Intermittency of Gravity Wave Momentum Flux in the Mesopause Region Observed with All Sky Imager in Maui and Cerro Pachón

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1. Introduction

Gravity waves (GWs) are mostly excited in the lower atmosphere and they can transfer energy and momentum to higher atmosphere as they propagate upward and finally break due to instability. In current climate models, the influence of GWs is not explicitly resolved due to coarse resolution. So the effects of GWs on the general circulation should be parameterized. Since the waves with specific properties will not generally be occurring throughout the model area at all time, factors that can describe the spatial and/or temporal intermittency should be included in the model. In this work, multi-year all sky OH airglow imager data is used to analyze the intermittent nature of gravity waves in the mesopause region. This goal is achieved by calculating and analyzing the probability density functions (pdfs) of gravity wave momentum flux.

In Alexander [2010], Hertzog [2012] and Wright [2013], the intermittency of gravity waves in the lower stratosphere is investigated using the long-time duration balloon, satellite and numerical simulation data. Their results show that the pdfs tend to behave like lognormal distributions with a long tail (larger magnitude but rarer cases of momentum flux). Also, several factors are proposed to quantify the intermittency of gravity waves, like Bentolila proxy, percentile ratio (Hertzog et al. 2012) and Gini coefficient (Pasquon et al. 2013). From their dataset, which covers a large area and long time, some geographical and seasonal variation of gravity wave intermittency is found. They also find wave sources and background wind both play important roles in determining the intermittency of gravity wave momentum flux.

2. Data and Method

All sky airglow imaging system can be used to measure the mesospheric hydroxyl (OH) airglow emission at night time.

University of Illinois at Urbana-Champaign (UIUC) OH airglow imager was deployed in Maui (20.7° N, 156.7° W) from January 2002 to August 2007 and then relocated to Anda Lidar Observatory (Cerro Pachón, Chile, 30.0° S, 71.0° W) since September 2009.

Using the method developed by Tang et al. [2005] and improved by Li et al. [2011], high-frequency quasi-monochromatic (QM) gravity waves are firstly identified and wave parameters such as wavelength, period and momentum flux are derived from consecutive time-difference (TD) images.

Due to different camera exposure time and data processing procedures, the minimum wave observation intervals for Maui and Cerro Pachon are 6 and 3 minutes, respectively. Only momentum flux smaller than 200 m/s² is treated as valid measurements and considered in the next process.

Pdfs of the momentum flux is calculated based on the whole dataset. The occurrence of momentum flux in evenly selected bins has an extremely wide dynamical range, which covers 4-5 order of magnitude when corresponding momentum flux ranges from 0 to 200 m/s².

With limited dataset and in order to reduce the fluctuation of occurrence, variable bin width similar as Wright et al. [2013] is used. In most work, it means that wider bins are selected at larger momentum flux to include more valid wave measurements, and narrower bins are selected at smaller momentum flux to resolve the slight variations. Then, the occurrence of momentum flux in all bins with unequal width is normalized to uniform bins width to get the final pdfs.

3. Results: Lognormal Distribution

Pdfs of the total momentum flux smaller than the transition point is redrawn in linear space, the bin width is fixedly chosen as 0.1 m/s² for Maui and 0.2 m/s² for Cerro Pachon.

In Figure 3, we can identify the regular shape of lognormal distribution, with peaks (momentum flux with largest probability) near 1.5 and 2 m/s² for Maui and Cerro Pachon, respectively.

The momentum flux from Cerro Pachon is more concentrated than Maui.

3.4: Seasonal Variations

Recognize the multi-year data by month, and apply the same fitting on the monthly data.

For μ, which mostly determine the concentration of the lognormal distribution, results of two locations show some consistency from March to August.

For σ, which mostly determine the position of the peaks, the results show similar trend but with a constant disparity around 0.7.

For G, which is the slope of the power law in log-log space. The two locations seems to show opposite variation tendency.

3.5: Results: Relation to Gini Coefficients

The main body of the pdfs follows the lognormal distribution. From the definition of lognormal distribution, we can derive the intermittency factors, like Bentolila proxy, Percentile Ratio and Gini coefficient are all related to σ. Here we only consider the Gini coefficient, which is more accurate and without arbitrariness. Gini coefficient can be derived as $G = \frac{2 \cdot \text{pdfs}_0}{\text{pdfs}_0 + \text{pdfs}_1} - 1$ (3), and $G(x)$ is the cumulative density function of Standard Normal Distribution.

Gini coefficient calculated from fitted d shows similar tendency as the coefficient calculated directly from the momentum flux data.

A constant shift about 0.5 can be found between them, which could be contributed by the Pareto distribution part.

Figure 5 shows seasonal variation of the Gini coefficient calculated from original data and derived from the fitted parameters μ and σ.

4. Discussion and Conclusion

The pattern of observed gravity wave’s parameters reflects the nature of both the gravity wave sources and background through which the gravity waves have propagated. In our study, OH airglow data is from mesosphere, which is far away from the gravity wave sources. The pattern of intermittency is expected to be likely an indication of characteristic of background flow.

The instability of background flow can partly explain the intermittency represented by gravity wave momentum flux. The instability of background flow can partly explain the intermittency represented by gravity wave momentum flux. The instability of background flow can partly explain the intermittency represented by gravity wave momentum flux. The instability of background flow can partly explain the intermittency represented by gravity wave momentum flux. The instability of background flow can partly explain the intermittency represented by gravity wave momentum flux. The instability of background flow can partly explain the intermittency represented by gravity wave momentum flux. The instability of background flow can partly explain the intermittency represented by gravity wave momentum flux. The instability of background flow can partly explain the intermittency represented by gravity wave momentum flux. 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