A statistical study of inertia gravity waves over Syowa Station: comparison between the pansy radar and the ERA5 reanalysis

Lihito Yoshida[1], Yoshihiro Tomikawa[1,2], Mitsumu K. Ejiri[1,2],
Masashi Kohma[3], and Kaoru Sato[3]
[1]*The Graduate University for Advanced Studies, SOKENDAI*
[2]*National Institute of Polar Research*
[3]*The University of Tokyo*

Gravity waves (GWs) are atmospheric waves whose restoring force is buoyancy. They are originated mainly from mountains, jet-front systems, and convection, and can modify a global wind structure through momentum transport and deposit. They do not only decelerate the upper part of the mesospheric jets, but also affect the horizontal winds in the lower stratosphere and contribute to driving the global meridional circulation. However, GW observations are not enough to verify their behaviour especially in the Antarctic, due to the harsh environment there. In addition, GWs have a wide range of horizontal wavelength (i.e., from several km to several thousand km) and period (i.e., from Brunt-Väisälä period (approximately 5 minutes) to inertial period (over 12 hours)), which makes it difficult to reproduce GWs in the entire frequency range even in the state-of-the-art atmospheric models in spite of the recent increase of the model resolution. In order to implement the effect of subgrid-scale phenomena into the models, which are not explicitly represented, GW parameterizations are introduced. In general, nonorographic GW parameterization assumes nearly constant wave sources and instantaneous upward propagation, but in reality, the wave sources are not constant and GWs propagate horizontally as well (Sato et al., 2009; Geller et al., 2013; Plougonven et al., 2020). Thus, it is required to constrain the GW effect in the models based on observations which cover the whole frequency range of GWs and estimate the GW momentum transport in the Antarctic.

Intermittency, a measure of how transient or intermittent a GW event is, has recently received much attention. Even if the total amount of momentum flux is the same, continuous, small amplitude events deposit momentum to higher altitudes, while sporadic and large amplitude events deposit momentum to lower altitudes. As a result, the structure and strength of the driven meridional circulation depend on the GW intermittency (Hertzog et al., 2008). In Antarctica, intermittency has been studied using super pressure balloons (Hertzog et al., 2012) and the Program of the Antarctic Syowa MST/IS radar (PANSY radar) at Syowa Station (Minamihara et al., 2020), suggesting differences in the characteristics of intermittency due to different wave generation mechanisms and wave filtering.

Our purpose of this study is to investigate the characteristics of sporadic and large amplitude GW events that can have a large impact on the overall momentum transport, and also to investigate how well the reanalysis data reproduces the GW events in the Antarctic. We used the PANSY radar for the observation data and the ERA5 reanalysis for the reanalysis data. The PANSY radar, which was installed at Syowa Station (69°S,40°E) in 2011, observes vertical profiles of three-dimensional winds in the troposphere and lower stratosphere with high accuracy and fine temporal and vertical resolution (Sato et al., 2014). It is the only instrument in the Antarctic that enables us to capture GWs in the almost entire frequency range. The ERA5 reanalysis is the latest meteorological reanalysis dataset provided by the European Centre for Medium-Range Weather Forecasts. The ERA5 data is distributed at 137 vertical levels from the surface to 0.01 hPa with a horizontal spacing of 0.25 degree every 1 hour.

We use three dimensional winds of the PANSY radar and the ERA5 reanalysis during the period of October 2015 to September 2016, in which the PANSY radar was continuously operated (Minamihara et al.,2018). The inertia-GWs are extracted by applying a bandpass filter with a cutoff period of 4-24 h and a cutoff vertical wavelength of 0.8-8 km. As a result, we found many similar wave-like structures between the PANSY radar and the ERA5 reanalysis. In order to examine the propagation characteristics of inertia-GWs, we use a hodograph analysis. It utilizes the feature that the hodograph (i.e., vertical change of the horizontal wind vector drawn in the zonal and meridional wind space) becomes an ellipse, in which the amplitude, intrinsic period, vertical wavelength, phase velocity, and group velocity of GWs can be estimated. Although the hodograph analysis generally has an ambiguity of horizontal propagation direction by 180°, we exclude it by covariance of major axis amplitude $u_{\parallel}$ and vertical wind w and vertical wave number m (Minamihara et al.,2018). Since the GWs are assumed to be quasi-monochromatic in the hodograph analysis, three dimensional winds are separated into components with upward and downward phase velocities by a two-dimensional Fourier transform. This procedure makes it possible to extract quasi-monochromatic GW events that were previously impossible to extract.

The results of the hodograph analysis show that the intrinsic period and the direction of the horizontal wavenumber vector of GWs are in good agreement between PANSY and ERA5. On the other hand, vertical and horizontal wavelengths were found to be overestimated by ERA5. We also plan to discuss altitude variations in the reproducibility of momentum fluxes.

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