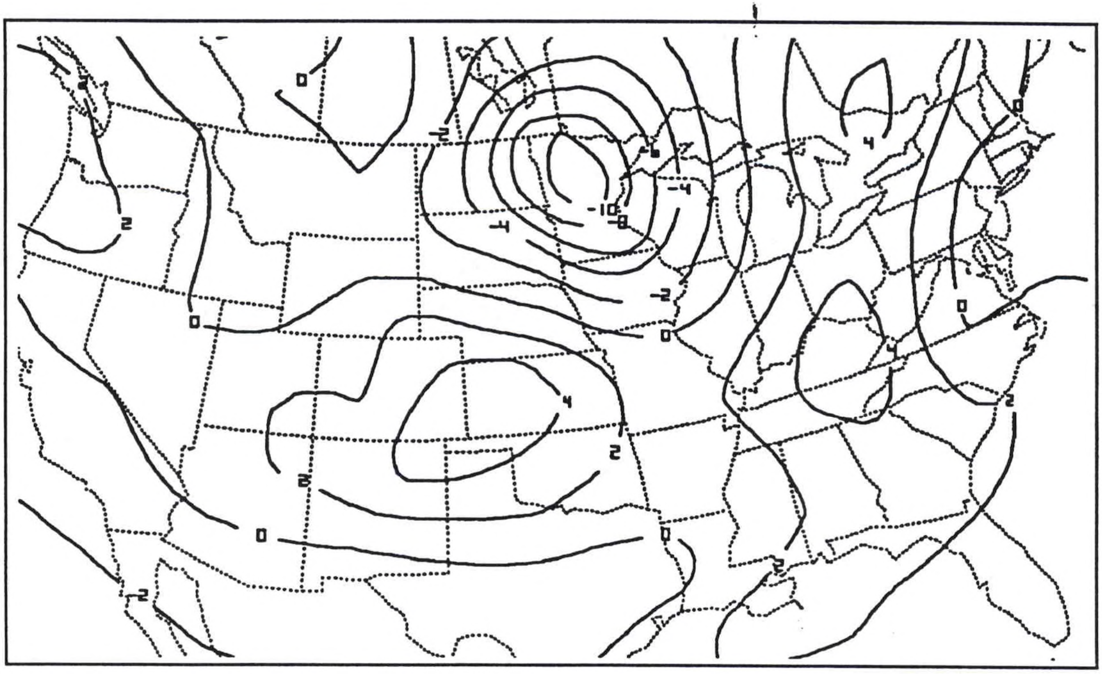

Figure 6. Differences between the NGM and Eta forecasts shown in Figures 4 and 5. Positive values, decameters, indicate where the NGM forecast higher pressure than the Eta.

C. Examination of Model Trend

Model forecast trend can be as important as the actual model forecast. The model comparison macro presented above can be altered slightly to compare two consecutive runs of one model instead of concurrent fields from two models.

Figure 7 is a macro that is similar to the one shown in Figure 3. This one compares the mandatory level height forecasts of two consecutive runs of one model. The files containing the consecutive runs of a specific model are opened before the macro is started. The first file opened should be the later run.

```
loop
sdif pres fil1 f00 pres fil2 ci03 f12 slvl msl
txt2 Pos values where later model run has higher pressure...3-mb
contours
endl
loop
pres fil1 ci04 f00 & pres fil2 f12 dash ci04
txt2 Pressure contours from previous run (dash) and latter run
(solid)
endl
loop
sdif pres fil1 f12 pres fil2 ci03 f24
txt2 Pos values where later model run has higher pressure...3-mb
contours
endl
loop
pres fil1 ci04 f12 & pres fil2 f24 dash ci04
txt2 Pressure contours from previous run (dash) and latter run
(solid)
endl
sdif pres fil1 f24 pres fil2 ci03 f36
pres fil1 ci04 f24 & pres fil2 f36 dash ci04
sdif pres fil1 f36 pres fil2 ci03 f48
pres fil1 ci04 f36 & pres fil2 f48 dash ci04
stop comm
```

Figure 7. A PCGRIDDS macro that shows model trend for mean-sea-level pressure. On the plot that is produced by this macro, positive values indicate where the model trend is toward higher pressure.

The displays from this macro are similar to those of the model comparison macro. The first display shows the model trend, the change in the forecast from one run to the next. Positive contours indicate where, and by how much, the value of a desired variable, such as 500-mb height, increased from the former run to the latter run. Following this display, the forecasts from the two model runs are presented together for the user to examine.

Forecasters can use the model comparison and trend macros to determine how reliable the model forecasts are, and decide on a "model of choice" for a particular forecast. Consistency of predictions between models, from one run to the next, indicate that the models may have a good handle on the weather situation. This may not always be the case, as illustrated in the next section.

D. Model Forecast Error Macros

Macros can be designed to compare model forecasts with later analyses and produce model error plots. Figure 8 is a macro that examines the accuracy of the 12-hour model forecast. The user simply opens three model files. The first one is the model analysis with which the model forecasts will be compared. The model analysis comparison macro mentioned above can be used to determine which model analysis to use. The second and third files are the model forecast files that will be checked for error. For example, if the user wants to compare the error of the NGM and Eta models for the 12-hour forecast period, then the second and third files are the NGM and Eta model solutions which were run 12 hours before the analysis.

```
sdif pres msl fil2 f12 pres msl fil1 f00 cin3 dneg
sdif pres msl fil3 f12 pres msl fil1 f00 cin3 dneg &
sdif hght 500 fil2 f12 hght 500 fil1 f00 ci30 dneg
sdif hght 500 fil3 f12 hght 500 fil1 f00 ci30 dneg &
sdif hght 850 fil2 f12 hght 850 fil1 f00 ci20 dneg
sdif hght 850 fil3 f12 hght 850 fil1 f00 ci20 dneg &
sdif temp 850 fil2 f12 temp 850 fil1 f00 cin3 dneg
sdif temp 850 fil3 f12 temp 850 fil1 f00 cin3 dneg &
sdif dwpt 850 fil2 f12 dwpt 850 fil1 f00 cin3 dneg
sdif dwpt 850 fil3 f12 dwpt 850 fil1 f00 cin3 dneg &
sdif temp 500 fil2 f12 temp 500 fil1 f00 cin3 dneg
sdif temp 500 fil3 f12 temp 500 fil1 f00 cin3 dneg &
bknt 850 fil2 f12 & bknt 850 fil1 f00
bknt 850 fil3 f12 & bknt 850 fil1 f00
bknt 500 fil2 f12 & bknt 500 fil1 f00
bknt 500 fil3 f12 & bknt 500 fil1 f00
sdif knot wspd 850 fil2 f12 knot wspd 850 fil1 f00 cil0 dneg
sdif knot wspd 850 fil3 f12 knot wspd 850 fil1 f00 cil0 dneg &
sdif knot wspd 300 fil2 f12 knot wspd 300 fil1 f00 ci20 dneg
sdif knot wspd 300 fil3 f12 knot wspd 300 fil1 f00 ci20 dneg &
stop comm
```

Figure 8. A PCGRIDDS macro that displays the amount of error for the 12-hour forecast period.

After the appropriate model files are opened, the user runs the macro. The macro shown in Figure 8 displays the amount of error with regard to the following fields: mean-sea-level (MSL) pressure, 850-mb temperatures, 850-mb dew points, 850-mb winds, 850-mb heights, 500-mb heights, 500-mb temperatures, and 300-mb winds. This macro can be edited to produce other fields. The displays that are produced show forecast error, with positive values indicating where the model forecast was too high, and negative values indicating where the forecast was too low.

When using PCGRIDDS macros to study the models, the following points should be remembered:

1. model forecast error can be large, especially during the 36-hour and 48-hour forecast periods;
2. two model solutions that are in agreement are not necessarily accurate;
3. when two model solutions are in disagreement, there is no guarantee that either one is more accurate than the other.

Figures 9 shows the 36-hour forecast MSL pressure field from the 1200 UTC December 3, 1993 run of the Eta model. Figure 10 shows the amount of forecast error for the Eta solution. The NGM solution was almost identical to the Eta solution. As a result, the magnitude and location of error for the NGM was nearly identical to that shown in Figure 10. In this case, the model solutions had pressure values that were 8 to 12 millibars too high across the northern Plains and northern Rockies, and pressure values that were too low across the southern Rockies. Despite the fact that the NGM and Eta forecasts were in agreement, both had large error. All three of the points given above were illustrated in this example.

The model forecast error macro can be used in research studies to examine model error, and determine model bias in common weather situations. The macros not only show the actual amount of error, but also display the patterns of error across the United States.

3. Summary

Numerical models play an important role in the forecast process. However, they are not perfect. Model solutions can contain a large amount of error, especially in the 36-hour and 48-hour forecast periods. Forecasters can use

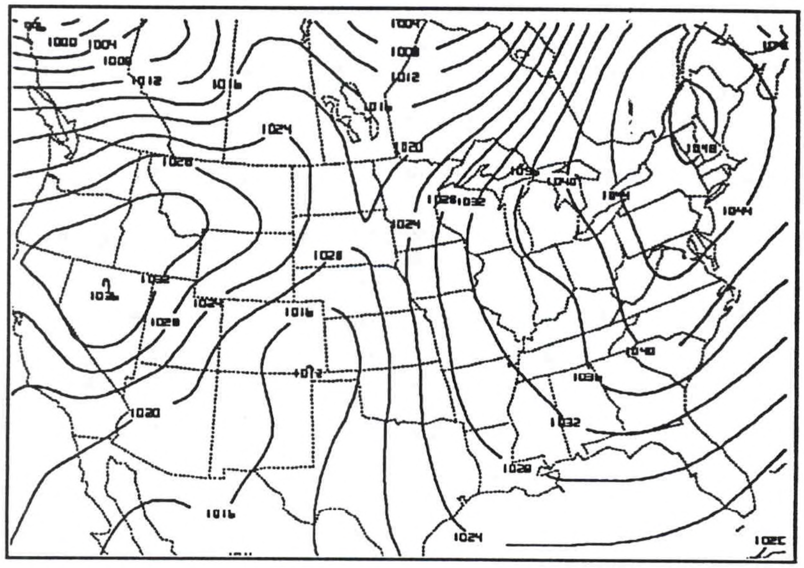

Figure 9. A 36-hour Eta forecast of mean-sea-level pressure.

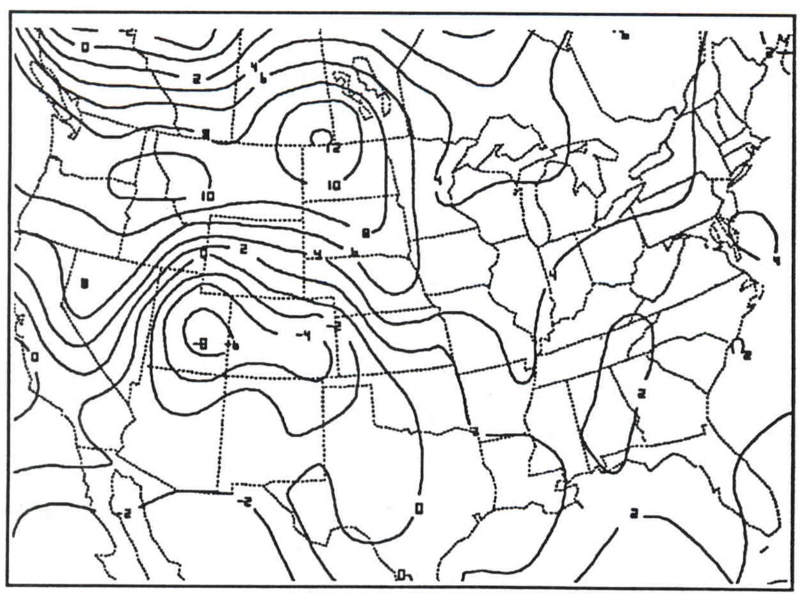

Figure 10. 36-hour error for the forecast shown on Figure 9. Positive values indicate where the model forecast was too high. Values are in millibars.

PCGRIDDS macros to efficiently examine model analyses and forecasts, compare model solutions, and study model forecast trends, all of which are important steps in the design of accurate forecasts.

Forecast error macros can be a useful research tool for examining model error and bias. They can be used to compare model forecasts with later model analyses, and study the magnitudes and patterns of forecast error.

Despite the limited amount of time available for data analysis and forecast design, operational forecasters need to find a way to examine the model solutions carefully. PCGRIDDS macros can help forecasters accomplish this in an efficient manner.

4. References

Baker, D. 1992: The PCGRIDDS Command File Menu Program. U.S. Department of Commerce, 5 pp.

Meier, K. W., 1993: PCGRIDS User's Manual. U. S. Department of Commerce, 26 pp.