Implementing the UFS Unified Gravity Wave Physics (UGWP) parameterization in MPAS-A

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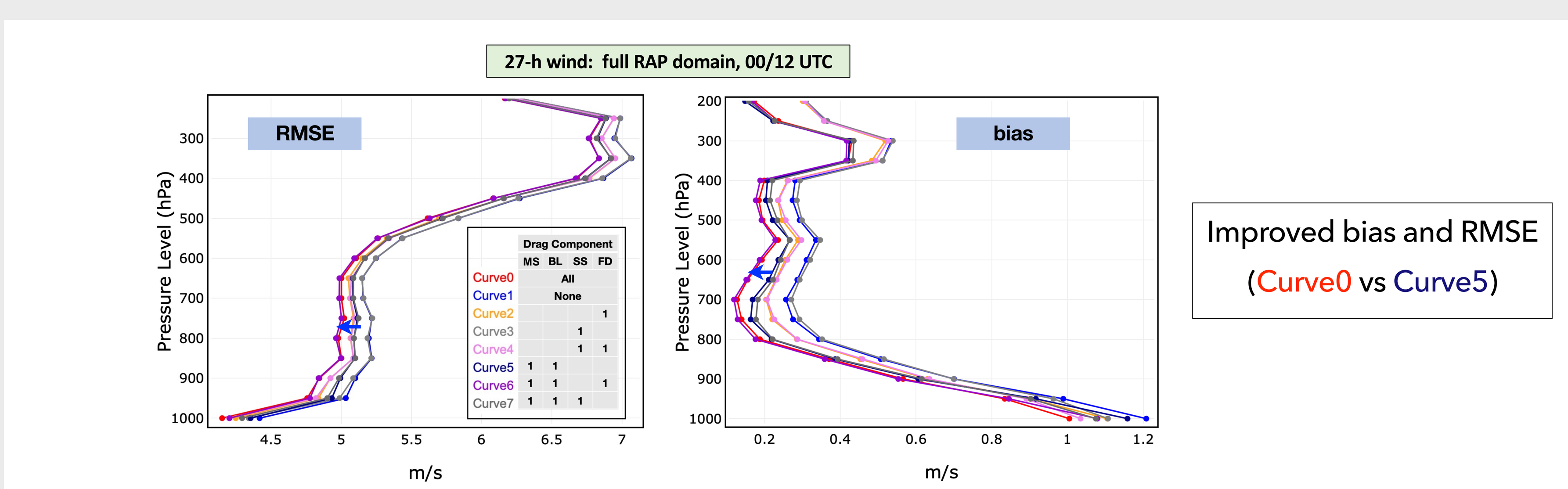
Introduction

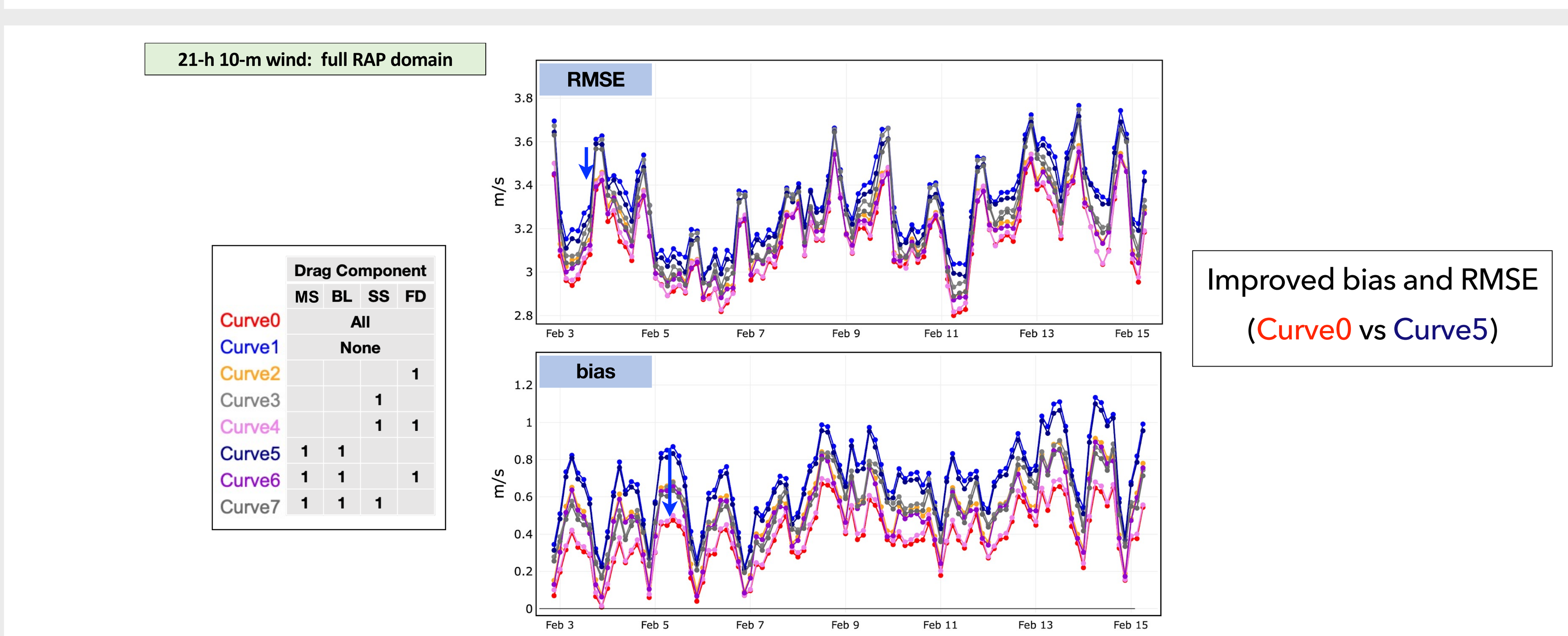
Gravity wave drag (GWD) parameterizations in numerical weather prediction models provide the drag tendencies of the mean (resolved) flow caused by the vertical propagation and breaking of gravity waves formed by sub-grid scale (unresolved) topography, deep convection, and frontal instability. Low-level flow blocking due to unresolved topography in the lowest model levels is also parameterized. The atmospheric component of the NCAR Model for Prediction Across Scales (MPAS-A) (Skamarock et al. 2012) includes the same orographic gravity wave drag and low-level blocking (OGWD+BLK) parameterization used in the Weather Research and Forecasting (WRF) Model. There is ongoing effort to improve weather forecasting skill through GWD parameterization development.

We have implemented the NOAA Unified Forecast System (UFS) suite of GWD parameterizations in MPAS-A and are currently testing its performance. The Unified Gravity Wave Physics (UGWP) suite (Toy et al. 2025) includes modified versions of the OGWD+BLK WRF schemes and three additional parameterizations: 1) non-stationary GWD (NGW) representing GWD from non-orographic sources, such as deep convection and frontal instability (Yudin et al. 2018); 2) turbulent orographic form drag (TOFD) (Beljaars et al. 2004); and 3) small-scale GWD (SSGWD) (Tsiringakis et al. 2017). The latter two schemes include the effects of horizontal topographic variations down to the ~1km scale.

Impact of TOFD + SSGWD schemes (in RAP)

The two figures below show the effects of each of the four orographic components of the UGWP suite on forecast skill in early tests of the current NOAA Rapid Refresh (RAPv5) NWP model (13km horizontal grid). The experiment consists of a series of reforecasts initialized every 3 hours starting at 0000 UTC 2 Feb 2019 and continuing through 0000 UTC 15 Feb 2019. The addition of TOFD and SSGWD improves forecast skill and we anticipate similar improvement in MPAS-A applied to a regional domain.

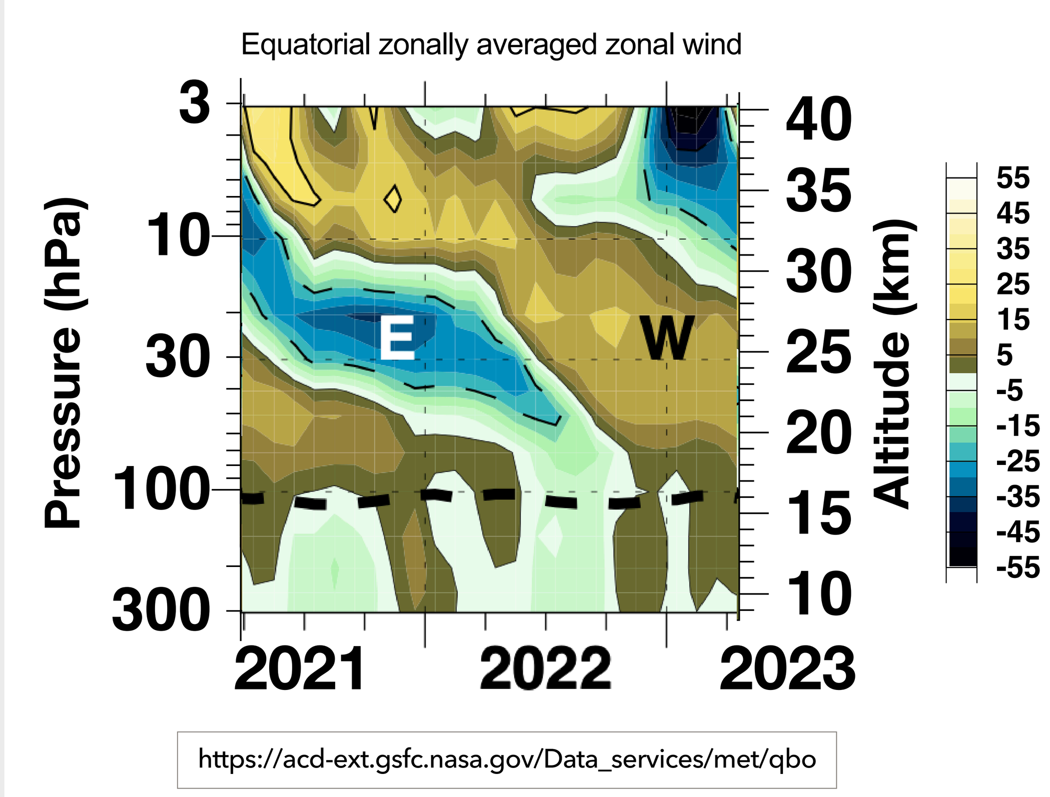




Impact of non-stationary GWD parameterization on simulated stratospheric winds

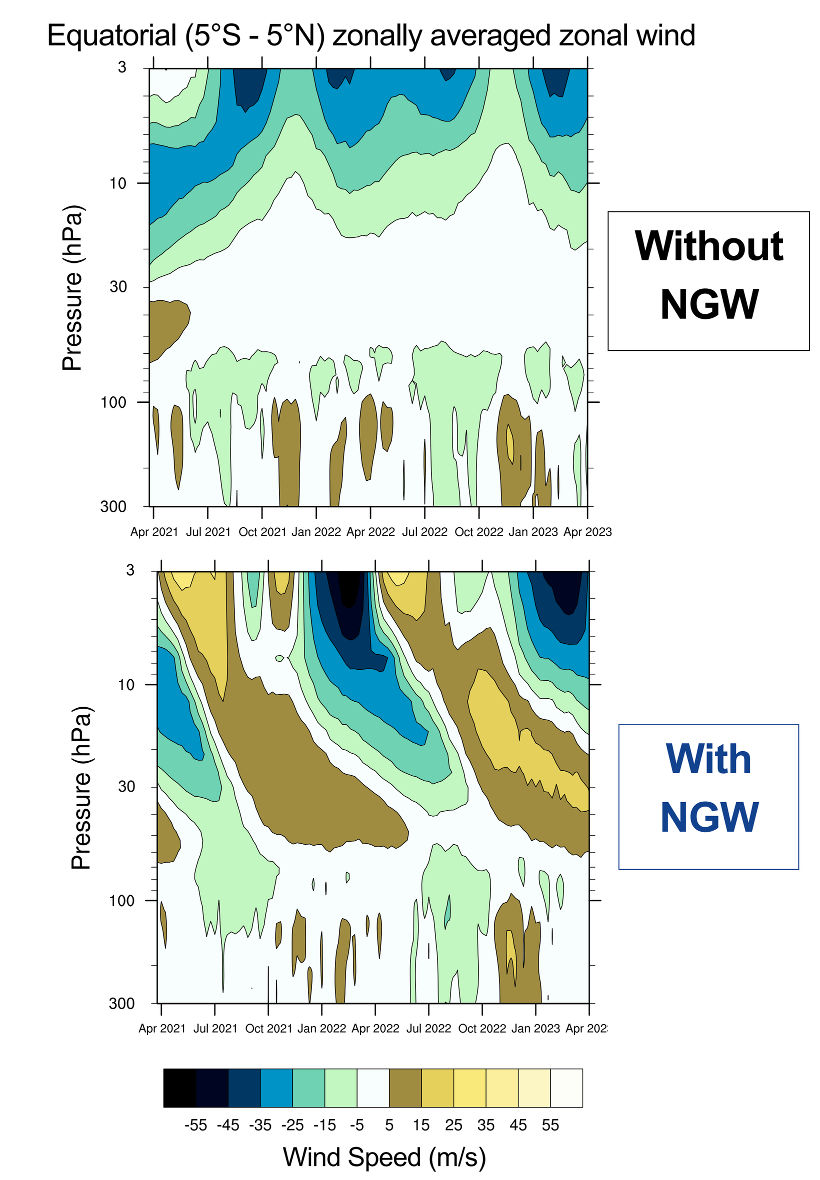
A 2-year global simulation illustrates the impact of the NGW parameterization on the evolution of the equatorial stratospheric winds. Inclusion of the NGW scheme results in a 'QBO-like' downward propagation of easterly and westerly winds, however, with an oscillation period of about one year instead of two, which points to the need for further tuning.

Observed Quasi-biennial Oscillation (QBO) from NASA'S MERRA-2 reanalysis



MPAS-A simulation

- 28 Mar 2021 thru 01 April 2023
- Initialized with GFS analysis
- 74km model top, 125 levels
- 240km quasi-uniform global mesh
- 'mesoscale_reference' physics suite + UGWP drag



Summary

We have introduced the UFS UGWP suite of drag parameterizations in MPAS-A and have performed initial testing. Improvement to wind forecast skill compared to the default GWD scheme for regional forecasts are anticipated. The addition of the non-stationary GWD scheme produces the downward propagation of easterly/westerly winds in the stratosphere as observed in the QBO.

References

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