EGU23-14145, updated on 27 Apr 2024
https://doi.org/10.5194/egusphere-egu23-14145
EGU General Assembly 2023

Comparison of Stratospheric Gravity Waves in a High-resolution General Circulation Model with 3-D Satellite Observations

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Recently, high-resolution satellite instruments and general circulation models (GCMs) which resolve gravity waves explicitly are becoming available. However, because of their small temporal and spatial scales, the entire spectral range of gravity waves cannot be fully detected by global observations or simulated by a GCM. To enhance our understanding of the characteristics of gravity waves in the middle atmosphere, quantitative comparison between observed and model-simulated gravity waves is of great importance. The aim of this study is to make a quantitative comparison between gravity waves observed by the Atmospheric Infrared Sounder (AIRS) on NASA's Aqua satellite and those simulated by a gravity-wave permitting GCM, named JAGUAR. As a nadir-viewing satellite instrument, AIRS has relatively high horizontal resolution varying from ~13.5 km to ~41 km and coarse vertical resolution of 7–20 km over the altitude range of 15–60 km. JAGUAR is a hydrostatic spectral GCM with a T639 triangular truncation. This model contains 340 layers from the ground to the model top of ~150 km with a constant log-pressure height interval of 300 m. We first applied a vertical filter simulating the observational filter of AIRS to the output data of hindcast simulations in the 2018/19 boreal winter performed with JAGUAR. Then, the filtered model data were resampled as AIRS observational granules. Gravity waves were extracted by subtracting a fourth-order polynomial fit in the cross-track direction of a granule, whose data length is 1780 km. A three-dimensional Stockwell transform was utilized to examine the amplitudes and wavelengths of dominant waves. Stratospheric gravity waves in the model results are compared with those in AIRS observations. It was shown that amplitude, zonal momentum flux, and meridional momentum flux of the gravity waves are in good agreement between the JAGUAR and AIRS data. These results support the validity of studies on gravity waves and their roles in the middle atmosphere by using the JAGUAR model. Peaks of gravity-wave amplitudes are observed along the winter eastward jet and summer westward jet. The peaks located in the former region got weaker, and the latter got stronger as the stratospheric sudden warming in January 2019 progressed. Compared to waves in the model data without the vertical filter applied, dominant waves in the filtered model data are half the amplitude in the regions where strong gravity waves are observed. This difference is most remarkable in eastern Eurasia, where the vertical wavelengths of dominant waves are relatively short. This fact implies the importance of careful consideration on the underestimation of wave amplitudes due to AIRS observational filter especially where waves having short vertical wavelengths are likely dominant.