Interactions between GFDL Cloud Microphysics and RRTMG Radiation in NCEP FV3GFS

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Clouds play a critical role in regulating the radiative transfer through the atmosphere and the energy budget at the surface. Whether a given cloud will heat or cool the atmosphere and the surface depends on several factors, including the cloud's altitude, its size, and the properties of the particles that form the cloud. Cloud properties defined by the RRTMG radiation module implemented in the current NCEP FV3GFS include cloud fraction, contents and particle sizes of cloud liquid water, cloud ice, rain, and snow. In the early implementation of the interaction between the GFDL cloud microphysics scheme and the RRTMG radiation in the FV3GFS, all the cloud hydrometeors are combined and then partitioned into cloud liquid water and cloud ice based on a temperature-dependent empirical function before they are passed to the radiation. The radius of cloud liquid water is a function of temperature and land surface type. The radius of the ice particles is a function of temperature and cloud ice content (Heymsfield and McFarquhar, 1996). One drawback of this approach is that certain types of liquid hydrometeors from the GFDL microphysics might be incorrectly treated as ice, and vice versa, in the radiation. Figure 1 illustrates the effect of this approach on hydrometers seen by the radiation. The top left panel shows the zonal-mean cloud liquid water and rain from cloud microphysics. The top right panel shows the zonal-mean cloud liquid water after the combination and partitioning. There is much more liquid in the latter case, indicating some of the ice has been regrouped into liquid cloud water. To correct this mismatch, a new cloud-radiation interaction scheme between the GFDL cloud microphysics (Zhou et al., 2019) and RRTMG radiation was implemented into the FV3GFS. In the new scheme, the water contents and effective radii of individual cloud hydrometeors from the GFDL cloud microphysics are directly passed into the RRTMG radiation. -- Note that graupel is treated as snow because there is no graupel category in RRTMG.

A fully cycled experiment (named FV3GRADR1) with data assimilation was run for three months to test the new cloud-radiation interaction scheme. The experiment covers the period from October 1st, 2018 through December 31st, 2018. Results from this experiment were compared to the experiment with the old cloud-radiation interaction scheme (named FV3GFS). Shown in Figure 2 are temperature biases, verified against each experiment's own analysis, in the Northern Hemisphere. The cold bias found in the old experiment is reduced throughout the troposphere in FV3GRADR1, and the warm bias in the lower stratosphere is also reduced. This reduction in bias is also presented in the verification against rawinsonde observations. Temperature biases in the Northern Hemisphere at the 24 and 48 forecast hours are reduced in FV3GRADR1 except at layers from 450 hPa to 200 hPa. RMSE is improved at all layers. A similar improvement is also found in the Southern Hemisphere (figures not shown). In the tropics, temperature RMSE is greatly reduced around 200 hPa (Figure 3). Wind RMSE is reduced in the tropical region. Other noticeable improvements in FV3GRADR1 over FV3GFS include the smaller OLR biases and less prominent 2-meter temperature cold biases over the polar region.

References

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[2] Zhou, L., S.-J. Lin, J.-H. Chen, L.M. Harris, X. Chen, and S.L. Rees, 2019: Toward Convective-Scale Prediction within the Next Generation Global Prediction System. *Bull. Amer. Meteor. Soc.*, *https://doi.org/10.1175/BAMS-D-17-0246.1*, *in press.*

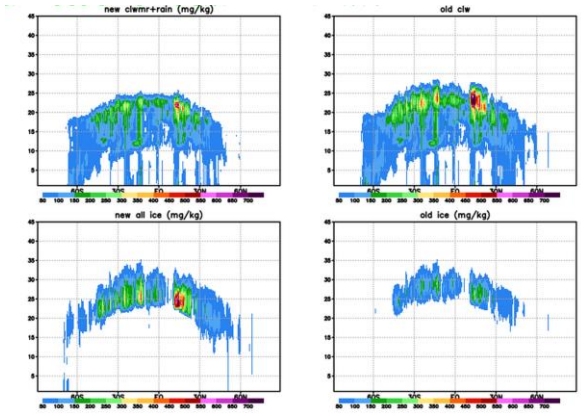

Figure 1: Zonal means of original rain+clould liquid water(top left), original snow+ice+graupel (bottom left); combined and partitioned cloud liquid water (top right), combined and portioned ice(bottom right)

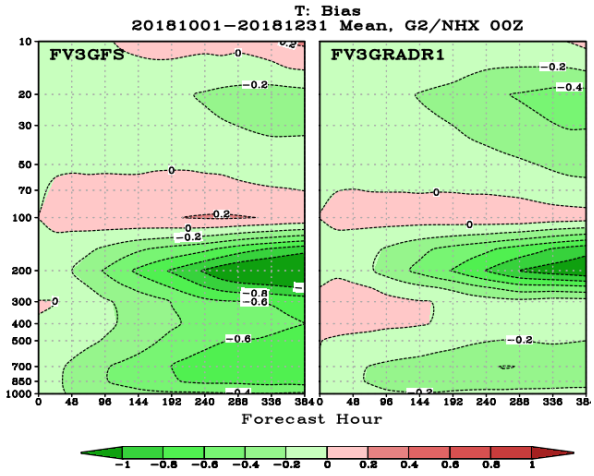

Figure 2: Temperature bias in the FV3GFS (left) compared with its analysis and temperature bias in the FV3GRADR1 compared to its analysis(right)

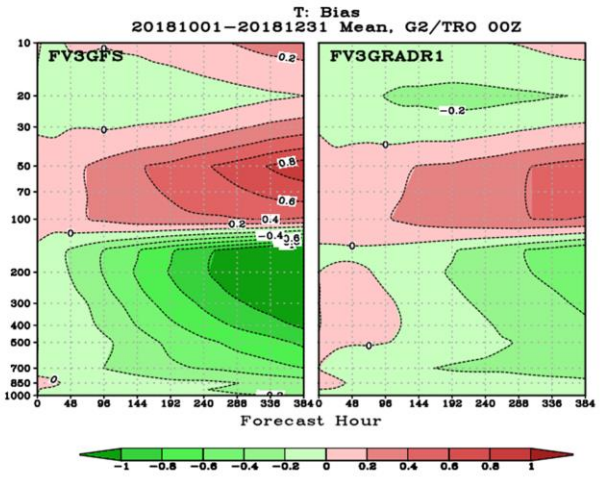

Figure 3: Temperature bias in the FV3GFS (left) compared with its analysis and temperature bias in the FV3GRADR1 (right) compared to its analysis