Impact of Cycled 3DVar Assimilation of COSMIC Observations on Nor’easter Simulations

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The NSPO/UCAR COSMIC mission produces 1,800+ uniformly distributed Global Positioning System (GPS) radio occultation (RO) profiles daily. Given its global coverage, high vertical resolution (< 100 m), and temperature and moisture data retrievals from data sparse regions, it has garnered much interest amongst the atmospheric modeling community for its potential applications in numerical weather prediction models. Published research studies have demonstrated reductions in stratospheric temperature root mean square error (RMSE) and increased 200-hPa temperature anomaly correlation scores for both the ECMWF and GFS models, respectively, once COSMIC was assimilated.

Motivated by these results our study focused on the impact of 3D cycled COSMIC RO data assimilation on Weather Research and Forecasting (WRF) Advanced Research WRF (WRF-ARW) model simulations of eight intense, wintertime cyclone events impacting the Northeastern United States (nor’easters) that were initialized 72 hours prior to rapid cyclogenesis. We also determined how variable COSMIC assimilation period length during the pre-cyclogenesis phase impacted our simulations. We evaluated model performance via three parameters: Sea-level based storm track, energy norm, and RMSE.

Inter-WRF comparisons revealed that most (6 of 8 cases) WRF-COSMIC runs (those with COSMIC assimilation) lead their non-COSMIC counterparts by as much as 36 hours. Even with this lead, all simulations sans one case (April 2007) still lagged GFS model analysis by as much as 48 hours. The source of this general time lag lies in WRF simulations of dynamical fields, most notably 500-hPa geopotential height. Next, both our energy norm and RMSE analysis show statistically insignificant p-values from two-tailed Student T-tests between WRF-COSMIC and WRF simulations. Their verdict on its contribution to WRF model performance was mixed. Energy norm analysis results show a positive contribution by COSMIC only in 58 (20.97%) and 95 (38.31%) of 248 total time steps when it was assimilated for 48 and 180 hours, respectively. On the other hand, COSMIC RO simulations performed better during 6 of 8 cases, when only the rapid cyclogenesis phase (forecast hours 72-120) was considered. In contrast to our energy norm results, RMSE analysis (sea-level pressure, 850-hPa temperature and 500-hPa geopotential height) of our 180 hour COSMIC data assimilation WRF runs revealed an average reduction in RMSE in 178 of 248 (71.6%) total time steps. We hypothesize these contradictory results may originate from COSMIC RO data assimilation errors in the upper troposphere, and this hypothesis is checked through an analysis of the vertical structures contributing to the energy error norm.