

# *RAMS*

Regional Atmospheric Modeling System

Version 6.0

## **User's Guide - Introduction**

*by*

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## *RAMS User Guide*

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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, and for depicting the results.

**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**.

**Version 2c:** 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.

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

**Version 3b:** 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...

**Version 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.

**Version 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.

**Version 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...

**Version 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.

## ***Changes for RAMS Version 6.0***

There have been so many changes over the last several years in going from v4.4 to v6.0 that there will probably be several editions of this document as we recall more of them. We will divide this into several sections to hopefully help organize the list.

### **Code structure changes**

- **Memory structure** – the memory structure no longer uses the monolithic “A” array. All model fields have been defined by F90 user-defined data types.
- **IMPLICIT NONE** – All model and library routines now use explicit variables typing to help eliminate bugs
- **Use of F90 MODULEs** – 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++.
- **More code files** – continued division of the code into more code files and now a source subdirectory structure.

### **File format changes**

- **HDF5** – Here's a big one... 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.
- **New semantics for output files:** 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 eliminated the need to write a separate set of history files. To designate this change, our new semantics are that there is a set of *analysis files*:

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

## New features

- **FDDA obs nudging** – an observational data assimilation scheme based on “direct” nudging to the observations has been implemented
- **1-way nesting** – the ability to specify a nested grid boundaries from a coarser grid in a previous run has been added
- **History initial start** – a new run can be started from a state file of a previous run, allowing the grid structure to be changed entirely
- **ADAP** – the vertical coordinate can optionally be a “shaved-ETA” type of Cartesian system (this is experimental and should be used with caution).
- **E-eps, E-l subgrid schemes** – isotropic TKE parameterizations for high-resolution simulations (thanks to Silvia Trini-Castelli in Torino, Italy). We are considering these schemes experimental at this time.
- **Kain-Fritsch cumulus parameterization** – a modified version of the MM5/WRF scheme (thanks to Chris Castro at CSU).
- **Recycle initialization scheme** – ability to perform a history restart and use only the soil/vegetation characteristics from the previous run
- **Condensate nudging** – assimilation of vapor and condensate fields only from a previous run (experimental at this time)
- **Cumulus inversion technique** – a separate code has been written to take a RAMS simulation combined with observed precipitation rates and compute tendencies of convective heating. The separate code has not been included in the standard distribution. Please contact us if you are interested in testing this. (experimental at this time)
- **Urban canopy scheme** – a scheme to use a 3-D field of drag coefficients based on building characteristics. The coefficients must be computed separately on the RAMS grid structure. (experimental at this time)

## Modified schemes

- **Analysis nudging options** – 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.

### ***Obsolete or Deprecated Features for Version 6.0***

Some former options that have been removed from **RAMS** or marked as deprecated for likely removal in the future:

- Global model domain capabilities: This capability has been deprecated and will be continued to be removed from RAMS in future versions. This will be replaced by the new global OLAM (Ocean Land Atmosphere Model) under development at Duke University.
- Printed output

### ***Preview of Coming Attractions***

Following is a list of planned additions and modification for future versions:

- Lambert-Conformal projection option
- Integration with BRAMS development from INPE/CPTEC and the University of São Paulo in Brazil. Numerous new features:
  - Shallow cumulus scheme
  - Biomass burning scheme
  - Grell convective parameterizations