RECENT DEVELOPMENTS AND PLANS FOR MM5 VERSION 3.5 AND BEYOND

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1. INTRODUCTION

Last November we released Version 3.4 of MM5, the latest in a series of releases since Version 3.0 came out in June 1999. We have made an effort to reduce the frequency of releases since last year. The gap between releases 3.3 and 3.4 was about ten months, and Version 3.5 is due this summer. Despite the release of the Weather Research and Forecasting Model (WRF) in November 2000, it is recognized that there is a large number of continuing MM5 users, and we plan to continue supporting MM5 for several years yet. Development work on MM5 will certainly reduce as WRF's capabilities overtake it, but WRF will not have basic nesting capabilities for at least a year, and the physics and initialization options are still limited. The WRF timeline includes a research-quality release with 3DVAR in November 2002, and that could signal the beginning of the end for MM5.

MM5 users are encouraged to try out WRF in the meantime, and to give us feedback on its current basic version. Anyone wanting to do idealized studies should consider WRF rather than MM5 now, because it is easier to use in those applications.

Here we will outline the main changes in last year's 3.4 release, and describe some ideas we have for 3.5 and future releases.

2. CHANGES

Version 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 allow 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 is read in as a new value, not a tendency, and the old value is 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. The model reads 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 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. The switch *ISSTVAR=1* activates reading later LOWBDY files.

We also added 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. Before 3.4, 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 was 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 led to spurious drifts in ground temperature, even when it was supposed to remain constant for a water surface. While the drift was quite slow, long-term simulations may have shown some effects. It also appeared that some computers did not do the conversions between temperature and potential temperature accurately, and it led to a cold bias due to truncation errors. This was corrected in the 3.4 release by having ground potential temperature as a separate local variable in all the PBL schemes that call *slab.F*.

We made 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 now also has additional diagnostic fields for radiation. These are named in the Version 3 output as *SWOUT* and *LWOUT* for outgoing shortwave and longwave radiation to complement the *SWDOWN* and *LWDOWN* ground values. The new fields can be used to directly compare with satellite data, or generate quasi-satellite image plots, and are present for all radiative options except *IFRAD=0,1*.

For the MRF PBL, we have added diagnostic outputs of the 2m temperature and mixing ratio, and the 10 m winds, for comparison with standard surface observations.

We added a capability for time-series output for points selected by latitude and longitude. The model outputs 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. The switch *IFTSOUT* in the *OPARAM* namelist, together with strings of latitudes and longitudes (*TSLAT* and *TSLON*), produce additional outputs on unit numbers starting from 26 for domain 1.

We have also included a simple "bucket" soil moisture model option that allows representation of the gross effects of soil moisture variation without the need for a full land-surface model. This model keeps track of water gained or lost by the ground due to rainfall and evaporation, and changes the moisture availability accordingly. It simply assigns half of the precipitation as run-off that takes no further part in the budget. The moisture availability has upper and lower limits depending on land-use, and there is also a factor that restricts evaporation rate based on land-use. These values are controlled by an ascii file called BUCKET.TBL. It can be initialized with soil moisture information available from some datasets (*IMOIAV=2*), or the current land-use based value (*IMOIAV=1*).

The Pleim-Xiu land-surface package is now available. Details are given by the Pleim and Xiu (2000 MM5 Workshop abstract). It has two layers for predicted soil moisture and temperature, includes vegetation effects, and comes with its own PBL parameterization that is related to the Blackadar PBL scheme. This is activated with *IBLTYP=7, ISOIL=3*.

Occasional instability of the 5-layer soil model has led us to include a new namelist parameter, *SOILFAC*, that can be used to reduce the soil time-step to a more conservative value. The old value corresponds to unity, and increasing this to 1.25 is sufficient to prevent most instability problems. This only causes a minor increase in computing time (possibly of order one per cent).

The model now allows the user to change the time-step for a restart by simply changing *TISTEP*. Previously, changes to this namelist parameter would have been ignored in restarts. This is only to help debugging, or for time-critical situations, such as operational forecasts or long-term simulations, and is not generally recommended for scientific studies.

Numerous other changes and bug-fixes are listed in the *CHANGES* file.

3. PLANNED CHANGES

Version 3.5 and beyond

Version 3.5 is planned for the end of summer 2001. These are changes we are implementing for this release and in the near future.

Additional surface diagnostic (2m and 10m) fields are being output for the Blackadar and Eta (Mellor-Yamada) PBL options. Version 3.4 only had these for the MRF PBL.

The thermal roughness length (z_{0T}) is an area of great uncertainty in the current schemes. There is a debate as to whether roughness length for heat and moisture should differ from that for momentum, or even from each other. A recent paper by Pagowski and Moore (2001) mentioned that the thermal roughness length for heat and moisture should be the same. In the current surface scheme used in both the Blackadar and MRF PBL's, there is a viscous sub-layer for moisture fluxes, but for heat fluxes the roughness length is that used for momentum. For this release we are adding a new switch that selects some different formulations of thermal roughness length. *IZ0TOPT=0* gives the original Carlson-Boland formulation applied to moisture flux (Zhang and Anthes 1982) that has been used in MM5 for many years. *IZ0TOPT=1* gives the Garratt (1992) option, recommended by Pagowski and Moore. This has equal thermal roughness lengths for heat and moisture fluxes that are less than the momentum roughness length, and also has different formulations for land and water surfaces. *IZ0TOPT=2* gives the Zilitinkevich formulation, similar to what is used in the Eta model. Here the thermal roughness length over land is reduced and used for heat and moisture fluxes, but for water where the roughness length is small, there is no modification. The effect of using reduced roughness lengths is to restrict fluxes. These modifications produce quite large differences in fluxes (30-40 %), and, for water, options 1 and 2 produce respectively smaller and larger latent heat fluxes than option 0.

When using the land-surface model we already use the Carlson-Boland formulation for both heat and moisture. With this change, the land-surface model can also use the new z_{0T} formulations.

The Oregon State University / Eta Land Surface Model is now documented by Chen and Dudhia 2001. We are adding this to other PBL options, starting with the Eta PBL in 3.5, and later moving to the Blackadar and Gayno-Seaman PBL's.

In regional climate applications that use the LSM, there is a need for a time-varying green vegetation fraction. Currently this value remains at its initial value which is determined climatologically from global monthly fields. We want to extend this to have a climatologically varying value using this same data, but updating it daily while the model runs. The same can be done if a climatological sea-surface temperature is desired, using global monthly climatological SSTs. It is not yet clear whether this will be done in time for 3.5.

Another problem identified in MM5 simulations, particularly over tropical oceans, is continuous low cloud cover producing widespread light rain. This problem has recently been alleviated by a modification to the moist vertical diffusion scheme (*IMVDIF=1*) used by the Blackadar and MRF PBL schemes. A simple change allows the vertical mixing to follow moist adiabats not just within the cloud, as was formerly the case, but also at the cloud boundaries. This change mimics shallow convection by entraining drier air into the cloud, reducing its lifetime.

The *ISSTVAR* switch previously did not allow a specified snow-cover change, and the new release will allow this to also be updated when the lower boundary file (LOWBDY) is read periodically while using the *IFSNOW=1* option.

Release 3.5 is expected to have a simple snow-cover variation scheme (*IFSNOW=2*) that has so far been used in the global MM5 runs. This scheme is an additional capability in the *slab.F* routine to predict water-equivalent accumulated snow depth, and is therefore applicable to all the PBL schemes that call *slab.F*. The snow-cover prediction requires water-equivalent accumulated snow depth as an input field, and uses a heat and moisture budget to update the snow amount based on precipitation, melting and sublimation. It assumes melted snow runs off and is a single-layer model regardless of snow depth, but does allow the albedo and moisture availability to change with snow cover, and still includes the 5-layer soil model beneath the snow, so it should be considered a first-order approximation. It can be applied with the simple ice and other microphysical schemes.

We have a version of the CCM2 radiation scheme that directly interacts with the model clouds, rather than the relative humidity fields. Either in release 3.5 or soon thereafter it will replace the current code.

Also in the future there will be an effort to add a four-dimensional array for tracers, the fourth dimension being a user-specifiable number of tracers. These tracers will be advected and diffused like the other model scalars, and can be initialized by a user-defined subroutine. A difficulty in getting accurate tracer behavior is in their interaction with the PBL and cumulus schemes. Initially the MRF PBL can be easily modified to handle an arbitrary number of passive scalars, but more work is required to adapt any other PBL or cumulus schemes to transport them. Mass-flux type cumulus schemes such as Grell and Kain-Fritsch would be candidates.

A new version of the Kain-Fritsch convective scheme has been developed for the Eta model, and will probably be included in release 3.5. There is a new ensemble Grell scheme being tested for the RUC system that may be added to a future MM5 release. Both these schemes are also to be added to the WRF model physics choices probably within the next few months.

Another possible change follows from a recent paper by Xu et al. (2001), where there was a recommendation to allow user control over the background horizontal diffusion coefficient. They suggest that it can be expressed as $K_{H0} = \alpha \Delta x$ instead of being fixed as $K_{H0} = 0.003 \Delta x^2 / \Delta t$ m^{2}s^{-1}, where α is a namelist parameter, and $\alpha = 1.0$ ms^{-1} would give the same background diffusion when the standard "$3\Delta x$" rule is used for the timestep. This would remove an inherent time-step dependence in the background diffusion, making the results more similar for different choices of time-step for a given grid size.

4. REFERENCES

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