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Introduction

RAMS, the Regional Atmospheric Modeling System, is a highly versatile numerical code developed by several groups over the years, including the scientists at Colorado State University, the *ASTER division of Mission Research Corporation, and ATMET. ***RAMS*** is used for simulating and forecasting meteorological phenomena.

RAMS is primarily a limited area model, and many of its parameterizations have been designed for mesoscale or higher resolution scale grids. There is no lower limit to the domain size or to the mesh cell size of the model's finite difference grid; microscale phenomena such as tornadoes and boundary layer eddies, as well as sub-microscale turbulent flow over buildings and in a wind tunnel, have been simulated with this code. Two-way interactive grid nesting in ***RAMS*** allows local fine mesh grids to resolve small-scale atmospheric systems such as thunderstorms, while simultaneously modeling the large-scale environment of the systems on a coarser grid.

The atmospheric model is constructed around the full set of nonhydrostatic, compressible equations that atmospheric dynamics and thermodynamics, plus conservation equations for scalar quantities such as water vapor and liquid and ice hydrometeor mixing ratios. These equations are supplemented with a large selection of parameterizations for turbulent diffusion, solar and terrestrial radiation, moist processes including the formation and interaction of clouds and precipitating liquid and ice hydrometeors, kinematic effects of terrain, cumulus convection, and sensible and latent heat exchange between the atmosphere and the surface, which consists of multiple soil layers, vegetation, snow cover, canopy air, and surface water.

The ***RAMS*** User's Guide is intended as an aid to those who need to install ***RAMS*** on a computer system and/or run the model as a tool for studying atmospheric processes. It does not delve into many of the more technical aspects of the code. A separate ***RAMS*** Technical Description is available that describes the equations and parameterizations used in the model. A wide range of options is available for the user to select in configuring a model simulation or forecast, many or most of which are inappropriate for a particular application. The main reasons for the availability of options fall into two categories. First, certain options are required for some applications but not for others. For example, the parameterization of cumulus convection is intended for use on coarse grids where convective currents are not resolvable, whereas on fine grids, the model can simulate convection explicitly and cumulus convection should not be parameterized. Second, a variety of options are often made available to allow experimentation and testing of different parameterization schemes or parameter settings, as part of the ongoing research of improving atmospheric models. For research applications, ***RAMS*** should not be treated as a black box; as a minimum, it should be used as a "gray box", requiring considerable knowledge by the user for proper setting of the model flags and parameters. The primary intent of this documentation is to guide the user in setting up and running a model simulation. We have thus frequently injected our own experiences and advice, particularly in describing how to set values of the atmospheric model namelist variables, but it should be remembered that it is far from possible to cover all avenues in such descriptions. Our experience has been that additional direct consultation is frequently required for a user to come up to speed in using ***RAMS***.

RAMS Development History

RAMS is an outgrowth of two earlier atmospheric modeling programs conducted independently during the 1970's. A cloud model developed under the direction of Dr. William R. Cotton contributed state-of-the-art methods for modeling microscale dynamic systems and microphysical processes. A mesoscale model developed under the direction of Dr. Roger A. Pielke contributed expertise in the modeling of mesoscale systems and the influence of land surface characteristics on the atmosphere. In 1986, the process was begun of combining the capabilities of the two models into a unified multi-purpose modeling system, and thus was born the new ***RAMS*** code. In order to introduce a high degree of flexibility and versatility in ***RAMS***, particularly regarding its new grid nesting capability, and to take advantage of the ever-increasing capabilities in computer hardware and software, ***RAMS*** was built on an entirely new framework, with the numerical schemes and parameterizations from the earlier models mostly re-written for the new model structure. After two years of concerted effort, the first version of the new ***RAMS*** code was in use as a research tool. A major program of continued development has continued to the present day, resulting in many improvements and new capabilities.

The planning, design, and construction of the ***RAMS*** code have been conducted primarily by Drs. Craig J. Tremback and Robert L. Walko. This effort has been carried out with a major emphasis given to uniformity of design of the code, and nearly all developments have involved cross-discussion and/or debate that we hope has resulted in the best of our ideas being incorporated. Many valuable ideas and experiences with ***RAMS*** have been shared by the students of Drs. Pielke and Cotton and by other users over the years, which have led to significant improvements in ***RAMS***.

RAMS is now primarily supported for execution under the UNIX and Linux operating systems. The majority of the model code is written in FORTRAN, and requires a FORTRAN 90 compiler. Some use is made of C code to facilitate I/O procedures.

RAMS Version History

For a brief look back at the versions of RAMS:

This document is the sixth edition of the ***RAMS*** User's Guide, and describes Version 6.0 of ***RAMS.***

2 : Version 2c was the first version that was distributed outside of Colorado State University starting in 1991. The first edition of the User's Guide was written for the release. Code updates to Version 2c were distributed in March 1992 with a brief set of Update Notes.

3 : Version 3a of ***RAMS*** and the second version of the User's Guide were completed in December 1993.

3 : Version 3b of ***RAMS*** and the third version of the User's Guide were completed in August 1995.

During the relatively long period (4 years) following the release of ***RAMS*** (Version 3b), a large amount of model development took place, resulting in a few additional named versions that were never released nor widely used outside Colorado State University or MRC/*ASTER. Version 3c was developed alongside 3b, with the same improvements, except that it incorporated a new sub-model for soil, hydrology, snowcover, and biophysics called LEAF2. Version 3d followed from 3c with improvements to the bulk microphysics model including full prognosis of cloud water mixing ratio, supersaturation, and number concentration of all other hydrometeor species. Version 4a was developed concurrently with 3b, but with a parallel processing capability. Keeping 3c/3d separate from 4a facilitated the development of each, since major code changes were required for both. In early 1997, once the parallel processing, LEAF2, and new microphysics capabilities were functional and tested, versions 3d and 4a were merged into version 4.1, adopting a new naming convention.

Preparation of version 4.1 for general release was planned, but rapid development of the model continued including the addition of a global modeling capability, fully implicit algorithm for vapor and heat diffusion to hydrometeors, a new radiative transfer model, improvements to the objective analysis of observational data input to ***RAMS***, and modifications for the Linux and NT operating systems. In addition, automatic seasonal variation of vegetation parameters and sea surface temperature, plus easy handling of large sets of observational data files were implemented in order to perform long-term (seasonal, year-long, or longer) climate simulations, functionally similar to methods used in a version of 3b that was modified for climate simulations and was given the name Climrams. Finally….

4.3: The addition of these and other modifications to ***RAMS*** resulted in version 4.3, which became the first official released version since all these developments began.

4.4: Versions 4.4 followed with a number of added model capabilities. During 2003, v4.4 was converted to the GNU General Public License and released as free, open source software to ensure access to RAMS by all interested parties and to allow access to any modifications to be shared by the entire RAMS community. We expect all future versions of RAMS to continue as open source.

5.0: Version 5.0 began development in the late 1990's and encompassed a huge set of changes for the model code and capabilities. Beta versions of v5.0 were used by a small group of users starting in 2002, with several more versions over the past two years, working toward an official general release. Changes were very rapid with v5.0, so it never culminated with an official release until…

6.0: We decided to call the official release v6.0, so as to help avoid confusion with the v5.0 beta versions, since a major change was made to many file formats.

6.1: CSU releases from the van den Heever research group will begin with our version of RAMS 6.1 and continue thereafter. A future version 7.0 will include major modification to the parallel processing routines to eliminate the need for a Master Node and go directly to "distributed memory" equally across all CPU nodes. This has become necessary to run very large simulations on public computer clusters such as Yellowstone since no single machine has more than ~16 GB of RAMS. This architecture does not allow the requisite of a Master Node except for small simulations.

6.2: CSU now supports on the DM (ie. distributed memory) version of RAMS. The older version that required a master node for running in parallel was not practical for today's supercomputers due to limited memory on each node/core. The older version of RAMS required that the full model memory to be allocated on a master node. This is no longer possible for most supercomputers. This version 6.2+ is the DM version with grid nesting capability. The DM version in RAMS 6.1+ did not have the grid nesting capability. This is now online and has been tested on multiple supercomputers.

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- – the memory structure no longer uses the monolithic "A" array. All model fields have been defined by F90 user-defined data types.
- **I LICI E** – All model and library routines now use explicit variables typing to help eliminate bugs
- **F90 D LE** – All "include" files have been replaced by and many code files use the concept of the F90 MODULE, which has some of the characteristics of a "class" in C++.
- – continued division of the code into more code files and now a source subdirectory structure.
- **C** – In this distribution we have decided to modify the code structure to place all model files within the same directory tree (ie. rams/src/6.0/<file dir>/<file name>). This just seemed easier for the user to find files and does not make development any more difficult.

We also combined all build directory files into a single “include.mk” file and “Makefile”. This also seems easier for new users since they only have to modify a single file prior to compilation. This file also includes the list of compile object files at the bottom.

F

- **HDF5** –All intermediate and output files are now written in HDF5 format. The former “V” or “.vfm” format is no longer written, although for the current time, some “.vfm” files can be read for backwards compatibility.

: With the HDF5 output files, we now have a output files that are smaller than the previous .vfm analysis files and they are binary reproducible. Therefore, by adding a few extra fields to the files, we have elimintaed the need to write a separate set of history files. To designate this change, out new semantics are that there is a set of *a a i* files:

- o : an instantaneous snapshot of the model fields at a given point in time. These are the combined former history and analysis files.
- o : time-averaged files
- o : a user-defined subset of the fields that are written to the state files
- o : a user-defined subset of the fields that are written to the mean files

- **FDDA** – an observational data assimilation scheme based on “direct” nudging to the observations has been implemented
- **1-** – the ability to specify a nested grid boundaries from a coarser grid in a previous run has been added (not fully functional yet)
- **H** – a new run can be started from a state file of a previous run, allowing the grid structure to be changed entirely (not fully functional yet)
- **K -F** – a modified version of the MM5/WRF scheme (thanks to Chris Castro at CSU).
- – ability to perform a history restart and use only the soil/vegetation characteristics from the previous run (not fully functional yet)
- **C** – assimilation of vapor and condensate fields only from a previous run (not fully functional yet)
- **H I (D . 2010)** this is a more modern empirical relationship for heterogeneous ice nucleation that can be tied to an aerosol distribution for applied in a manner similar to the Meyers et al. (1992) ice nucleation scheme.
- **A (H 2013)**– this is a more advanced aerosol treatment scheme. There are 9 potential aerosol species, dust and sea salt source models, dry and wet aerosol scavenging representation, aerosol-radiation interaction within the Harrington radiation scheme, evaporative aerosol regeneration, aerosol/dust mass tracking.
- **F I A** – this scheme is applied to improve treatment of advection in the vertical direction. It is especially useful under conditions with strong stability and scalar variable discontinuities.

- **I** **&** – DPREP, ISAN, and RAMS have been updated to ingest 2 soil moisture and temperature layers as well as snow water content and snow depth from input GRIB datasets.

- **A** – numerous additional options to control the FDDA analysis nudging have been added.
- **LEAF3** – an update of LEAF2, now uses NDVI for computing leaf area index, vegetation fractional cover, vegetation albedo, and roughness height. The 30+ vegetation categories of LEAF2 (which came from BATS and LDAS) had a lot of duplication. These were consolidated down to 20 categories, whose parameter values were composited between BATS, LDAS, SiB2, and other values.

D F

- **ADA** – the cut-cell grid structure was initially started in RAMS 6.0 but never fully completed. It is however, complete in the OLAM model.
- **C** – this was begun in RAMS 6.0 but not fully completed and has been removed for now.
- – this was begun in RAMS 6.0 but not fully completed and has been removed. This will be replaced by the Town Energy Budget (TEB) urban model in a future release.
- **I** **-** – this was begun in RAMS 6.0 but not fully completed and has been removed.
- - this was begun in RAMS 4.3 and RAMS 6.0 but not fully completed and has been removed.
- **G** **D** - this was begun in RAMS 4.3 and RAMS 6.0 but not fully completed and has been removed. Users may move to OLAM for a global model similar to RAMS.
- **D** **I** **B** - this was begun in RAMS 4.3 and RAMS 6.0 but not fully completed and has been removed.
- - this was used in past versions for quick analysis and debugging and is considered obsolete and rarely used, and it has been removed.
- **F** – this was used at the isentropic analysis stage to tell the model whether you are using gridded pressure data or RAMS analysis files for creating varfiles. It is unclear if this was functional in RAMS 6.0. Given the propensity to use freely available gridded data, we have removed this option in RAMS and require input of gridded pressure data for creation of variable initialization and nudging files.

FOR MORE DETAILED INFORMATION ON CHANGES BETWEEN MODEL VERSION, WE REFER YOU TO THE DOCUMENT ON MODEL UPDATES. THIS IS GIVE YOU VERY DETAILED INFO ON CHANGES AMONG MODEL SUBVERSIONS.