Implementation and Evaluation of MG3 microphysics in FV3GFS

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Cloud microphysics is among the key physical processes that drive increases in forecast accuracy for global and regional numerical models. The Morrison and Gettleman double moment microphysics version3 (MG3) is physically comprehensive and computationally efficient within the FV3GFS (Finite-Volume version 3 Global Forecast System) and unified forecast system. MG3 [1] was ported from National Center for Atmospheric Research in February 2018. MG3 forecasts the number concentration and mass mixing ratio of cloud liquid, cloud ice, rain, snow and graupel/hail, and is now the most comprehensive microphysics at EMC. Other two-moment schemes, such as Thompson, do not forecast the number concentration of cloud water, snow, and graupel/hail. That is because in those schemes the numbers do not have local storage, but their mixing ratios do. This internal inconsistency can cause more rain, snow, and graupel/hail to be suspended in the atmosphere column because of the lack of ice nuclei (IN) and cloud condensation nuclei (CCN).

MG3 has many good features: 1) a unified treatment of cloud fraction in radiation and macrophysics, 2) subgrid-scale microphysics, 3) max-overlap and in-cloud precipitation fraction area, and 4) options for subcolumn microphysics. The subgrid-scale microphysics makes MG3 scale-aware. The subcolumn microphysics can be unified with the 3D/subcolumn radiation.

The coupling of MG3 with the aerosol has options for differing complexity, ranging from a simple constant aerosol mixing ratio to being fully coupled with MAM7 (the Modal Aerosol Model). The options are: 1) a constant aerosol mixing ratio, 2) climatology IN/CCN from the Community Atmosphere Model, version 5, 3) climatological aerosol from the Modern-Era Retrospective analysis for Research and Applications, Version2, 4) the Georgia Institute of Technology–Goddard Global Ozone Chemistry Aerosol Radiation and Transport, and 5) MAM7.

MG3 has been coupled with the CS-AW (Chikira Sugiyama-Arakawa Wu) scale-aware deep convection and tested for months to improve their performance. The time series of global mean precipitation, evaporation, and cloud faction are the basic metrics to test the stability, mass and water vapor conservation, and even scale-awareness for a numerical model. Figure 1 shows the results from a ten-day forecast run starting from 2016/12/06 using C768L65 with CSAW+MG3. The globally mean total precipitation is well balanced with the evaporation. Both are near 3 mm/day and have nice diurnal cycles (1a). The horizontal grid-size for C768 is nearly 13 kms and we expect a scale-aware deep convective scheme should give about the same precipitation as the large-scale precipitation from the microphysics. The large-scale precipitation would exceed the deep convective precipitation with a further increase of the horizontal resolution. Because the initial condition is from data assimilation based on SAS+GFDL microphysics, an initial spin-up with a sudden increase of total precipitation causes the decrease of the global mean precipitable water (1b), which is brought back within a few days. This shows good model stability and good self-adjustment to a premium state. The globally mean low-, middle-, and high-level cloud amount is near 35%, 20%, and 35% (1c), respectively. The total globally mean cloud amount is above 60%. All are in good shape and ready for tune-up for anomaly correlation (AC) score and root mean square score, etc. Limited case studies show that CSAW+MG3 can exceed the operational model in AC score, but more studies are needed.

CSAW+MG3 has also shown a strong ability in hurricane forecasting. A track forecast for hurricane Harvey was performed using FV3GFS initial conditions and ECMWF initial conditions (Figure 2). Harvey landed and hesitated in southern Texas and moved north-east in the best track. However, most numerical prediction models produced a west-moving track. The initial condition from FV3GFS has a strong east-moving signal/forcing and CSAW+MG3 can produce an east-moving Harvey starting from

2017/08/22, which is about 7 days in advance of its sudden eastward move and final landfall in Louisiana. The initial condition from ECMWF has a weak east-moving signal/forcing, but CSAW+MG3 can still produce a northeast moving hurricane starting at 2017/08/26.

Given the relatively recent implementation and testing of MG3, we expect more performance improvement by fixing its systematic biases and bugs in the future. The AC, RMS, and precipitation score will be compared with those from the operational model for a months- to years-long forecasting test.

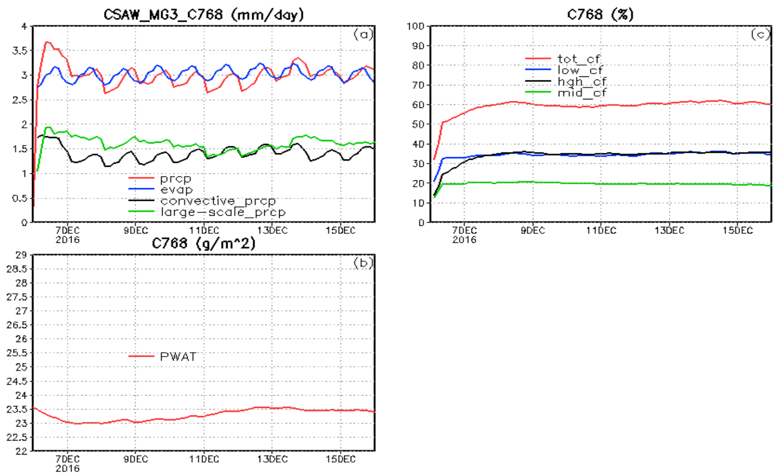

Figure 1. Time series from ten day forecast using CSAW+MG3 with C768L65 resolution.

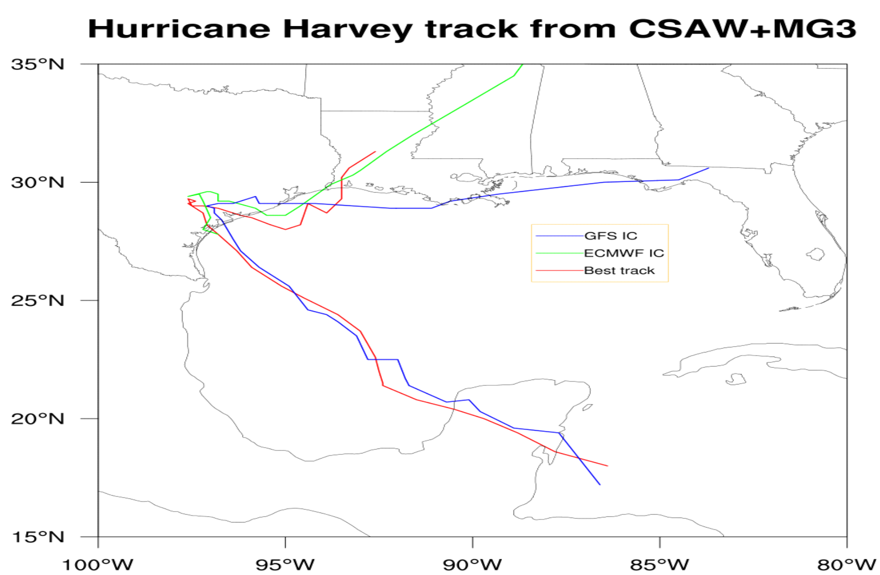

Figure 2. Hurricane tracks from FV3GFS using CSAW+MG3 with C768L65 resolution.

References

[1] A. Gettelman, H. Morrison, S. Santos, P. Bogenschutz, and P. H. Caldwell: Advanced two-moment microphysics for global models. Part II: Global model solutions and aerosol-cloud interactions. *J. Climate*, **28**, 1288-1307.