A Set of Diagnostic and File Utilities for MM5v3

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Introduction

One of the major practical challenges in numerical weather prediction and climate modeling is managing and analyzing the large amounts of data produced by the forecast model. Often one wishes to know simply what fields were generated, and how the data are distributed in space and time. In the process of debugging model software, it is useful to be able to extract representative values, or summary statistics for model fields. Model sensitivity studies often require the differencing of model data written to the same domain from different configurations of the same model. In all these—and many other—situations a set of flexible, extensible tools is desirable. In this paper we describe such a set of tools that is currently under development.

PIRCS Diagnostics Requirements

The software described in this paper was motivated by our participation in the Project to Intercompare Regional Climate Simulations (PIRCS) [1]. PIRCS Experiment 1a) and 1b) are simulations of the summer 1988 US drought, and the summer 1993 US Midwest flood, respectively. For both experiments participants were required to supply numerous fields [2]. Some of these fields were available as standard MM5 output, others were diagnostic quantities that had to be computed from the model output. The data submitted to PIRCS had to be written in their proprietary file format.

The requirement for a specific data file format motivated the creation of a set of file-handling utilities, and the need to compute a wide variety of diagnostic quantities motivated the development of a diagnostics library.

The Software

In response to our requirements for the PIRCS experiments, two sets of tools were created: A set of MM5V3 file inquiry and manipulation tools **V3_Tools**; a library of diagnostic functions **met_utils**. Both **V3_Tool**s and **met_utils** are written in fortran 90. They implement a modular design that maximizes code re-use. The software is portable to numerous unix platforms, including the SGI IRIX, IBM AIX, DEC ULTRIX, and the Cray UNICOS operating systems.

Each routine contains comprehensive argument and error checking. The interfaces to each routine are explicit, with argument types and intent (*i.e.*, **IN**, **OUT** , **INOUT**) specified completely. If a run-time error is encountered, an error message identifying the routine in which the error occurred, along with a short explanation of the error is output, and execution is terminated.

Each routine is written in a literate style, containing prologues that can be converted into **LaTeX** using the package **ProTeX** [3,4]. This enables

automatic generation of up-to-date, high-quality documentation using **make**. The use of **latex2html** allows this documentation to be translated directly to HTML.

File Utilities

The first piece of software created for **V3_Tools** was a fortran 90 module defining the MM5V3 file header format. This module is an extension of the module **v3_header_module** supplied with the source code of the MM5 tools **v22v3** and **v32v2** [5]. The following new public data members were added:

- Big header data structures **bhi** and **bhr**, and their respective descriptions **bhic** and **bhrc**.
- Definition of header flag, whose value determines what type of header is about to be read, or if the end of a time period has been reached.
- Constants defining the possible types of grid orderings and staggerings.
- Definition of integer and real versions of the MM5 missing data flag.

These additions to **v3_header_module** complete the software implementation of the set of descriptors defined in the definition of the V3 file format [6].

The header module was also extended by the addition of functions for reading details from the MM5 date variable **current_date**:

- **V3_date_to_year()** – return the year from **current_date**.
- **V3_date_to_month()** – return the month from **current_date**.
- **V3_date_to_day()** – return the day of the month from **current_date**.
- **V3_date_to_hour()** – return the hour from **current_date**.

This enhanced version of the v3 header module was used to construct tools for sampling data from MM5V3 history files. Each of these tools is an executable that takes an MM5V3 history file as its first argument. The set of file tools are:

- **V3_list_fields** *file* lists fields written to the history file and their descriptions.
- **V3_probe** *file* – produces a subheader listing for each field at each time, along with sample values from each field.
- **V3_stats** *file* – produces subheader listing for each field at each time, along with minimum, maximum, average, standard deviation
- **V3_grid** *file* – reports the type of horizontal grid, its resolution, vertical levels, and latitude and longitude at the corners of the domain.
- **V3_times** *file* – produces a listing of the time periods for which data is written in the file.
- **V3_time_average** *file av_file* – produces a time-averaged field for each field in file and writes it in MM5V3 format to *av_file*.
- **V3_compare** *file1 file2* – compares the contents of file1 and file2 to determine if they have identical spatial and temporal sampling. The two files have identical spatial and temporal sampling if they have the same horizontal and vertical grids, time sampling, and start and end times.
- **V3_diff** *file1 file2 file3* – subtracts the values in file2 from file1 and writes the result

to *file3*. The data files file1 and file2 must have the same spatiotemporal sampling as defined by **V3_comp**.

Diagnostics Utilities

The **met_utils** library is a set of routines that can be used to compute common diagnostic quantities using standard output variables from MM5. The library can be used either in applications that compute diagnostics off-line (*i.e.*, from the output file after the model has run) or as plug-ins to MM5 to compute diagnostics on-line. Some of the algorithms in this library are based on those implemented in the MM5 GRAPH utility [7], while others have been written from first principles. In most of the routines, the algorithm used is described, and its source identified.

The diagnostic quantities currently available are:

- Upper-air quantities: pressure, geopotential height, potential temperature, and specific humidity.
- Surface quantities: surface pressure, sea-level pressure, 2 meter air temperature, and surface wind stress (from frictional velocity).
- Surface radiative and heat budgets.
- Hydrological budget quantities: total precipitable water, total runoff, total precipitation, and total soil moisture content.
- Vertical integrals.
- Temporal statistics, including averages, integrals, and maximum and minimum values (and times) for a given time window.

The set of functionalities listed above is sufficient to compute the mandatory diagnostic quantities for PIRCS.

Conclusions and Future Work

This software described in this paper is not yet available to the public, but will be released later this year (2000).

The **met_utils** library will be expanded to meet the needs for the as-yet-to-be determined set of diagnostic quantities required for PIRCS 1c and PIRCS 2 experiments. The current set of diagnostics is rather small, and the MM5 community is cordially invited to join in an open-source [8,9] effort to produce a much more comprehensive and robust diagnostic library (and quickly!).

One possible future role for **V3_Tools** is to use it as part of an effort to consolidate the numerous file format transformation utilities that already exist (e.g. **tovis5d** and **mm5tograds**). It is very likely that **V3_Tools** will be expanded to allow translation of MM5V3 format data into netCDF format [10-12].

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Notes/References

[1] Takle, E.S., W.J. Gutowski, Jr., R.W. Arritt, Z. Pan, C.J. Anderson, R. Silva, D. Caya, S.-C. Chen, J.H. Christensen, S.-Y. Hong, H.-M. H. Juang, J.J. Katzfey, W.M. Lapenta, R. Laprise, P. Lopez, J. McGregor, and J.O. Roads, "Project to Intercompare Regional Climate Simulations (PIRCS): Description and initial results," *Journal of Geophysical Research*, **104**, 19,443-19,462 (1999).

[2] Required output fields for PIRCS experiments 1a and 1b are listed at www.pircs.iastate.edu .

[3] Sawyer, W., and A. da Silva, "ProTeX: A Sample Fortran 90 Source Code Documentation System," DAO Office Note 97-11, NASA Data Assimilation Office, NASA Goddard Space Flight Center, Greenbelt, MD 20771 (1997).

[4] ProTeX is available by anonymous ftp from the NASA Data Assimilation Office
ftp://dao.gsfc.nasa.gov/pub/papers/sawyer/protex1.4.tar.Z

[5] MM5 File conversion software packages v22v3 and v32v2 are available from NCAR's MMM anonymous ftp site.

[6] The MM5V3 file format is described on-line at
www.mmm.ucar.edu/mm5/mm5v3/v3-intro.html

[7] MM5 GRAPH is documented in the MM5 tutorial notes, available on-line at www.mmm.ucar.edu/mm5/mm5-home.html

[8] Raymond, E. S., "The Cathedral and the Bazaar," *First Monday*, **3**, No. 3 (March, 2000), available on-line at http://www.firstmonday.dk/issues/issue3_3/raymond/index.html

[9] Further details about open source development of Netscape's software are available at www.mozilla.org .

[10] Rew, R. K. and G. P. Davis, "NetCDF: An Interface for Scientific Data Access," *IEEE Computer Graphics and Applications*, Volume **10**, No. 4, pp. 76-82 (1990).

[11] The URL for the netCDF website is www.unidata.ucar.edu/packages/netcdf.

[12] The F90 module interface to netCDF was written by Robert Pincus of The University of Wisconsin, and is described at the following URL: www.unidata.ucar.edu/packages/netcdf/f90 .