Ad Hoc Meteorological Modeling Group: August 2000 Meeting Summary

Attendees:
Gopal Sistla, Michael Ku (New York Department of Conservation)
Chris Emery (Environ)
Don Olerud (MCNC)
Larry Gautney[1] (Tennessee Valley Authority)
James Red, Shannon Minto (Texas Natural Resource Conservation Commission)
Jeff Stehr, Bruce Doddridge, Da-Lin Zhang, Zhan Zhang, Russ Dickerson (Univ. of MD)
Scott Leopold (Illinois EPA)
Jeff Jaros (Michigan Department of Environmental Quality)
Matthew Johnson (Iowa Air Quality Bureau)
Wusheng Ji (Wisconsin Department of Natural Resources)
Pat Dolwick, Brian Timin, Brian Orndorff (USEPA, Office of Air Quality Planning & Standards)
Jian Zhang (Virginia Department of Environmental Quality)
Jennifer Galbraith (New Hampshire Department of Environmental Services)
Dennis McNally (Alpine Geophysics)
Matthew Seybold, Michael Woodman (Maryland Department of the Environment)

Introduction:

The session was started with some encouraging remarks from the Chair of the University of Maryland (UMD) Department of Meteorology, Dr. Eugenia Kalnay. Prior to arriving at UMD, Dr. Kalnay was the Director of the Environmental Modeling Center (EMC) of the National Center for Environmental Prediction (NCEP). This group is responsible for advancing the state-of-the-science in numerical weather prediction. Dr. Kalnay shared her impression that the coupling of meteorological and environmental information was one of the most important tasks of the meteorological modeling community.

Upon completing introductions, it was observed that the membership of the Ad Hoc Meteorological Modeling Group (AHMMG) contained an interesting mixture of: a) air quality modelers and meteorological modelers, b) MM5 modelers vs. RAMS modelers, c) geographical experiences, and d) novice meteorological modelers vs. advanced meteorological modelers.

Purpose and Objective of the AHMMG:

[1] Attending in place of Steve Mueller.

It was agreed that the primary purpose of the group is to foster a community exchange of information related to numerical meteorological modeling for eventual air quality modeling (AQM) purposes. Furthermore, group members agreed that AHMMG should work closely with the two other ad hoc groups (emissions modeling and air quality modeling) to improve the overall practice of air quality modeling. There are similarities between this group and the annual MM5 User's Workshop organized by NCAR every year, however this group will consider: a) non-MM5 issues, and b) only those meteorological issues with relevance to air quality modeling.

There was some concern regarding the future of the "ad hoc" groups in light of the USEPA push for the formation of technical workgroups with the Regional Planning Organizations. As it stands presently, four workgroup subjects have been identified: air quality modeling, emissions modeling, data analysis, and monitoring. The consensus opinion was that there appeared to be on-going need for a group like the AHMMG.

Summaries/Results of Past/Present/Future Meteorological Modeling Exercises:

USEPA-OAQPS: Pat Dolwick outlined OAQPS plans for a multiply-nested set of MM5 runs over the eastern U.S. for the oft-modeled July 1995 episode. Four separate 4 km grids will eventually be modeled; the results of which will be fed into Models-3/CMAQ. There was some concern expressed by the group about the proximity of the 36 km grid to the 12 km grids and the choice of the cloud radiation scheme at resolutions greater than 4 km.

NYDEC: Michael Ku presented some MM5 results comparing the Blackadar planetary boundary layer (PBL) scheme versus the Gayno-Seaman (or TKE[2]) scheme. Generally the Blackadar scheme produced higher PBL heights due to its more efficient mixing. Other fields (T, u, v, q, etc.) also varied depending upon the chosen PBL scheme. PBL results were then shown after conversion to the AQM grid via the Models-3 Meteorology-Chemistry Interface Processor (MCIP). Interestingly, the rediagnosed PBL heights varied drastically (higher) from what was generated by MM5 which may be indicative of a problem.

Virginia DEQ: Jian Zhang presented a thorough examination of MM5 timing results on various computing platforms. This work was undertaken after initial MM5 testing over a 187*137*26 (4 day episode) grid took 86 days to complete on a SUN workstation. Interestingly, Jian found that the FORTRAN compiler version could affect the speed of MM5 (on a SUN). Jian concluded that the Alpha Servers were the fastest route by which to model MM5, followed by Linux PCS, desktop PCS, and then Sun workstations.

Peninsular Florida Ozone Study (PFOS): Dennis McNally presented a summary of PFOS

[2] PBL height was defined as the height at which TKE values dropped to 50% of the surface TKE value.

meteorological modeling plans. Initial modeling is underway. As many as nine episodes may be modeled. The nested 108-36-12-4 domain covers Tampa Bay, Orlando, and Jacksonville. The model configuration will consist of: Betts-Miller cumulus parameterization (ideal in tropics), the MRF mixing scheme, and the 5-layer soil model.

University of Maryland/Maryland DOE: Zhan Zhang presented results from a July 1997 MM5 application. The model is being initialized with data from the ETA model and was run for a large 36 and 12 km nested grid. The lowest vertical layer in the modeling had a top of approximately 10 meters. The model configuration consisted of the Kain-Fritsch cumulus parameterization, the Gayno-Seaman PBL scheme, the simple ice explicit moisture scheme, the simple cooling radiation scheme, and the shallow cumulus option turned on[3]. Model versus analysis fields of temperature and wind were displayed. Sensitivity tests were done for three separate PBL schemes (Gayno-Seaman, Blackadar, and MRF). Root mean square errors were calculated for each model configuration.

MCNC: Don Olerud presented a summary of the PBL sensitivity tests he has completed as part of the North Carolina MM5 modeling. For a July 1995 (MM5, vsn. 1) episode, a test version of the Gayno-Seaman scheme proved to best simulate the observed mixing height pattern at a key profiler site. For a June 1996 episode, the Blackadar scheme was chosen because surface temperatures were more accurately predicted. Don expressed the opinion that each episode is different and testing of various MM5 physics options will be required to see which best suits a particular scenario. Preliminary results from a July 1997 case were also shown. MM5 had considerable trouble with placement of tropical storms with the Gayno-Seaman scheme.

TVA: Larry Gautney showed results from two separate RAMS analyses of the July 1995 ozone episode: a) the OTAG modeling, and b) the Southeast Appalachian Modeling Initiative (SAMI) modeling. Both sets of meteorological fields were evaluated and judged acceptable for AQM purposes. However, the wind fields were drastically different in many instances (90 degrees offset or greater). Not surprisingly, this had a large effect on the eventual AQM results. TVA found that the effects of their local NOx reduction strategy varied by 50% depending upon which set of meteorological fields were used.

Lake Michigan Ozone Study: Jeff Jaros presented results from a MM5 and a RAMS[4] application for a 4 km grid centered over Southeast Michigan. Again, as in the TVA example, wind fields often varied dramatically. In considering spatial mean temperatures from the MM5 modeling, it appeared that 12 km temperatures were too warm at night and too coll during the day.

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[3] Some concern was expressed that this option was not presently recommended by the MM5 developers.

[4] There was a little uncertainty as to the pedigree of the RAMS run. Wusheng Ji speculated that it may be an older version 2c run that had been interpolated from 12 km to 4 km.

Environ: Chris Emery summarized four major meteorological modeling applications that Environ is involved in: Kansas City/St. Louis, El Paso/Juarez (RAMS), Eastern Texas, and Southern California. Environ typically initializes their MM5 runs with ETA data. Typical practice is to nudge thermodynamic variables within the mixed layer, which is a different approach than most users. Chris showed sensitivity results in the El Paso modeling which highlighted the sensitivity of the meteorological model to soil moisture inputs. More sensitivity tests were shown for the eastern Texas domain comparing PBL schemes, soil models, and FDDA techniques (effect of nudging w/in the PBL). One of the primary problems in the east Texas modeling is a surfeit of convection. In the El Paso region, it was speculated that a smaller grid size (~1km) may be needed due to the complex terrain.

Pat Dolwick agreed to compile a list of model configuration information for all available MM5 modeling applications, as well as to make as much of the presentation material as possible available on the AHMMG web page.

RAMS vs. MM5 -- Advantages and Disadvantages:

Gopal Sistla agreed to produce a list comparing MM5 and RAMS modeling options. The discussion highlighted two major issues which may prevent widespread usage of the RAMS modeling: a) cost (~ $8K) and b) the polar stereographic grid projection which will require some manipulation of the raw meteorological fields for AQM purposes. There was a brief discussion on the feasibility of loading AQMs with results from an archived meteorological dataset (e.g., Rapid Update Cycle (RUC) model). Nobody in the group had successfully completed such an exercise. *Pat Dolwick agreed to keep the group updated on the EPA's progress on this issue.*

Horizontal/Vertical Resolution -- Common Grid:

Brian Timin raised several issues regarding model resolution. First, in terms of common grids there appear to be two main centroids in use (40, -90) and (40, -100). However, because some groups use 108 km resolution for their outer grid and others uses 36 km, there is not much commonality in domain configurations at this point. It was generally agreed that the greatest need for a common grid was on the emissions modeling side (grid surrogates). Second, the issue of what meteorological modeling temperatures should be used for emissions estimation purposes. *Pat Dolwick agreed to tabulate what choices groups have made in this regard.*

There was a brief discussion regarding the validity of interpolating 12 km meteorological fields to 4 km. Potential mass balance problems were raised. Chris Emery mentioned that Environ had concluded in one instance that using extrapolated 4 km meteorology over a 12 km grid yielded better AQM results. In terms of ultra fine domains, Dennis McNally mentioned a CO exercise in Denver which required the use of a 1.3 km grid to capture an important meteorological feature (drainage flow).

Finally, the ideal depth of the surface layer in a meteorological model was discussed. There

appear to be two basic vertical configurations: a) surface layer = 10m, or b) surface layer = ~ 36 meters (sigma = 0.995). Those that modeled with a surface depth of 10m (UMD) did so primarily for ease of comparisons against ambient meteorological data. Those that modeled with a thicker surface depth were concerned that a 10 m surface layer begins to capture some of the effects that are parameterized within the model. *Dennis McNally thought that the PFOS modeling may test these two vertical configurations and agreed to share the results of any subsequent modeling in this regard with the group.*

Model Physics Options:

Cumulus Parameterization: It was agreed that the Betts-Miller scheme is likely the most appropriate cumulus parameterization scheme when modeling in the tropics, or other cases with a moist-adiabatic PBL. For most cases, however, the choice comes down to the Grell and Kain-Fritsch (K-F) scheme. Da-Lin expressed a preference for the K-F scheme and this appears to be the parameterization of choice for most groups in the mid-latitudes (e.g., non-tropical systems) and using resolutions of 36 and 12 km, although the best choice may vary from scenario to scenario. *Don Olerud agreed to place some of his Grell vs K-F sensitivity analyses on the AHMMG web page.* There was an acknowledgment by the group of a "gray area" between parameterizing sub-grid scale convection and modeling it explicitly. While nobody had any quantitative information regarding this gray area, it is generally considered to be an problematic issue for 4-5 km grid resolutions. A common problem is many groups MM5 runs is too much convection.

Convective/PBL schemes: The three primary choices appear to be Blackadar, MRF, and Gayno-Seaman. Of all of the physics options this one appears to be the subject of most sensitivity testing before the final model configuration is established. Some groups have had trouble with the MRF scheme in the past (e.g., Don has had MRF produce erroneous-looking maximum PBL values over large regions.). The coupling between various PBL schemes and soil models was discussed, as was the new asymmetric convective method (ACM) approach which should be released shortly in conjunction with the Pleim-Xu land surface model. The problem of very low sub-cloud PBLs was also discussed. (Resolution: rediagnosing PBL via a postprocessor may eliminate this problem.)

Explicit Moisture, Radiation, and Ground Temperature Schemes: The discussion was rather limited on these issues (the end of a rather long day). Most groups tend to use the Simple Ice (Dudhia) scheme, although Dennis McNally will commonly use the Mixed-Phase (Reisner) scheme. In terms of the radiation scheme, the point was made that one generally needs resolved scale clouds before one should use the cloud radiation scheme. Da-Lin recommended using the CCM2 radiation scheme (RH based) for 36 and 12 km grids and the Cloud Radiation scheme for finer resolutions. Few groups have any experience to date with the Land-Surface model. Don Olerud noted the sensitivity of model results to soil type and cautioned against relying too heavily on existing soil type data.

Initialization/Boundary:

In terms of 1-way versus 2-way nesting, both options have been used by AHMMG members. Dennis is switching from 2-way to 1-way in some of his MM5 applications due to occasional spurious fields along the grid interface (e.g., sea breezes in PFOS domain). NYDEC uses 2-way nesting along their 12 and 4 km interface. Many groups use 2-way nesting, but turn off feedback (IFEED=0)[5]. This allows for boundary conditions to be provided every time step as opposed to every hour with the NESTDOWN approach. Most groups that use 2-way nesting, with feedback employ a 9-cell weighted average.

For the NYDEC and UMD MM5 runs, MM5 will be providing output at temporal resolutions of every half-hour as opposed to hourly. NYDEC have even considered matching AQM and meteorological modeling time steps. Nobody has completed any AQM sensitivity tests measuring the impact of sub-hourly meteorological input. MCNC has also completed AQM runs with sub-hourly time steps in their real-time modeling. Also, there was some consensus that initializing the MM5 modeling with ETA analysis fields was a good idea given the additional information (satellite, Doppler, etc.) that is gathered in the EDAS fields.

Four-Dimensional Data Assimilation:

Da-Lin provided a short refresher course on the principles of and reasoning behind FDDA. In terms of the dynamic initialization used in MM5, there are two main approaches: analysis nudging and observational nudging. Da-Lin recommended nudging coefficients of 10^{-4} s^{-1} for 108 and 36 km type grids to provide as accurate as possible information from the coarser grid lateral boundaries. He recommended 10^{-5} s^{-1} for 12 and 4 km type grids to allow model physics to dominate while limiting error growth. The nudging coefficients should be about 50% less for moisture than for winds and temperatures.

Most groups generally do not nudge temperatures and moisture within the PBL. Alpine generally uses only limited FDDA. MCNC typically runs 4 km fields without any analysis nudging, and uses observational nudging only to suppress convection at that resolution. UMD has used "pseudo-soundings" in the past, but most groups do not have experience in that regard.

Model Data Bases:

Dennis McNally mentioned that in many cases, groups will find that it is cheaper and more efficient to purchase an NCAR computing account and access your data on your own as opposed to waiting for Data Support Services.

Computing Platforms:

[5] This approach is generally referred to then as 1-way nesting.

Matthew Johnson discussed the computing configuration at Iowa AQB. They have a cluster of eight 600 MHZ PCS and are using Red Hat LINUX 6.0. Presently, they are having some problems with the MPP version of MM5. Matthew cautioned that model scalability will be a function of network speed. Dennis McNally gave a tip regarding stack size in a MM5 LINUX deck file (set to a large value, e.g., 128). Brian Timin discussed potential MM5 computing configurations from a cost/speed perspective. He concluded that if speed is paramount that the latest Alpha servers offer the best turnaround times, if speed is less of an issue he recommended LINUX PCS.

Model Analysis:

Dennis McNally gave a brief presentation on MAPS, which is a tool for the generation of graphical and numerical analyses of model performance. Don Olerud discussed PAVE and MCNC's plans to incorporate the ability to overlay observations atop model prediction fields. In terms of model performance evaluations, Da-Lin mentioned that there is presently no good method by which to evaluate (in the AQM sense) mesoscale meteorological model performance. Some groups evaluate model performance based on areal-average performance statistics (ambient vs. simulated residuals). Others check model performance from a phenomenological perspective; i.e., how well does the model reproduce the meteorological features relevant to the air quality modeling. Still others evaluate model performance relative to past experiences (experienced-based analysis).

In terms of model visualizations, several tools are being used by the AHMMG community: GRAPH, RIP, GRADS, Vis5D, PAVE/MCPL, MAPS, and GEMPAK. Chris Emery mentioned that Environ has a MM5 to PAVE (I/O API) converter available from their FTP site.

Transformation of Meteorological Modeling Results to AQM Fields:

Chris Emery and Dennis McNally presented a brief summary of the MM5CAMX, MM5CAMX2, and RAMSCAMX tools. Each of these preprocessors is designed to adapt MM5 output to CAMx inputs. Windowing in the horizontal and aggregating in the vertical are common features of the code. These preprocessors typically expect MM5, version 2 data, so the NCAR V32V2 program may be needed. The MM5CAMX code allows for multiple diffusivity options.

Don Olerud presented a brief summary of MCPL, MCNC's tool to convert MM5 data to MAQSIP or CMAQ inputs. MCPL is more of a "pass-thru" processor. It is actually inserted into MM5 and outputs needed AQM inputs without rediagnosis. Pat Dolwick discussed some of the issues encountered in applying the Models-3 meteorological preprocessor MCIP. To date, problems have been encountered with maximum PBL settings and handling the new 24 land use categories in MM5 version 3. Both of these problems have patches now. Environ has code to convert the land use data provided by EPA in the M3/CMAQ distribution (centered at 40N, 90W) to any desired projection.

Future of the AHMMG:

Items in italics are action items to be completed before the next time the group meets. Dennis McNally graciously agreed to provide web space at the Alpine Geophysics site to foster communication among AHMMG members between meetings. Additionally, EPA will look into setting up an e-mail list to facilitate such discussion. *(Pat Dolwick discuss issue with Marc Houyoux to see if we can setup something similar to the Ad Hoc Emissions Group.)* Tentative plans were made to meet again in February 2001 in the RTP area, possibly in conjunction with the Ad Hoc Air Quality Modeling Group. More details will be forthcoming. Periodic conference calls will also be scheduled.

By virtue of his considerable experience in meteorological modeling, Da-Lin agreed to compile a list of useful references involving meteorological modeling and its application in AQM exercises. Pat Dolwick will assemble and distribute a questionnaire designed to elicit feedback on improving future AHMMG meetings. It is hoped that all of the presentation material will be on the AHMMG web page by September.