南極対流圏・下部成層圏重力波に関するPANSYレーダーを用いた観測的研究

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

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Gravity waves (GWs), which 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 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 (69.0S, 39.6E). Note that continuous observations over such a long duration are unprecedented as observations by high-power MST radars at any location.
The frequency power spectra of horizontal wind fluctuations ($\omega P_u(\omega)$ and $\omega P_v(\omega)$) have an isolated peak around inertial frequency (f) in the lower stratosphere (Figure 1a). For $\omega Pw(\omega)$, high frequency components are dominant and an isolated peak is not seen (Figure 1b). The zonal momentum flux spectra ($\omega Re[U(\omega)W^*(\omega)]$) are strongly negative around (Figure 1c). It is considered that the waves having a quasi-inertial frequency observed by the PANSY radar are likely such inertia-GWs as reported by Sato et al. (1999).
Vertical fluxes of horizontal momentum are estimated using a dual-beam method proposed by Vincent and Reid (1983). It is seen that negative is dominant in the stratosphere. On the other hand, does not show systematic features. , and variances of the horizontal wind fluctuations are relatively large in the lower stratosphere compared with those in the troposphere. In contrast, variances of vertical wind fluctuations are large in the lower troposphere and weak in the stratosphere. In the lower troposphere, large momentum fluxes and horizontal wind fluctuation variances are sporadically seen for all seasons. Furthermore, strong sporadic features from the surface to the lower stratosphere are seen in all components several times a year.
Next, a statistical analysis is performed focusing on the GWs with a quasi-inertial frequency (QIGWs) that are dominant in the lower stratosphere. We extract the fluctuations with period from 6 h to 24 h and vertical wavelength shorter than 5 km as the 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.
QIGWs with upward group velocity are dominant in the lower troposphere and in the lowermost stratosphere, whereas a considerable proportion of QIGWs propagating energy downward in the upper troposphere in all seasons, and in the stratosphere above the height of 15 km in winter. These results

suggest that there are QIGW sources on the ground surface and around the tropopause in all seasons, and in the stratosphere and/or above in winter.
It is also shown that vertical and horizontal wavelengths and intrinsic frequency have large vertical dependences and do not largely depend on the season and the vertical energy propagation direction.
A statistics of the intrinsic and ground-based phase velocity of QIGWs are also examined. It is interesting that most are about 0 ms^{-1} for the QIGWs propagating energy upward while a significant proportion of QIGWs propagate energy downward have large pointing to the east in the lower stratosphere. These results support the inference that most QIGWs with upward group velocity are likely waves that were orographically-forced near the ground surface and that QIGWs propagating energy downward are originated from sources moving eastward in the stratosphere and/or above. A likely candidate of such GW sources is the polar night jet blowing eastward in the winter stratosphere.

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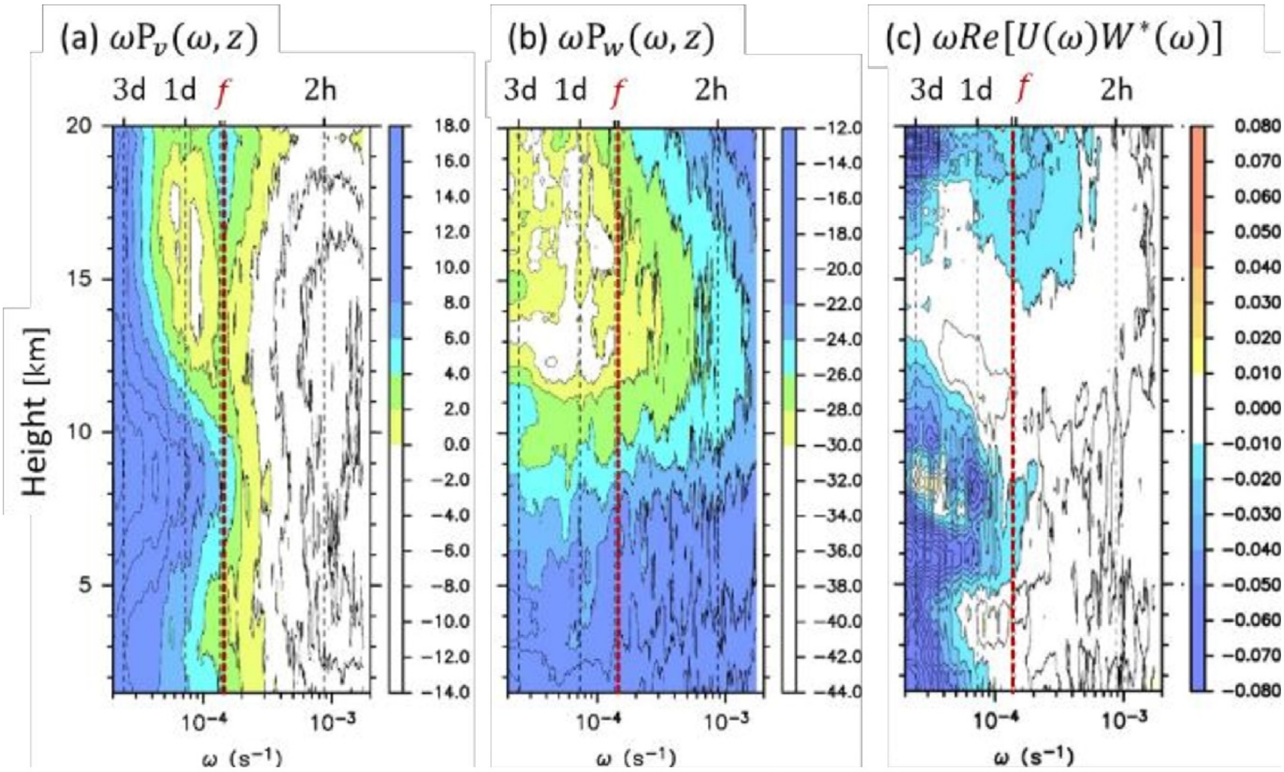

Figure 1. Frequency power spectra of (a) zonal ($\omega P_u(\omega)$) and (b) vertical wind fluctuations ($\omega P_w(\omega)$) and (c) the zonal momentum flux spectra ($\omega Re[U(\omega)W^*(\omega)]$) in the energy content form as a function of height in the frequency range of $2\pi/(3\,d)$-$2\pi/(1\,h)$.