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Forecast sensitivity to different cloud microphysics and cloud fraction algorithms with the RRTM radiation

(**Original title**: Comprehensive results of NEMS from different cloud microphysics, cloud fraction, and the related radiation physics)

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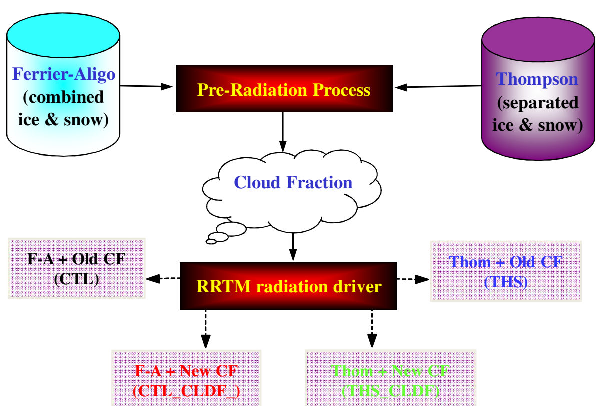
Subject

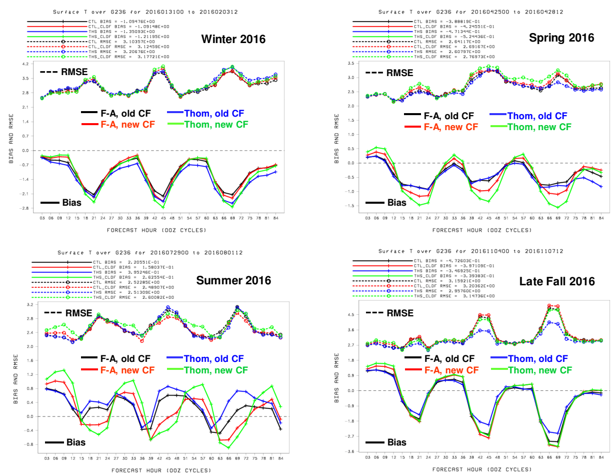
As part of ongoing studies looking to improve cloud-radiation interactions, a new algorithm was used to estimate cloud fractions from the various water and ice species provided from the cloud microphysics. All of the cloud properties were then used as input to the RRTMG radiation within the regional NOAA Environmental Modeling System (NEMS). Forecast sensitivities were then assessed using either the Ferrier-Aligo (F-A) or Thompson (Thom) microphysics combined with two different cloud fraction (CF) algorithms. The old CF algorithm is the default calculation in which cloud fractions were a function of the cloud water/ice content only, while the new CF algorithm is based on Mocko and Cotton (1995), in which subgrid-scale clouds start to form when the relative humidity exceeds a varying threshold (near 80%). The new CF algorithm is based on setting the option icloud=3 within WRFv3.7, and it is currently also being run in the operational HWRF system. In runs using the F-A microphysics, the cloud ice and snow were combined and the effective radius of ice was calculated using the default algorithms within the RRTMG codes provided by the global modeling group, while in runs using the Thompson microphysics the effective radius for cloud ice and snow were calculated separately and provided as input to the RRTMG radiation.

Case study design

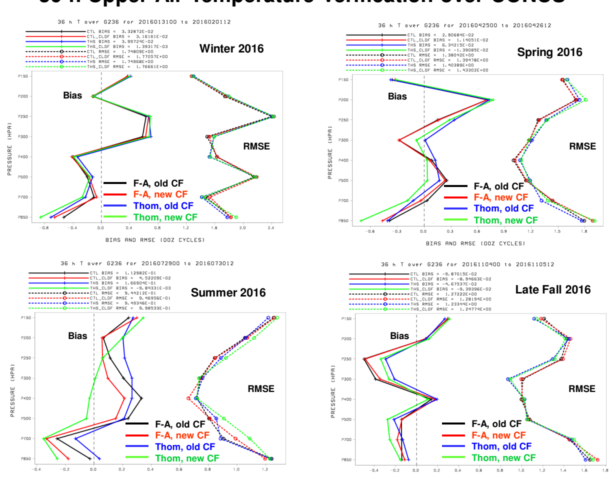
Forecasts were made using the Nonhydrostatic Multiscale Model on the B-grid (NMMB) with a 12-km/60L domain (30 hPa top) that covered most of North America. The default configuration of the model was similar to the operational NAM (using the MYJ surface layer and PBL, BMJ convective scheme, gravity wave drag and mountain blocking, and RRTMG radiation). Sensitivity tests compared changes to 1) the cloud microphysics, 2) the treatment of snow in the RRTMG radiation, and 3) the cloud fraction used as input for the radiation. Forecasts were run over all four seasons in 2016 (00Z cycles only), specifically for the following periods: **(a) 01/24-02/06 (winter), (b) 04/18-05/01 (spring), (c) 07/26-08/07 (summer), (d) 11/03-11/05 (late fall).** After reviewing all FVS plots of the cases, we choose one case of each period to best represent the general situation of that period.



Surface 2-m Temperature Verification over CONUS



36-h Upper-Air Temperature Verification over CONUS



Summary

I. The 2-m temperature verification plots over CONUS (left) and Alaska (below) show:

A. The new CF algorithm generally increased cloudiness, which led to cooler daytime temperatures due to less incoming (downward) shortwave radiation reaching the surface and slightly warmer nighttime temperatures due to more incoming (downward) longwave radiation reaching the surface. Increased cloudiness is known to dampen the diurnal variability of 2-m temperature forecasts.

- The cooler daytime temperatures over CONUS using the new CF scheme exacerbated the daytime cold biases already present, particularly during the spring and summer.
- The warmer nighttime temperatures over CONUS using the new CF scheme were helpful in reducing the nighttime cool biases during winter, but exacerbated the warm biases during the summer.
- The new CF had a small, mixed impact over Alaska during the winter (which is dominated by nighttime conditions) depending in the microphysics. But during the summer when daytime conditions dominate over Alaska, the new CF increased the cold biases.
- The impacts of the new CF algorithm seemed more amplified when used with the Thompson microphysics

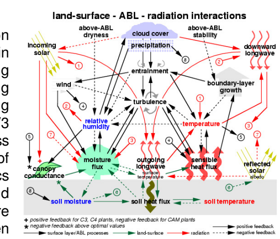
B. In terms of the cloud microphysics, the two schemes had similar forecast RMSE for most seasons, except during the late fall when runs using the Thompson microphysics with the old CF scheme had smaller forecast errors.

II. The upper-air temperature verification plots at 36 h show:

A. All four configurations had a cool bias in the lower atmosphere at 850 and 700 hPa.
B. Biases at higher levels were mixed and varied between different seasons.
C. Forecast RMSE were generally similar between the four configurations. Runs using the new CF algorithm with the Thompson microphysics had slightly larger errors (with a larger cool bias) in the lower atmosphere during the summer.

Conclusions

All four configurations of cloud microphysics and cloud fraction algorithms generally resulted in forecast cool biases at 2 m and in the lower atmosphere for all seasons except over CONUS during the summer. In all instances the cool biases were worse during the day and less so at night. EMC is currently transitioning development work from the regional NMMB to GFDL's FV3 model. As part of this effort, work is also underway to address these cold biases by looking more closely at the treatment of surface albedos through collaborations between physics developers who work on the RRTMG radiation and the land surface model. Improving lower atmospheric temperature forecasts often requires addressing multiple interactions between land and atmospheric physics (right).



(Courtesy of Mike Ek)

Extra Note: FVS (Alaska) surface 2m Temperature