Equatorial Waves Simulated by Kyushu University GCM in the Lower Thermosphere

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1. Introduction

It has been revealed that global scale wave motions such as Kelvin waves are the important components of wave disturbances in the Mesosphere and the lower Thermosphere region (hereafter, the MLT region; 80-120km in heights) by rocket and satellite observations.

In this research, we focus on the 2-3day periods eastward propagating zonal wavenumber 1 type wave structure in the MLT region simulated by the T42L250 version of middle atmosphere general circulation model (hereafter, KYUSHU-GCM). It is shown that the wave has the structure of the Kelvin waves with 2-3day periods.

2. Data

KYUSHU-GCM is a general circulation model that covers from the surface to about 150km in height with 250 vertical layers [1]. The vertical resolution of KYUSHU-GCM is about 500m in the MLT region and with a horizontal resolution of triangular-truncation at horizontal wavenumber 42. In the present paper, the bi-hourly sampled dataset in the MLT region such as the zonal wind, the meridional wind, the temperature, and the geopotential height fields from January 25 to February 8 are used.

3. Results

According to observation data, it has been revealed that the 2-3day periods zonal wavenumber 1 type equatorial Kelvin waves are the important components in the lower Thermosphere [2]. First, the components which periods are longer than 3day and shorter than 2day at the height 120km are filtered out by a band pass filter. Results are shown in figure 1, which shows that in the zonal wind, geopotential height, and temperature fields, the 2-3day period components propagate toward east while in the meridional wind field they propagate toward west. The maximum in the zonal wind field is about 40ms^{-1}, in the geopotential height field is about 1000m, and in the meridional wind field is about 32ms^{-1}. The minimum in the zonal wind field is about –40ms^{-1}, in the geopotential height field is about –600 m, and in the meridional wind field is about –32ms^{-1}.

Zonal wavenumber 1 components are dominant in the components propagating eastward. Zonal wavenumber 1 components of 2-3day periods of each field are shown in figure 2, and it can be seen that zonal wavenumber 1 components of zonal wind and geopotential height fields propagate eastward and the maximum of each field is 30 ms^{-1} in zonal wind field and 800m in geopotential height field. Zonal wavenumber 1 components of the meridional wind field propagate westward with the maximum amplitude of 10ms^{-1}.

Along the phase line about 2.2day period of zonal wavenumber 1 components, we do the composite analysis in the region from 47°S to 47°N at 120km height. Results are shown in figure 3. The maximum amplitude of the zonal wind field appears at the equatorial region and is about 14ms^{-1}. The maximum amplitude of the geopotential height field also appears at the equatorial region and is about 250m. The positive region of zonal wind field corresponds to the high pressure region of the geopotential height field, and this phase relationship just satisfies the relationship of equatorial Kelvin waves theoretically found by Matsuno (1966) [3]. It is seen that the meridional wind field appears in the equatorial region about –0.6 ms^{-1} while the maximum of that appears around the 35°S around 3 ms^{-1}.

As it can be seen that amplitudes of the zonal wind filed and the geopotential height fields are not trapped in the equatorial region but extend to high latitude about 50°S and 50°N. By solving the Laplace's tide equation with setting the zonal wavenumber as 1 and the period as 2.2day that propagates toward east, it is found that the Kelvin wave solution has the equivalent depth is 4043m, the vertical wavelength is about 50km and the amplitude shows the maximum just above the equator and extends to about 50°S and 50°N as shown in figure 4. The similar solution also can be found in Forbes (2000)[4]. It is found that the latitude distribution of the wave in the KYUSHU-GCM is wider than the analytic solution. The reason of this difference is not clear.

To figure out the vertical structure of the Kelvin wave, the same composite analysis at 2.1°N between 80km and 120km heights is done and shown in figure 5. It can be seen that in this case the phase propagates downward which means that excitation sources should exist in lower layer. The maximums of the zonal wind field and the temperature fields are 15ms^{-1} at 110km height, and 10K at 110km height in the temperature field. In this case, the vertical wavelength is about 40km which is consistent with theoretical wavelength is about 50km.

4. Concluding Remarks

In present analysis, we only use the composite analysis to confirm the structure in longitude-latitude plane at 120km height and the vertical structure of 2-3day period equatorial Kelvin waves. For more detail analysis, it is necessary to separate the eastward propagating components and the westward propagating components in each field. By doing this, we may get more detailed structure of equatorial Kelvin waves in the lower Thermosphere.

According to observational data, it has been found that the equatorial Kelvin waves have different periods in different height region. We will try to figure out the vertical distribution of periods of the equatorial Kelvin waves simulated by KYUSHU-GCM and structures of the equatorial Kelvin waves with various periods. With analyzing the vertical variation of equatorial Kelvin waves, the excitation sources will be able to be discussed.

Acknowledgment

The figures are produced by GFD-DENNOU Library.

References

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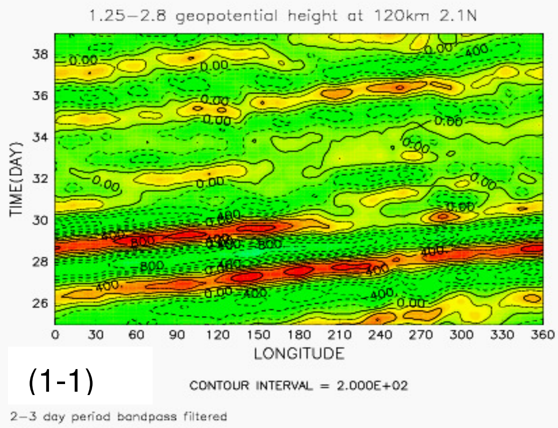
[2] Riggin et al., Radar observations of a 3-day Kelvin wave in the equatorial mesosphere, Journal of Geophysical Research, Vol. 102, No. D22(26), 141-157, 1997.

[3] T. Matsuno, Quasi-Geostrophic Motions in the Equatorial Area, Journal of the Meteorological Society of Japan, Vol. 44, No. 1, 25-43, 1966.

[4] J. M. Forbes, Wave coupling between the lower and upper atmosphere: case study of an ultra-fast Kelvin Wave, Journal of Atmospheric and Solar-Terrestrial Physics 62(2000), 1603-1621.



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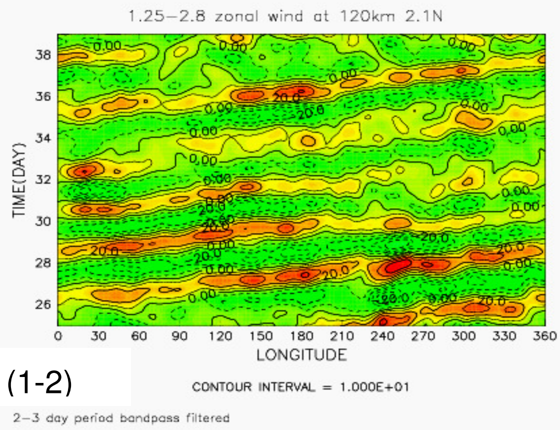

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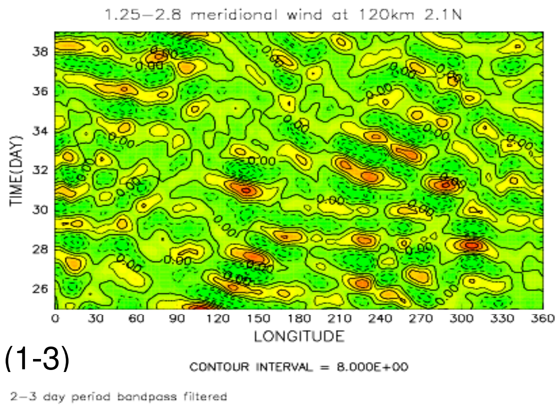
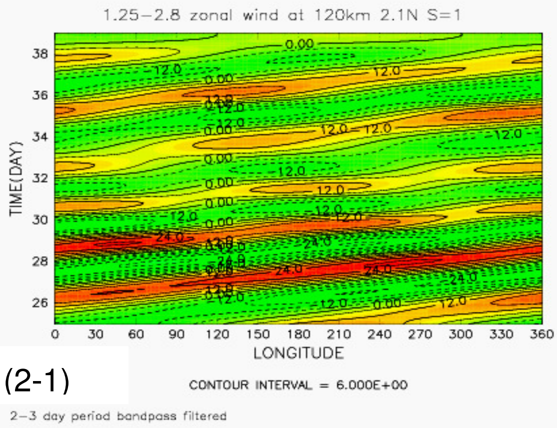


(1-3)

Figure 1: Time-longitude diagrams of 2-3day periods components of the zonal wind (1-1), the geopotential height (1-2), and the meridional wind fields (1-3).



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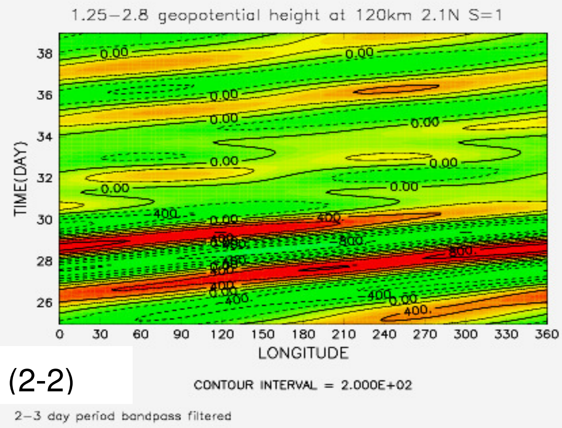

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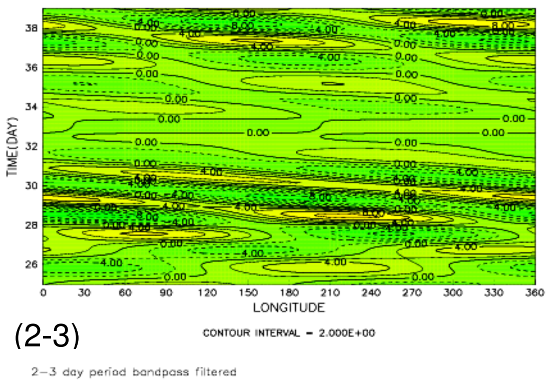
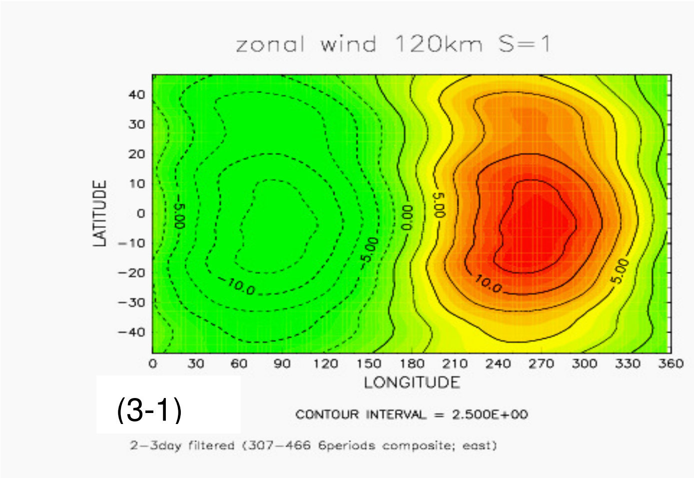
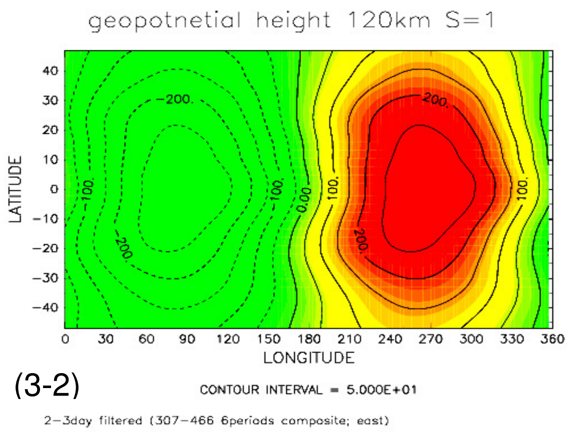


(2-3)

Figure 2: Time-longitude diagrams of zonal wavenumber 1 components of 2-3day periods components of the zonal wind (2-1), the geopotential height (2-2), and the meridional wind fields (2-3).





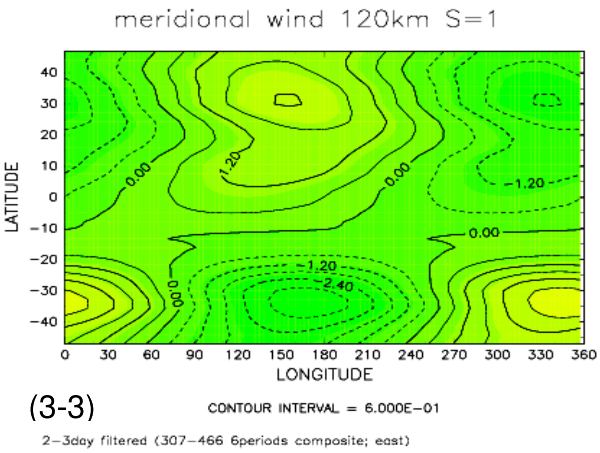


Figure (3): Results of composite analysis along the eastward propogating phase speed from January 25 to February 8, the zonal wind field (3-1), the geopotential geight (3-2), and the meridional wind field (3-3).

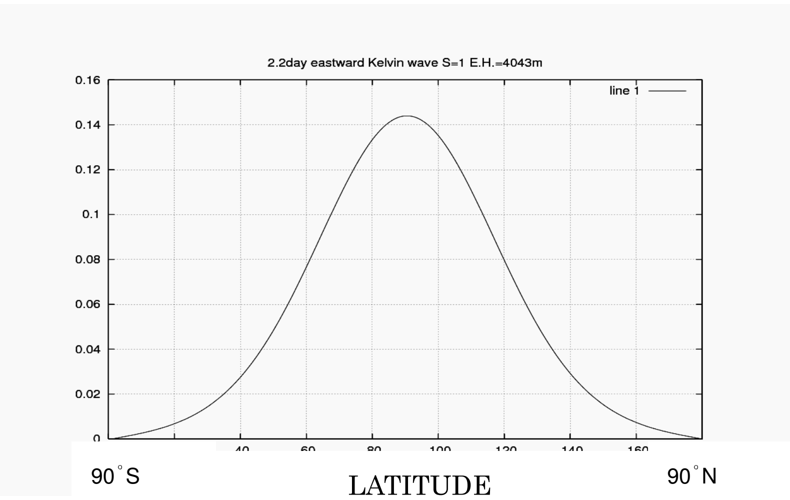
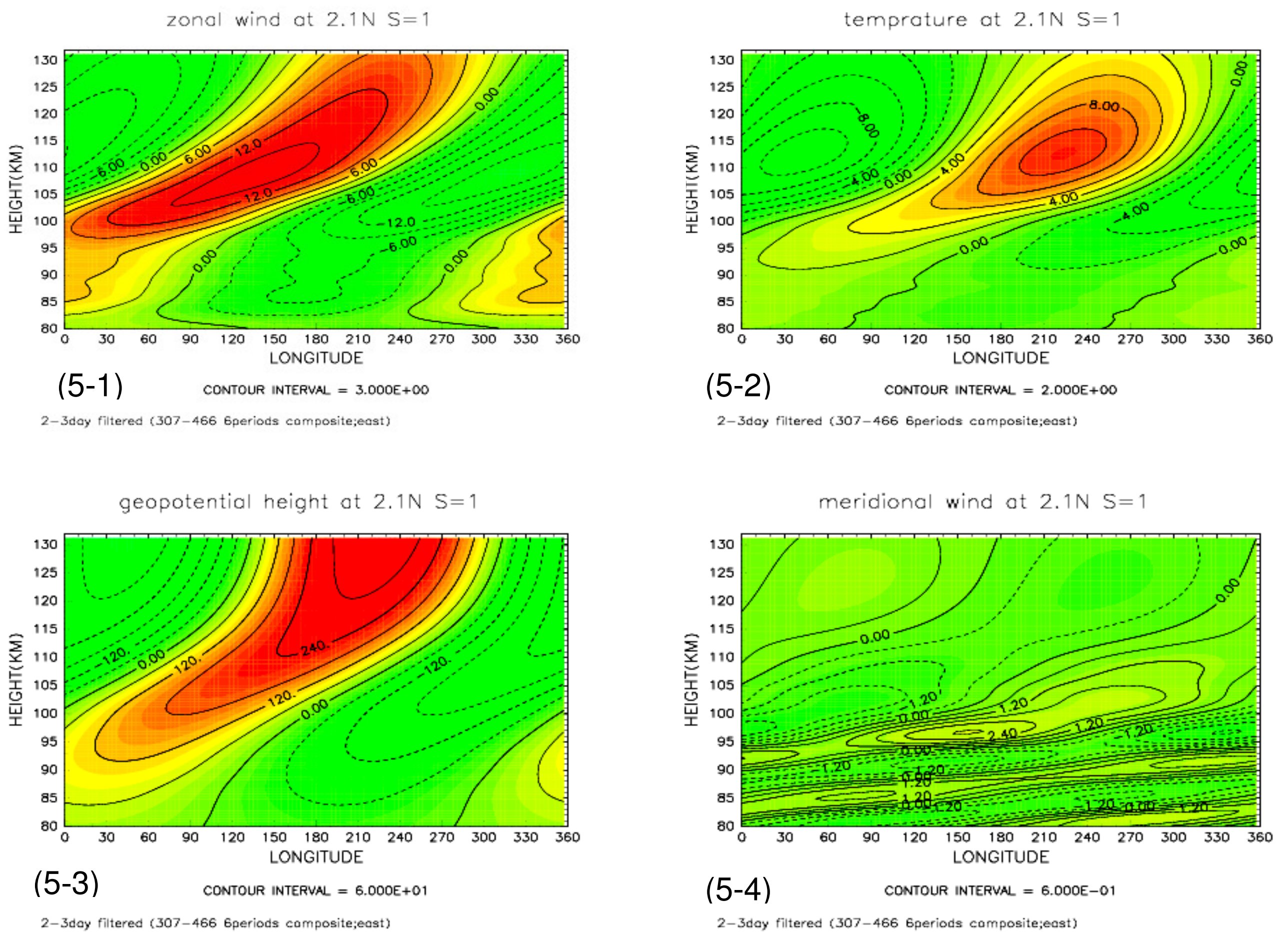


Figure (4): Kelvin wave solution of Laplace's tidal equation with 2.2day period eastward propagating mode.



Figure(5): Results of composite analysis along the eastward propogating phase speed from January 25 to February 8 at 2.1°N between 80km and 120km in heights. Figure (5-1) is the zonal wind field, figure (5-2) is the temperature field, figure (5-3) is the geopotential height field, and figure (5-4) is the meridional wind field.