A statistical analysis of gravity waves in the troposphere and lower stratosphere over the Antarctic observed by the PANSY radar

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Gravity waves (GWs) are atmospheric waves whose restoring force is buoyancy. Compared to Rossby waves, GWs have small temporal and spatial scales. Through vertical transport of momentum, GWs play important roles in determining the position and strength of the tropospheric jet. In addition, GWs contribute to the formation of stratospheric and mesospheric general circulation and equatorial large-scale oscillations. In the Southern Hemisphere, GWs converge toward the polar night jet, and the 60-70°S region is known as a region of strong GW activity (Sato et al., 2009). In this study, we performed a statistical analysis of observations from a VHF radar at Syowa Station (69.0°S, 39.6°E; PANSY radar; Sato et al., 2014), with the aim of clarifying seasonal changes in the dynamical characteristics of GWs at high latitudes in the Southern Hemisphere.

The data of PANSY radar observations for 7 years (October 2015-September 2022) is used. Two types of disturbances, short-period GWs and short-vertical-wavelength GWs, are extracted. The former is defined as fluctuations with wave periods shorter than 1 day while the latter is fluctuations with vertical wavelengths shorter than 6 km. Hereinafter, the background and disturbance of a physical quantity A are denoted as $\bar{A}$ and A', respectively.

The climatological seasonal variation of kinetic energy and momentum flux of GWs in the altitude range of 1.5-22 km are calculated. Using the ratio of the variance of vertical wind fluctuations to horizontal wind fluctuations, a theoretical equation is newly derived to statistically estimate the intrinsic frequency $\hat{\omega}$.

Figure 1a shows the background vertical wind $\bar{w}$. The value of $\bar{w}$ tends to be positive on average in the troposphere below the altitude of 10 km. The magnitude is particularly large in the altitude range of 1.5-4 km. In the stratosphere, the downwelling is observed from January to March while the upwelling is dominant in other seasons. Figure 1b shows the vertical flux of zonal momentum $\overline{u'w'}$. The value of $\overline{u'w'}$ is generally negative below 3 km throughout the year. Above the altitude of 3 km, $\overline{u'w'}$ tends to be positive in the region of $\bar{u} = 0 - 10\ \mathrm{m/s}$ and negative in the region of $\bar{u} > 10\ \mathrm{m/s}$, except during summer. The value of $\overline{u'w'}$ is largely negative in the altitude range of 15-22 km in fall to spring whereas it is generally weakly negative in the summer stratosphere. Figure 1c shows the kinetic energy by horizontal wind component $KE_{(h)}$ ($\equiv \rho_0(\overline{u'^2} + \overline{v'^2})/2$). The GW kinetic energy is large during winter and spring in the altitude range of 15-22 km, and is maximized in September, which is consistent with previous studies based on radiosonde observations (Yoshiki and Sato, 2000; Yoshiki et al., 2004). Figure 1d shows $f/\hat{\omega}$. Throughout the year, a maximum is observed around an altitude of 8-9 km (the altitude of the tropopause and slightly below) while in the stratosphere, $f/\hat{\omega}$ becomes large in summer compared to other seasons.

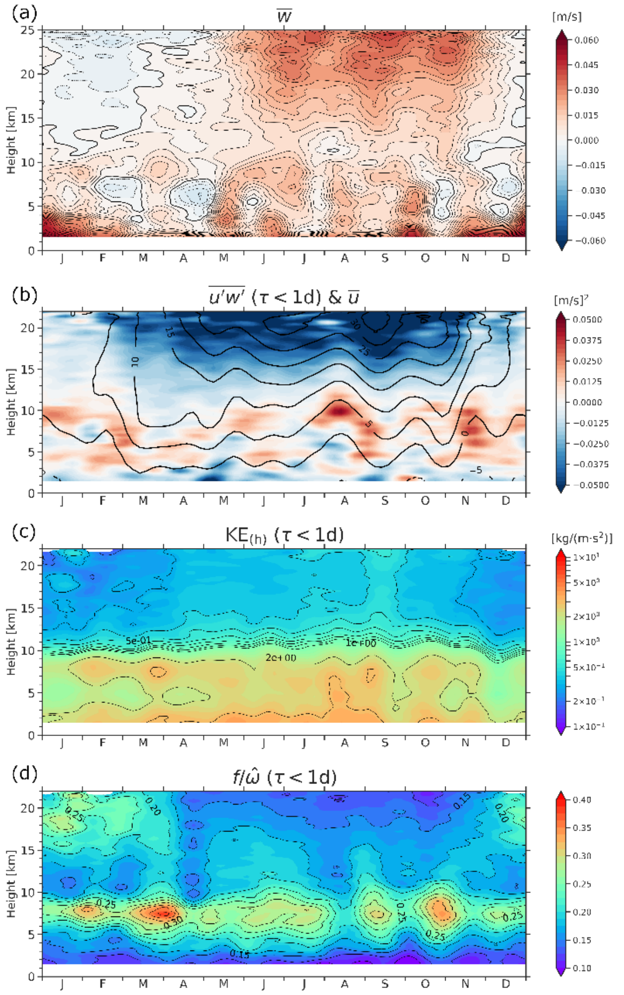

Figure 1. Time-height sections of (a)the climatological mean of the background field of vertical wind $\bar{w}$ and climatology of (b)the vertical flux of zonal momentum $\overline{u'w'}$ (color) and the background field of zonal wind $\bar{u}$ (contour), (c)the horizontal kinetic energy $KE_{(h)}$, and (d) ratio of the Coriolis parameter and the intrinsic frequency $f/\hat{\omega}$.

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