Reviewer #1,

The authors greatly appreciate the reviewer's critical reading of our manuscript and constructive comments. We have revised the manuscript as much as possible following the reviewer's comments.

Our response to each comment is described in the following.

Response to comments:

1. **On Page 7, the discussion starting at line 10 should include reference to the paper by Reid and Vincent 1987 doi:10.1016/0021-9169(87)90110-3. This reference considers the sensitivity of the radar system to waves of varying horizontal wavelengths for the velocity extraction method they use, and so is relevant here.**

The reference (Reid and Vincent, 1987) has been added to Page 8, line 1-3.

2. **There are aspects of the "manual wave packet tracing" that are not clear. The description of how the position of the packet is determined (P17, L18-21) and should be expanded.**

A detailed description about the determination of the wave packet has been added to Page 18, lines 11-22.

3. **In addition, the envelope function does not seem to be extracting an envelope as I would expect. In Figure 11, where both the zonal velocity and the envelope function are displayed, the envelope seems to mostly be the absolute value of the velocity. This is not the case in Sato et al. (2013). Is it possible that the direction in which the envelope function is applied is not optimal? At present, the function is not convincing.**

The envelop function is calculated in the time direction in this study. Since the extended Hilbert transform can be made in a direction that the wave is distinguished from mean field (Sato et al., 2013), the direction in which the envelop function is calculated should be optimal.

A possible reason why the envelop function does not seem appropriate is that a spectral range of a bandpass filter is too broad to extract a clear wave packet of quasi 12 h inertia-gravity waves (with cutoff wave periods of 6 h and 24 h). To explore this possibility, we have applied a narrower bandpass filter with cutoff wave periods of 8 h and 15 h to the large-scale inertia-gravity wave fields (Fig. A in this reply). Compared with Figs. 11a and b in the main text, Figure A shows that the horizontal maps of the envelop function does not change by the use of the narrower bandpass filter, although the peak values of fluctuations are slightly reduced. Thus, it is suggested that the width of the bandpass filter used in this study is proper enough to extract a wave packet. The reason why the envelope seems to mostly be the absolute value of the velocity is likely because the dominant wavelength of the fluctuations is close to the spatial scale of the wave packet. The sentence about the validity of the width of the bandpass filter has been added (Page 18, lines 2-3).

4. **The use of "manual wave packet tracing" is novel and seems to have merit but some comments on why it is used and what advantages it brings would be valuable. The comment on line 13 of Page 18 that the manual and idealized ray tracing agree is contested because in Fig 13d, the idealised ray travels at right angles to the manual ray. This should be noted and commented on.**

The advantage of the manual wave packet tracing is that a specific location of a possible wave source can be directly examined. The sentence about this advantage has been added to Page 18, lines 9-10. The difference in the idealized and the manual rays for the packet (i) has been described in Page 19, line 17.

5. **The description of the compositing that leads to Fig 10 is unclear. What is being composited? Can the maps being composited be moved N-S or just E-W in the process of forming the composite.**

We calculated the composite of the zonal wind components. As a reference for the composite, the location with local maxima of zonal wind components near Syowa Station along a latitude of 69°S is determined. In other words, the horizontal maps of zonal wind components are moved in the zonal direction and are then averaged. Thus, this composite procedure makes an averaged phase structure of zonal wind components near Syowa Station. The description about the composite (Page 16, lines 19-24 and Page 17, lines 1-7) and Fig. 10 have been revised to clarify this point.

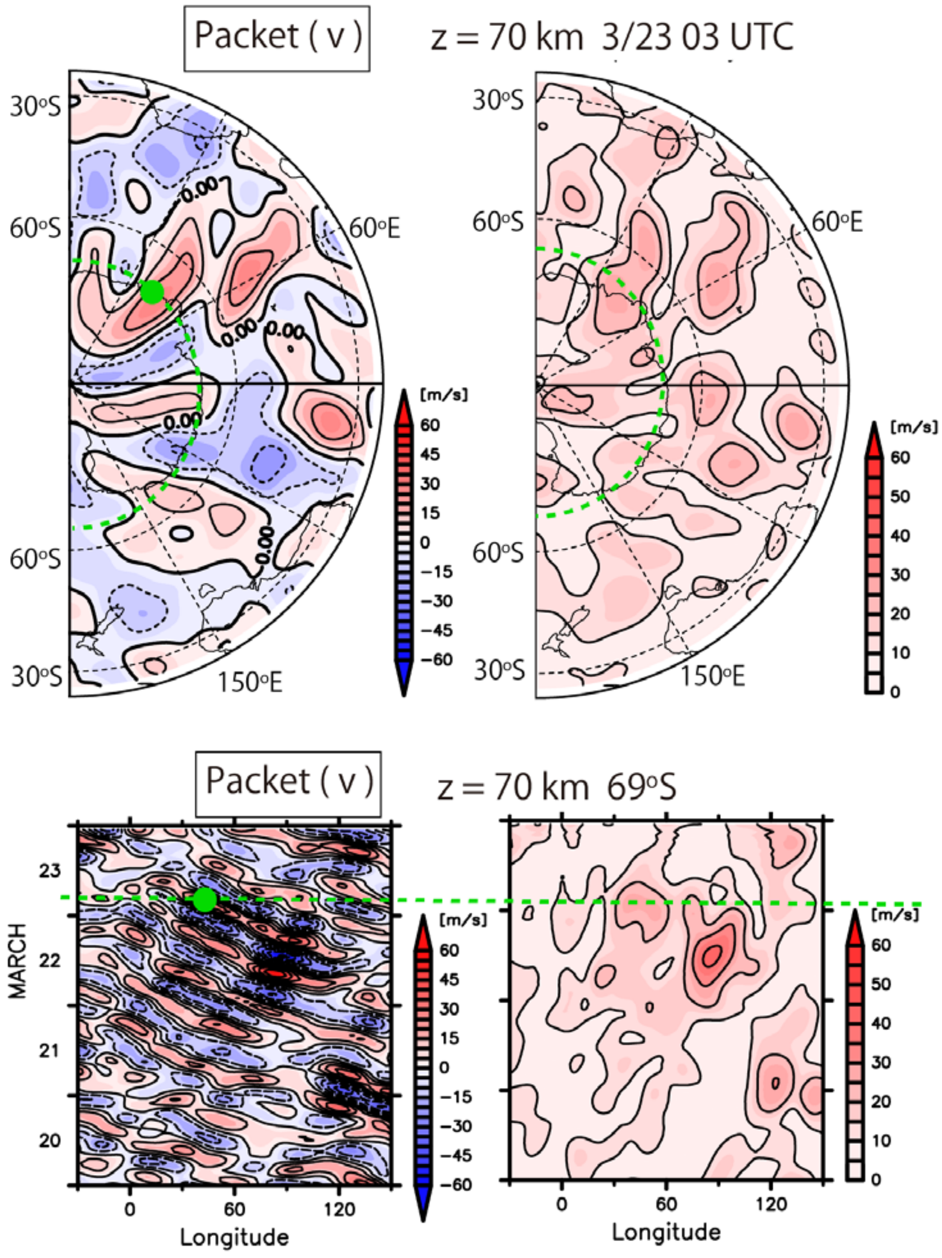

Figure A: Snapshots of the zonal wind components and their envelope function of the large-scale inertia-gravity waves at the height of 70 km at 03 UTC 23 March 2015 with a narrow bandpass filter, corresponding to the packet (v). Hovmöller diagrams of the zonal wind components and their envelope function of the large-scale inertia-gravity waves at the height of 70 km at 69°S for the period from 20 to 23 March. The green dashed curves denote the cross section taken in each figure. The green circles are locations of traced wave packets determined by the method discussed in the text. The contour intervals are 10 m s^{-1}.

Reviewer #3,

The authors greatly appreciate the reviewer's critical reading of our manuscript and constructive comments. We have revised the manuscript as much as possible following the reviewer's comments.

Our response to each comment is described in the following.

Response to comments:

1. **It appears that both observations and simulations presented suggest wave period between 11-12 hours. The consistency is certainly satisfying, but it is not clear from the analysis (especially the analysis of simulation results) why this period range is "preferred"(vs a broader spectrum). Is this more related to the wave source, or the wind system at the time of the observation?**

Recently, Sato et al. (2017) showed that zonal (meridional) momentum flux spectra at the summer mesosphere over Syowa Station are mainly positive (negative), and an isolated peak of the momentum fluxes is observed near a frequency of 12 hour, using continuous observations of polar mesosphere summer echoes at heights from 81–93 km by the PANSY radar. The signs of momentum flux suggests that gravity waves propagate from low latitude regions on the assumption of upward propagation. Yasui et al. (2016) also suggested that gravity waves in the summer mesosphere may originate from the tropical convections using the MF radar observation at Syowa Station. Sato et al. (1999) indicated that such meridional propagation of the inertia-gravity waves from the low latitude region and the critical-level filtering mechanism can explain the isolated energy peak near the inertia-frequency (near a frequency of 12 hour at Syowa Station). Moreover, the tide-induced spontaneous radiation mechanism proposed in this study (discussed in this reply to the comment#2) implies frequent generations of quasi 12 h inertia-gravity waves at the polar vortex. Further studies are needed to clarify physical mechanisms for the existence of the isolated energy peak near 12 hour in the mesosphere at Syowa Station. This discussion has been added to Section 5 (Page 24, lines 20-25 and Page 25, lines 1-8).

2. **The authors cite spontaneous radiation from a balanced polar night jet (page 20) as a possible source of wave package (i). This part of the discussion appears to be rather speculative, and I wonder if they could be more specific and quantitative. For example, if they think quasi-resonance mechanism is**

responsible, is it possible to examine the flow and see if some quasi-resonance condition is satisfied?

To make the discussion more specific and quantitative, we proposed a new spontaneous radiation mechanism associated with the semi-diurnal migrating tides. Figures. 17 and 18 have been added to explain this mechanism. One of the quantitative necessary conditions for the spontaneous radiation mechanism is the time-scale matching of gravity waves to the large-scale flow, and the other is that the Lagrangian Rossby number R_{Lagr} is larger than unity, which was in McIntyre (2008). We have confirmed that these two necessary conditions are satisfied in this mechanism (please see the main text).

Discussions have been revised in Section 4.2 (Page 21 lines 14-25, Page 22, and Page 23, lines 1-15).

3. **The observation was made from 16 to 24 of March 2015. This is the time when the polar night jet is forming in the Southern hemisphere, and one may expect that the jet to be not very steady. I wonder if this is the case for the observational period, and if it has any implications for the wave generation.**

Figure A1 in this reply shows a seasonal change of the potential vorticity in the equivalent-latitude coordinate at 1450 K corresponding to an altitude of about 45 km, using the JRA-55 reanalysis datasets. Figure A2 shows a seasonal change of the latitudinal gradient of the potential vorticity in the equivalent-latitude coordinate at 1450 K. The region where the gradient of the potential vorticity corresponds to the edge of the polar vortex. As the reviewer suggested, the polar night jet was just forming in the Southern hemisphere during the observational period examined in this study.

However, currently, it is still difficult to understand how the steadiness of the jet streak is related to the wave generation. Although the wave generation mechanisms associated with a jet streak have been theoretically examined recently, these studies assume a steady jet structure such as a vortex dipole (e.g., Viúdez, 2007; Yasuda et al., 2015). Thus, to clarity this point, it is needed to compare the behaviors of the wave generation both under a steady jet streak such as a winter polar vortex and under an unsteady jet streak such as an autumn/spring polar vortex. The authors have simulated behaviors of inertia-gravity waves in the mesosphere through a year as statistical analyses using NICAM, and would like to examine this point. The sentence about the state of the polar vortex has added to Page 10, lines 19-21.

4. **Questions with regard to PANSY (page 6): Is the time resolution in the mesosphere also 1 minute? Although it is stated that the height range of PANSY is 1.5-500km, the figures suggest there is an observation gap between 30-60km. Please explain.**

The time resolution of the PANSY radar in the mesosphere is also 1 minute. The observation gap between 30-60 km is due to the lack of the atmospheric radar backscattering in this height region (Sato et al., 2014). In the tropo/stratosphere, such backscattering is caused by atmospheric turbulence and water vapor fluctuations in the background gradient of air density. In the mesosphere, the ionization process and atmospheric turbulence become a major contributor to the backscattering. Thus, such an observation gap can be explained by the observation technique of the PANSY radar. The sentence has been added to clarify these points (Page 6, lines 14-21).

5. **Page 8 lines 12-13: According to the formula given, glevel-8 corresponds to a resolution of 28km, not glevel-7.**

We are very sorry that the description of the horizontal resolution was wrong. The sentence about the horizontal resolution has been revised. (Page 8, lines 18-19)

6. **Page 10 lines 13-14 and Figure 2a: It is stated that the PMWEs are likely associated with solar flares on March 17, but the peak echoes are found on 21st. Is such a delay of 4 days expected?**

This solar flare event was reported as the strongest geomagnetic disturbance of the current solar cycle, which is called the St. Patrick's Day storm, occurring on 17–18 March 2015 (e.g., Kataoka et al. 2015; Jacobsen and Andalsvik 2016; Cherniak and Zakharenkova 2016). Although almost all studies focusing on the St. Patrick's Day storm examined the aurora event observed in the northern hemisphere, Cherniak and Zakharenkova (2016) examined geomagnetic parameters in the Southern polar cap during March 15–20, 2015. According to their Fig.2, it was shown that the ionospheric plasma irregularities last after the event, at least until 20 March 2015. Thus the echoes observed by the PANSY radar was likely initiated by this strong solar flare event. The physical reason why the PANSY radar can receive such a strong winter echo in the mesosphere has just been examined by the PANSY research group. The sentences have been revised and the references (Jacobsen and Andalsvik 2016; Cherniak and Zakharenkova 2016) have been included (Page 10 lines 17-19).

7. Page 12-13: Is it possible to quantify the uncertainty in k_h estimation?

The wave parameters ($\hat{u}$, $\hat{v}$, ω, θ_u, θ_v, u_o and v_o) are determined using a nonlinear least square method so that the residual $\sqrt{(u'_{\mathrm{obs}} - u')^2 + (v'_{\mathrm{obs}} - u')^2}$ is smallest. By using the magnitude of the residual, the uncertainty of the wind amplitude by the nonlinear least square method and the associated uncertainties of the wave parameters are estimated in Table 1b, on the assumption that the uncertainties of the estimation of the zonal and meridional wind amplitude are the same magnitude. It seems that the estimated horizontal wavelength at heights of 70.8 km for March 23 has a large uncertainty ($|2\pi/\overrightarrow{k_h}| = 990 \sim 7778$). However, the case for the largest horizontal wavelength corresponds to a particular case in which the fluctuation becomes almost a pure inertial oscillation with $|\overrightarrow{k_h}| \sim 0$. The discussion about the uncertainty has been added (Page 13, lines 20 -23 and Page 14, lines 1-4) and Table 1b has been revised.

8. Page 13 line 23: "vertical wavelength of less than 1km", but 2km was given from earlier discussion.

The sentence has been revised (Page 14, lines 15-16).

9. Page 4 line 10: change to ", present in most climate models in the polar..."
10. Page 6 line 22: change to "with the complete system..."
11. Page 17 line 10: change to "at the height of 70km"
12. Page 17 line 12: remove "spatial"
13. Page 22 line 23: "examined the energy density[?]". "by dividing [the total energy density?]"

The sentences have been revised following the reviewer's comments.

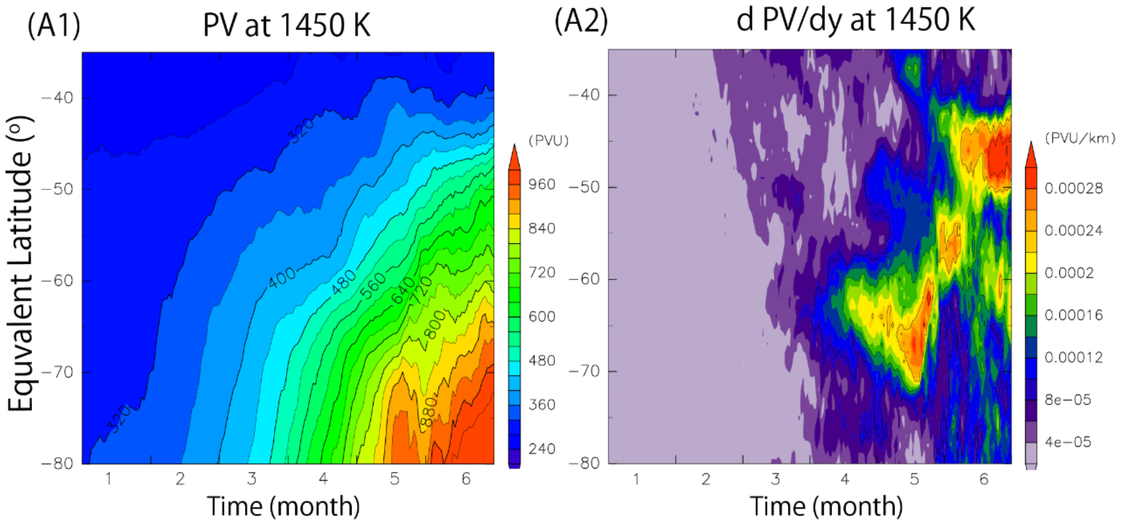

Figure A: a seasonal change of (A1) the potential vorticity and of (A2) the latitudinal gradient of the potential vorticity in the equivalent-latitude coordinate at 1450 K corresponding to an altitude of about 55 km, using the JRA-55 reanalysis datasets.