wrf2gem: A Program to Convert WRF netCDF Output to GEMPAK Format

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1. Introduction

Currently, it is customary to execute the Weather Research and Forecasting (WRF) model such that its output is encoded in netCDF (network Common Data Form) format. NCAR officially supports two display methods that can handle that output natively, NCL (NCAR Command Language) scripts and the RIP4 (Read/Interpolate/Plot version 4) program. However, many other programs can be used to interrogate model output (or more generally, gridded data), but they cannot handle netCDF data natively. Thus, NCAR officially supports two methods of post-processing WRF output, one for use with GrADS (Grid Analysis and Display System), the other for use with Vis5D.

Another suite of programs that is commonly used to analyze model data is the collection known as the GEneral Meteorology PAcKage (GEMPAK). Because GEMPAK is a Unidata-supported program suite, its use is particularly widespread in the university community. Although demand for the ability to view WRF output using GEMPAK has been strong at previous WRF users' workshops (J. Otkin, personal communication), a straightforward method for doing so has not been available, until now.

Freely available source code is now available for a program, known as wrf2gem, that reads WRF netCDF output and converts it into GEMPAK format.[1] The program includes numerous diagnostics and can be trivially modified to place in the GEMPAK output grids any variable included in the WRF netCDF file. In addition, other diagnostics can be integrated into wrf2gem with ease once the diagnostic function itself has been written.

2. Program Structure

The conversion program is written in standard Fortran 90 (Metcalf and Reid 1999) and consists of the five source files described below:

wrf2gem.f90 The main program. Requires no modification for additional diagnostics.

netcdf.f90 Contains functions that read data from WRF netCDF output files. Requires no modification for additional diagnostics.

gempak.f90 Contains functions that write data to GEMPAK files. Requires no modification for additional diagnostics.

registry.f90 Contains basic information for each WRF variable and diagnostic. Requires modification for additional diagnostics.

diagnostics.f90 Contains functions that compute nontrivial diagnostics. Often requires modification for additional diagnostics.

In addition to these five files, compilation of wrf2gem depends on the netCDF and GEMPAK libraries. Compilation and execution of wrf2gem has been tested using the Portland Group Fortran 90 compiler only, but the code has not been written to depend on that compiler, so it should work for others as well.

The user has control over wrf2gem through a namelist input file named `convert.nl`. For example, the namelist file determines which netCDF file(s) should be converted to GEMPAK, what the GEMPAK file should be called, the maximum number of grids to allow in the GEMPAK file, whether an existing GEMPAK file can be overwritten, whether the GEMPAK grids should be stored using GRIB style packing, which fields should be output to the GEMPAK file, and how interpolation to isobaric coordinates should be handled, among other things.

3. Diagnostics

At the present time, approximately 60 WRF variables and diagnostics are programmed into wrf2gem. These possible outputs can be categorized into three groups. The first group consists of those variables that are directly available in the WRF netCDF output. Examples in this group include terrain height, perturbation pressure, and the water vapor mixing ratio. The second group consists of diagnostics that are interpolated to a set of equally spaced isobaric levels. Examples in this group include geopotential

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[1]The wrf2gem package is available for download from http://speedy.aos.wisc.edu/~sgdecker/wrf2gem/.

height, the three wind components, and temperature. Because GEMPAK can automatically calculate many quantities (e.g., dewpoint, potential temperature, vorticity, etc.) from others, only the most basic diagnostics have been programmed in this category. The final group consists of all other diagnostics, including those output on the native WRF vertical coordinate, which, for GEMPAK's sake, is considered to be sigma ("SGMA"). Examples in this group include precipitation accumulations over certain time intervals, severe weather parameters, sea level pressure, unstaggered wind components, and many others.
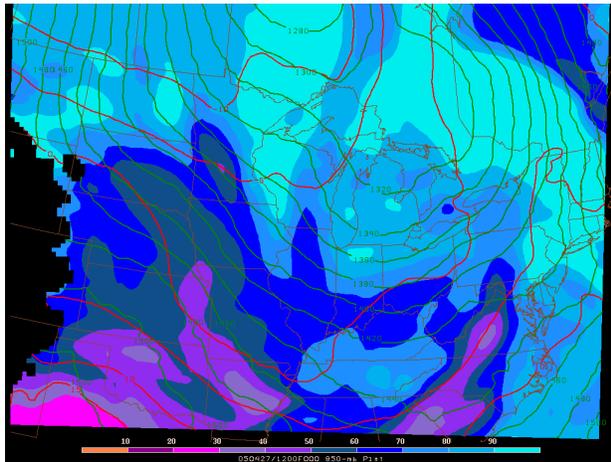

Figure 1. 850-mb plot of relative humidity (shaded, %), temperature (red, contour interval 5^oC), and heights (green, contour interval 20 m) using wrf2gem and the GEMPAK program gdplot2.
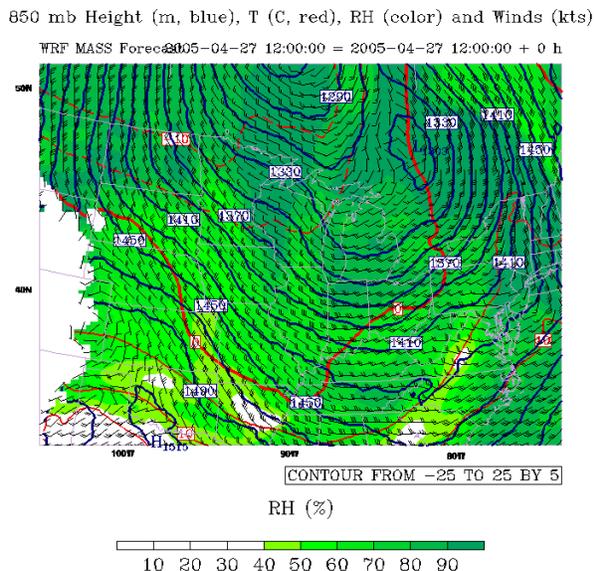

Figure 2. Same as Fig. 1 but using the WRF NCL scripts. In addition, relative humidity uses a different color scale, and heights are contoured in odd multiples of 10 m.

4. Validation

The conversion program produces results that, when plotted using GEMPAK, appear identical (or nearly so) to plots produced using the NCL scripts. As an example, Figure 1 shows an 850-mb plot from a particular WRF integration. Figure 2 shows a plot from that same integration valid at the same time, but produced using the WRF NCL scripts. These figures show that, at least for the cases of relative humidity and temperature, the two methods produce identical plots. The height contours are also very similar, but it is harder to tell how well they match due to differing contour intervals.

An additional issue arises when calculating geopotential heights, and that is the question of how those heights should be interpolated in the vertical. Two reasonable interpolation schemes to use are linear interpolation of heights with respect to pressure (hereafter referred to as "linear interpolation") and, informed by the hydrostatic equation, linear interpolation of heights with respect to the natural logarithm of pressure (hereafter referred to as "logarithmic interpolation"). Furthermore, there are two points in the processing at which this decision must be made, first when vertical unstaggering occurs, and the second when the heights are subsequently interpolated to the desired equally spaced isobaric levels. The method that appears to work best (hereafter referred to as "partial logarithmic interpolation") uses linear interpolation for the unstaggering step and logarithmic interpolation for the vertical interpolation step.

Figure 3 compares the results of using the methods described above on a 6-hr WRF forecast along with the corresponding 6-hr NAM forecast. In general, the partial logarithmic interpolation method matches the NAM forecast the best, and this is also true at the initial time (not shown). Also important to note is that the different interpolation schemes produce results that differ in magnitude by much less than the spread between the NAM and WRF integrations. Finally, a close comparison (not shown) indicates that the WRF NCL scripts use linear interpolation (i.e., WRF NCL script-derived height contours match the dotted red lines).

5. Extending wrf2gem

The wrf2gem program is designed to be readily extensible. For the case of a WRF variable (i.e., a variable directly available in the WRF netCDF output), only four lines of code (one of which is a comment) need be added to `registry.f90` to allow wrf2gem to handle that additional WRF variable.
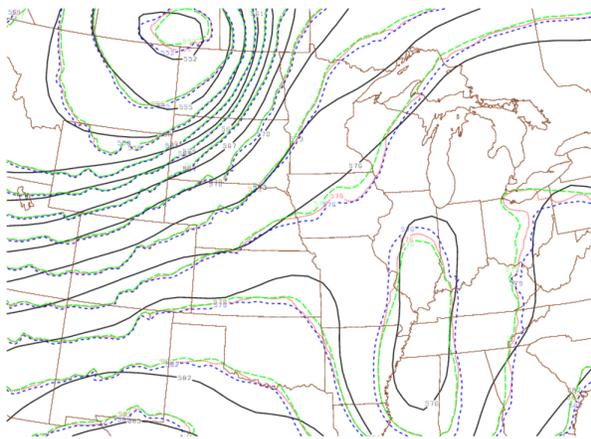
Figure 3. 500-mb heights from 6-hr forecasts of the NAM and WRF models, each initialized at 0600 UTC 2 June 2005, and a contour interval of 3 dam. Solid black lines show the NAM forecast. For the WRF forecast, dotted red lines show the result of using linear interpolation in wrf2gem, long dashed green lines show the result of partial logarithmic interpolation in wrf2gem, and short dashed blue lines show the result of logarithmic interpolation in wrf2gem.

Adding additional diagnostics requires more work, but once the diagnostic function itself is written and tested, its integration into wrf2gem is straightforward. The `README` file included with the wrf2gem package contains complete instructions for adding more variables and diagnostics to wrf2gem.

6. Final Remarks

A conversion program called wrf2gem has been implemented that converts WRF model output into GEMPAK format. In this way, the well-known suite of GEMPAK programs may be used to interrogate the model output. The availability of this tool may help foster the use of the WRF model in the atmospheric science community[2].

However, wrf2gem does have limitations in at least two areas. First, the WRF polar projection is not yet supported. Second, GEMPAK grids output on equally spaced isobaric surfaces are set to "missing" for regions where a pressure surface is underground. Although this behavior is identical to that of the WRF NCL scripts (see Figs. 1 and 2 over the Rocky Mountains), some users may wish to have these regions filled with values derived from interpolation from above the ground. A method to interpolate geopotential heights underground using a standard lapse rate is currently being implemented.

7. Reference

Metcalf, M. and J. Reid, 1999: *Fortran 90/95 Explained.* 2nd ed. Oxford University Press, 339 pp.

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[2]The author is aware of some MM5 users who have not switched to the WRF model simply because they cannot use GEMPAK on the WRF output.