Title: Assessing the Impact of Ground-Based Wind Measurements on Mesospheric and Lower Thermospheric Weather Through Assimilation in a Whole Atmosphere Model

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Abstract: Mesospheric and lower thermospheric (MLT) dynamics play a crucial role in the vertical coupling of the whole atmosphere and are a key component of space weather processes. However, accurately representing the MLT in whole-atmosphere models remains challenging due to sparse observational coverage and limited assimilation of high-altitude wind data. In this study, we evaluate the feasibility and impact of assimilating MLT wind observations from ground-based SuperDARN and meteor radar networks into the Whole Atmosphere Community Climate Model (WACCM) using the Ensemble Adjustment Kalman Filter (EAKF) within the Data Assimilation Research Testbed (DART). Two Observing System Simulation Experiments (OSSEs) were conducted for the 2018/2019 Northern Hemisphere winter. Both assimilated synthetic observations of lower atmospheric state variables, SABER neutral temperature, and MLS neutral temperature. In the second OSSE, additional synthetic ground-based MLT wind measurements were assimilated to assess their added value. Results show that assimilating meteor radar winds leads to localized improvements in neutral wind fields near observation sites, while SuperDARN winds have limited impact due to their lower spatial coverage. Notably, the assimilation of ground-based MLT winds results in substantial and widespread reductions in neutral temperature error, highlighting strong wind–temperature correlations within the model ensemble. However, wind corrections remain largely confined in both space and time, emphasizing the need for improved data assimilation tuning. These findings demonstrate the potential of ground-based MLT wind assimilation to enhance upper atmospheric state estimation and emphasize the importance of optimizing localization, inflation, and multivariate update strategies.