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Final Report

USRA Subcontract 5555-31

The Grid Analysis and Display System (GrADS)

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USRA 5555-31 Final Report

During the period 1 September 1993 - 31 August 1994, further development of the Grid Analysis and Display System (GrADS) was conducted at the Center for Ocean-Land-Atmosphere Studies (COLA) of the Institute of Global Environment and Society, Inc. (IGES) under subcontract 5555-31 from the University Space Research Association (USRA) administered by The Center of Excellence in Space Data and Information Sciences (CESDIS). This final report documents progress made under this subcontract and provides directions on how to access the software and documentation developed therein. A short description of GrADS is provided followed by summary of progress completed and a summary of the distribution of the software to date and the establishment of research collaborations.

1. GrADS - Program Summary

The GrADS program is an interactive desktop tool that is currently in use worldwide for the analysis and display of earth science data. GrADS is implemented on all commonly available Unix workstations and DOS based PCs, and is freely distributed over the Internet. GrADS provides an integrated environment for access, manipulation, and display of earth science data.

GrADS implements a 4-dimensional data model, where the dimensions are usually latitude, longitude, level, and time. Each data set is located within this 4D space by use of a data description file. Both gridded and station data may be described. Gridded data may be non-linearly spaced; Gaussian grids and variable resolution ocean model grids are directly supported. The internal data representation in a file may be either binary or GRIB.

Since each data set is located within the 4D data space, comparison of disparate data sets is greatly facilitated. Operations may be performed between data on different grids, or between gridded and observational data. Data from different data sets may be graphically overlaid, with correct spatial and time registration.

The user accesses data from the perspective of the 4D data model. A *dimension environment* is described by the user as a desired subset of the 4D space. The full volume of data may be subsetted in any dimension allowing any rectangular subvolume to be chosen. Data access, manipulation, and display are limited to the selected subset which allows simple customization of displays and optimizes input/output and computation.

Operations may be performed on the data directly, and interactively, by entering expressions at the command line. The expressions resemble Fortran in their structure, so that earth and space scientists who are familiar with programming in the Fortran language can easily adapt to the GrADS command language. A rich set of built-in functions are provided. In addition, users may add their own functions as external routines written in any language. The expression syntax allows complex operations that range over very large amounts of data to be performed with simple expressions.

Once the data have been accessed and manipulated, they may be displayed using a variety of graphical output techniques, including line, bar, and scatter plots, as well as contour, shaded contour, streamline, wind vector, grid box, shaded grid box, and station model plots. Graphics may also be output in PostScript format for printing on monochrome or color PostScript printers. The user has wide control over all aspects of graphics output, or may choose to use the geophysically intuitive defaults.

A programmable interface is provided in the form of an interpreted scripting language. In the GrADS Scripting Language (GSL), a script may display widgets as well as graphics, and take actions based on user point-and-clicks. Quite sophisticated data graphical interfaces can, and have, been built. The scripting language can also be used to automate complex multi-step calculations or displays. GrADS can be run in a batch mode, and the scripting language facilitates using GrADS to do long overnight batch jobs.

2. Progress Completed

During the subcontract period, we have developed version 1.5 of GrADS, which is currently being made available to users. New capabilities and features in this version are described below.

GUI: The capability to run GrADS in a point-and-click mode represents a customizable graphical user interface (GUI) and has been greatly expanded in this version. The fundamental capability to display and control graphical widgets from a script has been provided. In this version, only one initial widget has been implemented, namely, the button. This and future widgets are fully scalable, so that the window may be any size. In addition, any graphic plotted on the screen may be treated as a widget, and users may interact with that graphic by selecting points or regions for some action. Our beta testers very quickly made use of the new capabilities and had developed many scripts of tens of thousands of lines of code before the new version was distributed to the wider user community.

Fonts: Hershey fonts were added to GrADS for this version. These fonts provide several different typefaces, along with special symbols. Proportional spacing is now supported, along with super and sub-scripting.

I/O: Several important improvements were made to the input/output (I/O) layer. These include improvements to support for the GRIB data format. GRIB versions 0 and 1 are now both supported. GRIB bit maps are also now supported. To make this support efficient, a substantial amount of code had to be developed to cache various subsets of the I/O stream internally within GrADS. Our beta testers have been extremely impressed and pleased with the speed and efficiency with which GrADS handles the GRIB data format. In addition to the GRIB improvements, caching of station data was also added. Certain types of displays commonly used with station data now can be performed up to ten times faster than before. Users of large volumes of observational data, such as satellite soundings, found this improvement to be extremely important.

Linefill: A new graphics output type was added where the areas between two line plots can be shaded with any color. Different colors to indicate the regions above and below are supported. Since

the capability was added in a general way, plots with varying colors to indicate distance between the lines can be produced.

Pre-Projected Grids: By default, GrADS assumes that the horizontal spatial data dimensions are longitude and latitude, and that the grids are rectilinear in longitude and latitude. While this is a valid assumption for most data, there are many data sets expressed on grids that are rectilinear only when overlaid on a map projection such as polar stereographic or Lambert conformal. GrADS can now support those grids directly. This is done by an automatic interpolation from the grid space into a specified latitude-longitude space via bilinear interpolation. This interpolation is controlled by the user, and when it is in force, information messages are displayed to inform the user.

Hardware Layer: The interface between the graphics hardware and the rest of GrADS is well defined and layered. This interface has worked well for the last three years, but the requirements for GUI enhancements, along with efforts to port GrADS to the MS Windows environment, have shown that the old interface was inadequate. In this version, this layer has been completely rewritten, so that GrADS now supports graphics segments at a low level, and buffers graphics contents internally. For the X Windows interface, this allows the window contents to be re-written when the window is resized or re-displayed after being hidden. It also enhances the hardcopy support, allowing the screen contents to be written out at any time, and providing the possibility of direct hardcopy output from GrADS in various formats. This enhancement is the major part of the work required to port GrADS to the MS Windows environment, which is expected to be completed over the next few months.

3. Software Distribution and Research Collaborations

As this final report is being prepared, there are over 400 earth and space scientists at over 150 institutions worldwide who are actively using GrADS. The program is being distributed via anonymous ftp over the Internet. Due to the open distribution of the program, we cannot provide a more precise estimate of the size and demographics of the user community. The estimate above is based on the number of users who have directly requested the program via electronic mail. Since GrADS is also being distributed via anonymous ftp from the SSL at University of Colorado, GSFC, NCAR, and MRI (Japan), it is impossible to determine the total number of users. We suspect the actual user base is at least double this estimate.

We provide executables for a large variety of Unix platforms, including SGI, IBM, DEC Alpha, DEC Ultrix, HP, NeXT, Linux, and Sun. We also support a version that runs on DOS based PCs. The DOS version has proven to be particularly valuable to overseas users, especially those in developing countries.

We have recently installed a WWW server and have developed a Mosaic home page with related information. We will be distributing GrADS and GrADS related materials via Mosaic in the near future.

While development has been underway, we have continued to support the rapidly growing user community by answering email queries, providing specialized GSL scripts to users for customizing their data analysis using GrADS, and giving lectures at various institutions and conferences.

During the subcontract period, we have given lectures at the following institutions:

- GSFC - NASA Goddard Space Flight Center (Greenbelt, Maryland)
- NMC - National Meteorological Center (Camp Springs, Maryland)
- NRL - Naval Research Laboratory (Monterey, California)
- LLNL - Lawrence Livermore National Laboratory (Livermore, California)
- University of Washington (Seattle, Washington)
- CCC - Canadian Climate Centre (Victoria, Canada)

and a presentation was made at the following conference:

- Conference on Visualising the Atmosphere and Oceans
  University of Technology of Sydney
  Sydney, Australia: 25-27 February 1994

We continue to discuss future design plans, both formally and informally, with users and other software developers. Discussions in past years have been very fruitful, giving us valuable information on the direction we should be going. We believe we have also made significant contributions to other development projects, both in ideas and tangible products. We have had extensive discussions on GrADS development with the following groups:

GSFC: Several organizations at NASA Goddard Space Flight Center have become heavy GrADS users, and we meet frequently with users there to discuss their future needs. We have received valuable guidance on the design for extending the GrADS data model. We are also working with some individuals at NASA on adding capability to GrADS to handle the NetCDF and HDF data formats.

NMC: The National Meteorological Center, particularly the Development and Climate Analysis Divisions, make extensive use of GrADS, and have made significant investments in writing GSL programs in the tens of thousands of lines. Development of GRIB capabilities in GrADS has been largely driven by their needs, and we meet frequently with users there to discuss future needs, such as additional GRIB capabilities, BUFR capability, additional graphics capabilities, image handling, and enhancements to the data model.

NRL: The Naval Research Laboratory (NRL) is using GrADS as an important tool for analysis and comparison of output from different models and observational data. GrADS has also become an important part of a newly developed shipboard briefing tool. We visited NRL again this year at their invitation, and, in addition to assisting them with development of a large set of GSL scripts, we also discussed their needs for future development, particularly in the handling of image data.

PCMDI: The Atmospheric Model Comparison Project (AMIP), being conducted at the Program in Climate Model Data Comparison (PCMDI) of LLNL, invited us to present GrADS to their group in June 1994. We had discussions on extending the GrADS capabilities to handle many different kinds of data. We continue to discuss and collaborate with PCMDI on extending GrADS to handle their internal data format (DRS) along with the NetCDF and HDF formats.

A common thread to these discussions is that three major new GrADS enhancements are needed:

Data Handling: Improved data handling to address more data formats, such as BUFR, NetCDF, HDF, FORTRAN formats, and internal data standards.

Image Support: Support for satellite images integrated into the rest of the software, including support for performing data calculations on images.

GUI: Users are quite anxious to see the existing script-based GUI capabilities expanded.

We have recognized that some of this work is beyond our resources, and have entered into formal development collaborations with other groups so that we can deliver new capabilities to users more rapidly. Toward that end, we have established the GrADS Development Group (GDG) which is a multi-national, multi-institutional working group which will develop the next release of GrADS in about nine to 12 months. The participating institutions in the GDG along with the individual at each institution who is leading the collaborative effort are as follows:

- COLA: Center for Ocean-Land-Atmosphere Studies - B. Doty (Calverton, Maryland)
- IMGA: Istituto Metodologie Geofisiches Ambientale - A. Navarra (Modena, Italy)
- CINECA: Centro di Calcolo Interuniversitario dell'Italia Nord-Orientale - S. Bassini (Bologna, Italy)
- MPI: Max Planck Institut für Meteorologie - R. Budich (Hamburg, Germany)
- DKRZ: Max Planck Institut fur Meteorologie - M. Böttinger (Hamburg, Germany)
- University of Washington - J. Sirott (Seattle, Washington)
- LLNL: Lawrence Livermore National Laboratory - M. Fiorino (Livermore, California)
- FUNCEME: Fundação Cearense de Meteorologia e Recursos Hidricos - F. Viana (Fortaleza,Brazil)

It is expected that the GDG will convene a workshop in Hamburg, Germany in March-April 1995 and a new release of GrADS will be made available to the user community in September-October 1995.

List of acronyms:

AMIP	Atmospheric Model Comparison Project
BUFR	Buffered Data Format
CESDIS	Center of Excellence in Space Data and Information Sciences
CINECA	Centro Calcolo Interuniversitario dell'Italia Nord-Orientale
COLA	Center for Ocean-Land-Atmosphere Studies (IGES)
DEC	Digital Equipment Corporation
DKRZ	Max Planck Institut fur Meteorologie
DOC	Department of Commerce
DOE	Department of Energy
DOS	Disk Operating System (PC)
DRS	Data Retrieval System
4D	Four Dimensional
FUNCEME	Fundação Cearense de Meteorologia e Recursos Hidricos
GDG	GrADS Developers Group
GrADS	Grid Analysis and Display System
GRIB	Gridded Binary Format
GSFC	goddard Space Flight Center
GSL	GrADS Scripting Language
GUI	Graphical User Interface
HP	Hewlett-Packard
HSF	Hierarchical Data Format
IBM	International Business Machines
IGES	Institute of Global Environment and Society, Inc.
IMGA	Istituto Metodologie Geofisiches Ambientale
I/O	Input/Output
LLNL	Lawrence Livermore National Laboratory (DOE)
MPI	Max Planck Institut für Meteorologie
MRI	Meteorological Research Institute
MS Windows	Microsoft Windows
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NetCDF	Network Common Data Format
NMC	National Meteorological Center (DOC/NOAA/NWS)
NOAA	National Oceanic and Atmospheric Administration
NRL	Naval Research Laboratory (USN)
NWS	National Weather Service
PC	Personal Computer
PCMDI	Program in Climate Model Data Comparison
SGI	Silicon Graphics Incorporated
SSL	Software Support Laboratory
USN	U.S. Navy
USRA	Universities Space Research Association
WWW	World Wide Web

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13. ABSTRACT *(Maximum 200 words)*

The Grid Analysis and Display System (GrADS) is an interactive desktop software tool that is in use world-wide for the analysis and display of earth science data. GrADS provides an integrated environment for access, manipulation, and display of geophysical data sets. This report documents progress on the development of GrADS under USRA subcontract 5555-31 during the period 1 September 1993 through 31 August 1994.

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