Summary of Clouds and Radiation Working Group

Attendees were Brad Ferrier, Sarah Lu, Man Zhang, Greg Thompson, Robert Pincus, Ruiyu Sun, Jian-Wen Bao, Paul Ginoux, Yu-Tai Hou, Ligia Bernardet, Anning Cheng, Qingfu Liu, Jim Doyle, Zhanqing Li, Seoung-Soo Lee, and Michelle Harrold (note taker).

Grid-scale microphysics parameterizations

The following microphysics schemes were discussed. They all calculate changes in water vapor either in the form of specific humidity or water vapor mixing ratio.

1. Thompson *et al.* (TH, partial two moment). Mixing ratios of cloud water, cloud ice, rain, snow, graupel/hail; number concentrations of cloud ice and rain. Currently being tested in the GFS; available in HWRF and NMMB as well. OU-CAPS/SPC annual spring experiment consistently ranks as top performer MP scheme in ARW.
2. Thompson and Eidhammer (TE, partial two moment). The "aerosol aware" version of TH, includes number concentration of cloud water. Also includes hygroscopic aerosol (cloud condensation nuclei, CCN) and non-hygroscopic aerosol (ice nuclei, IN) that are fully coupled to RRTMG radiation scheme for treatment of both aerosol direct and indirect effects. Currently run in the RAP/HRRR; also ported to NMMB.
3. Morrison-Gettelman version 2 (MG2, two moment). Advects mixing ratios and number concentrations of cloud water, cloud ice, rain, and snow. Can run with GOCART bulk aerosol scheme (15 species) and will be coupled with MAM7 modal aerosol scheme (7-mode, 31 species). Liquid activation parameterization follows Fountoukis and Nenes (2005) and Abdul Razzak and Ghan (2002). Ice activation follows Barahona and Nenes (2008, 2009). Currently being implemented and tested in the NEMS GSM.
4. Ferrier and Aligo (FA, one moment). Advects mixing ratios of cloud water, rain, total ice (cloud ice + snow/graupel), and ice density (rime factor variable). Includes variable intercept parameterizations for drizzle and stratiform rain based on comparisons with TH. Intercepts and mean diameters of snow/graupel also vary. Currently run in HWRF, HiResW NMMB, and NAM.[1]
5. WSM6 microphysics (one moment). Advects mixing ratios of cloud water, cloud ice, rain, snow, and graupel. Currently run in the HiResW ARW and in the NSSL ARW run, and also being tested in the GFS.
6. GFDL scheme (one moment). Advects mixing ratios of cloud water, cloud ice, rain, snow, and graupel/hail. A variation of the Lin et al. (1983) microphysics that runs in FV3.

The general rule is that total run times increase by ~5% for every additional field that is advected. Although initial tests would be run in the GFS, more confidence in the results would be gained once testing was done in FV3.

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[1] Microphysics tests made by the DTC in 2016 found that the TH scheme required >50% more resources to run the NMMB model than the FA scheme. Internal regional tests indicate the FA scheme is at least 15% faster in terms of total run times than WSM6.

Requirements versus recommendations

Which of the following attributes are determined to be requirements versus recommendations for the initial development effort?

A. Advecting suspended precipitation. Some NCEP testbed have requested products derived from suspended precipitation from past experiments, particularly during high-impact weather events.
B. Two-moment treatment of clouds and aerosols. Could improve longer range forecasts by accounting for cloud indirect effects, forecasts of dust and particulate matter (PM), and forecasts of drizzle and light rain from low-level shallow clouds. But is the science mature enough to be incorporated into full resolution weather forecasts?

While including one or more of these factors for the October 2018 target would “future proof” the microphysics, it will also require more computational resources that may not lead to better forecasts that are of importance to the overall user community. Given current uncertainties in future computing resources and that predicting aerosols is not an initial requirement for full-resolution NGGPS FV3 weather forecasts, then the general consensus within the group was that the TH scheme would be the most likely candidate to be considered for NGGPS physics testing.

Timelines

- November 2016. As of now the TH microphysics is considered to be the likely for the NGGPS advanced physics package based on Ruiyu’s tests in the GFS.
- April 2017. A preliminary recommendation for testing in the FV3 will be made at the request of the convection group.
- October 2017. The latest date for when a final recommendation for the microphysics scheme will be made.
- October 2018. NGGPS physics development is frozen, pre-implementation testing is started.
- October 2019. Pre-implementation testing is completed with operational implementation scheduled sometime thereafter.

The period between April and October 2017 will be a time when there is frequent information exchanges between the PBL+convection and clouds+radiation working groups.

Beyond the initial plans outlined above, Greg Thompson mentioned a proposed effort within NCAR to unify microphysics across different groups between lead developers Thompson, Morrison, and Gettelman. If funded, the unified scheme may be available for possible phase 2 (or day 2) testing.

Radiation parameterization

There was a general consensus that the RRTMGP radiation package should be part of early NGGPS testing. The code is designed to be efficient and flexible, allowing users to specify the cloud optical properties (effective radius, cloud fractions, cloud optical thickness/depths, single scattering albedos, etc.) with greater ease than the RRTMG package. It should be possible for developers to check out the RRTMGP code now and incorporate it into the NEMS physics driver after some modifications. Improvements will continue to be made to the science code, such as incorporating better gaseous absorption, revising lookup parameters, etc.

Cloud macrophysics

This area of scientific development involves the treatment of the following cloud properties that are beyond what are considered within the grid-scale microphysics.

1. Assumed probability density functions (PDF) of clouds within the grid. Current options assume uniform, triangular, normal (Barahona 2015), and binormal (SHOC) distributions. These assumptions can lead to different grid-averaged cloud fractions.
2. Overlap assumptions within contiguous cloud layers and between different cloud layers separated by some amount of clear air conditions (e.g., random vs maximum/random algorithms).
3. Other prognostic quantities associated with convection and/or turbulence that are exchanged onto the resolved grid, such as TKE (turbulent kinetic energy).
4. Cloud optical properties required by the radiation, such as the effective radii for the various hydrometeor species.

Timelines concerning these issues were not discussed during the breakout session.

Metrics and observations

The metrics and their associated observational sources are listed below.

1. A wide suite of surface and upper-air verification statistics, which include both comparisons to analyses (i.e. 0-h initial conditions) and station observations.
2. Precipitation verification over CONUS using the Stage IV and CCPA precipitation analyses.
3. Verifying other sensible weather elements, such as cloud ceiling heights, visibility, and precipitation type against METARs.
4. Comparing satellite observations against forecast (synthetic) satellite radiances, in which over time this effort should be done within the GSI analysis by comparing forecast minus observed radiances.
5. Surface and top of the atmosphere (TOA) short- and long-wave radiative fluxes available from satellites (e.g. CERES) and surface observations (USCRN, SURFAD).
6. Various cloud properties, such as cloud fractions, cloud phase, cloud optical depths, and characteristic particle sizes. Some of this information is available from polar-orbiting (e.g. CLAVRx) and geostationary (GOES-R) products, which provide good cloud phase

information for single-layer clouds. Pilot reports (PIREPS) and ARM data could be useful for high-impact case studies. EMC is already comparing monthly forecasts of various cloud properties (cloud fractions, optical depths) against MODIS, ISCCP, and other observational sources.

7. Radar reflectivity over regions with a dense radar network, such as over CONUS and parts of Europe.
8. Aerosol optical depths (AOD), single-scattering albedos (SSA) from AERONET stations, GOES-based satellite retrievals. Various cloud and aerosol properties can be compared against the NASA A-train (Cloudsat, CALIPSO).

Among the various modeling groups within EMC, verification metrics are currently being used to make decisions in association with #1, #2, #3 (except precipitation type), and #7. Supplemental verification efforts within EMC also include parts of #5, #6, and #8. The diurnal, monthly, and seasonal variability of many of these quantities are also important to take into consideration. It will be challenging to determine where the error source(s) come from, since most of these metrics do not provide error information directly attributable to the microphysics. The analogy is that we solve puzzles even though there are a lot of pieces missing. The initial benchmark will be comparisons against the current GFS, but as time proceeds it should transition to control runs of the FV3. The dashboard of verification statistics that the DTC is developing will be very helpful in providing high-content summary information of how well the experimental runs fare against their benchmark.

Tools

The following tools were identified during the breakout group discussion.

- Single column modeling with prescribed forcing.
- 2D and 3D idealized test cases, preferably over a limited area. The FV3 does not currently support a standalone limited area run, but instead the user must run it as a global model with different grid and/or nesting methods to focus in on an area of interest.
- Output of various source/sink terms, hydrometeor fall speeds, different particle moments (number concentrations, mean diameter, etc.), and other grid-scale microphysical quantities. Vertical cross sections of these and other quantities (e.g. radar reflectivity) can provide useful insights into how the model microphysics is behaving.
- Column-integrated values and column maximum values of various microphysical fields help to display aspects of 3D fields onto 2D maps. Maximum hourly composites of different types of surface precipitation, as well as the column-integrated/maximum fields listed previously, can also reveal complex temporal aspects useful for assessing forecasts of high-impact events.
- Comprehensive verification statistics also serve as arguably the most important tool.