2011 HFIP Physics Workshop (summary and action items)

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1. Introduction

1) Purpose of the workshop

Identify the role of the Planetary Boundary Layer (PBL) and microphysical (MP) processes on the track and intensity forecast skills of the operational hurricane models – what we currently know/don't know and how we can improve them.

Questions to be answered:

i) Are the current PBL schemes used in the operational hurricane models appropriate to hurricane situations, such as high wind shear in a moist adiabatically neutral environment?
ii) If inappropriate, what kind of scheme is good and why?
iii) Are roll-vortices in a highly sheared hurricane boundary layer playing an important role? Is this worth investigating?
iv) Do microphysical processes play a vital role in hurricane track and intensity?
v) Do we need higher-moment MP schemes in order to get the realistic simulations of hurricanes? What are the pros and cons of higher moment and lower moment schemes?
vi) Is it worth to use bin-microphysics schemes in order to calibrate bulk-microphysics schemes?

2) Format

- Less presentations with more discussion
- Set clear goals for the workshop and stick to them during the whole workshop
- Balanced approach, giving a chance for both research and operational points of view to be expressed

Example of the Workshop Schedule

First Session: Perspective from Operational Models
Overview of the PBL/MP schemes in hurricane models (30 min)
Brief descriptions of the operational schemes (10 min each)
Second Session: Discussion (1.5 hours or more)
Third Session: research point of view
Talks from research community (15 min each)
Fourth Session: Discussion (2.5 hours)

3) Participants

A total of 41 people attended the workshop. Some are from operational agencies and others are from the research community. Participants are affiliated with twelve government agencies (CIRA, DTC, EMC, ESRL, GFDL, HFIP, HRD, JPL, NASA, NCAR, NHC and NRL) and six universities (ODU, UCLA, U of Hebrew, U of Miami, URI and U of Washington)

2. Planetary Boundary Layer

1) Are the current PBL schemes in the operational models appropriate?

No. The scheme used in the operational models (HWRF/GFDL) is too diffusive, so it produces taller PBL height compare to observations. There are also debates about how to define the PBL height in hurricanes, using the height of either the mixed layer or the inflow layer. The observations show that the heights of the mixed and inflow layers are very different in hurricanes. There is a perception that the inflow layer is a better representation of the PBL height but this needs more careful evaluation.

2) If inappropriate, what kind of scheme is good and why?
   - It seems that TKE-based local mixing schemes are more appropriate in hurricane environments – high wind shear and convectively neutral conditions.
   - Two possible approaches are recommended.
     A. Tuning the current scheme
        i) Change the momentum/enthalpy diffusivity (km/kh) to be closer to the observed value
        ii) Modify the critical Richardson number (Ri_c) and mixing length
        iii) Identify the parameters which may impact the boundary layer structure through a series of sensitivity experiments, and modify them for producing reasonable hurricane boundary layer structures
     B. Testing new PBL schemes
        i) TKE-based local mixing schemes (e.g., Mellor-Yamada-Janjic, MYJ) seem to be the best choice. However, previous experiments have shown that the local schemes degrade the track forecast skill. Need to fix the degradation of track forecast skills.
        ii) It was tentatively concluded that the usage of a local scheme may degrade large scale flow, which in turn negatively impact the forecast of the hurricane track. The effort of developing a PBL scheme which is able to represent both environmental PBL and hurricane PBL is needed.
        iii) The Yonsei University (YSU) scheme is another promising candidate because it produces a lower PBL height because of inclusion of PBL top entrainment.

3) Are roll-vortices in a highly sheared hurricane boundary layer playing an important role? Is this worth investigating?
   - Roll vortices may have a big impact in the hurricane boundary layer because vertical mixing will be greatly enhanced when these rolls are formed. Observation suggest that these roll vortices are common in hurricane regions.
   - In order to parameterize the effect of roll vortices, we have to know the conditions for formation of roll vortices, the vertical/horizontal scale of the rolls, and the increase in mixing by the rolls. It might take several years of research work for the community to understand these conditions and to establish the roll-vortex parameterizations with reasonable accuracy.
   - Several research institutes are currently working on this subject (HRD, U. of Hebrew, U. of Washington and URI) and making substantial progress. When it matures, this scheme can be tested in operational configurations.

4) Other issues

- In order to evaluate the weakness of the PBL schemes used in operational hurricane models, the development of a sophisticated diagnostics method is essential. To avoid the problem of lower temporal and spatial resolution of observational data, comparing model output to composited observations is recommended.

3. Microphysics

1) Are the current Microphysics (MP) schemes in the operational models appropriate?
   - Probably not. Because of the lack of the observation of microphysical species in hurricanes, it is hard to tell whether the current MP schemes used in the operational models are appropriate or not at this time. However, it is consensus among the experts that the simple versions of MP schemes used in the operational models (single moment with several simplifications) may not be able to capture the complicated microphysical processes in a hurricane. It is also concluded that there should be more efforts to explore the observational data already obtained (JPL, HRD and other agencies), and to request more resources for observational study in hurricane microphysics.
2) Do microphysical processes play a vital role in hurricane track and intensity?
   - Yes. The sensitivity tests shown by several presenters indicate that the intensity and track forecasts are greatly modulated by MP schemes and its parameters as well. Therefore, the use of right MP schemes may be essential for hurricane models to produce accurate predictions. Also, the importance of the interactions between MP processes and other physics are recognized, especially interactions with radiative and convective processes.
3) Do we need a higher-moment MP scheme in order to get realistic simulation of hurricanes? What are the pros and cons for higher moment and lower moment schemes?
   - It should be theoretically possible for higher moment schemes to produce more realistic characteristics of MP features with better track and intensity forecasts. However, the computational resources needed to run higher moment schemes hinder their use, as well as our limited understanding of some important microphysics processes (ice multiplication, initial nucleation of ice, collection efficiency and so on) that may dominate in primarily tropical oceanic convection. There should be an effort to incorporate/emulate the effects of the higher moment schemes into the simpler schemes used in the operational models.
   - There are two recommended approaches
     A. Short term
        i) Modify the fall speed of some species: slower fall speed for ice and faster fall speed for rimes
        ii) Tune the auto-conversion parameter between cloud water and rain
        iii) Change collision/collection efficiency
        iv) Use of an idealized simulation capability for evaluating scheme performance
     B. Long term
        i) Tune the parameters of bulk MP schemes using the output of bin MP schemes
        ii) Develop more sophisticated diagnostics tools for rigorous evaluations of MP schemes
        iii) Enhance efforts to collect new observational data in hurricanes

iv) Investigate the interactions with other physical processes

4) Is it worth to use bin MP schemes in order to calibrate the bulk MP schemes?
   - Yes but it will be a long term project with much help from the research community.

4. Research – Operation collaboration

1) DTC is currently focused on HWRF model.
2) Good progress has been made to keep the community and operational codes in sync. Work is going well with HRD and EMC to bring all developments to DTC repository. The next goal is the unification of the EMC and DTC repositories, so the model developers and community users are able to obtain the HWRF model code from the same location.
3) Several bugs have been found by DTC and fixed by EMC and DTC.
4) DTC is also working on the physics inter-operability. Suggestions were made to establish a priority of the physics schemes which can be useful for the developers instead of making all the physics options work for HWRF.
5) Need a long term plan in case of HWRF migrating to NEMS (NCEP Environmental Modeling System).

5. Action Items

1) PBL scheme

i) Short term

A. Tuning parameters of the current operational scheme

a. Perform a series of sensitivity tests to identify the critical parameters of the current PBL scheme

b. Modify the momentum and enthalpy diffusivity to match them to observed values

c. Tune critical Richardson number and mixing length to produce a reasonable PBL height

d. Test new PBL schemes which can be easily connected to the current operational configurations (e.g., YSU/New GFS). Evaluate the performance of these schemes not only in terms of track and intensity but also in terms of the PBL structure.

B. Evaluate the PBL structure with observational data by collaborating with HRD, NASA, JPL and other agencies. The composite method was recommended to overcome the scarcity of the observational data.

C. Use idealized experiments in order to evaluate the performance of the new schemes and the impact of changed parameters

ii) Long term

a. Test more complicated and appropriate PBL schemes in hurricane environments. It was recommended to test local mixing schemes (e.g., MYJ, KPP, Bougeault schemes and so on)

A. Support the efforts of parameterizing hurricane boundary layer roll vortices, which may have a large impact on the heat and momentum mixing in the hurricane PBL

B. Build a diagnostics capability in order to evaluate the detailed structure of the simulated hurricane boundary layer

C. Develop a PBL scheme able to predict the boundary layer structure under hurricane environments as well as outside of hurricane regions.

2) Microphysics scheme

i) Short term

A. Test possible upgrades of the operational scheme

a. Modify the fall speed for ice and rime. Set slower ice fall speed and faster rime fall speed.

b. Advect separate hydrometeor species instead of total water condensate (need little more extra, about 15% computational resources)

c. Test a newly developed cloud water-rain auto-conversion method

B. Tune bulk schemes using the output of more sophisticated higher moment schemes

a. Use non-constant intercept parameters to mimic the size-sorting effect of higher moment schemes

b. Conduct sensitivity experiments on collision/collection efficiency

ii) Long term

A. Develop a sophisticated observation/diagnostics tools in order to examine the current operational MP schemes

B. Establish the idealized simulation capability in order to evaluate the effect of future upgrades and implementations of MP schemes
C. Calibrate a bulk MP scheme using the output of bin-microphysics schemes
D. Investigate the interactions of microphysics with other physical processes such as convection, radiation and boundary layer schemes

3) Research and Operations collaboration

i) Short term

A. Use the Regional Modeling Team of HFIP as the forum to coordinate efforts among all organizations working on physics diagnostics, testing, and development for regional hurricane models
B. Consolidate all development for the HWRF model under the new HWRF Code Management procedures outlined by EMC and DTC, in order to facilitate the interactions among developers and the transition of new code both to operations and to the larger community