Doctor Thesis

Spatial and Temporal Variabilities of Mesospheric Concentric Gravity Waves Revealed with a Space Borne Visible Spectroscopic Instrument

（衛星搭載分光器による
中間圏同心状大気重力波の空間・時間変動）

Septi Perwitasari
(セプティ・ペルウィタサリ)

Department of Geophysics
Graduate School of Science
Tohoku University

Thesis Committee Members

Associate Professor Takeshi Sakanoi (chair, supervisor)
Professor Takahiro Obara
Professor Yasumasa Kasaba
Associate Professor Isao Murata
Associate Professor Atsushi Kumamoto
Assistant Professor Mitsumu K. Ejiri (NIPR)

2016

Abstract

This thesis focuses on the spatial and temporal variability of concentric gravity waves (CGWs) in the mesopause region based on the O_2 A-band (762 nm) nightglow data obtained with IMAP/VISI. Atmospheric gravity waves (AGWs) have been studied intensively because of their major role in the atmospheric dynamics, such as transporting energy and momentum and interaction to the mean wind and thermal structure of the middle atmosphere. CGWs are one of the most distinct features of gravity waves, which show a direct coupling between lower and upper atmosphere. The past studies have revealed the general properties of CGWs, such as launching mechanism and effect of the background wind profile. However, these are mostly based on a single event, which give only local information. Thus, a statistical approach with space-based observations is ideal since they cover wider area globally and can measure atmospheric gravity waves without cloud obscuration.

For the data analysis, we used the airglow data measured with the Visible and near-Infrared Spectral Imager (VISI) of the IMAP mission on the International Space Station (ISS). IMAP/VISI was operated from October 2012 until August 2015 in the nightside hemisphere with geographical latitude range of +/- 51°, measuring mainly three different airglow emissions of OI at 630 nm, the OH Meinel band at 730 nm and the O_2 (0-0) A-band at 762 nm at an altitude of ~400 km with the typical spatial resolution of 16 – 50 km.

The present study of CGWs is divided into two parts; the first part is a case study using the coordinated observations of IMAP/VISI and ground-based all-sky imager at Rikubetsu, and the second part is a statistical study on the global distribution and seasonal variability of CGW. Here we examined a partial CGWs case observed in northeastward of Japan on October 18, 2012. IMAP/VISI measured an arc-like shaped; partial CGWs pattern around the mesopause (~95 km) in the O_2 762-nm airglow emission at 1204 UT. The maximum radius of CGWs was ~1400 – 1500 km. Similar patterns were also observed by the all-sky imager at Rikubetsu (43.5°N, 143.8°E) in OI 557.7-nm and OH-band airglow emissions from ~1100-1200 UT. Horizontal wavelengths of the observed small-scale gravity waves are ~50 km (OH-band and OI 557.7-nm) and ~67 km (O_2 762-nm). From MTSAT and TRMM data the source is suggested to be a deep convective activity over Honshu island (33°N, 136°) which likely to be related to a typhoon in the south of Japan. Background winds and temperature on the propagation mechanism were analyzed with MERRA, Wakkanai MF Radar and SABER data. Using atmospheric temperature profiles, we conclude that this long-distance propagation of the waves could be caused by thermal duct in the middle atmosphere in the altitude range of 45 to 110 km. The zonal and meridional wind profiles could produce the arc-like shaped CGWs in which the wind filtering effect plays a role on the suppression of wave propagation in the particular direction.

We also conducted a statistical study using 235 CGWs events obtained from 3 years data of IMAP/VISI to clarify the spatial and temporal variability of CGWs in the mesopause. We found the horizontal wavelength ranging from 40 to 250 km and maximum radius of 200 to 3000 km, clearly demonstrating the fact that the small-scale gravity waves can travel for a long distance up to 3000 km. The zonally averaged latitudinal distribution of the CGWs occurrence maximized at mid-latitudes (40°N and 40°S) and minimized at low latitudes (10°S). It is interesting to note that more events were found in the summer hemisphere mid-latitudes, with a rapid transition between northern and southern hemisphere around the equinoxes. Occurrence probability of the CGWs was significantly high during non-solstice months (February-May and August–November) than solstice months (June-July and December-January), suggesting that they are able to survive breaking and critical level absorption in the middle atmosphere to reach the mesopause region more often during these periods. Information regarding localized regions of high CGW activities seen in the global map and the seasonal variability are useful for the future mesospheric and upper atmospheric studies.