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Evaluation of gravity wave forcing of the winter stratosphere circulation in high-resolution GEOS simulations

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The representation of small-scale gravity wave drag is a primary factor controlling model biases in stratospheric winds and temperatures. Current methods for controlling these biases involve tuning of gravity wave drag parameterizations and time-consuming model iterations and diagnostics whenever changes are made to the model system. Ideally we would like to observe the wave drag to constrain models, but unfortunately this is impossible. The best any observations can do is to show us a subset of the waves at certain locations in space and time. High-resolution models are being used to help fill in the gap and provide guidance for gravity wave parameterizations. Here we use a set of validated high-resolution GEOS simulations to evaluate resolved gravity wave forcing of the winter stratosphere circulation in validated high-resolution experiments to guide parameterized gravity wave drag updates in coarser-resolution runs.

In our high-resolution GEOS simulations, the large-scale (>600 km) winds remain very close to the observed winds, while the small-scale (∼6-600 km) waves in the forecasts evolve in a natural way depending on the topography and the flow in the jet stream and stratospheric vortex conditions. Here we use AIRS to validate the waves in the GEOS simulations. Because of AIRS's weak sensitivity to short vertical wavelength waves, the observation of waves in AIRS is very sensitive to the stratospheric winds. Thus the realism of the large-scale winds in the high-resolution GEOS simulations permit direct validation of individual simulated wave events. We use wavelet analysis methods to perform global analyses of local wave properties. The validation includes quantitative statistical comparisons of wavelengths, propagation directions, amplitudes, and day-to-day variability of geographic patterns, as well as detailed analyses of major mountain wave events identified with an amplitude threshold.

Following the validation of the GEOS waves, we evaluate the spectrum of Eliassen-Palm flux and estimate the force on the circulation due to different components of the spectrum as the divergence of the flux at key intervals during the season, including changes surrounding stratospheric sudden warming events and the final warming that marks the transition to spring easterly wind conditions