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Effects of high-impact orographic gravity wave events on extratropical stratospheric circulation and transport

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Recent research has highlighted that gravity waves play an important role in stratospheric transport, affecting chemical lifetimes, stratosphere-troposphere exchange, and variability in radiatively active gases, all of which have effects on climate. One of the key results that underscores the importance of gravity waves in the stratosphere is that observational and modeling studies have both revealed infrequent but very high-impact gravity wave events in the stratosphere. These are highly intermittent gravity wave events with large momentum fluxes that are the most important drivers of circulation and transport in the stratosphere, yet they are not treated correctly in most global models. In this work we combine satellite data with a global spectral model to obtain gravity wave drag estimates and examine the dynamical consequences of realistic strong, localized, and intermittent drag on the stratospheric transport circulation and the effects on chemical tracers. Here we will present some of our initial results on orographic gravity wave events and discuss our future plans.

For satellite data, we primarily use HIRDLS and AIRS to derive detailed gravity wave properties and obtain new quantitative estimates of the local and intermittent gravity wave drag in the stratosphere. The combination of high-vertical resolution (1 km) and near-global (60˚S to 80˚N), close horizontal sampling (100 km) makes HIRDLS temperatures the best available dataset for retrieving gravity wave properties needed to diagnose gravity wave effects on circulation. We also use AIRS brightness temperature images, which reveal high-spatial resolution detail of long vertical wavelength waves, to obtain day-to-day variability in orographic gravity wave events. The AIRS and HIRDLS datasets complement each other well since the two instruments have very different resolutions and horizontal sampling. Orographic wave events in strong winds are revealed by AIRS, then as winds weaken the high vertical resolution HIRDLS measurements reveal their breakdown and dissipation. The cycle is observed locally through synoptic weather changes and globally through stratospheric sudden warming events. We have developed a global spectral model to quantify the impact of these high-impact events on extratropical stratospheric transport. The model is forced with the localized orographic drag estimates obtained from HIRDLS and AIRS, and we examine the effects on the residual circulation and transport. With our model we will be able to quantify spatial and temporal variations in orographic gravity wave drag and associated changes in transport that influence stratospheric polar temperatures, water vapor and ozone.