Long-term variation of horizontal phase velocity spectrum of mesospheric gravity waves observed by an airglow imager at Shigaraki : Comparison with tropospheric re-analysis data

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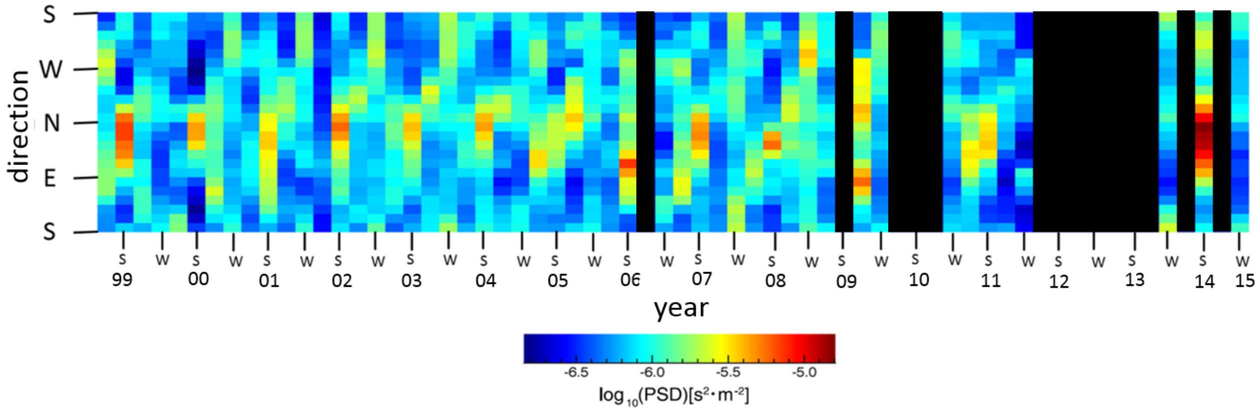
Atmospheric gravity waves (AGWs) generated in the lower atmosphere transport momentum into the upper atmosphere and release it when they break near the mesopause region. The released momentum drives global-scale pole-to-pole circulation in the upper atmosphere, causing global mass transport. The AGW propagation and its momentum transport depend on horizontal phase velocity of AGWs. There were many studies about the AGWs in the past by using radars, lidars and airglow imagers, and various AGW parameters such as wavelengths and phase velocities were studied. However, long-term (>10 years) variation of horizontal phase velocity spectrum of the mesospheric small-scale AGWs, which can be measured by airglow imagers, has not been studied yet.
In this study, we analyze the horizontal phase velocity spectrum of AGWs by using mesospheric 557.7-nm airglow images obtained at Shigaraki MU Observatory (34.8 deg N, 136.1 deg E) of Kyoto University over ~17 years from October 1, 1998 to July 26, 2015. We use 3-dimensional Fourier analysis procedures of airglow images proposed by Matsuda et al. (JGR, 2014), making it possible to analyze large amount of data.
Seasonal variations of propagation direction of AGWs was clearly identified (Spring : North-East and South-West, Summer : North-East, Fall : North-West, Winter : South-West). Several longer-term variations of direction / intensity were identified for each season with a time scale of several years. The power spectrum density of horizontal phase velocity changes with 7-8 years timescale in winter and 2-3 years in spring.
The east-west anisotropy (summer: eastward, winter: westward) of AGW propagation is probably caused by filtering of gravity waves due to mesospheric jet (summer: westward, winter: eastward) (e.g., Nakamura et al., EPS, 1999; Ejiri et al., JGR, 2003). However, north-south anisotropy (summer: northward, winter: southward) cannot be explained by mesospheric jet. Then we investigate the location of possible AGW sources relative to Shigaraki by using tropospheric re-analysis data about vertical flow velocity to understand the north-south anisotropy. There are regions of strong vertical velocities at south of Japan due to the Baiu seasonal rain front during summer and at north-east of Japan due to wintry low pressure during winter. Thus we consider that the north-south anisotropy of AGW propagation direction is due to the location of AGW sources in summer and winter.
Next, we investigated the relationships of longer-term variations of power spectrum density (PSD) of horizontal phase velocity of AGWs with tropospheric re-analysis data, NINO index, AO index and sunspot numbers particularly for summer and winter. There is a correlation between longer-term variations of PSD and tropospheric re-analysis data at south of Japan during summer and north-east of Japan during winter. These regions nearly correspond to the rain front in summer and the wintry low pressure in winter, as we described before. Thus we think more certainly that the north-south anisotropy of AGW propagation direction is controlled by the relative location of AGW sources. We could not find any clear correlations of PSD variations with NINO index, AO index and sunspot numbers.

Keywords: mesospheric gravity waves, horizontal phase velocity spectrum, long-term analysis, airglow imager, tropospheric re-analysis data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year
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