RECENT DEVELOPMENTS AND PLANS FOR MM5

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1. INTRODUCTION

Last June we released Version 3.0 of MM5 that included a land-surface model, a new file format, and several code efficiency improvements in the model. The hydrostatic option was also discontinued with this release. Since then there have been three updates as follows.

- Version 3.1 on 31 July 1999.
- Version 3.2 on 24 September 1999.
- Version 3.3 on 25 January 2000.

Here we will outline the main changes since last year's release, and describe some ideas we have for future releases.

2. CHANGES

a. Release 3.1

A new switch, BUFFRQ, was added to allow the model to use different output files for different times. The switch determines how many time periods will be in each file. The file names are MMOUT_DOMAIN1_01, MMOUT_DOMAIN1_02, etc. Restarts also increment the output file number to avoid over-writing.

The reference state was enhanced to allow an isothermal layer at the top. A parameter called TISO was added to the reference-state specification in INTERPF. This is the isothermal temperature which serves as a minimum value for the reference state. It allows the model reference-state temperature to stay close to actual temperatures in the stratosphere, so that a reference pressure of, for instance, 50 hPa corresponds to actual pressures close to that. This isothermal layer makes it easier to put the model top higher because the reference state does not become unrealistically cold at high elevations, as it does with the reference lapse rate.

b. Release 3.2

The model was modified to be more flexible in reading input soil temperature and moisture for the land-surface model. New namelist variables ISTLYR and ISMLYR allow the model to recognize soil temperature in layers other than 10, 200 and 400 cm, and soil moisture at other than 10 and 200 cm.

The model now also outputs soil temperature and moisture fields for use in 1-way nesting. The NESTDOWN program handles the necessary land-sea masking required for interpolating these fields.

A sea-surface temperature array was added in the model. For 3.2 this was not used, only passed from input to output. This was the first stage in enabling sea-surface temperature variation at the lower boundary.

The look-up table version of the Reisner mixed-phase scheme was repaired, as it had not worked since Version 3.

A major correction was made for nested runs using the IOVERW=2 (reading the TERRAIN file) option. This was an inversion of the map-scale factors that had been incorrect since Version 3.0.

The Gayno-Seaman scheme had some corrections to a Taylor expansion approximation and its diffusion coefficient calculation, and was made to work with FDDA.

There were other minor changes documented in the CHANGES file.

c. Release 3.3

A new and more accurate longwave radiative scheme was made available (IFRAD=4). This is the Rapid Radiative Transfer Model (RRTM, Mlawer et al., 1997) described by Guichard and Dudhia (1999 MM5 Workshop abstracts). The scheme uses a correlated-k method in 16 wavelength bands. It allows for ozone, that is specified climatologically in MM5 as in the CCM2 radiation scheme, and for some trace gases that MM5 currently sets to zero. It also allows for cloud optical depth, that we obtain from MM5's water path for each cloud or precipitation variable. As shown by Guichard and Dudhia, we expect this scheme to produce smaller and more realistic downward longwave fluxes, permitting more nocturnal cooling of the ground under clear-sky conditions. In release 3.4 we are converting a large section of code that is just DATA statements into a new RRTM input file RRTM_DATA in the $rrtm$ directory. This will dramatically reduce code size and will save compilation time on several platforms, such as Cray and SGI.

The sea-surface temperature (SST) was added to the LOWBDY file, and is now used to initialize surface water temperatures in the model. Having the SST field allows a better representation of water temperature in nests that use the TERRAIN input file to start them, because now the SST field can be used to give an improved representation of land-water ground temperature variations at the nest's coastline.

The definition of the GLW term for CCM2 was made consistent with all the other radiation schemes. It is now defined as the longwave downward component of the flux, so output plots are now comparable. This also fixed a problem coupling the CCM2 scheme with the new land-surface model. A correction was also made to the CCM2 scheme to prevent spurious behavior with thick clouds. This problem would have started with changes made a few years ago in Version 2, but has only recently been discovered.

The multi-layer soil model's timestep calculation in $slab.F$ was made more conservative to avoid sporadic blow-ups, particularly with coarse grid meshes. There is some evidence that a further change will be required in release 3.4, because blow-ups are still seen, though rare. We will probably add a namelist parameter to allow the user to decide how conservative to make the soil sub-steps.

The Anthes-Kuo scheme had a correction made to water vapor tendencies. This was an error introduced in Version 3.0 and will affect results done prior to this release. The vertical advection of water vapor had a minor change made also for this scheme.

The logarithmic interpolation of moisture and "θ" interpolation of temperature for vertical advection were restored as options, having been accidentally deactivated in moving to Version 3. The default is still linear interpolation of both variables.

The shallow convection scheme was made more robust by the addition of some checks. However, this scheme is still undergoing changes, and one severe error was recently discovered that makes the scheme fairly inactive for Version 3. We hope to further improve the scheme by release 3.4. There are situations where it is becoming clear MM5 needs a good shallow convection scheme to properly represent cloud cover, particularly in oceanic regions, and this is a priority for the physics development.

3. PLANNED CHANGES

a. Release 3.4

MM5 is being increasingly run on long time scales for regional climate and air-quality applications. Beyond seven days or so, it becomes necessary to consider sea-surface temperature variations with time, and up until now the standard MM5 code has not had a mechanism for automatically including these. From release 3.4 we will be allowing the LOWBDY file to have time-varying fields that are periodically read into the model, much like the lateral boundaries. However, unlike the lateral boundaries, the SST field will be read in as a new value, not a tendency, and the old value will be overwritten when it is read in. INTERPF and NESTDOWN are modified to provide the time-varying LOWBDY with the same frequency as the BDYOUT file. Snow-cover variation will be done the same way. The model will read the LOWBDY file when it reaches the end of the valid time for the lower boundary fields, which is information in the fields' sub-headers. We also plan to allow separate nested input files of LOWBDY for high-resolution SST information. If these are not provided, the model interpolates the new coarse-mesh values to each active nest.

We are adding the capability for interpolating LSM fields to nests, so that starting a nest by interpolation during an LSM run gives reasonable values at coastlines. This requires logic to correctly mask the land and water while doing the interpolation of certain fields such as soil temperature and soil moisture. Up until now we have not recommended using the IOVERW=0 option with the LSM, and instead either running a one-way nest, or inputting the nested fields (IOVERW=1), because REGRID and NESTDOWN already have the correct masking interpolation.

A long-standing problem in most of the boundary-layer schemes is the conversion of ground temperature, TGB, to potential temperature, and back to temperature in the $slab.F$ routine, then back to potential temperature, and finally to temperature at the end of the PBL routine. This can lead to spurious drifts in ground temperature, even when it is supposed to remain constant for a water surface. While the drift is quite slow, long-term simulations may show some effects. It also appears that some computers do not do the conversions between temperature and potential temperature accurately, and it can lead to a cold bias due to truncation errors. This is being corrected in the next release by having ground potential temperature as a separate local variable in all the PBL schemes that call $slab.F$.

We are making several changes to the model output for release 3.4. One problem that has been solved is the drift of the real-number output times such that occasional outputs may be a time-step later than the nearest time to the exact requested output time. This is solved by using integer calculations to determine when the model outputs, so that the model will always output at the $nearest$ time to a requested time.

The model output will also have additional diagnostic fields for radiation. These will be OSW and OLW for outgoing shortwave and longwave radiation to complement the GSW and GLW ground values. The new fields can be used to directly compare with satellite data, or generate quasi-satellite image plots.

We are adding a capability for time-series output for points selected by latitude and longitude. The model will output certain surface quantities and integrated cloud water for every time step at the nearest model point to the selected position. The time-series output is an easily read ASCII file that can be fed to plotting packages.

We also want to include a simple “bucket” soil moisture model option that will allow representation of the gross effects of soil moisture variation without the need for a full land-surface model. This model will keep track of water gained or lost by the ground due to rainfall and evaporation, and will change the moisture availability accordingly. It could be initialized with some soil moisture information available from other models.

It is possible that the Pleim-Xiu land-surface package will be available by release 3.4. The code has been added to Version 3.3 and is being tested and prepared for release. Details are given by Pleim and Xiu (2000 MM5 Workshop abstract).

b. Later changes

Another land-surface model by Moelders (2000 MM5 Workshop abstract) is currently being tested as a possible future addition to the standard model. Further LSMs that various groups already have put in their versions of MM5 include PLACE from NASA Goddard and Penn State, and the Smirnova LSM from the RUC model at the Forecast Systems Laboratory (NOAA). The Common Land Model, developed by the University of Arizona and others, is another candidate. To incorporate such a large number of LSMs it will be necessary to develop a generalized interface between them and the model, rather than couple them to specific PBL schemes as is currently done. The general interface would include a surface-layer scheme incorporating similarity theory or an equivalent scheme for surface layer properties in the atmosphere, the LSM, and a PBL scheme to take the fluxes from the LSM and handle vertical fluxes in the atmosphere. These three components could all have options that could be mixed in any combination.

We would also like to add 2 meter temperature and 10 m wind fields to model output to more easily compare model output with observations. Currently these are hard to derive accurately from standard output because stability information is also required to apply similarity theory for vertical interpolation to the correct levels.

Some work has been done on adding a “sponge” upper boundary condition option for MM5 that could be used as an alternative to or in addition to the upper radiative option, and we would like to generalize this for a future release.

4. REFERENCES

Mlawer, E. J., S. J. Taubman, P. D. Brown, M. J. Iacono and S. A. Clough, 1997: Radiative transfer for inhomogeneous atmospheres: RRTM, a validated correlated-k model for the longwave. *J. Geophys. Res.* **102(D14),** 16663–16682.