A study of gravity waves in the Antarctic troposphere and lower stratosphere observed by the PANSY radar

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Gravity waves (GWs) are mainly generated in the troposphere, propagate into the middle atmosphere, and deposit the momentum in the mean field through dissipation and breaking processes. Since GWs have temporally and spatially small scales, observations of GWs are quite limited especially in the polar region due to its harsh environment there. The purpose of this study is to conduct a statistical analysis of the GWs in the Antarctic troposphere and lower stratosphere based on continuous observation data over a year from October 2015 to September 2016 by the full system of the PANSY radar, the first Antarctic Mesosphere-Stratosphere-Troposphere (MST) radar, installed at Syowa Station (69.0°S, 39.6°E). Note that continuous observations over such a long duration are feasible by realizing of energy-saving system for the PANSY radar.

The frequency power spectra of horizontal wind fluctuations have an isolated peak around inertial frequency (f) in the lower stratosphere. For power spectra of vertical wind fluctuations, such an isolated peak near f is not seen but high frequency components are dominant. The zonal momentum flux spectra ($\omega\mathrm{Re}[U(\omega)W^{*}(\omega)]$) are strongly negative around f. Sato et al. (1999) showed using a GW-permitting GCM that power spectra of horizontal wind fluctuations have an isolated peak near f of each latitude in the lower stratosphere. It is considered that the waves having a quasi-inertial frequency observed by the PANSY radar are likely such inertia-GWs.

A statistical analysis is performed focusing on the GWs with a quasi-inertial frequency (QIGWs) in the lower stratosphere. We designated fluctuations with frequencies (ω) of $2\pi/(24\,\mathrm{h}) < \omega < 2\pi/(6\,\mathrm{h})$ and vertical wavenumbers (m) of $2\pi/(5\,\mathrm{km}) < m$ as QIGWs. Furthermore, a two-dimensional Fourier series expansion method is used so as to separately analyze the QIGW with upward and downward phase velocities. A hodograph analysis is performed for the respective QIGW components at each time and height.

The percentage of QIGWs propagating energy downward is examined. A striking feature is that the percentage of QIGWs propagating energy downward is significantly large above the height of $z \sim 15$ km in winter, although that of QIGWs propagating energy upward are more than half in the stratosphere. These results suggest that the sources of QIGWs propagating energy downward exist in the stratosphere and/or above in winter.

Statistical characteristics of ground-based phase velocities ($\boldsymbol{c}$) of QIGWs in the lower stratosphere is also examined. The distribution of $\boldsymbol{c}$ is much different between the QIGWs propagating energy upward and downward. A significant proportion of QIGWs propagating energy downward have large $\boldsymbol{c}$ pointing to the east, whereas most QIGWs propagating energy upward have $\boldsymbol{c}$ around 0 ms^{-1}. These results also support that the QIGWs propagating energy downward originate from the sources moving eastward and suggest that the most likely candidate is the polar night jet blowing eastward in the winter stratosphere.